AVL Simulation and Testing Solutions

Dear Valued Customer,

It is a pleasure for us to present you with the new edition of the AVL Simulation and Testing Solutions Catalog. As we talk to our customers and partners, we see the continuation of some of the main global megatrends of the automotive industry: a tightening of CO_2 and emission regulation; the globalization of markets, suppliers and products; and the need to handle increasing vehicle and powertrain complexity while keeping development effort to a minimum.

It is our mission to provide you with the right tools, methods and services to master those challenges successfully. Based on close cooperation with our clients and AVL's automotive know-how of nearly 70 years, we have established a unique and consistent development platform for our clients. Our portfolio offers you the most advanced and accurate simulation and testing solutions for every step of the powertrain development process – from the first concept study all the way through to series production. We seamlessly integrate the worlds of simulation and physical testing, incorporating the latest methodology ideas. This enables you to execute development tasks at an early stage of the development process. This can help save time, increase quality and keep costs under control. It is the foundation for efficient development operations in the new age of the connected vehicle.

Whether you are interested in a single measuring instrument or need a complete turnkey test facility – more than 8,050 of our employees in over 45 countries are dedicated to exceeding your expectations. We hope that you will choose AVL when looking for a partner to help you to achieve your business goals.

Yours sincerely,

Dr. Gotthard Rainer
Vice President

Kai-Uwe Voigt
Executive Vice President

Dr. Hannes Schmüser
Executive Vice President

AVL Simulation and Testing Solutions Guide
Less paper. More fun.

Finding the latest information on AVL Simulation and Testing solutions has never been easier. Now right on your tablet you will have quick and easy access to information on AVL's most up-to-date product, service and solution.

AVL at your fingertips.

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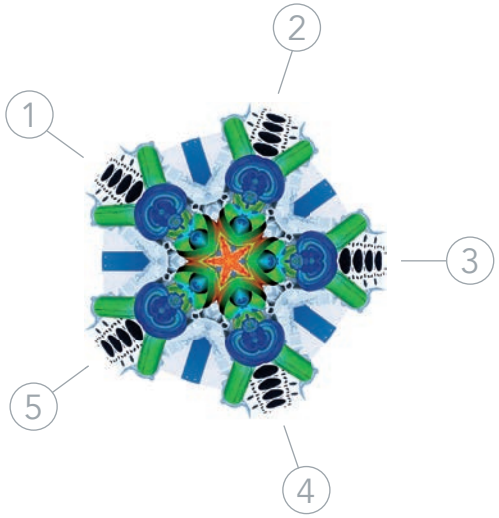
Available on the App Store

Why choose AVL?



At AVL, we are committed to delivering the most diverse and best caliber simulation, measurement and testing technology available and to provide our customers with outstanding assistance and support.

1. GLOBAL PRESENCE

AVL's worldwide network gives you peace of mind. Wherever your R&D challenges take you, we are always close at hand, ready to provide the service you need.

2. SOLUTIONS FOR THE ENTIRE POWERTRAIN

We offer leading simulation, measurement and testing solutions for the entire powertrain development process, based on a consistent, integrated and open platform.

3. COMPREHENSIVE APPLICATION EXPERTISE

AVL is consistently at the forefront of powertrain engineering. This insight enables us to speak your language and to provide you with practical solutions for your engineering challenges.

4. EFFICIENT AND RELIABLE PARTNER

Trust and integrity are the cornerstones of our identity. We are committed to you, our customer, to keeping our promises, to delivering efficiently and to making your project a success.

5. DEDICATION TO CUSTOMERS

For us, the customer always comes first. For over 65 years, and in the years to come.

All contents at a glance.

Future Mobility

ELECTRIFICATION AND HYBRIDIZATION

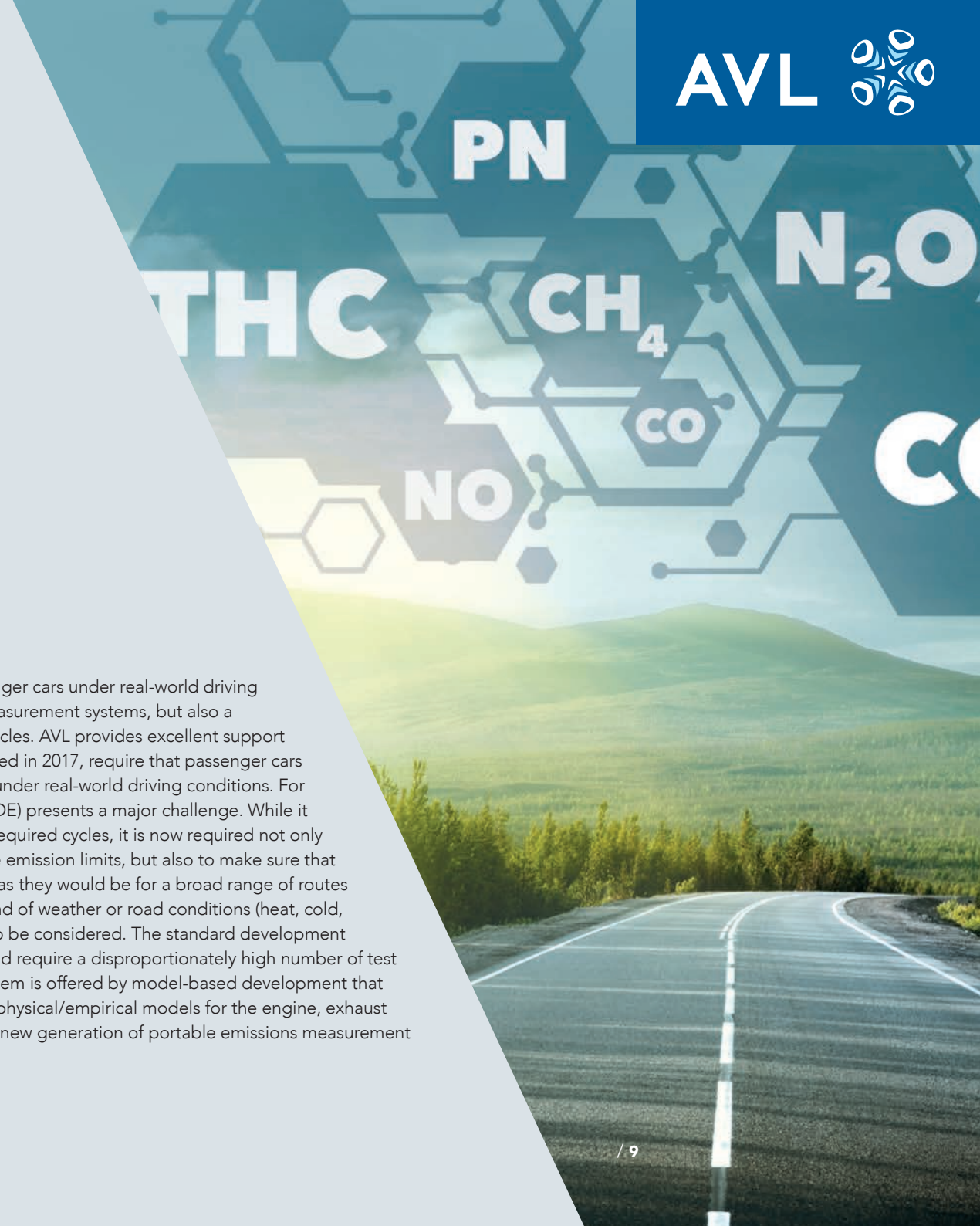
With increasingly strict CO_2 restrictions across the world and demand for affordable vehicles with low fuel consumption and no sacrifice of comfort, the automotive industry is facing enormous challenges. The electrification and hybridization of powertrains, along with further optimization of combustion engines, are forward-looking steps to satisfy this demand. It is already possible to travel short distances 100 % electrically and locally emission-free at reasonable cost using plug-in hybrid vehicles. Even bigger advances in the development of battery life and fuel cells will be needed to put more electrically powered vehicles on the road. Infrastructure upgrades, like quick charging stations and intelligent traffic management systems, will also contribute to efficiency improvements in the use of future vehicles.

CROSS-LINKING, INFOTAINMENT AND AUTONOMOUS DRIVING

Cross-linking a vehicle with its surroundings and other vehicles (Car2X-Communication) may contribute to better operating strategies in the future, for example by allowing a hybrid electric powertrain to "predict" the most efficient source of power. Drivers will also want to be more connected in the future: cars must satisfy this desire by offering a wide range of infotainment and communication possibilities. To enable a driver, for example, to use a touch screen while driving, initially only in certain traffic situations, autonomous and partially autonomous driving will become evermore important.

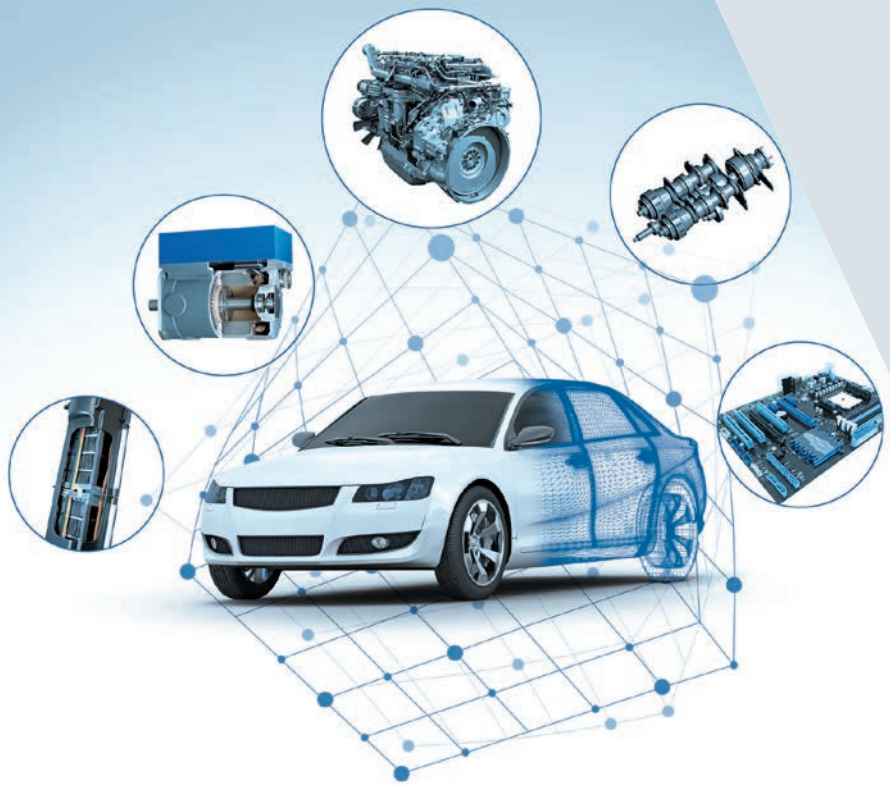
AVL's cutting-edge test environment, which enables interaction between virtual development and the testbed, helps developers understand and work with constantly increasing complexity, from the component level right through to the complete vehicle.

Emission and CO_2



EFFICIENT REDUCTION OF REAL DRIVING EMISSIONS

Demonstrating compliance with the emission limits for passenger cars under real-world driving conditions requires not only a new generation of portable measurement systems, but also a totally new methodology for developing powertrains and vehicles. AVL provides excellent support in both areas. The Euro 6c Emission Standards, to be introduced in 2017, require that passenger cars and lightduty vehicles prove compliance with emission limits under real-world driving conditions. For OEMs, ensuring compliance with "Real Driving Emissions" (RDE) presents a major challenge. While it used to be sufficient to optimize emissions within the legally required cycles, it is now required not only to tune the vehicle's entire operating range to optimally fit the emission limits, but also to make sure that the adjustments are just as functional for standard conditions as they would be for a broad range of routes (urban, countryside, highways, etc.), traffic situations or any kind of weather or road conditions (heat, cold, rain). The impact of different driver types additionally needs to be considered. The standard development methodology has started to reach its limits, because one would require a disproportionately high number of test runs to fully cover all driving situations. A solution to the problem is offered by model-based development that optimizes the development tasks considerably by employing physical/empirical models for the engine, exhaust gas aftertreatment and the entire system. RDE also requires a new generation of portable emissions measurement systems (PEMS).



Handling Complexity and Speed

COMPLEX WORLD – SIMPLE QUESTION

The automotive industry is experiencing dramatic changes. Tectonic shifts of markets, tougher legislative requirements and highly varying consumer demands have created unprecedented challenges to automobile manufacturers. Serving new regions and covering every market niche has become a matter of survival. With this increasing number of variants and today's complex powertrains, it is becoming more difficult to meet the development targets of quality, cost and time. Looking at this challenge, powertrain engineers must consider one key question: How can I find the ideal combination of tools, processes and methodologies that best support my development work?

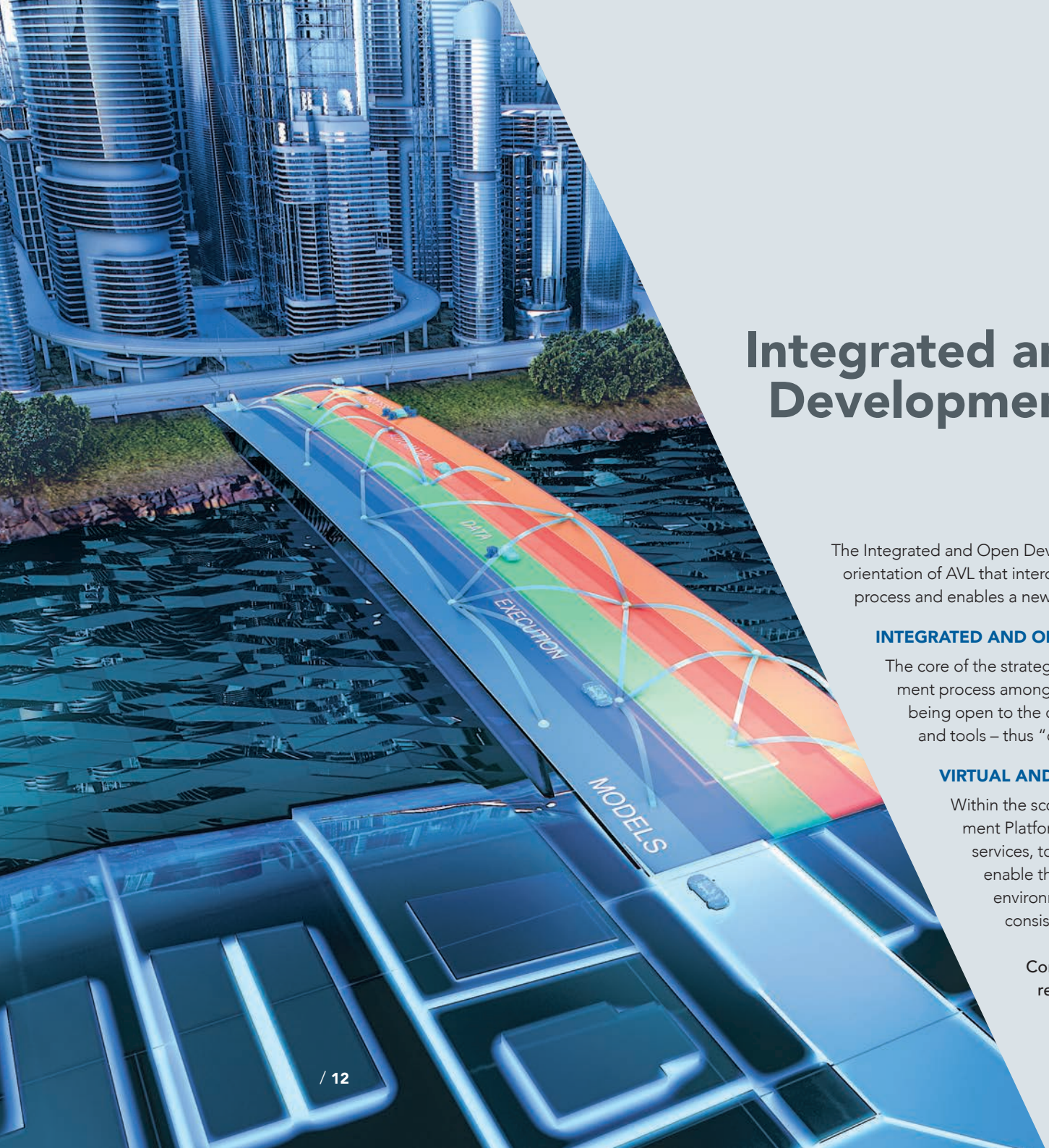
THE FUTURE OF POWERTRAIN DEVELOPMENT

Leading powertrain experts agree that the frontloading of development tasks and the networking of development environments offer huge potential for increasing development efficiency. With AVL's tried and tested model-based development approach you are able to seamlessly connect simulation with the physical world to speed up development. Models developed with AVL CRUISE to predict a future vehicle's performance can be directly used and refined with a real powertrain on an AVL PUMA Open™ testbed. This validated model of a lead variant can then be used again in the virtual world to start implementing base calibrations with AVL CAMEO™ for new and upcoming variants. This helps to dramatically speed up iterations in the development cycle. AVL is working hard to enable you to shift development tasks from vehicle to testbed to simulation: to do emission certification on a powertrain testbed – while the real vehicle body is still under development; to shift driveability development work from the road to the chassis dyno, reduce cost, increase development speed and shorten time-to-market. All this is a reality today, it is called AVL Active Frontloading. When developing the powertrain of the future, we are certain you can do it more efficiently with AVL.

Global Markets and Operations

NETWORKING R&D

While optimizing local development operations directly contributes to better local products, it does not necessarily lead to a global optimum efficiency in development. Differences in culture and mindset, hurdles in information exchange and almost incomparable test data can lead to parallel developments and other inefficiencies. It is a major task for any distributed R&D organization to overcome such issues and excel in aligned global operations. AVL can help you to do this. Our expertise in powertrain development and test operations guarantees that we understand the challenges you face. We are your partner for analyzing existing processes and can help you to transform your individual test facilities into a globally aligned network operation. We provide solutions that are available worldwide and strongly supported locally. This is achieved by means of a tested set of tools that can reliably generate and handle comparable test data on a global level, through methodologies designed to speed up the development of local variants, and by experts that share one goal: your success.



Integrated and Open Development Platform

The Integrated and Open Development Platform (IODP) is a strategic orientation of AVL that interconnects the whole vehicle development process and enables a new way of model-based development.

INTEGRATED AND OPEN

The core of the strategy is to connect all elements of the development process amongst each other – thus "integrated" – whilst being open to the customers' diverse landscape of methods and tools – thus "open".

VIRTUAL AND REAL

Within the scope of the Integrated and Open Development Platform, customers benefit from unique products, services, toolchains and know-how, all designed to enable the seamless integration of models, execution environments, data, automation and processes, consistently from the virtual to the real world.

Connect the best of the virtual and the real world.

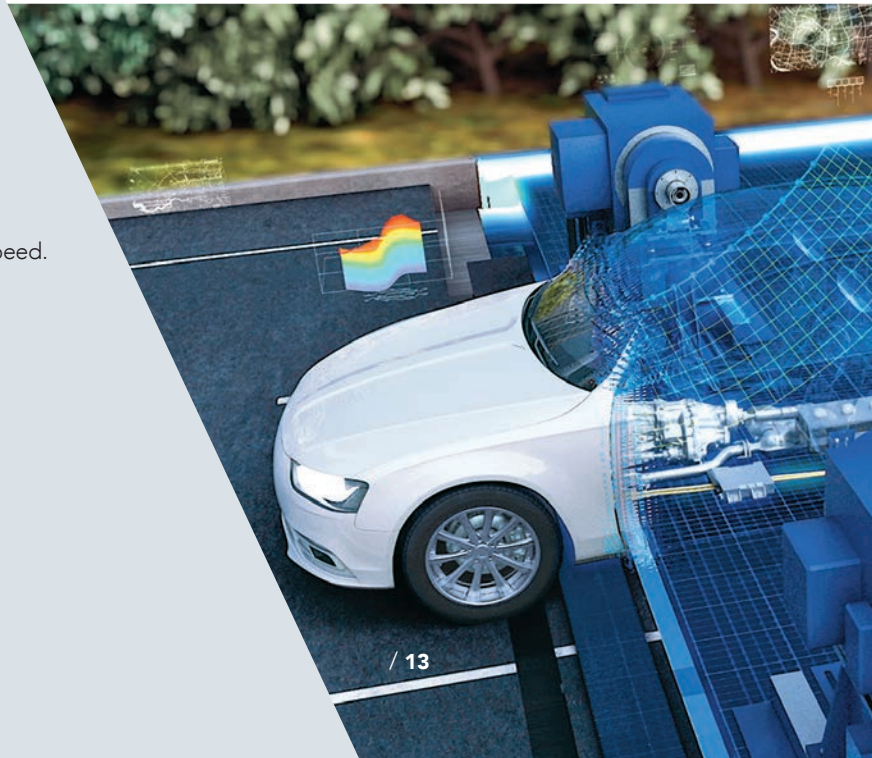
"TO MASTER CHALLENGES SUCH AS THE GROWING COMPLEXITY, VIRTUAL AND REAL WORLDS NEED TO BE INTERCONNECTED. THE INTEGRATED AND OPEN DEVELOPMENT PLATFORM IS AVL'S ANSWER TO MAKE THIS VISION A REALITY."

(Prof. Dr. h. c. Helmut List, CEO)

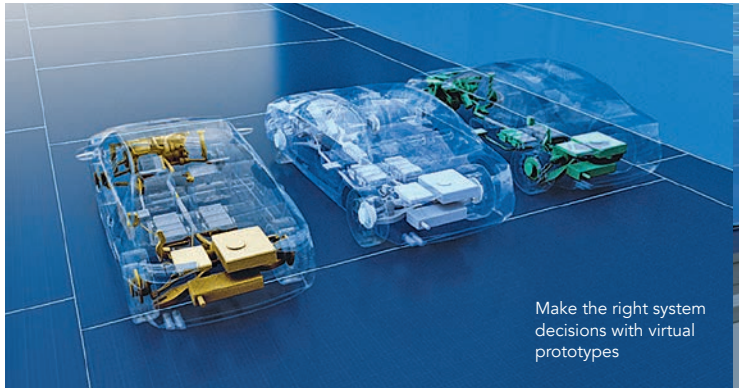
PRESERVING WHAT ALREADY EXISTS WHILE ENTERING A COMPLETELY NEW ERA OF DEVELOPMENT

In essence, this is the agenda behind AVL's Integrated and Open Development Platform (IODP). Within this strategy, AVL brings together what has always belonged together: physical testing and virtual prototyping. By combining and enhancing simulation models, execution environments, data storages, automation systems, capabilities and processes, the IODP enables the view on the overall system and the interaction of all its components at all times during the development process. Thus, an early, open and consistent functional integration is made possible allowing to master complexity and speed.

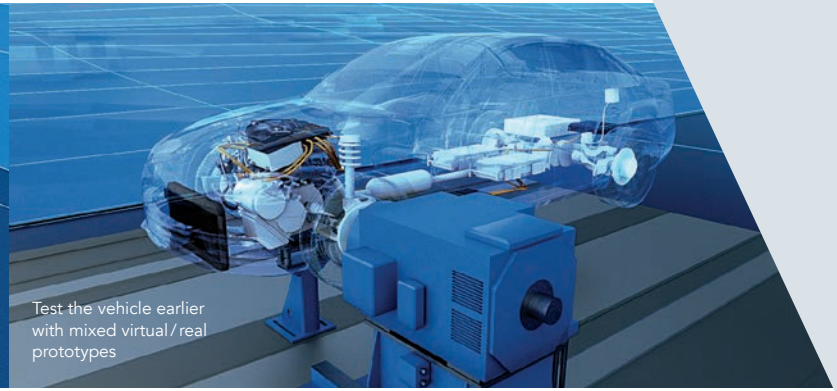
Make sound decisions rapidly with a comprehensive view of the whole.



Product News



Make the right system decisions with virtual prototypes



Test the vehicle earlier with mixed virtual / real prototypes

Model.CONNECT™

INTEGRATION OF VIRTUAL AND REAL COMPONENTS

WHAT'S THE CHALLENGE?

Early evaluation and validation of the entire system within the vehicle development process is the key to efficiently master the challenge of developing high-tech vehicles.

- Complex mechatronic systems require the interoperability of a large number of components and functions from various domains
- A high number of models, which were developed with specific simulation tools from different tool vendors and which have established themselves in the organization, must be connected
- Simulation and testing will become highly integrated through a model-based development approach

ENRICH YOUR REALITY

Model.CONNECT™, an integration product out of the Integrated and Open Development Platform, allows the implementation of model-based development by closing the gap between virtual and real worlds. This results in increased cost benefits and efficiency across your development process.

Model.CONNECT™ creates vehicle prototypes built with virtual and real components that are well-established in your development landscape. Being available at every vehicle development step, it is suitable for a broad range of powertrain and vehicle applications, e.g. integrated safety, vehicle dynamics, energy management, real driving emissions, advanced driver assistance systems.

Model.CONNECT™ also interconnects all AVL products and solutions.

WHAT'S UNIQUE?

Model.CONNECT™ is AVL's integration platform for setting up and executing system simulation models consisting of subsystem and component models from multiple model-authoring environments. Models can be integrated based on standardized interfaces, such as the Functional Mockup Interface (FMI), or based on specific interfaces with a wide range of well-known simulation tools.

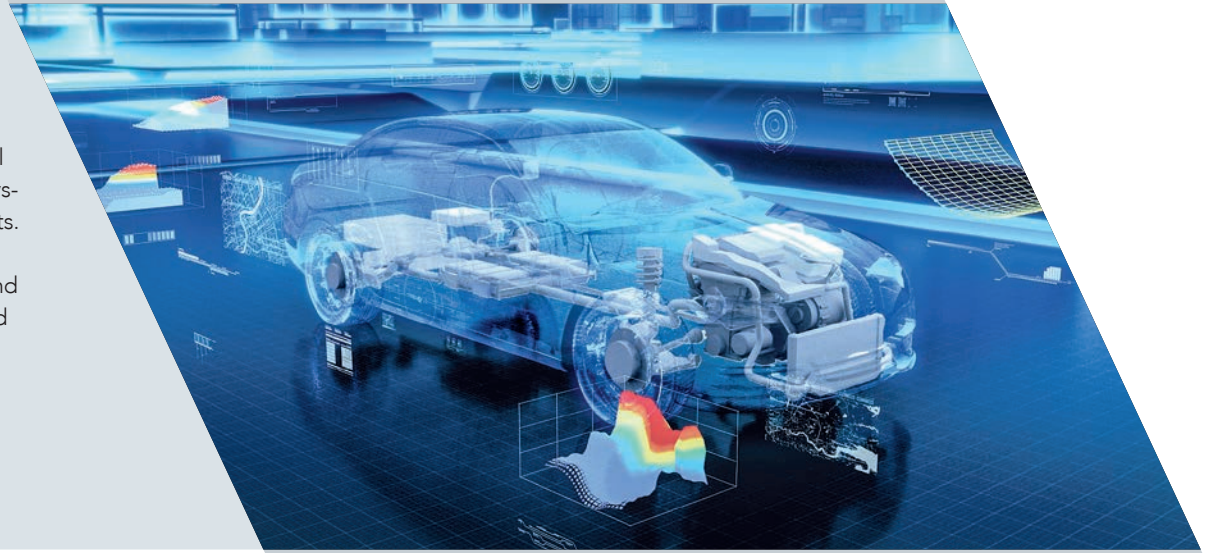
Model.CONNECT™ contains different "execution engines", which handle the complex communication between virtual and real components with highly sophisticated coupling algorithms. These coupling algorithms enable stable and energy-conserving coupling of simulation models and simulation models with and on real-time systems, consistently over the development process.

Furthermore, the user is supported in organizing simulation model variants. These variants may describe different configurations of systems as well as different testing scenarios and testing environments.

Model.CONNECT™ features powerful model parameterization and batch simulation capabilities, online monitoring, result analysis and reporting functionalities. Interfaces to various optimization tools enable design studies and optimizations.

AT A GLANCE

- Industry-leading co-simulation and coupling error compensation algorithms
- Connect on and with real-time systems to local and distributed co-simulation
- Support of more than 25 simulation tools for various domains (e.g. AVL CRUISE, MATLAB, ECS Kuli, Dymola, MSC Adams, LS-DYNA, AMESim, GT Power...)
- Supports Functional Mockup Units compliant with FMI standard 1.0 and 2.0 for co-simulation and model exchange
- Integration of models not supporting FMI
- Suitability for a broad range of powertrain and vehicle applications (e.g. integrated safety, vehicle dynamics, energy management…)
- Proven in customer projects for model integration – in the office, on HiLs and on testbeds



Product News

AVL TEAM SUITE™

Succes based on interplay

Today´s requirements in powertrain development move forward every second. Complex systems, shorter time to market and a global world of opportunities challenge you to be better, more flexible and faster than your competitors.

In this world, development tasks aren't stand-alone. And it is not just about how good single individuals or tools are…

… it is all about how well they work together.

POWERTRAIN DEVELOPMENT IS A TEAM SPORT

Our approach is to support your team play with an extendible group of highly skilled players. Software components that can be stably and flexibly combined into systems that assist you in solving your testing tasks in powertrain development.

Improved collaboration, outstanding usability and open interfaces to adapt and enlarge your team – in addition to your existing players.

The comprehensive portfolio coupled with many years of expert knowledge available within AVL guarantee an effective, stress-free and comfortable workplace through tailored solutions. The AVL Team SUITE™ is an open system of measurement and test system software in the area of automation, control, simulation, calibration, emission testing, certification, data management- and analysis and test process management that acts as a team, fielding individual players or resources according to the current challenge: and this with maximum performance, simple operation and high customization. Moreover, the individual players in the AVL Team SUITE™ support current standards such as ASAM-ODS or ASAM-ACI. A wide range of open interfaces enables the integration of measurement and test devices, and 3rd party products.

AVL TEAM SUITE™ AND IT´S MEMBERS:

- AVL PUMA Open 2™
- AVL EMCON 6™
- AVL LYNX 2™
- AVL SANTORIN MX 2™
- AVL TFMS 1™
- AVL CAMEO 4™
- AVL CRETA 4™
- AVL CONCERTO 5™
- AVL-DRIVE 4™
- AVL VSM 4™
- AVL ARTE.Lab 5™
- AVL InMotion 5™
- AVL IndiCom 2™
- AVL TESTGATE 1™
- AVL iGEM 2™

… and more joining soon

Product News

AVL iGEM 2™

Emission testing, simplified

The new generation of AVL iGEM 2™ offers a quantum leap in emission test automation. The new application fully utilizes the powerful platform products AVL PUMA Open 2™ and AVL CONCERTO 5™ and takes you to new levels of reliability and flexibility. All that is combined with outstanding usability, which reduces training and maintenance efforts.

QUICK FACTS

- Most efficient use of test equipment
- Unique, easy-to-use parameterization concept
- Powerful and open toolkit for R&D and certification

Further product information can be found on page 220

AVL eSpares plus™

Easy. Connected. Transparent. – A smarter way to find and order the spare part you need.

AVL eSpares plus™ is an easy-to-use web shop featuring all of AVL's standard spare parts. You can easily identify parts, check their availability and place and track orders online at any time. Standard parts ordered via AVL eSpares plus™ are typically shipped within 24 hours.

BENEFITS AT A GLANCE

After 14 years of successful utilization, our well-established part identification platform has been updated and offers new features:

- A new intuitive look & feel
- Advanced search functions
- Structured technical details provided by eCl@ss
- Media galleries with high quality pictures, including a zoom-viewer
- User manuals and technical descriptions
- Personalized favorite lists

Further information on AVL Spare Parts Management can be found on page 246

AVL E-MOTOR EMULATOR

High-technology for inverter testing

The AVL E-Motor Emulator (E-ME) is the core component of a power Hardware-in-the-Loop test environment for inverters and revolutionizes the test process in product development and EOL tests. A real e-motor is not required; high-dynamic processes can be analyzed and reproduced in a safe environment at any time without any mechanical restrictions.

BENEFITS AT A GLANCE

- Cost reduction by reducing development time significantly
- Highly dynamic power electronics enable a broad test field in all development tasks
- All in one: various motor types and load profiles are available
- High test quality thanks to numerically correct representation
- Comprehensive fault stimulation for testing functional safety criteria

Further product information can be found on page 62

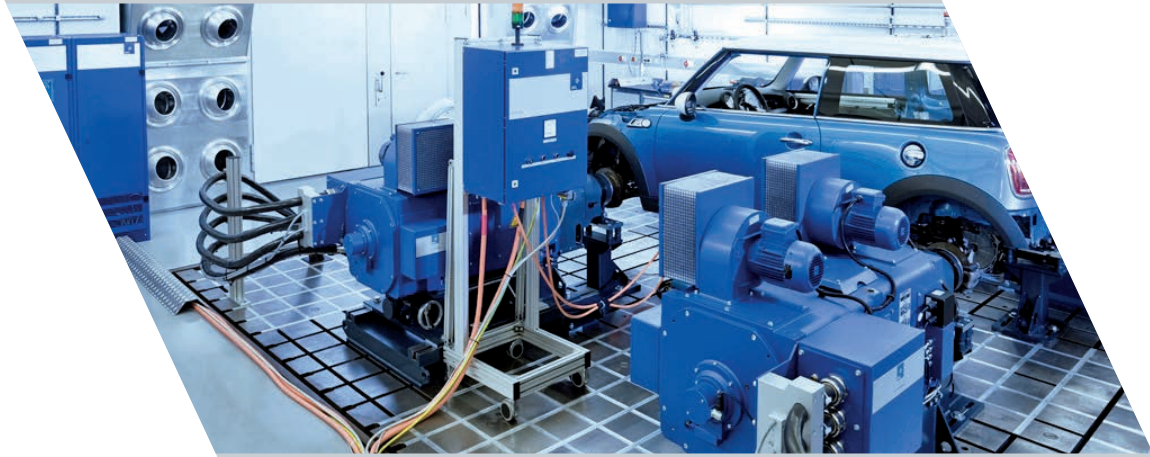
AVL E-INTEGRATION TEST SYSTEMS

The AVL E-Integration Test System allows the testing and validation of all electrical high-voltage components for their functionality and reliability. The use of emulators leads to a considerable increase of the test system's efficiency.

BENEFITS AT A GLANCE

- Shorter development times and increased test efficiency
- High productivity due to automized test routines and automated data evaluation via test reports
- Enhanced flexibility thanks to fully automated switching between real and emulated components in accordance with safety regulations

Further product information can be found on page 64



Product News

AVL CONCERTO 5™
Experience the harmony

The brand new generation of AVL CONCERTO 5™, a generic data processing platform, specializes on visualization, analysis and reporting of simulation and measurement data. For specific applications, AVL CONCERTO 5™ provides individual solutions: Pro Apps and toolboxes.

QUICK FACTS

- Highest data performance, intuitive data search and interactive calculations
- Consistent pre- and post-processing
- What-You-See-Is-What-You-Get reporting
- Fully automated evaluations and integration of third-party algorithms

Further product information can be found on page 241

AVL SANTORIN MX 2™
Unleash data power

AVL SANTORIN MX 2™ is an intelligent measurement data management system, based on ASAM-ODS, which helps our customers to handle their growing data volumes.

QUICK FACTS

- Central and intelligent storage of heterogeneous data from different test facilities or locations
- Easy, fast and secure data access to fully harmonized data with AVL NAVIGATOR
- Automated server-based data processing and analysis
- Seamless integration of data analysis tools such as AVL CONCERTO 5™

Further product information can be found on page 240

AVL PUMA Open 2™

The ease of automation

The new generation of AVL PUMA Open 2™ offers excep-
levels of improvement in operability. An outstanding user
perience, conceived for new and experienced users, is just one
the highlights. Efficient parameter configuration and immediate
validation enables the relocation of testbed work into the office.
As a result of this, testbed downtime can be reduced and costs
lowered.

An even deeper integration and merging of indicating systems and calibration tools into the AVL PUMA Open 2™ automation platform permits significantly more efficient execution of modern calibration tasks.

The automation system AVL PUMA Open 2™ remains as reliable and stable as it has been for many years, despite its enhanced functionality.

QUICK FACTS

- Cutting edge usability for new and experienced users
- More productive testbed time due to the possibility to edit and validate parameters upfront in the office
- Integrated diagnostic features lead to significant increase of runtime and substantial reduction of useless data
- Powerful interfaces between AVL CAMEO 3™ – AVL PUMA Open 2™ – AVL IndiCom 2™ permit the execution of transient and dynamic calibration methods
- AVL ActiveLink™: automatic and fast integration of measurement devices

Further product information can be found on page 216

Product News

AVL CONCERTO 5™ Road Converter

Road-to-rig in just one click. This customizable AVL CONCERTO 5™ Pro App provides an analysis and workflow for test run generation out of real or virtual test drives. It's as easy as turning on the lights.

QUICK FACTS

- Bridges the gap between road, lab and math
- Includes trip analysis (e.g. RDE conformity)
- Output formats: AVL iGEM™, AVL PUMA Open™, AVL ISAC™, AVL VSM™, AVL InMotion™/CarMaker and customer-specific data formats

Further information on the new generation of AVL CONCERTO 5™ can be found on page 242

AVL InMotion 5™

Test driving starts now

The new AVL InMotion 5™ is a system-driven test solution that supports OEMs and suppliers to bring road conditions back to the testbed using the benefits of model-based development.

From road-to-rig-to-report: AVL InMotion 5™ has what it takes to make your development story a success. It maps the vehicle DNA directly into your test processes.

QUICK FACTS

- Now compatible with the latest release of IPG CarMaker 5®
- Even more robust, reliable and industrialized interfaces with new testbed integration packages
- Supports all AVL testbeds, including engine, powertrain, chassis, e-motor, battery and fuel-cell

Further product information can be found on page 86

AVL CAMEO 4™

Makes complexity easy

AVL CAMEO 4™ – much more than DoE! With the new generation of AVL CAMEO™ the road for the future is set and prepared. AVL CAMEO 4™ offers a complete solution for powertrain testing and optimization demanded by the RDE legislation.

QUICK FACTS

- One software environment to cover the whole calibration workflow
- Fully-automated and self-adaptive test runs to ensure highest efficiency
- Optional programming interfaces for user-specific solutions and adaptions

Further product information can be found on page 226

AVL CONCERTO 5™ Map Expert

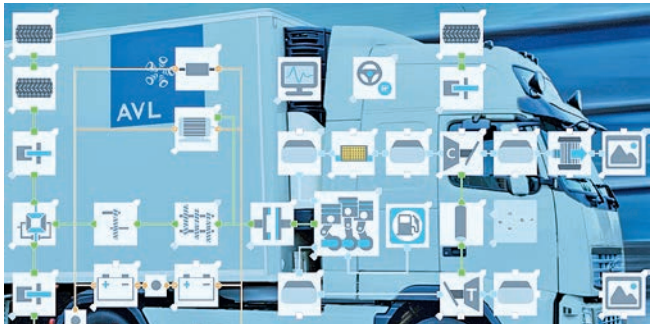
It takes only one click from measured, calculated or simulated data to calibrated ECU labels. AVL CONCERTO 5™ Map Expert combines the strength of data processing and visualization with outstanding ECU label handling and calculation.

QUICK FACTS

- Interactive xCU map editing
- Automatic xCU map calculation

Further information on the new generation of AVL CONCERTO 5™ can be found on page 242

Product News



AVL CRUISE™ M

AVL's multi-disciplinary system simulation tool AVL CRUISE™ M offers a new extension with focus on electrification. It enables the integration of electrical components, as well as modeling and simulation of any vehicle configuration such as conventional, HEV and pure EV.

QUICK FACTS

- Vehicle Energy Management System (VEMS) development
- Arbitrary number of standalone or interconnected electric networks
- Generic (resistor, capacitor, etc.) and dedicated (battery, e-machine) components
- Serial and parallel connections for free definable e-network configuration

Further product information can be found on page 204

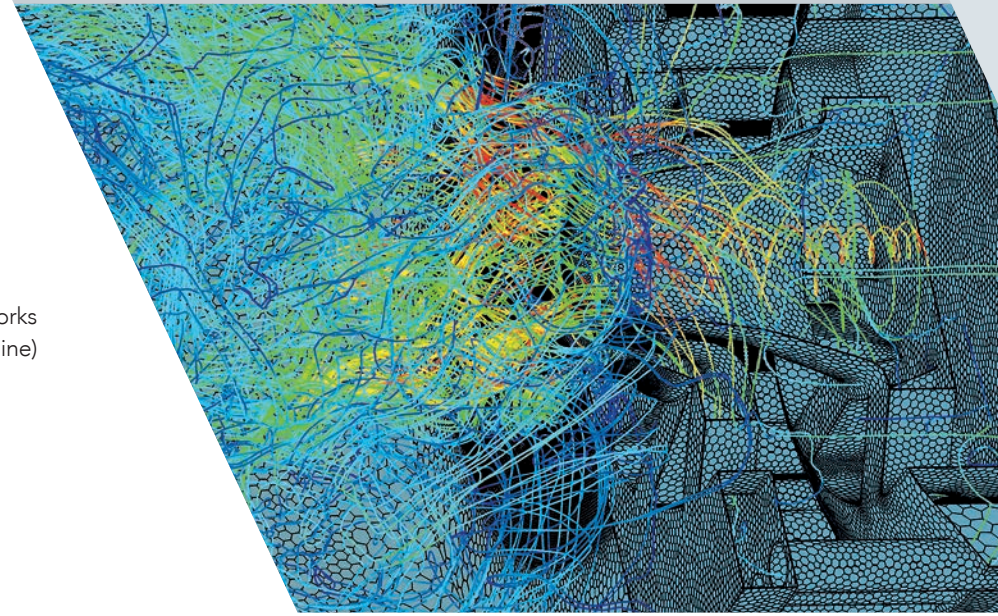
AVL TABKIN™

AVL TABKIN™ pre-calculates combustion chemistry and efficiently maps the results to the flow field computed with CFD.

QUICK FACTS

- Improved speed and predictivity of combustion CFD simulations
- 50 % reduction of cost-per-useful-answer (est.)
- Reduced number of hardware prototypes and shorter time-to-market

Further product information can be found on page 212



APC^{plus} – NOW AVL CPC INSIDE

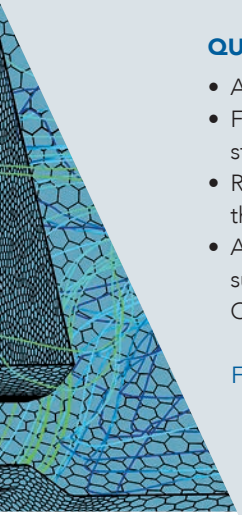
Count on it

APC^{plus} – The industry standard for particle number measurement is now improved with the AVL Condensation Particle Counter (AVL CPC). The new core sensor AVL CPC with enhanced functionality further increases APC^{plus} performance by optimizing maintenance and calibration costs and service lead times at the same time.

QUICK FACTS

- APC^{plus} further enhanced with the new core sensor AVL CPC
- Fulfills 100 % of current legislation with highest calibration standards (ISO 17025)
- Ready for high-end development requirements to be ahead of the RDE challenge
- AVL ActiveLink™ for a more efficient and flexible use of AVL measurement instruments, especially in combination with AVL PUMA Open 2™ testbed automation systems

Further product information can be found on page 176



MSS^{plus} – AVL MICRO SOOT SENSOR

The new generation Micro Soot Sensor offers several improvements along with new features. With the support of customer feedback, latest application requirements and the experience gained over the last decade, it was possible to develop the new MSS^{plus} with an enhanced functionality and reduced maintenance effort meeting the steadily increasing testbed demands.

QUICK FACTS

- Transient measurement of soot concentration [mg/m^3]
- Sensitive to soot (not interference to other components)
- High sensitivity (resolution 0.01 µg/m^3, detection limit 1 µg/m^3)
- Wide measuring range (1 – 1000 mg/m^3)
- AVL ActiveLink™ for a more efficient and flexible use of AVL measurement instruments, especially in combination with AVL PUMA Open 2™ testbed automation systems

Further product information can be found on page 178

Product News

AVL PN PEMS iS

Your Fast Track to RDE Success

The brand-new AVL M.O.V.E PN PEMS iS is the latest member of the industry standard M.O.V.E iS for RDE measurements on light duty vehicles. The combination of the best available on-board sensor technology and the robust dilution system brings you the highest efficiency and reliability for your RDE challenge.

QUICK FACTS

- Seamless integration into the M.O.V.E iS platform
- Advanced Diffusion Charger technology customized for PN on-board measurements
- Maximum instrument utilization due to the extended operating range
- Reliable operation due to the high reproducibility and stability of the measured value

Further product information can be found on page 186

AVL X-ion™

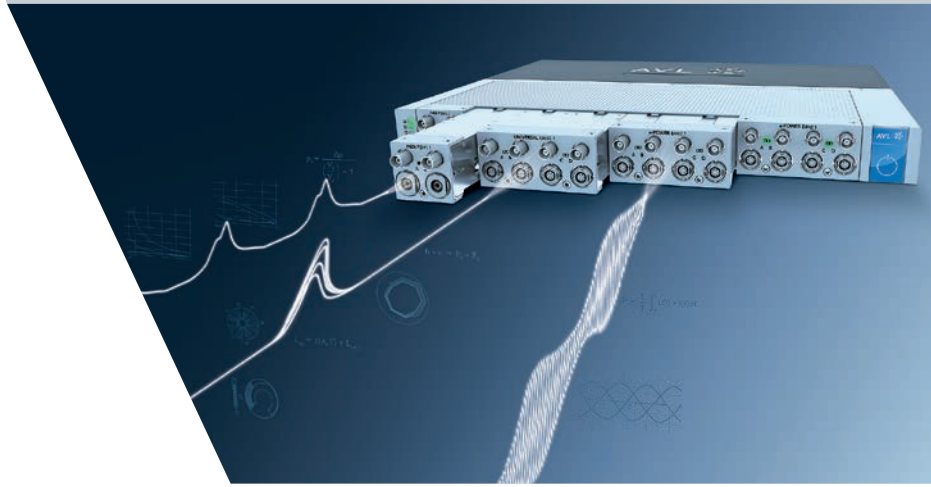
Adapts. Acquires. Inspires.

AVL X-ion™ is the new high-speed data acquisition platform dedicated to powertrain development. AVL X-ion™ is a modular acquisition system that can be easily adapted to different units under test and test environments. It combines AVL's know-how and expertise in several application areas, namely indicating/optical combustion analysis, and e-Power analysis.

QUICK FACTS

- Unique modular concept (swappable application-oriented X-FEM front-end modules)
- Increased efficiency based on reduced number of tools in the test facility & in the office
- Stress-free transition to electrification: Investigate combustion engines & e-motors or hybrid powertrains
- Powered by AVL IndiCom™

Further product information can be found on page 158



AVL EPOS™

Predictably Powerful

AVL EPOS™ combines AVL's class-leading measurement technology with AVL's outstanding expertise in engineering of large engines. AVL EPOS™ is a unique expert condition monitoring system for large engines in the field, providing valuable information on imminent malfunctions or failures of the engine. Available also for the simultaneous monitoring of multiple engines and fleets.

AVL EPOS™ NO_x MODULE

AVL EPOS™ NO_x module is the world's first model-based expert system for emission monitoring (currently covering NO_x, SO_x and CO_2). AVL's approach is to determine the NO_x emission with the help of a physical model based on the cylinder pressure measurement – therefore, avoiding the installation of delicate, costly and often unreliable emission analyzers.

AVL EPOS™ supports you to

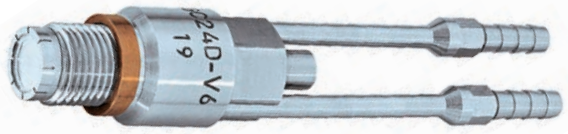
- Increase engine efficiency and reduce fuel consumption
- Prevent engine damages and downtime
- Introduce condition based maintenance
- Monitor engine emissions (AVL EPOS™ NO_x Module)

QUICK FACTS

- Engine condition monitoring system based on cylinder pressure measurement (possible integration of additional sensors, signals and third-party systems)
- Applicable to all kind of large engines (2- and 4-stroke, all fuel types)
- Customer specific combination of software and measurement hardware components (sensors, data acquisition hardware)

Further product information can be found on page 162

Product News



WATER-COOLED CYLINDER PRESSURE SENSOR GC24D

The water-cooled cylinder pressure sensor GC24D completes the product family of M8 sensors together with the well-established sensor GU24D. The watercooled pressure sensor can also be used without water cooling but the setup is optimized for usage with water cooling to achieve excellent thermodynamic results.

QUICK FACTS

- High sensitivity and best thermodynamic properties due to the integrated water cooling
- Applicable up to 400 °C without water cooling because of the piezoelectric material GaPO4
- No damaging of the cooling nipples by the use of a hexagon mounting tool
- Compatibility with all typical mounting bores of size M8

Further product information can be found on page 156

NEW MEASUREMENT SPARK PLUG ZI22

Enables an easy measurement of combustion pressure even in engines with the highest ignition voltage demands. The piezoelectric pressure sensor integrated in the M10 spark plug provides improved precision comparable with directly installed cylinder pressure sensors and completes the family of measurement spark plugs together with ZI33 and ZI45.

QUICK FACTS

- Emulation of the original ignition function due to high electric strength of 45 kV and minimum eccentricity of the insulator
- Availability of different sealings, thread lengths, heat ranges and spark protrusions
- Use of a high-precision pressure sensor without additional mechanical changes to the cylinder head
- Adjustment of the spark plug to the original installation with different ignition coil connectors and defined electrode position

Further product information can be found on page 156

AVL E-STORAGE BTE™

Join us in exploring new e-horizons

The new AVL E-STORAGE BTE™ is a scalable system that can be used as a battery tester and battery emulator (simulator) to validate and test batteries as well as e-motors and inverters in all development phases. The AVL E-STORAGE BTE™ can precisely emulate a real-world battery and follow a predefined load profile to expose the device under test to real-world operating conditions.

QUICK FACTS

- Outstanding measurement and control accuracy combined with a selectable dynamic performance to expose the devices to real operating conditions
- Highly reproducible dynamic charge and discharge load profiles with synchronous recording of system-relevant variables
- Optimized testing by using different battery models
- Safe and secure exploration of the components' limits

Further product information can be found on page 57

AVL e-POWER ANALYSIS SYSTEM

e-miles ahead

The AVL e-Power Analysis System is a modular and powerful solution with a high-speed 16-channel data acquisition and processing unit for AC and DC voltages. The system is based on the new AVL X-ion acquisiton platform and designed for measurement and analysis of pure electric as well as hybrid powertrains.

QUICK FACTS

- Designed for testbed environments: modular and flexible
- Easy set-up, Plug & Play, user-friendly operation
- Pure electric or hybrid powertrains: one system serves all

Further product information can be found on page 66

Why Choose AVL as a Simulation Partner?

HIGH-FIDELITY SYSTEM SIMULATION MODELS

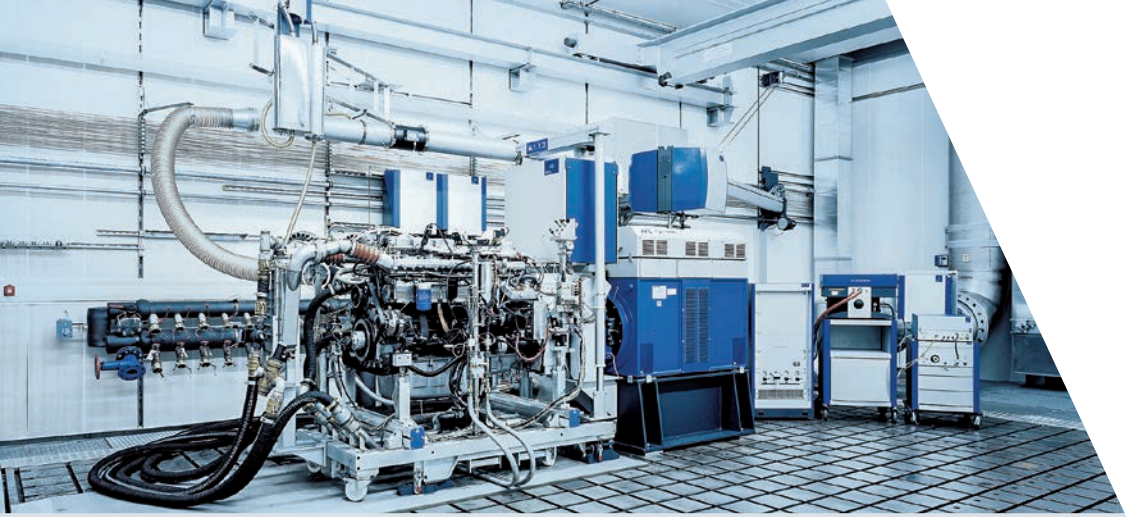
AVL provides fully interactive and integrated tool chains including AVL's own and third-party software tools. To obtain the best results throughout the development process, we created consistent simulation models for all of the development phases: fast simulation models together with DoE and optimization for the concept phase, very accurate simulation models for the design and development phase and real-time simulation models parameterized by highly accurate simulation models for engine and powertrain calibration.

POWERTRAIN ENGINEERING INSIDE

AVL's extensive engineering expertise is the strong basis for all of our software tools and methods. By analyzing the powertrain development processes, we have defined software application tasks which cover all of the aspects of powertrain development. Due to the complexity of these tasks, we place the emphasis on application-focused workflows which guide the user through to practical engineering solutions. Simulation results are displayed in the same easy-to-interpret way as test results.

CLOSE LINK TO TESTING

AVL's software tools are closely linked to and compatible with AVL's instrumentation and measurement tools. It is becoming more and more important to provide the development engineer with simulation results directly on the testbed based on test results. This leads to more insight into the powertrain, and subsequently a shorter test cycle.

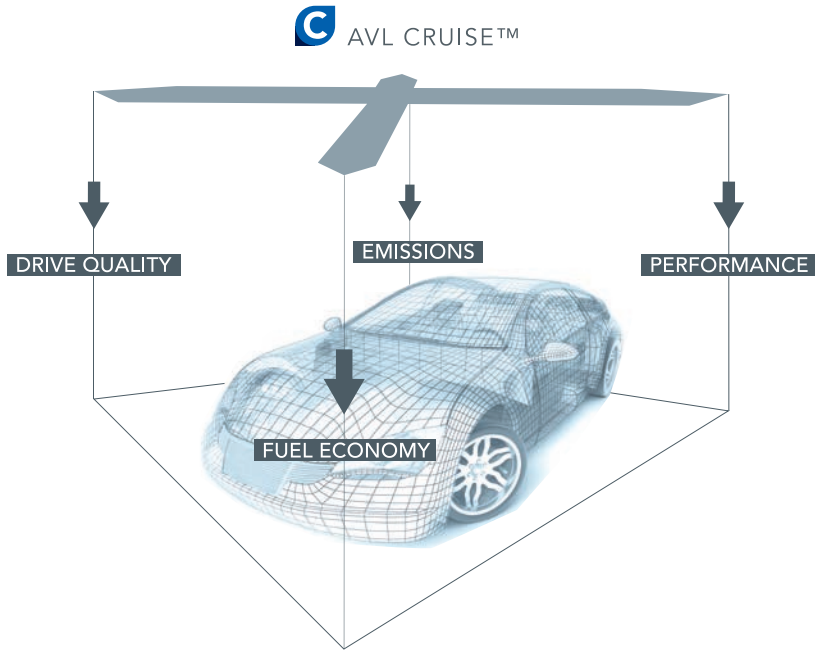


A KALEIDOSCOPE OF SIMULATION POSSIBILITIES

AVL's simulation software development is based on the unique environment available from AVL. Powertrain Engineering, Instrumentation and Test Systems and Advanced Simulation Technologies are the three pillars of the company which provide a huge reservoir of synergies. AVL's simulation software development is driven by five core values that position AVL Advanced Simulation Technologies as a strong partner for all of your calculation tasks.

- High-fidelity system simulation models
- Seamless simulation workflows
- Powertrain engineering inside
- Close link to testing
- Simulation support worldwide

HIGH-FIDELITY SYSTEM SIMULATION MODELS
SEAMLESS SIMULATION WORKFLOWS



Vehicle System

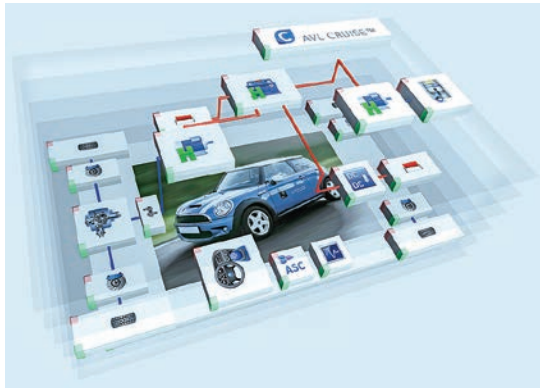
AVL CRUISE™ is featured industry-wide as the most mature and advanced system-level vehicle powertrain simulation package. It is able to handle the current and future complexity of powertrain structures with an extremely flexible but nevertheless user-friendly and easy-to-use concept.

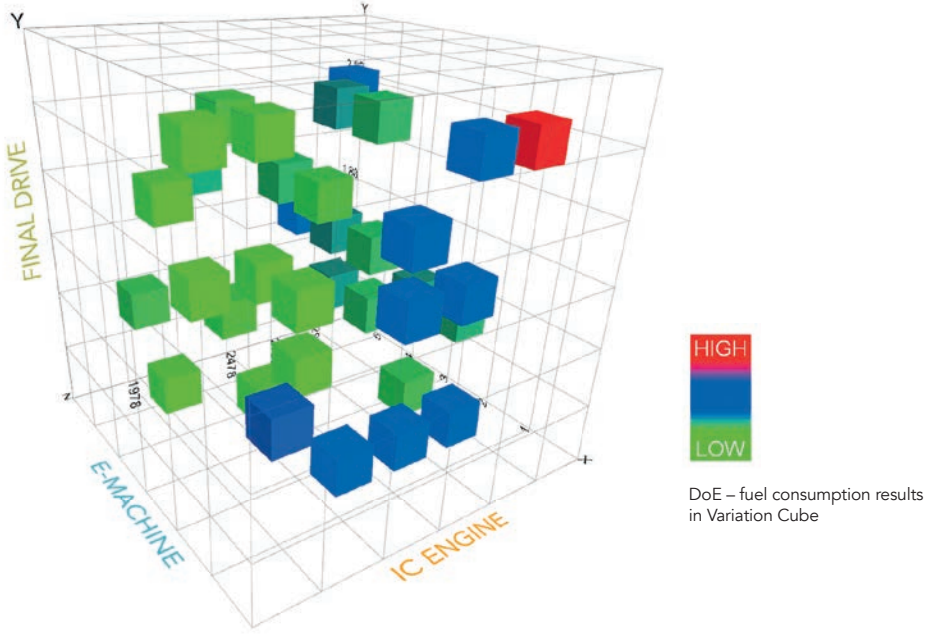
FROM CONCEPT STUDIES TO CALIBRATION AND TESTING

AVL CRUISE™ offers all of the flexibility needed to build up a system model, which can be easily adjusted to all application requirements through the entire powertrain development cycle. It supports everyday tasks in vehicle system and driveline analysis throughout all of the development phases, from concept planning and design in the office to calibration and verification on hardware test systems. Starting with only a few input parameters in the early stages, the maturity of the model grows during the development process according to the continuously increasing simulation needs in calibration. Model re-use in consecutive or iterative development approaches ensures consistent decision processes and saves valuable engineering time by keeping the focus on the targets:

- Optimizing vehicle fuel efficiency
- Reducing emissions
- Improving vehicle performance and driveability

Range Extender Vehicle Simulation Model





DoE – fuel consumption results in Variation Cube

MANAGING CHANGES WITH EFFORTLESS EASE

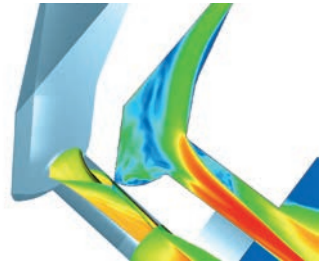
Today's multi-system vehicle powertrain concepts are pushing the complexity of system simulation models to the extreme. The highly adaptable system/subsystem structure of AVL CRUISE™ allows drivetrain concepts to be changed by a mouse click. Vehicle hybridization and model configuration changes to fit application needs in different phases are carried out within minutes, allowing more time to be spent on the engineering, calibration and testing tasks, without having to deal with mathematical equations and coding.

SOLUTION ORIENTED OPEN CONCEPT IN ALL TASKS

AVL CRUISE™ is more than just a vehicle simulation model. Streamlined workflows are realized for all kinds of parameter optimization, component matching and subsystem integration. The modular structure –with its wide range of interfaces to other simulation tools, ready-to-use analysis tasks and data management capabilities – are only a few of the key reasons why a growing number of leading OEMs and their suppliers have chosen to establish AVL CRUISE™ as their powertrain integration platform on a system level.

Heavy Duty Long Haul Truck Model

Injection Nozzle Flow, Cavitation and Erosion

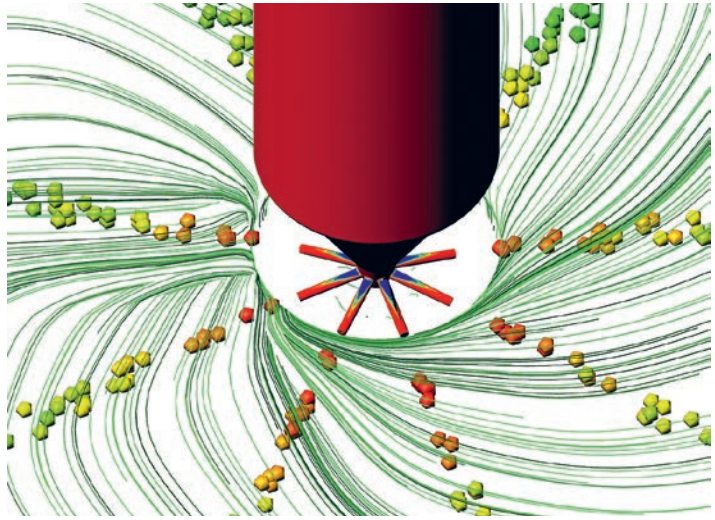


LES applied on a realistic diesel injector featuring three-phase flow and needle movement

AVL BOOST™ HYDSIM and AVL FIRE™ offer indispensable capabilities when it comes to the development and optimization of injection nozzles. While one-dimensional AVL BOOST™ HYDSIM models typically reflect the complete injection system from fuel tank to the injector, AVL FIRE™ focuses on the three-dimensional calculation of fluid flow in the injection nozzle.

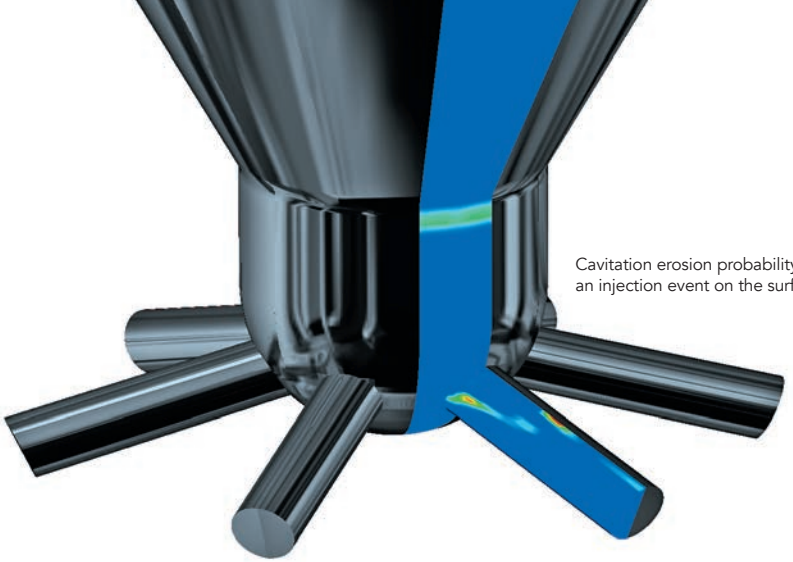
In an early engine design stage, fuel injection details, such as needle lift and inlet pressure level are not known. In a virtual prototyping environment, coupled 1D/3D fuel injection simulations are extremely valuable. While AVL BOOST™ HYDSIM provides the information about longitudinal and radial needle displacements as well as pressure levels, AVL FIRE™ improves the accuracy of the 1D solution by providing pressure forces acting on the needle and local flow rates.

Cavitating internal nozzle flow applied as input for combusting in-cylinder flow



THE TRUTH IS MULTI-PHASE

Modern injection systems make use of high pump pressures to enhance droplet break-up and mixture formation in the combustion chamber, targeting high performance, high efficiency and low engine-out emissions. The resulting huge pressure differences between the fuel supply line and the combustion chamber lead to a phase change from liquid fuel to fuel vapor. While the vapor reduces the effective orifice outlet area and, therefore, the amount of liquid fuel transported into the combustion chamber during a single injection event, it also affects the conditions that determine the release of the fuel droplets furtherdown the nozzle orifices. To accurately account for the effect of cavitation on fuel penetration and propagation in the combustion chamber, AVL FIRE™ offers advanced cavitation modeling. This capability enables accurate prediction of transient discharge rates and detailed insight into the instationary flow conditions in the nozzle orifice exit areas.



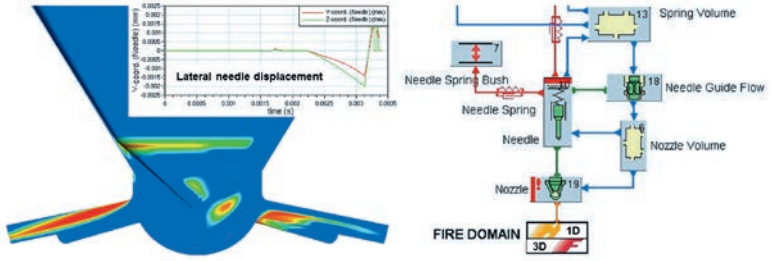
Cavitation erosion probability averaged over an injection event on the surface of the spray hole

NOZZLE INTERFACE

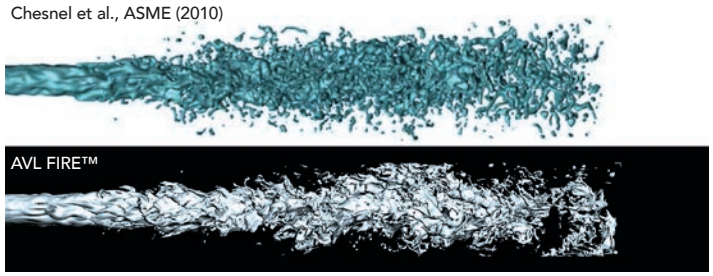
The flow conditions predicted at the nozzle orifice exit plane are recorded during the AVL FIRE™ injector flow simulation and serve as input for AVL FIRE™ in-cylinder mixture formation and combustion simulations. That way, a perfect correlation can be established between the flow conditions inside the nozzle and the conditions under which fuel enters the combustion chamber. This correaltion also takes into account the non-uniform flow out of the injector.

EROSION MODELING

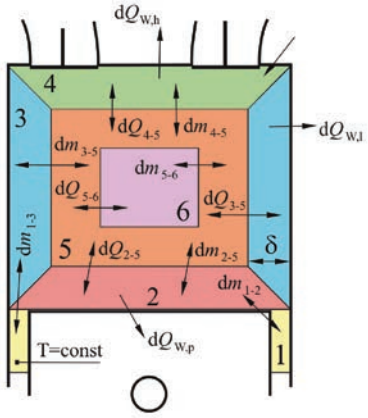
Cavitation in injection nozzles often causes material erosion and is strongly related to the durability of injection components. Prediction of erosion probability helps to define the design parameters of the nozzle in order to decrease the flow aggressiveness in critical areas and assure the best possible break-up of the fuel discharged into the combustion chamber or into the port.



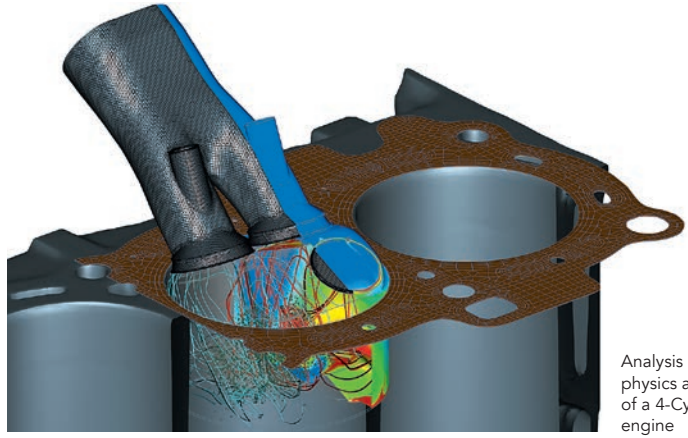
Coupling of AVL BOOST™ HYDSIM and AVL FIRE™ allowing for prediction of lateral needle forces and displacements



Application of LES together with the Volume-of-Fluid surface tracking method to capture spray propagation details



Multi zone combustion modeling in AVL BOOST™



Analysis of in-cylinder physics and chemistry of a 4-Cylinder gasoline engine

Combustion and Emissions

AVL BOOST™ and AVL FIRE™ are the industry's prime choice when reliable results are needed for engine thermodynamics and combustion/emission development. The intelligent integration of the two software tools facilitates solutions for complex tasks early in the development phase and unsurpassable accuracy during the detailed design phase.

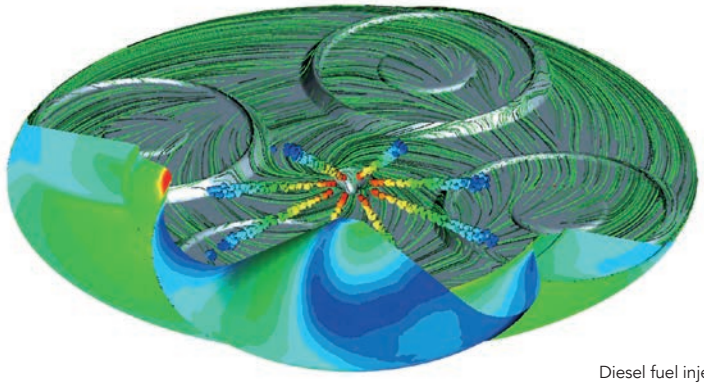
SPEEDING UP YOUR PROCESSES

The time required to create moving meshes for complex geometries of modern IC engines is reduced to merely hours with AVL FIRE™'s highly specialized, automated and parallelized pre-processing tool FAME™ Engine Plus. Key features include hexahedron dominated grids, local grid refinements and user-controlled constant grid boundary layer supporting accurate heat transfer calculation.

REFLECTING REALITY

AVL FIRE™ offers validated in-depth modeling of fuel sprays, ignition, combustion and emission modeling. Spray modeling includes primary and secondary break-up, droplet/droplet as well as droplet/wall interaction. Both spray and wall film models are capable of handling multi-component fuels, surrogate fuels and fuel blends. Combustion modeling is performed by deploying either intrinsic multi-zone models or by solving detailed reaction schemes using the chemistry solver integrated into AVL FIRE™. A very exciting new approach for predictive combustion simulation is offered by AVL TABKIN™. AVL TABKIN™ pre-calculates combustion chemistry and stores the result in reference tables. These tables are accessed and evaluated during the AVL FIRE™ in-cylinder flow simulation. In comparison to conventional approaches, using AVL TABKIN™ results in extremely short simulation times, even when using extremely large reaction mechanisms. Additionally, the results' accuracy is improved.

The AVL FIRE™ main program supports the accurate simulation of IC Engine in-cylinder phenomena by offering advanced modeling capabilities for turbulence (k-z-ζ, PANS, LES), wall treatment and heat transfer.



Diesel fuel injection

FEWER EXPERIMENTS, MORE CREATIVITY

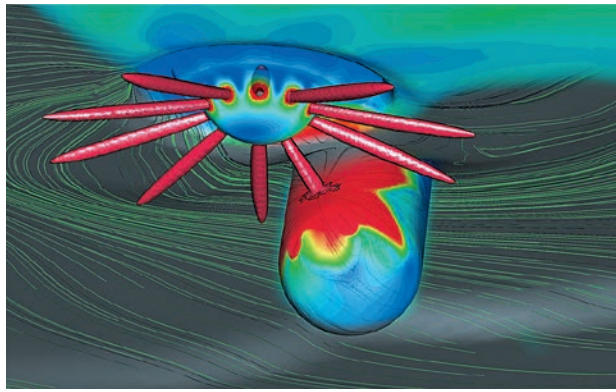
The capabilities offered by AVL BOOST™ and AVL FIRE™ enable accurate simulation of all relevant physics and chemistry in internal combustion engines and engine components, thus allowing the virtual testing of a large number of design possibilities while reducing the need for costly and time-consuming experiments.

1D/3D COUPLED SOLUTIONS

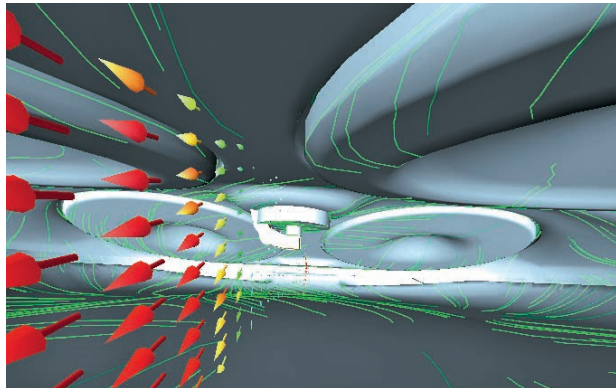
For highest accuracy and highest performance AVL BOOST™ and AVL FIRE™ can be executed as co-simulations exchanging pressure, temperature and species concentrations at the interface boundaries. That way it is possible to consider 3D geometrical effects in an otherwise 1D Model and to immediately see the impact of design changes on the overall system performance. Common 1D/3D applications include intake and exhaust manifold development, optimization of exhaust gas return and combustion/ emission prediction.

SYNERGIES BETWEEN SIMULATION AND TESTING

The direct integration of AVL BOOST™ in the testing environment allows you to calculate additional results online during the engine test – a tremendous timesaving benefit valued especially when being engaged in the most complex projects.



Gas injection onto a glow plug



Flow pattern in a gasoline engine

Turbocharging

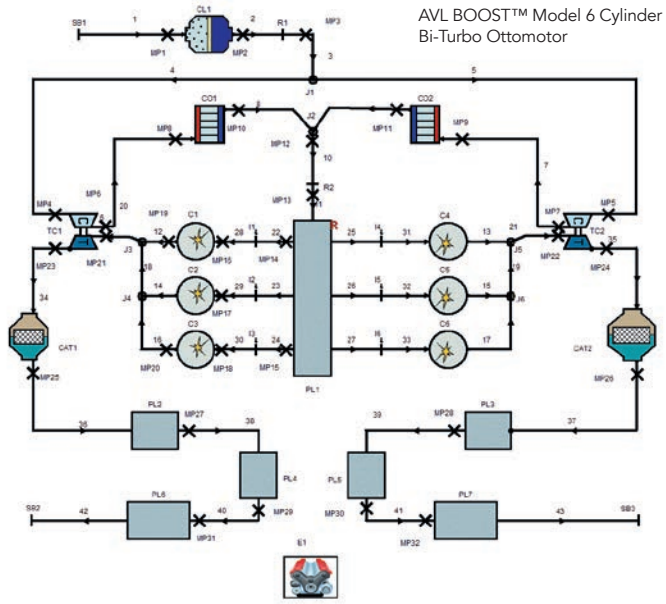
AVL BOOST™, AVL EXCITE™ and AVL FIRE™ allow advanced compressor and turbine component design and turbocharger matching as part of an overall engine system. This integrated approach accommodates the complex interaction between the system components to create the most effective low emission engines possible.

ENGINE PERFORMANCE AND EMISSIONS

CO_2 reduction and energy efficiency are the main technology drivers for pressure-charged engines. Turbocharging allows car manufacturers to reduce their engine sizes and emissions while continuing to deliver the power and performance customers demand.

PRESSURE WAVE SUPERCHARGER

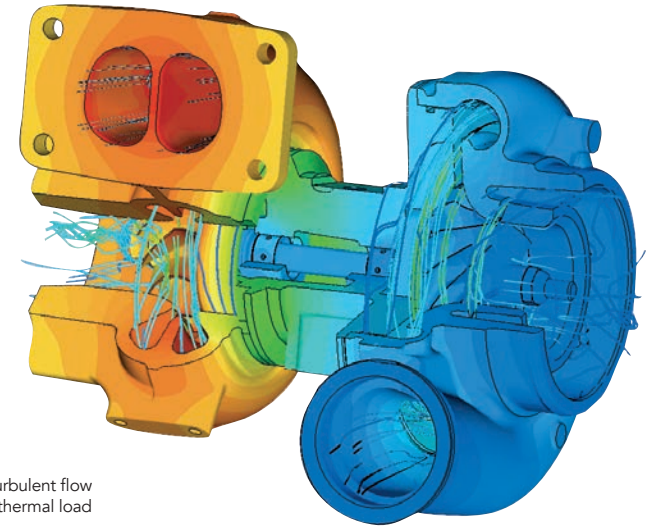
In contrast to standard pressure charging devices, the pressure wave supercharger process is a direct gas-dynamic transfer of exhaust gas energy to the fresh charge in the channels of the rotor via traveling shock and expansion waves. The underlying physics allow highly predictive 1D modeling where the performance is a simulation result. No maps for mass-flow or efficiency characteristics are necessary.



AVL BOOST™ Model 6 Cylinder Bi-Turbo Ottomotor

MULTILEVEL SIMULATION DEPTH

Basic thermodynamic matching of the turbocharger is performed for steady-state operation, continued by the optimization of the transient response. The matching calculation is iterative, based on compressor and turbine maps, as well as the most important engine data. Engines equipped with the charging system can be integrated into the vehicle simulation tool AVL CRUISE™, to analyse the overall system of the engine and vehicle within a driving cycle.



Complex turbulent flow and thermal load

REDUCING CO_2-EMISSIONS

AVL BOOST™ and AVL FIRE™ offer an advanced pressure charging simulation system. Users benefit from the ability to:

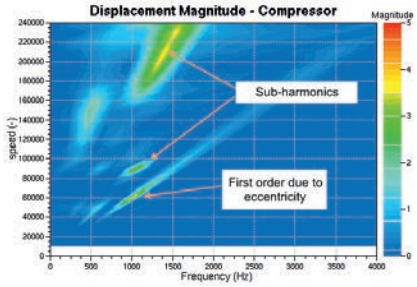
- Select a turbocharger to match a given engine
- Design new turbochargers with engine matching at every design stage
- Readily change compressor and turbine sizes and predict the effect
- Rapidly improve the turbocharging system, and determine the impact of wastegates, variable geometry, exhaust gas recirculation and component losses

ROTOR DYNAMICS AND BEARING ANALYSIS OF TURBOCHARGING SYSTEMS

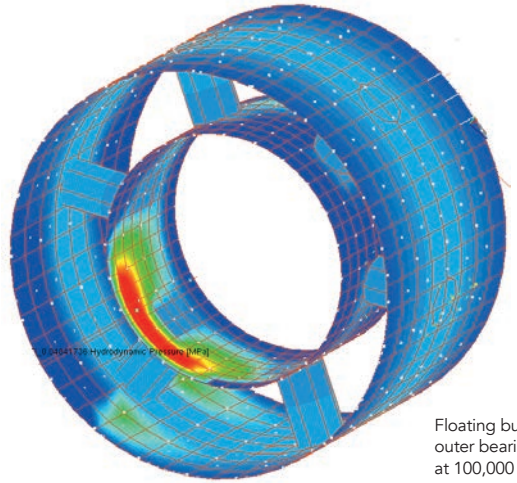
The investigation of the dynamic stability of the rotor bearing system is an important analysis target for the design of automotive and industrial turbochargers. This requires a multi-body dynamic solution including non-linear models for slider bearings with floating bushings capable of calculating the dynamic system behavior for rotor speeds up to 250,000 rpm.

AVL EXCITE™ considers all these effects with different levels of detail. The run-up calculation approach supports the detection of critical speeds caused by torsional and bending resonances. The elasto-hydrodynamic bearing model is applied to include the influence of full or semi floating bushing configurations including bores in the bushing to connect the inner and outer oil film of the bearings.

The results obtained with AVL EXCITE™ allow engineers to find an optimal matching of design parameters for damping the rotor system, oil mass flow and sensitivity for resonances.



Rotor dynamics – first order excitation and sub-harmonics



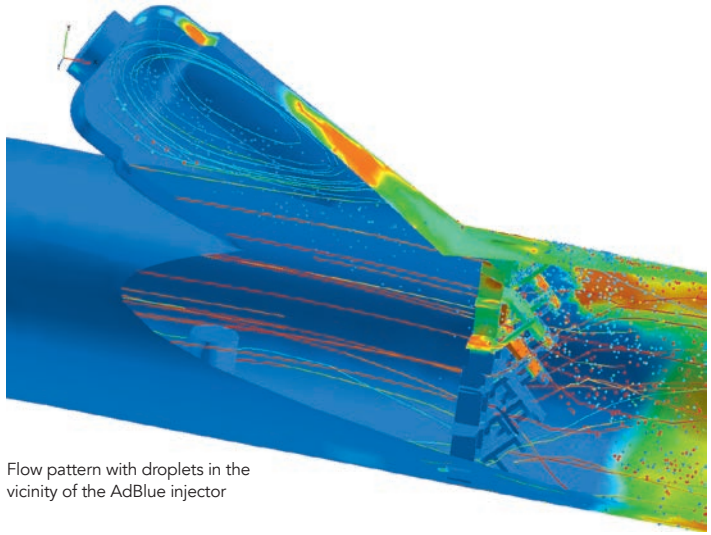
Floating bushing – inner and outer bearing oil film pressure at 100,000 rpm

Exhaust Gas Aftertreatment

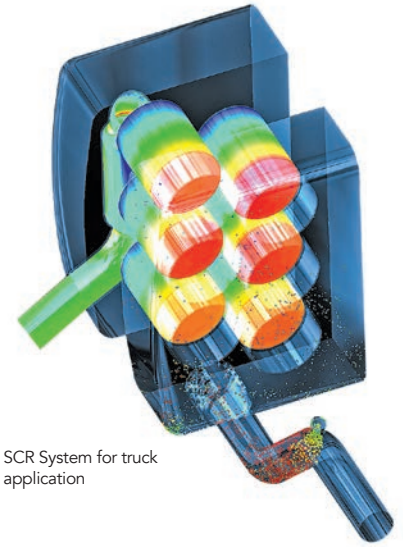
The AVL Aftertreatment simulation suite, consisting of the tools AVL BOOST™, AVL CRUISE™ and AVL FIRE™, is a unique open and scalable solution. It enables consistent modeling of all physics and chemistry relevant to exhaust gas aftertreatment systems during all stages of the development process.

UNMATCHED PERFORMANCE

AVL BOOST™ is in the vast majority of projects the starting point for development and optimization of aftertreatment systems and offers absolutely simple model setup and extremely short simulation times, close to or even faster than real time. This as well as the ability to model all common aftertreatment systems made the tool the undisputed market leader among 1D aftertreatment simulation software. It masters kinetics parameter identification, large parameter variations and system optimization with sovereign performance delivering the highest quality results.



Flow pattern with droplets in the vicinity of the AdBlue injector



SCR System for truck application

SEAMLESS INTEGRATION

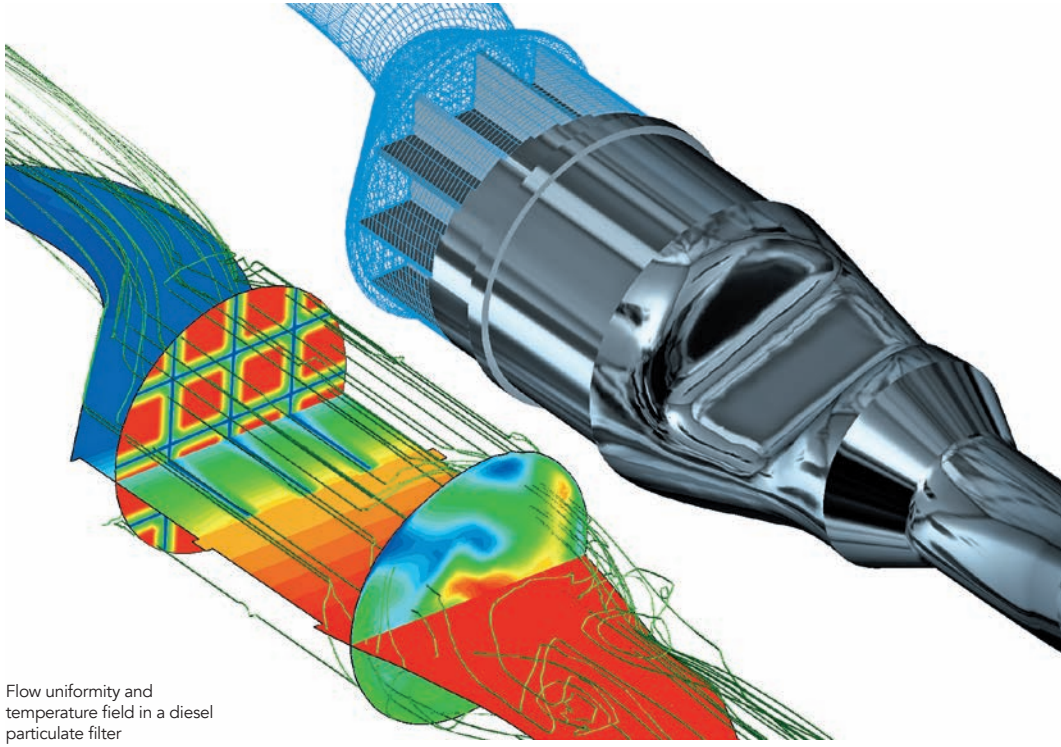
AVL BOOST™ and AVL FIRE™ feature the industry's only seamless integration of 1D, 2D and 3D exhaust gas aftertreatment system simulation tools. Both tools offer perfectly identical mathematical, physical and chemical models. The development engineer, hence, can select at any time in the development process the tool that matches best his needs for performance and accuracy. Switching from 1D AVL BOOST™ Aftertreatment to 3D AVL FIRE™ Aftertreatment or even in the other direction is possible without loss of consistency. Simulation setups can be directly imported from one tool to the other by just being applied to models that differ in respect to their dimension in space. Aftertreatment system performance data calculated using AVL BOOST™ and assembled to maps can also be integrated in AVL CRUISE™ models to predict drive cycle tailpipe emissions.

EASY HANDLING

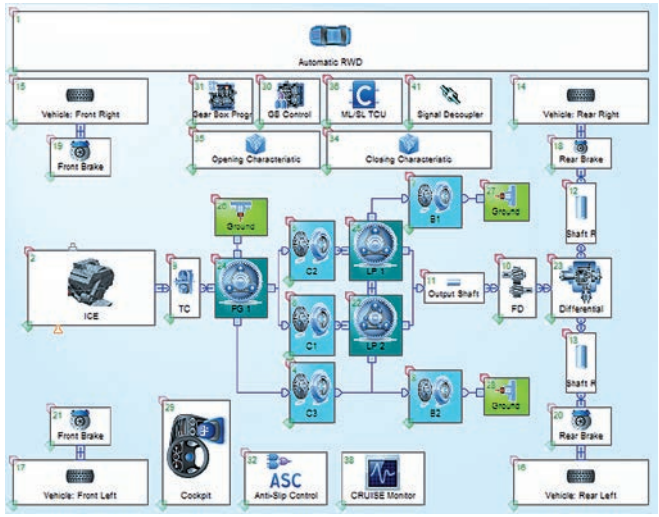
Pre-defined reaction schemes for all common aftertreatment systems are offered in both AVL BOOST™ and AVL FIRE™. The user also has the freedom to modify or to replace the offered schemes. AVL BOOST™ model set-up files can be imported in the AVL FIRE™ Solver GUI. This saves users from the time consuming and error-prone re-entering of model data when switching from 1D to 2D/3D CFD.

OPENNESS AS KEY TO SUCCESS

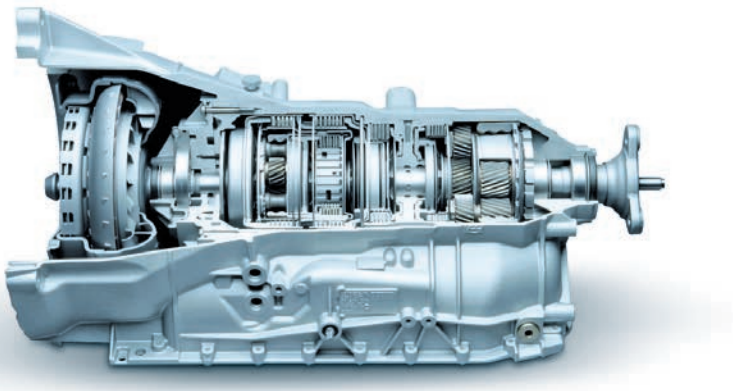
Both AVL BOOST™ and AVL FIRE™ support deploying user defined code extensions in the simulation procedure. For this purpose, both products offer the conventional possibility of linking user-defined functions to either tool. Recently AVL released the standardized AVL User Coding Interface AUCI. This enables an engineer to deploy any reaction mechanism of choice without having to program a single line of source code. Saving the input C-Code is generated automatically and the compiled object can be used with AVL BOOST™ and AVL FIRE™ equally without any further effort. AUCI also supports the exchange of the code between different parties involved in the development of an aftertreatment system. Before saving the input, the engineer can decide which part of the content shall be hidden/disclosed to the person that will actually use the compiled code. Thus, proprietary information remains protected while it is ensured that everyone involved can produce the same results.



Flow uniformity and temperature field in a diesel particulate filter



AVL CRUISE™ model with detail gearbox



Transmission and Driveline

Scalability and consistency is a central philosophy of AVL's simulation tool chain. The program portfolio offers transmission and entire driveline modeling capabilities on all the required levels. It answers the needs of diverse applications in component and control development and vehicle integration, from general system behavior to detailed analysis of losses to NVH and durability of single components.

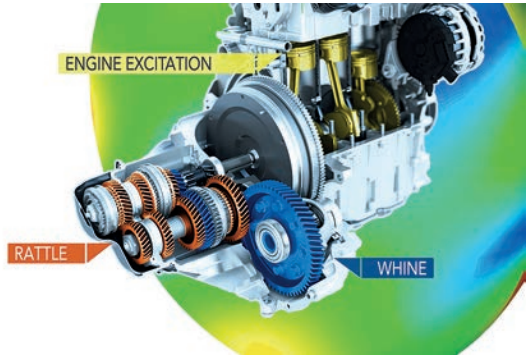
EFFICIENCY ENHANCEMENT – UNDERSTANDING COMPONENTS AND SYSTEMS

When searching for energy saving potential in already extensively optimized drivelines, a primarily component-focused approach, which was standard and normally sufficient in the past, is no longer appropriate. The entire energy flow from drive power generation to the power at the wheel needs to be investigated, taking into account the loss contribution of each component to vehicle CO_2 emissions.

This requires a comprehensive systematic approach with an integrated subsystem and detailed component investigation.

Using AVL EXCITE™, component and subsystem analyses are performed in order to derive friction maps for each of the loss-contributing parts. These maps are then used in AVL CRUISE™ for vehicle system investigation, such as the power flow and loss distribution analysis during drive cycle tests. This type of tool interaction makes it possible to understand the impact of each component as well as its modifications on vehicle fuel efficiency which in turn allows one to invest in component improvements with the highest cost/benefit ratio.

AVL EXCITE™ – influence of gearbox rattle and whine on the radiated noise



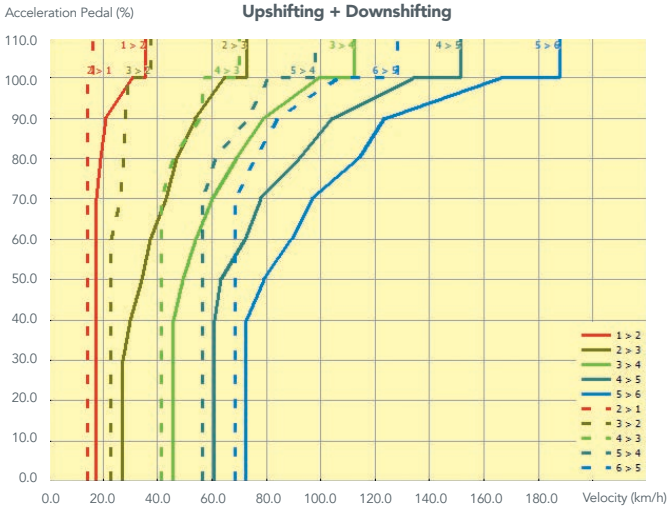
VIBRATION, STRENGTH AND ACOUSTIC OPTIMIZATION

With different modeling levels based on a rigid/flexible multi-body dynamics solution, AVL EXCITE™ supports the transient vibro-acoustic analysis of conventional and hybrid automotive and non-automotive drivelines up to 3 kHz. One simulation target is the investigation of the dynamic behavior and acoustic noise phenomena in drivelines under stationary and non-stationary operating conditions (e.g. tip-in/back-out, start-stop) such as boom, clonk, rattle, whine, chatter, whoop or shudder. For the analysis of vehicle chassis vibrations, the excitation forces from driveline dynamics are applied to the car body at mounting points such as the power unit mounts.

EFFORT REDUCTION IN GEAR SHIFTING PROGRAM DEVELOPMENT

To achieve CO_2 targets while still providing a competitive balance in terms of vehicle performance and driveability, automated transmission technologies such as AMT, DCT, AT and CVT are appearing more and more frequently on the market. Finding the right gear shifting program for the combination of vehicle type, powertrain technology and component limitations is creating new challenges in the vehicle development process.

AVL CRUISE™ GSP (Gear Shifting Program) represents the most efficient way to optimize the development of gear shifting programs. In early concept phases, AVL CRUISE™ GSP enables engineers to automatically generate gear shifting maps for different vehicle powertrain variants within seconds, improving the accuracy of simulated fuel consumption and vehicle performance results. Later on, calibration engineers can start with a gear shifting program which is near-optimized for fuel efficiency, performance and drive quality before having put the real vehicle on the road or testbed. This significantly reduces the development time and in-vehicle testing costs.



AVL CRUISE™ GSP – Generate & Optimize Gear Shifting Strategy towards given targets

Durability and NVH

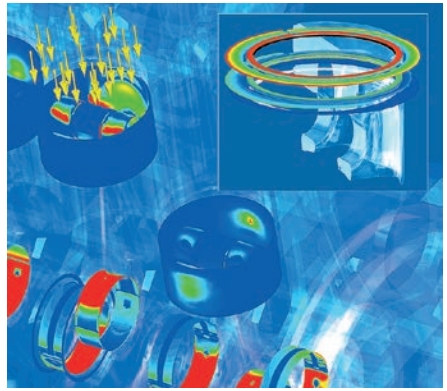
AVL EXCITE™ has been chosen by the majority of engine manufacturers worldwide as their main platform for strength, durability and NVH simulations of power units. This makes it the leading software on the market for durability analyses of engine components, valve train and timing drive dynamics, tribological analyses of lubricated engine contact points, cylinder kit design and NVH optimization.

REAL LIFE CONDITIONS FOR PRECISE RESULTS

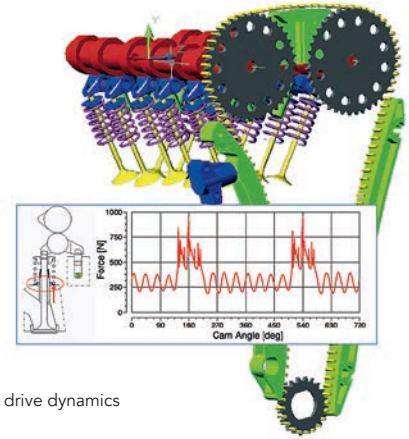
AVL EXCITE™ calculates complex dynamic models considerably faster than multipurpose tools. Short turnaround times are achieved by robust and optimized solvers even with complex models. The accurate consideration of non-linearities in lubricated engine contact points provides results which are similar to real life. Outstanding elastohydrodynamic (EHD) contact models for slider bearings and piston/piston ring liner contact facilitate detailed investigations of contact behavior, including the calculation of friction and wear. In this way the simulation assists the engineer in making the right design decisions efficiently and facilitates a significant reduction costly testing.

POWERTRAIN ORIENTED SOLUTION

Powertrain-analysis-specific workflows and automated model generation as well as result evaluation capabilities help the engineer to achieve short project lead times. For example, AVL EXCITE™ AutoSHAFT is a significant time saver for crankshaft model generation. Based on files from CAD, a dynamic crankshaft model can be generated within hours. AVL EXCITE™ calculates transient engine run-up and in-stationary conditions without relying on unrealistic speed steps. In this way, critical operating conditions can be detected reliably without the time-consuming interpretation of incomplete results.



Four cylinder inline engine – friction in lubricated crank-train contacts



Valve train and timing drive dynamics

MULTI-LEVEL SIMULATION MODELS

Different modeling levels for single components as well as for the entire system help the engineer to use an optimum balance of model depth in terms of required accuracy for the application target and the modeling and simulation time. The simulation models can be extended as needed during the development process, saving costs by eliminating the need to rebuild models for each step.

INTEGRATION AND CUSTOMIZATION

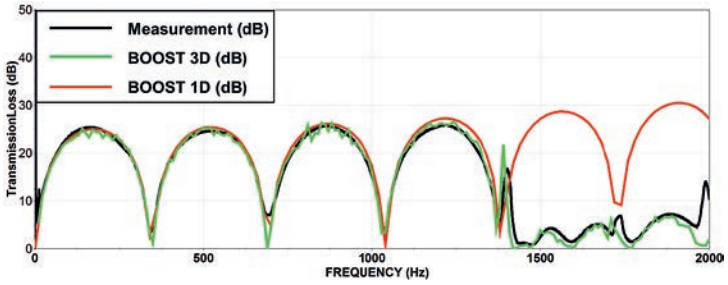
Interfaces for third-party FE and fatigue software enable the seamless integration of AVL EXCITE™ in the customer CAE environment. With the integrated finite element solver of Abaqus™ and the fe-safe™ based fatigue strength analysis tool AVL EXCITE™ Fatigue, the application workflows for fatigue and NVH analysis can be carried out optionally by AVL EXCITE™. For extensive design variation, parameter identification and optimization tasks, the integrated tool Design Explorer as well as interfaces to commercial optimization software are provided. Furthermore, AVL EXCITE™ offers customer-definable template models, plot and report generation, workflow descriptions and a customizable GUI.

DUCT ACOUSTICS IN TIME AND FREQUENCY DOMAIN

AVL BOOST™ offers linear and non-linear acoustics modules for the simulation of free field and in-duct acoustics in order to support

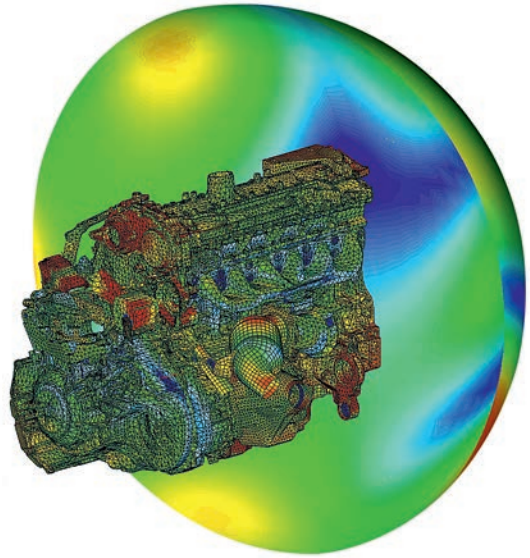
- Muffler design
- Intake and/or exhaust orifice noise reduction
- Sound engineering etc.

The resulting pressure waves can be used as excitation for shell noise simulation with AVL EXCITE™.



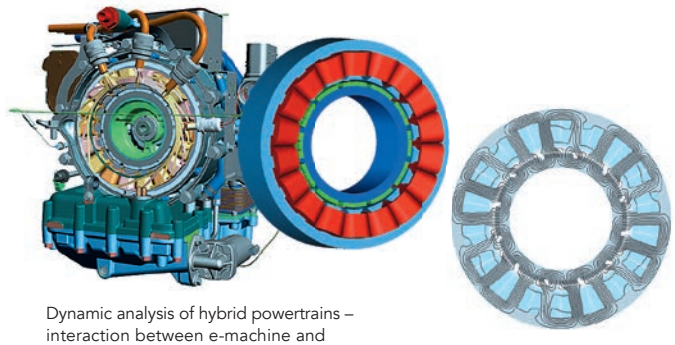
Higher Order Modes correctly predicted by AVL BOOST™ 3D

Acoustic of power units – structure borne noise and noise radiation (AVL EXCITE™ Acoustics)



Electrification

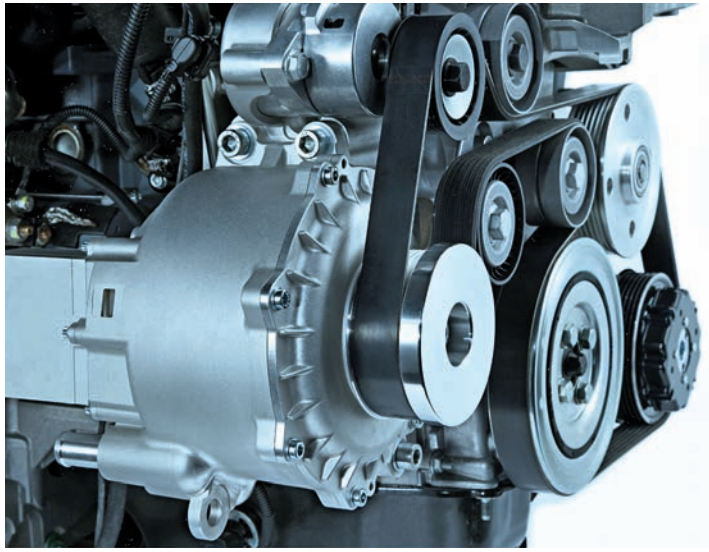
The simulation of vehicles with different levels of electrification (from HEV to PEV), the optimization of electrical systems and their components (such as electric drives, batteries and fuel cells) under completely new operating conditions and improvement in the performance of electrical turbochargers are just a few examples of AVL's innovative simulation capabilities in the huge field of new and challenging technology trends.



Dynamic analysis of hybrid powertrains – interaction between e-machine and IC engine (AVL EXCITE™)

HIGHLY DETAILED NVH ANALYSIS OF ELECTRIFIED POWERTRAINS

AVL EXCITE™'s domain is a detailed component and system analysis in terms of the dynamics, strength, durability and acoustics of hybrid powertrains and gen-set configurations. Analysis targets are e.g. the detailed investigation of the interaction between e-machine and the cranktrain of belt-driven starter-generator or mild hybrid systems, the dynamics and NVH of transmissions under combined non-stationary loading conditions or the influence of grid connection maneuvers on the dynamic behavior and load conditions of gen-sets.

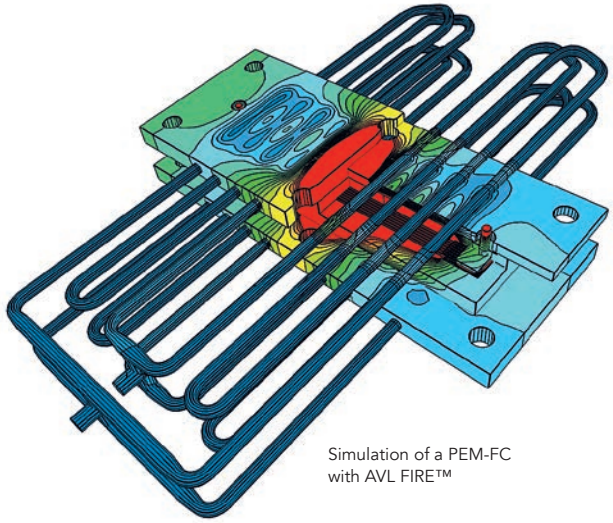


OPTIMIZING ENERGY STORAGE AND COOLING SYSTEMS

AVL FIRE™ makes it possible to predict the overall behavior of a Li-Ion battery cell, module or complete battery during transient charging and discharging processes. Critical conditions can be identified, thereby helping to optimize the system in terms of electro-chemistry, performance and thermal management. In order to accomplish these tasks, AVL FIRE™ offers thermo-electrical as well as predictive electro-chemical battery models which enable the simulation of electric charge transport in active layers and positive and negative collectors as well as heat conduction in thermal masses, while considering electric and thermal contact resistance.

UNDERSTANDING THE FUEL CELL

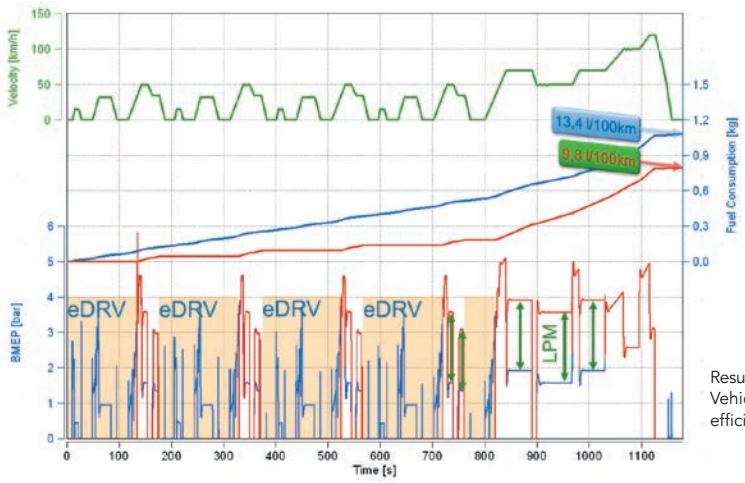
A comprehensive set of electro-chemical and physical models is offered by AVL FIRE™ in order to simulate the processes taking place in polymer electrolyte membrane fuel cells (PEM FC). AVL FIRE™ also solves the electro-chemical reactions in the catalyst layers. Water transport and the transport of hydrogen ions and gas species are calculated in the membrane. Phenomena handled in the gas diffusion layer include the capillary flow of liquid water and electron conduction. In addition, phase change due to evaporation and condensation, multi-phase momentum transfer, the multi-component diffusion of gas species and multiphase heat transfer are modelled. Heat and electron conduction are calculated in the bi-polar plates. Simulation of the cooling channels is also provided to measure convective heat transport.



Simulation of a PEM-FC with AVL FIRE™

ENERGY EFFICIENCY IS THE FINAL GOAL

Vehicle component and subsystem development cannot be done in isolation if the goal is to improve the fuel economy, performance and driveability. The acceptance and success of a new vehicle is determined by its strategic target definition, the choice of the powertrain configuration including the selection and sizing of the components in the early vehicle development phase. AVL CRUISE™ offers a wide range of implemented electric components on a system level, dynamic visualization of power flow and energy distribution analysis, as well as user specific model integration from other tools. These attributes provide an sustainable base for all hybrid concepts as well as control function development for all vehicle types from PEV to full HEV and other alternative powertrain solutions.



Results from AVL CRUISE™: Vehicle electrification efficiency assessment

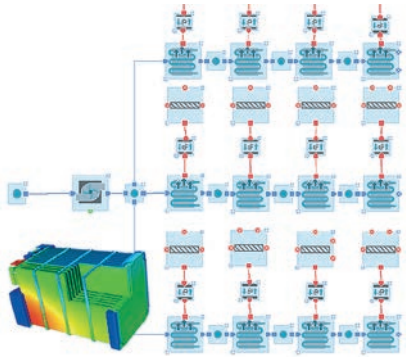
Thermal Management and Aerodynamics

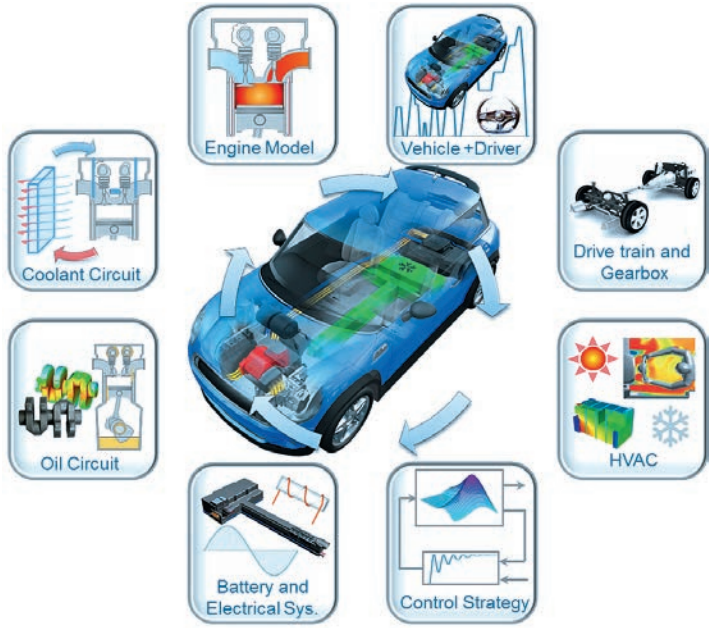
The component development tasks for the engine and vehicle are distributed over a number of departments. Using consistent simulation models delivers a virtual overall system simulation environment that is consistently detailed during the design process. This enables the sharing of relevant data across the various disciplines required for the study of vehicle thermal management systems (VTMS).

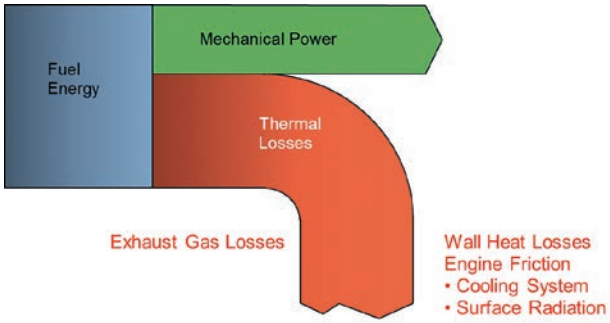
WHY THERMAL MANAGEMENT

A well designed engine cooling system enables fast engine warm-up

- To reduce friction losses
- To allow minimum time for aftertreatment system light-off
- To quickly clear the windshield of ice and condensation
- To ensure adequate cooling of all engine components under all operating and weather conditions
- To allow comfortable cooling or warming of the passenger compartment







SIMULATION ENABLES PERFORMANCE

To assist in the optimization of VTMS systems, AVL has established a comprehensive methodology for advanced vehicle simulation, including the simulation of:

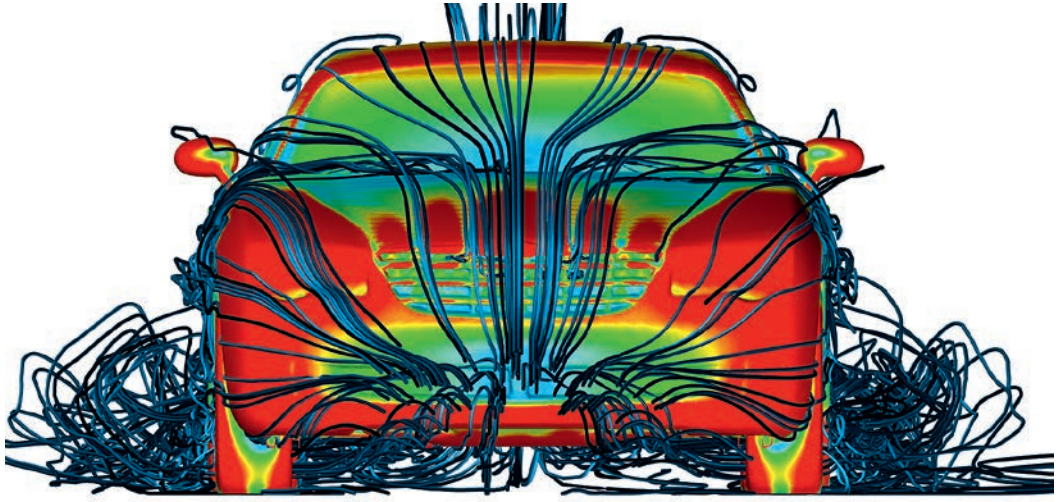
- Engine performance
- Exhaust gas aftertreatment
- Cooling and oil circuits
- Engine compartment flow
- Heat transfer between fluids and structure

SUPERIOR TOOLS FOR SUPERIOR SOLUTIONS

AVL offers an integrated set of tools consisting of:

- AVL BOOST™, for calculating 1D gas dynamics, performance, cooling and oil circuits and exhaust aftertreatment
- AVL CRUISE M, the industry standard for integrated vehicle simulation on system level
- and AVL FIRE™, 3D CFD for IC engine and vehicle development

These tools facilitate the seamless development and optimization of vehicle thermal management systems and control strategies.



External aerodynamic prediction with AVL FIRE™

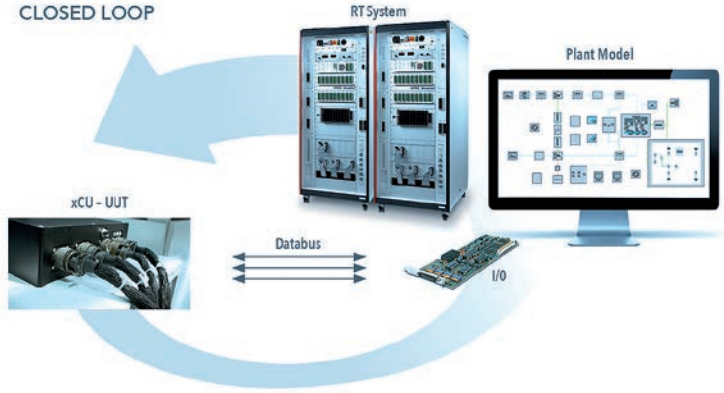
Calibration and Testing

The growing number of closely interacting components and control systems and the increasing complexity of control functions require the testing of an exhaustive number of new test case combinations. AVL CRUISE™ M MOBEO real-time models add more flexibility and productivity to HiL targets, such as AVL PUMA Open™ testbeds, dSPACE, ETAS, National Instruments and Opal RT.

CAE AND TEST WITH THE SAME PLANT MODEL

System models, set up in the office for solving powertrain analysis and optimization tasks using AVL CRUISE™ M MOBEO, can be used again in the field of components and control systems testing (engine testbed, Hardware-in-the-Loop). This is possible thanks to the use of the same system solver, which has been optimized for office as well as real-time applications. In this way, the effort required to exchange models in both directions between the office and test systems is kept to a minimum. This consistency between the model and solver forms the basis for achieving comparable high-quality results throughout the whole development cycle.

Model based component test

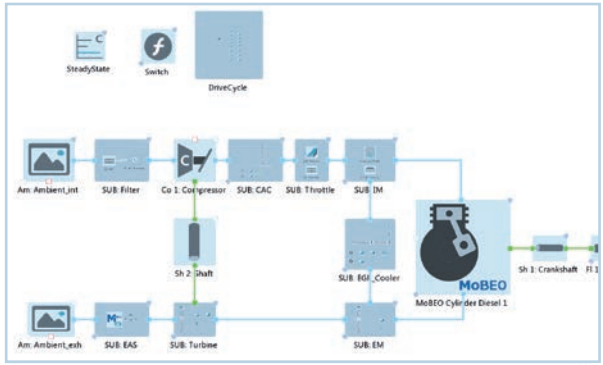


SEAMLESS CONTROL FUNCTION DEVELOPMENT AND CALIBRATION

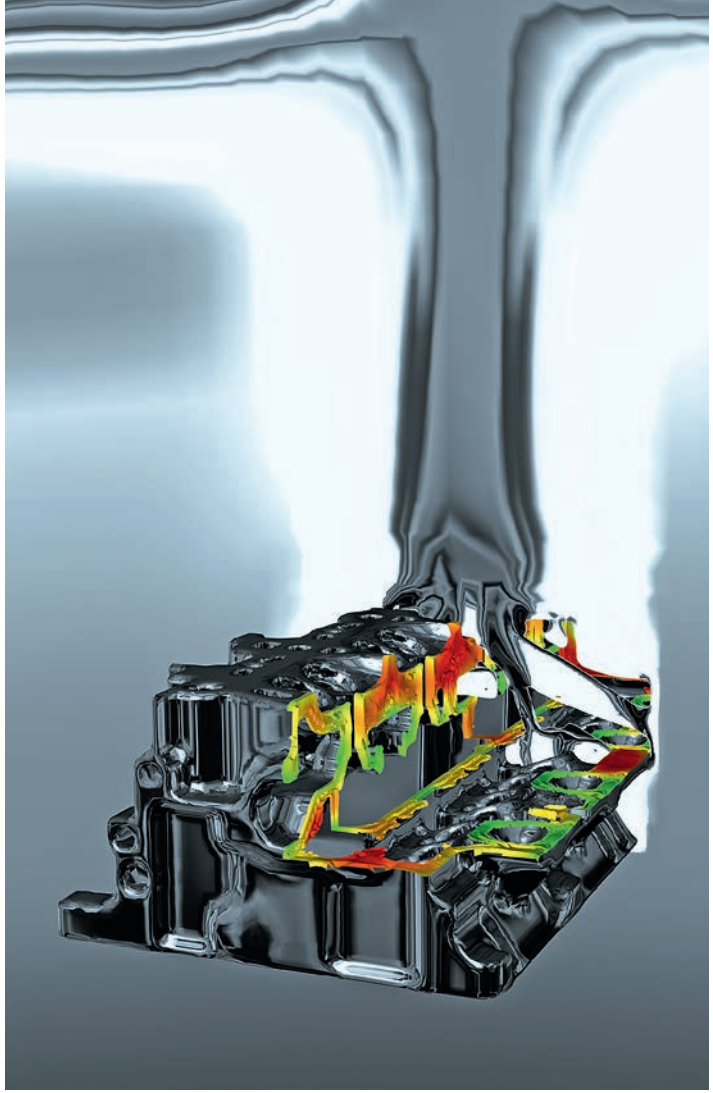
AVL CRUISE™ M MOBEO offers semi-physical modules for gasoline and diesel cylinder and exhaust gas aftertreatment system simulation, integrated into AVL CRUISE™ M. These modules with incorporated AVL engineering expertise combines the strengths of both physical and empirical modeling available for office and Hardware-in-the-Loop environments. AVL CRUISE™ M MOBEO enables an automated engine calibration backed up by powertrain engineering know-how.

AVL CRUISE™ M is a real-time capable simulation environment dedicated to the investigation of transient offline operating conditions in office and testing environment. AVL CRUISE™ M supports engine performance, fuel consumption, combustion, emissions, aftertreatment and cooling application.

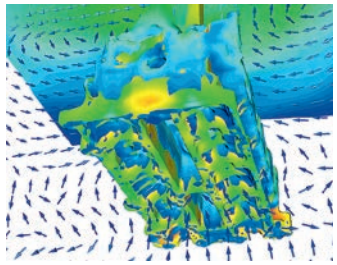
The modular modeling concept of AVL CRUISE™ M MOBEO allows setting up of and switching between subsystems with various levels of detail within a single plant model. This significantly reduces the effort of parameter changes and model maintenance, and enables a quick adjustment to specific needs for different working environments. Interfaces to a wide range of modeling and programming tools and control test platforms provide engineers with the openness needed to expand model fidelity in well-defined areas, and to incorporate them into a seamless development workflow from MiL to SiL or HiL.



Model based calibration with AVL CRUISE™ M MOBEO model on AVL Virtual Testbed™



Aluminum cylinder head quenched in water

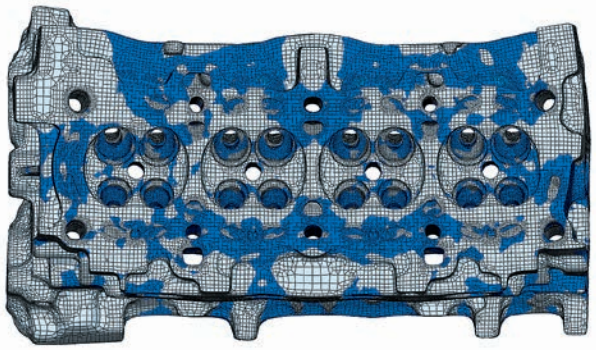


Submerged cylinder head during quenching; water flow disintegrating the vapor film during transition boiling

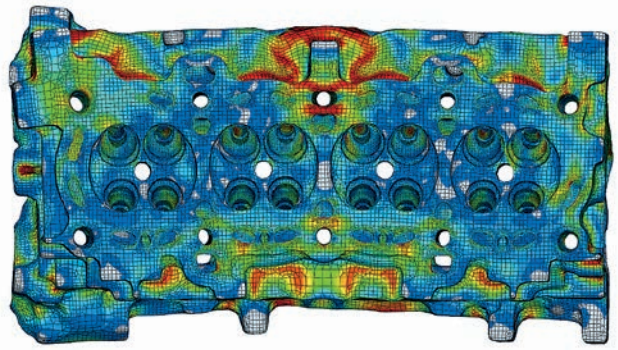
Quenching

Quenching is a common heat treatment technique used in production of cast parts or otherwise produced metal components. In particular, immersion or direct quenching processes are widely adopted procedures in automotive and aerospace industries to minimize the formation of undesirable thermal and transformational gradients, which may lead to increased distortion and cracking.

AVL FIRE™ offers state-of-the art modeling functionality in the field of quenching. Various quenching approaches can be simulated; air quenching followed by spraying and finally direct quenching. Different numerical models cover physical specifics of the thermal treatment process, which significantly influences the properties of cast materials. Commonly investigated components are cylinder heads or engine blocks made of aluminum, which can, under certain circumstances, undergo exceedingly high operational loads leading to material failure. Cracks commonly appear as a consequence of downsizing and weight reduction. An everyday application thereof would be the weight reduction of passenger cars to minimize tailpipe emissions. Despite the complexity of the investigated problem and long physical times, short turnaround times offer a great platform for virtual prototyping.



Von Mises stresses during quenching simulated by AVL FIRE™; five seconds after submerging



Von Mises stresses during quenching simulated by AVL FIRE™; 30 seconds after submerging

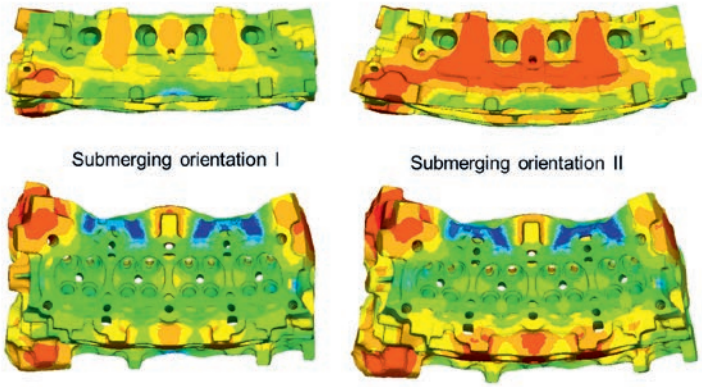
BOILING REGIMES DURING DIRECT QUENCHING

Physically, the most challenging quenching approach is submersion (or direct) quenching where reheated components are submerged in the water pool. Initially, film boiling slows down the heat removal, followed by nucleate boiling and finally single phase cooling after the solid has cooled down beneath the saturation temperature of the quenchant. Predicting different boiling modes and the transition is the key. AVL FIRE™ has proven to be an accurate and reliable numerical tool in numerous test configurations and full complexity cases, such as cylinder heads. The quenching process is affected by solid piece orientation, initial solid temperature, water temperature and more, therefore accurate prediction of local temperature histories within the structure is crucial for final prediction of residual stresses resulting from the production process.

THERMAL STRESS PREDICTION

Solid temperature results obtained with AVL FIRE™ serve as input for Finite Element Analysis of thermal loads and deformations. A simple GUI-based mapping step is performed to produce input data for Finite Element Analyses. Finally, predicted residual stress levels are compared with operational loads. If residual stresses superimpose the operational loads, the thermal treatment is to be changed. A different submerging direction or quenchant temperature may completely change the nature of residual stresses in critical areas and thereby improve the quality and safety of components in operation. When investigating quenching of steel components one needs to account for the release the latent heat during the martensitic phase transformation. In such case AVL FIRE™ is used to predict the boiling process on the fluid side, and is online coupled with a Finite Element simulation tool utilizing dante®, a coupled thermal, carbon diffusion, solid mechanics program. Needless to say, this extends the lifetime of the product and reduces the risk and warranty costs of OEMs in the market.

Cylinder head deforming in FEA simulations utilizing AVL FIRE™ quenching results as input



AVL Test Systems – Innovative Solutions for the entire Powertrain

SOLUTION

With decades of experience, AVL provides a wide range of solutions for developing and testing modern powertrain systems, from testbeds for optimizing internal combustion engines or transmissions, test systems for all components in an electrified powertrain to roller testbeds for full vehicle development and testing. AVL is the only company in the world to combine competence in powertrain design with competence in state-of-the-art measurement, testing and simulation technology, competencies which are completed with embedded methodology know-how.

Many instruments and test systems are already based on the AVL Open Development Platform, which considerably boosts the efficiency of the testing process. Using numerous shared software and hardware technologies, AVL test systems offers consistent, comparable results that significantly help to achieve lower development times and costs. This makes them an ideal, integrated tool chain for developing efficient and environmentally friendly powertrains.

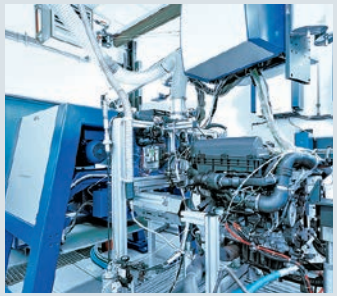
TASK

The higher complexity of modern powertrains is placing increasing demands on the instrumentation and test systems used in development and testing. At the same time, more customers wish to perform development activities at the earliest possible stage. To allow this when testing individual components, full systems or even entire vehicles, AVL test systems must precisely emulate reality. The interaction of several active components in the vehicle means electrified powertrains for hybrid vehicles are becoming particularly complex. The challenge for developers today is to put all components (internal combustion engine, e-motor, battery, inverter, gears and driving modes) together into a single harmonious system. From testing a high-voltage battery in an emulated vehicle environment to testing a full system or complete vehicle with an electrified powertrain, AVL offers all testing systems necessary. Consistency between all the different systems must be guaranteed to keep data acquisition and management as simple and efficient as possible over all test runs. All AVL test systems, therefore, use a common measurement and parameter database.

BENEFITS AT A GLANCE

- Broad experience from more than 4,500 test system installations
- High measurement precision and reproducibility of measurement results
- Consistency between AVL test systems
- Easy expansion of existing testbed systems for developing hybrid powertrains by means of upgrades
- Worldwide training by AVL personnel in local language
- Global service and support
- Integrated Open Development Platform leading to consistent results in development
- AVL Virtual Testbed™ Integration ensures highest testing flexibility

CONSISTENCY BETWEEN THE VARIOUS AVL TESTING SYSTEMS CONSIDERABLY BOOSTS EFFICIENCY IN DEVELOPMENT.



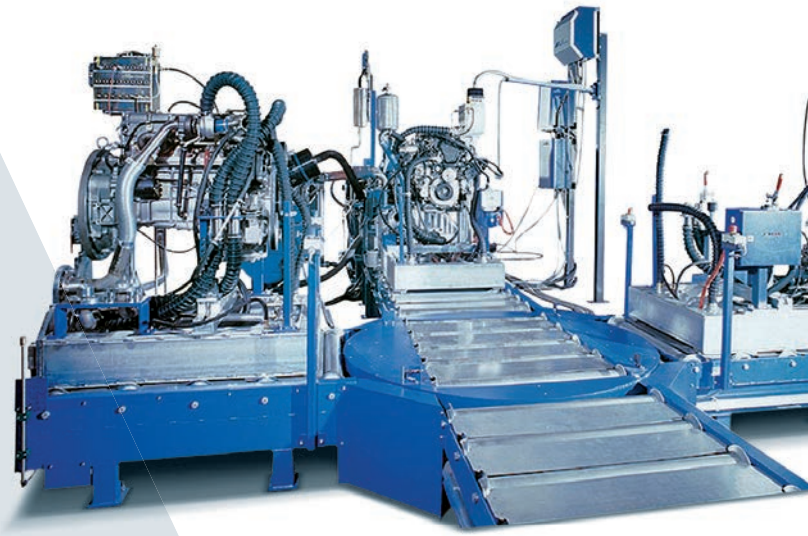
PORTFOLIO

Test systems for internal combustion engines and for components
The range spans from research on a single-cylinder testbed to development of complete combustion engines on designated testbed systems. Systems with virtual engine for model-based development complete the portfolio.

E-Motor, battery and inverter testbeds
AVL offers testing systems tailored to each component in the electrified powertrain. These are used for testing individual components (e.g. in a virtual vehicle environment) as well as full systems and entire vehicles.

Powertrain and roller testbeds
The application range of these testbeds is constantly expanding: Alongside endurance, strength, emissions, acoustic and EMC testing, they are increasingly used in driving-maneuver-based tests and for optimizing electrified powertrains.

End-of-line testing systems
AVL end-of-line testing solutions, which perfectly integrate into the production process, cover all functionality verification procedures, from subsystems on the assembly line to hot and cold tests to quality audit tests.



Electrification: Future-oriented know-how from AVL

The electrification of the powertrain means developers are faced with many challenges. Electrification does not only increase the complexity of systems but the range of solutions as well. Therefore, a partner with both comprehensive component know-how and a holistic perspective on the system is critical. AVL provides its customers with exactly this comprehensive expertise.

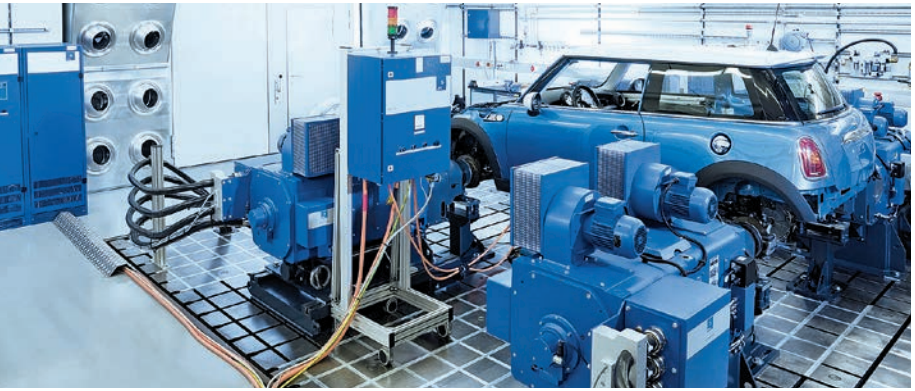
TEST SYSTEMS FOR ALL ELECTRICAL COMPONENTS

AVL offers test systems for development, durability testing, and quality assurance for all components of the electrified powertrain, electric motors, high-voltage batteries and inverters.

AVL battery test systems serve to optimize the service life, safety, performance and cost-efficiency of energy storage systems. Using the AVL E-Motor test systems, all types of electric motors can be checked for functionality, reliability and endurance. AVL inverter test systems emulate the electric motor. All electrical and mechanical conditions can easily and quickly be simulated using parameterization. Furthermore, the function of the inverter can be tested with different designs of the electric motor and diverse error scenarios on the basis of emulation without requiring a physical electric motor.

With the AVL E-Integration test systems, all components of the electrified powertrain can be tested, both individually and within the system. Additionally, customers are provided with the advantage that the electrical assemblies can be tested together with the entire powertrain of a hybrid vehicle (internal combustion engine, transmission, etc.) or with the entire vehicle on the testbed. In addition, by using the simulation platform AVL InMotion™, realistic performance results (energy optimization, drivability, etc.) can be achieved on the component and/or the system level.

The electric AVL EVARE MINI with range extender on the testbed



The scalable AVL E-STORAGE product line

All AVL measurement and test systems for the electrification of the powertrain can be integrated into an existing AVL test environment in a quick and easy manner (automation, data analysis, host systems, test field management, etc.).

NEW AVL E-STORAGE PRODUCT LINE

To offer a test system that is as modular as possible and that can be adapted precisely to the respective requirements of the customer, AVL has developed a scalable E-STORAGE product line which offers a class-leading combination of outstanding dynamic performance with the highest measurement and control accuracy.

For developing and testing electric motors and inverters, the system is configured as the AVL E-STORAGE BE™ (Battery Emulator). This system accurately emulates the interaction of the electrical energy storage unit with the vehicle (discharge, behavior during acceleration and/or recuperation, state of charge, etc.).

For battery development and testing, the AVL E-STORAGE BT™ (Battery Tester) integrates the battery test automation software AVL LYNX™ ensuring a complete battery testing application meeting the latest test run standards.

For the ability to test batteries as well as e-drive components, the AVL E-STORAGE BTE™ (Battery Tester and Emulator) as a combined system is the best solution.

The AVL E-STORAGE LV™ (Low Voltage) is optimized for the development and testing of low voltage micro and mild hybrid systems. This low-voltage variant is also equipped with AVL LYNX™ and the advanced AVL Battery Models.

To successfully address the customers' new requirements in a quick and resourceful method, AVL E-STORAGE can be extensively implemented on-site in a cost-efficient manner.

AVL Battery Test Systems

AVL battery test systems are developed for testing high-voltage batteries for use in hybrid and electric vehicles. These tests can be implemented both at cell and module level as well as at the battery pack level. The highest degree of flexibility allows the integration of the battery management system (BMS), external measurement devices, climate chambers, and conditioning units with least effort.

Using the AVL battery test systems, all common types of energy storage systems (super capacitors, nickel metal hydride and lithium ion batteries) can be tested and optimized for different fields of application, both passenger and commercial vehicles. From the first prototype creation and pre-production to the final series production, the testbed solutions are suitable for use across the entire vehicle development process.

The most important development tasks are as follows:
- Durability (calendric service life and cycle stability)
- Safety (during operation and in the event of accidents)
- Performance capability
- Energy storage capability
- Cost reduction

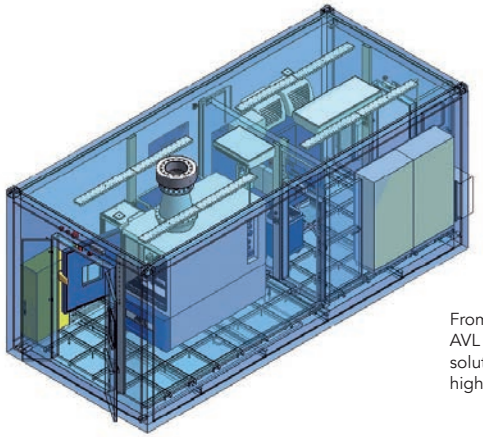
All customer-specific as well as standardized (e.g., according to ISO 12405, VDA, etc.) test procedures can be implemented and executed easily.

TESTBED CONFIGURATION

The “Plug & Play” AVL battery test systems are available in test cell or container design for flexible and/or location-independent application. Both standard solutions and customized systems are available. The AVL E-STORAGE BT™ (Battery Tester) from the AVL E-STORAGE product line, actuated by the automation system AVL LYNX™, is the core component of the system. AVL LYNX™ is characterized by an easy to operate interface and perfect integration into many further AVL software tools , e.g. AVL SANTORIN HOST™, a central data management system for managing test data from several test systems in an easy way.

CLIMATE CONDITIONING

High precision climatic chambers (with the temperature range from –40 to +80 °C) are specifically suitable for simulating environmental conditions and for testing energy storage systems and nearly all battery pack sizes. These simulations are part of test runs, for example high temperature change rates within the framework of shock tests. The climatic chambers are completely integrated in the AVL safety concept which is certified by the Technical Control Board.



From concept to reality – AVL offers complete turnkey solutions for testing high-voltage batteries

FEMS AND PLC CONTROL AS AN OPTION

By means of cascadable front end modules (FEMs), an additional measurement system can be designed to check voltage, temperature, and current at battery cell, module and packl level. Additionally, the testbed can be extended by a Programmable Logic Controller control system monitoring the test chamber according to the specified safety matrix, including climatic chamber test station and initiating defined reactions.

VIRTUAL PROVING GROUND TECHNOLOGY

The integration of the "Virtual Proving Ground" technology based on AVL InMotion™ offers a time and cost-efficient development. A test environment is also provided to shift integration, optimization and validation tasks to earlier phases of the development process. The test specimen is integrated into a virtual vehicle environment and is tested systematically with reproducible driving maneuvers ("virtual fleet test").

BENEFITS AT A GLANCE

- Complete turnkey solutions for testing battery cells, modules and packs, including battery management system
- Suitable for use in both research and development and in the field of production thanks to the multifunctional layout design
- Reduction of the development time due to consequent application of the "Virtual Proving Ground" approach
- Short delivery and commissioning times
- Global distribution and service network

AVL E-STORAGE BT™ (cycling unit) from the AVL E-STORAGE product line

AVL E-Motor Test Systems

Using AVL E-Motor testbeds, all kinds of different electric motors – both for hybrid vehicle drives and for all-electric vehicle drives – can be developed and tested for durability. The modular testbed concept allows for testbed design in different performance and speed classes and additionally offers the option of functional testbed expansion – by adding software or instrumentation systems; it is even possible to add a climatic chamber module later. This makes the AVL test system a secure investment for the future.

APPLICATIONS

The AVL E-Motor testbeds are used for analyzing and determining electrical, mechanical, thermal and acoustic properties. Functionality, reliability and durability tests and cold start performance measurements can be implemented under realistic conditions. The integrated AVL PUMA Open™ automation system allows for fully automatic runs, so time and cost-efficient test ones for all relevant test procedures. All measurement data is saved with a uniform time stamp and can be processed further with the data postprocessing tool, AVL CONCERTO™.

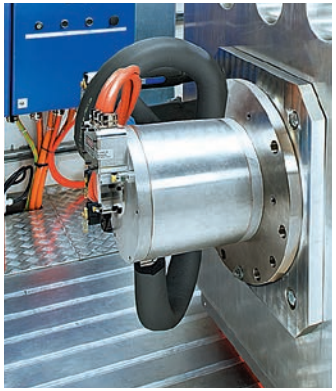
The optional integration of the "Virtual Proving Ground" technology-based on AVL InMotion™ also offers a virtual development and test environment to implement integration, optimization and validation tasks even on the testbed. The test specimen is (by means of simple parameterization) integrated in a virtual vehicle environment and tested systematically with reproducible, realistic driving maneuvers. Control units within the vehicle can be emulated in AVL InMotion™ or connected as real devices to AVL InMotion™.

AVL E-Motor testbed with climatic chamber module

TESTBED CONFIGURATION

AVL E-Motor testbeds are available as a standardized system or as a tailored testbed solution. A special adapter system used initially to set up test specimens allows for quick and simple coupling of test specimens to the dynamometer. Shaft connections are available for both low- and high-speed applications. Special integrated instruments with extremely high levels of accuracy are used to measure torque and/or efficiency.

AVL offers four-quadrant-dynamometers in a variety of performance and speed classes for the entire operating range of the specimen, from zero speed up to positive/negative maximum speed. AVL's high quality dynamometers are also characterized by very low torque cyclic irregularities resulting in the delivery of measurement results with high levels of accuracy.



AVL E-Motor testbed fitted with climatic chamber module

AVL Electric Mobility Center, Graz
Electric motor and battery testbeds

ENVIRONMENT SIMULATION

To perform test runs under realistic environmental conditions, AVL E-Motor testbeds are equipped with a coolant conditioning system (single- or two-circuit system) for electric motors to be tested, the relevant inverter and, optionally, a climatic chamber which enables environment simulation within the typical temperature and air humidity ranges specified in the European and Chinese testing recommendations.

ENERGY SUPPLY

Different systems of the AVL E-STORAGE product line are available for supplying the unit under test with energy: starting from a bi-directional DC power supply with excellent dynamic behavior, the AVL E-STORAGE Battery Emulator (BE) is capable of realistically emulating the behavior of a vehicle battery, such as discharge or recharge by energy recovery.

BENEFITS AT A GLANCE

- Flexibility thanks to modular design with matched and tested components
- The highest data quality due to excellent system precision
- Dynamometers up to 20,000 rpm
- "Virtual Proving Ground" concept based on AVL InMotion™
- Applications know-how based on the operation of its own testbeds at AVL
- Global distribution and service network

UNIVERSAL INVERTER

State of the art IGBT technology and device features like 4-quadrant operation, field weakening, DC link voltage span from 50 V to 750 V (1,000 V), selectable IGBT switching frequency from 4.5 kHz to 15 kHz makes it fit to handle a wide variety of e-motors.

AVL Inverter Test Systems

Modern powertrain systems have achieved a high degree of complexity. In order to validate these powertrains in all operating conditions, a broad test coverage is needed. In addition, the ability to test components in an early stage of development helps to minimize validation time. The complexity is more apparent in electrified powertrains, where the interactions between the different components have a significant influence on each other. Therefore, the benefit of testing components individually in a virtual environment using the original interfaces at full power and overload conditions is substantial.

To meet these requirements, AVL offers test systems with different voltage and current ranges supporting high-dynamic and high-fidelity emulation of the unit under test.

INVERTER TESTING

The AVL inverter testbed provides a comprehensive environment for the development, testing and validation of inverters. While the AVL E-STORAGE Battery Emulator (BE) guarantees the realistic simulation of the vehicle battery, the E-Motor Emulator (E-ME) reproduces the behavior of an electric motor, including its rotor position sensor and temperature measurement.

Due to its flexibility, the system allows to operate all inverter types – from start-stop system inverters, converters for mild and full hybrid vehicles to pure electric vehicles. It is designed for a broad range of applications, such as hardware and software development, endurance testing and fault simulation.

Example of an AVL Inverter testing area

AVL E-Motor-Emulator

DC/DC CONVERTER TESTING

Regardless of whether the function is integrated in the inverter or not, AVL can emulate low voltage accessories by means of a DC load unit.

SAFETY FIRST

The development of power electronic components is a challenging task, as numerous safety-related functions in the system need to be taken into consideration (ISO 26262). Thanks to decades of experience, AVL is able to provide not only high-end test solutions but solutions that are also safe and easy-to-use.

SYSTEM EXTENSIONS

- Extreme testing needs extreme equipment. AVL offers climatic chambers and climatic coolant conditioning systems for inverter testing, which can be adapted to meet customer requirements.
- Our virtual road, vehicle and driver environment (AVL InMotion™) enables maneuver-based testing and can even generate vehicle vibration via a vibration table.
- In order to simulate fault scenarios, such as short circuits or open circuits, additional auxiliary components can be adapted.

AVL ambient inverter chamber

BENEFITS AT A GLANCE

- Flexible, high-precision testing environment
- Safe test environment; ideal for deployment in laboratory
- Validation of maps even under failure scenarios
- Easily and quickly available test results
- Flexible, easy-to-use and configurable automation system
- Full compatibility with AVL InMotion™ Real Life Test System
- High reproducibility of AC and DC load cycles
- Energy-efficient test system thanks to power recovery

AVL E-Integration Test Systems

New hybrid and electric powertrain technologies and their components still feature a high degree of innovation. The interaction and testing of the electric components such as e-motor, battery, power electronics and onboard charger are very complex and a challenging task for the development and test team. A flexible and efficient test system is mandatory to ensure the safety of a new vehicle in the required short timeframe.

TEST SYSTEM DESCRIPTION

The AVL E-Integration Test System allows the testing of all electrical components for their functionality and reliability. The test system can be designed for the whole car, the powertrain or just for the propulsion-relevant components, which can be tested in combination or also independently. Climatization of e.g. the battery, the power electronics or the onboard charger in a climate chamber also enables thermal load tests of the components.

For various reasons, not all HV components are available or functioning during the vehicle's development and validation phase. In order to avoid any delays during the development process, the missing components can be replaced by battery, e-motor or power electronics emulators. This leads to a significant reduction of the development time of a vehicle. Furthermore, the use of emulators enables both reproducible test procedures and test safety-relevant functions by running the emulator at exceeded limits.

Due to the usage of emulators, the AVL E-Integration Test System consists of various configurations called operating modes. Switching between the operating modes is realized fully automatically without manual interaction.

Parallel operation of two independent test systems is possible due to the application of a second automation system. This leads to a further efficiency increase of the testbed and acceleration of the test processes.

PARAMETERIZING THE TEST CASES

Numerous test cases are required for validation. These can be generated easily via drag-and-drop function using the toolbox of the test run editor. Test procedures can be saved in libraries and re-used in every other test run. The parameterization of the test cases can also be carried out offline in the office environment using the software PUMA Office.

MEASUREMENT SYSTEM AND DATA HANDLING

The AVL measurement system offers optimized solutions for different measurement requirements. The E-Integration Test System provides low- (1 Hz – 1 kHz), middle- (up to 50 kHz) and high-frequency (up to 2 MHz) measurement systems.

The AVL e-Power Measurement System was especially designed for power measurement and analysis of hybrid and electric powertrains and is fully implemented into the AVL PUMA Open 2™ automation system. All measurements, including the bus data, are stored centrally and time-synchronized on PUMA. The data can be evaluated fast and easily, using AVL CONCERTO.

REST BUS SIMULATION

For components that are not present or replaced by emulators, the AVL E-Integration Test System provides a rest bus simulation (RBS). Depending on the operation mode, the related RBS will be loaded automatically.

GRID EMULATION

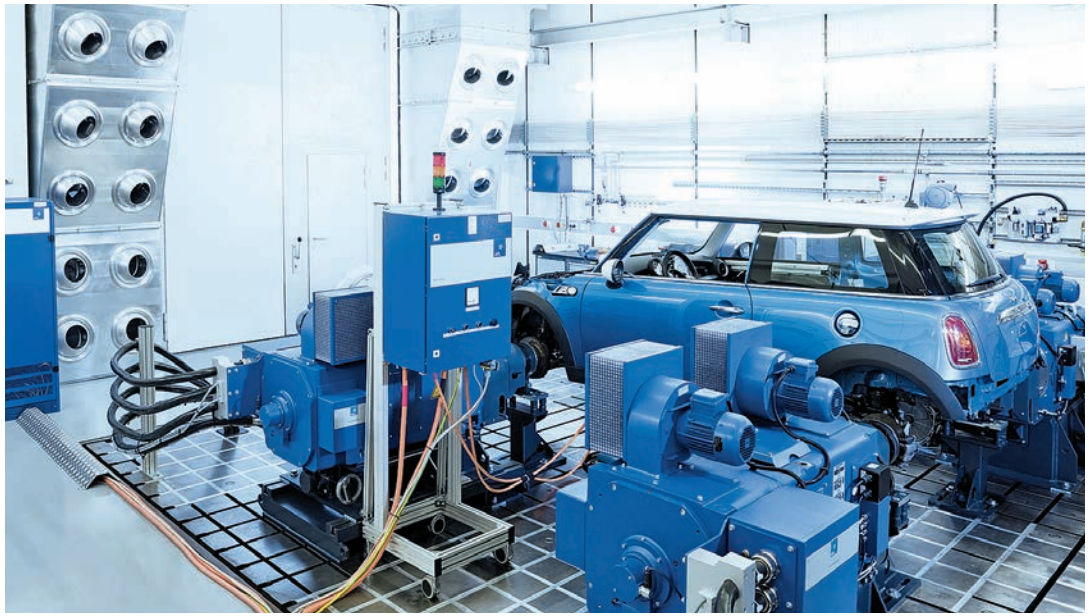
For onboard charger testing, the AVL Grid Emulator simulates all kind of worldwide grid shapes.

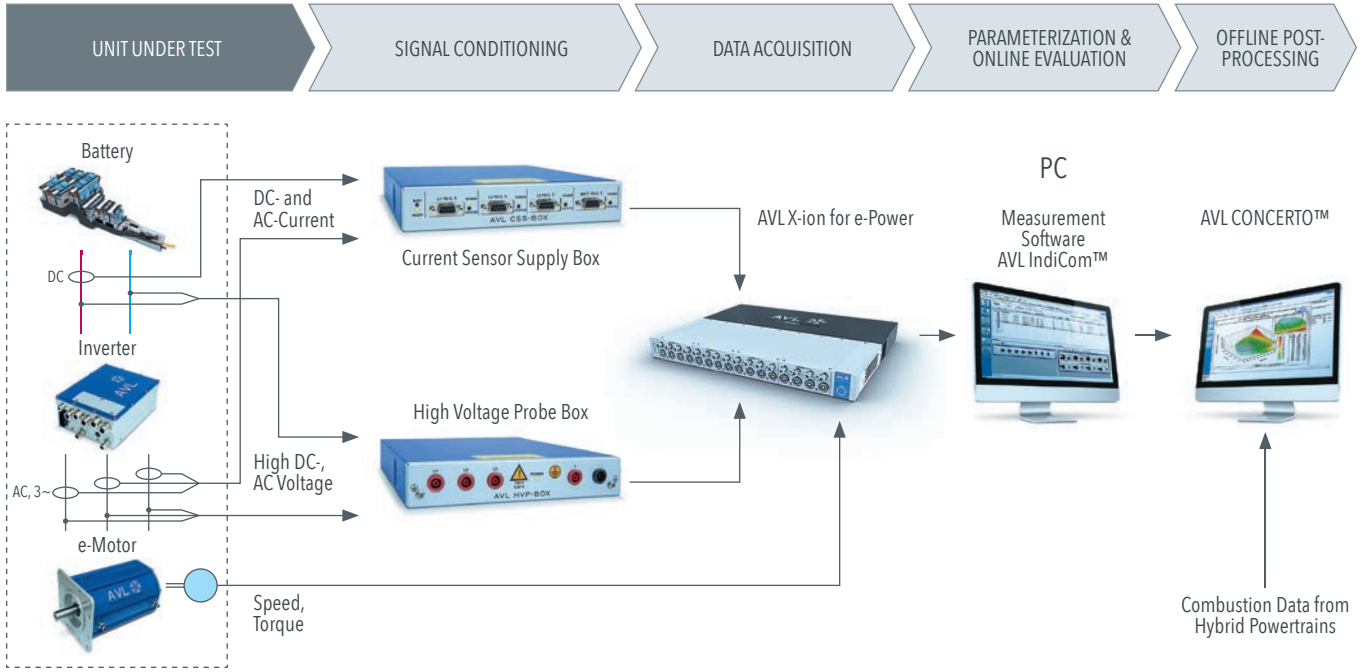
DATA ANALYSIS

Due to a great number of testing tasks and measurements, there are high volumes of data sets. Using the AVL CONCERTO 4™ software, an automated test report can be created in order to keep track of the test results.

BENEFITS AT A GLANCE

- Shorter development times and increased efficiency
- Minimized risk due to professional validation process
- Simplification of complex integration tasks
- Enhanced productivity due to highest degree of automation





New AVL e-Power Analysis System

The AVL e-Power Analysis System is a modular and powerful solution with a high-speed 16-channel data acquisition and processing unit for AC and DC voltage. The system is based on the new AVL X-ion acquisiton platform and designed for measurement and analysis in purely electric as well as hybrid powertrains.

SYSTEM DESCRIPTION

The AVL e-Power Analysis System offers fast measurement of voltages, currents and the speed and torque of the e-motor. The raw data are transferred to a computer and the AVL measurement software supports the user during parameter set-up, measurement and data processing.The results are characteristic values such as true RMS values, electric power (active, reactive, apparent), mechanical power (in conjunction with a torque flange), efficiency, harmonics, fundamental e-motor cycle time, power factor and other relevant parameters. Result values can be represented online in the form of both numerical values and trend charts, and can be transferred to an automation system. In addition, raw data can be acquired during a definable measurement time and stored in a data file easily, allowing for advanced post-processing data analysis.

Automatic detection of the electrical period as well as an automatic calculation of the line voltages out of the measured phase to phase voltages makes the use of an external neutral point adapter unnecessary. This together with more standard calculations are pre-defined as graphical calculation models, fully extendable according to an engineer's need.

COMPONENTS OF THE MEASUREMENT CHAIN

The AVL IndiModul.xEV is perfectly suited to acquiring raw voltage and current data of electrical systems and making them available to the processing software for online evaluation or data storage. Acquisition is performed in a high speed time-based mode and takes advantage of capturing even transient phases.

The AVL HVP-Box is designed for the high voltages of DC and AC circuits on electric powertrains. It transforms four channels of high differential voltages (±700 Vpeak) to ground related low voltages (±10 Vpeak). The unit fits perfectly into the CSS-Box and the IndiModul.xEV DAQ-unit.

The AVL CSS-Box (Current Sensor Supply - Box) is designed as signal conditioning and supply unit for high precision LEM current transducers. The LEM current transducers allow the measurement of high currents up to 1,000 A in the DC and AC circuits of electric powertrains. The AVL CSS-Box supports up to four LEM current transducers and transforms the output current (±1 A) of the transducers to a voltage in the range ±10 V by using high precision shunt resistors.

APPLICATIONS

Pure electric or hybrid powertrains – one system serves all. Together with the operating software AVL IndiCom.xEV the raw data can be stored on the harddisk of the PC. With the post-processing software AVL CONCERTO™ data from combustion measurement can be merged to create a combined result data file in an absolute time synchronous matter.

AVL TIPPELMANN FLOW MEASUREMENT

Flow Test Benches R&D

PRINCIPLE

Modern combustion engines must meet continuously increasing demands for efficiency and exhaust gas quality. All air-conducting components, in particular the intake and exhaust ports in the cylinder head, determine the in-cylinder flow and thus have a decisive influence on the combustion characteristic. When evaluating these influences an accurate, reproducible measurement of qualitative and quantitative flow characteristics is essential.

The method to determine Tippelmann swirl and tumble numbers is based on the integral detection of the momentum components embedded in the cylinder flow. It has been developed and patented by AVL Tippelmann and is now established at all major engine manufacturers.

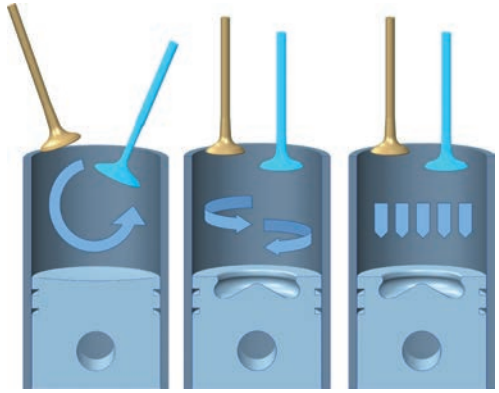
APPLICATION

AVL Tippelmann flow test benches are suitable for a wide range of applications, from motorcycle, car and truck up to big engines. The characteristic values measured allow a detailed analysis of the influence of the air-conducting components on the in-cylinder flow.

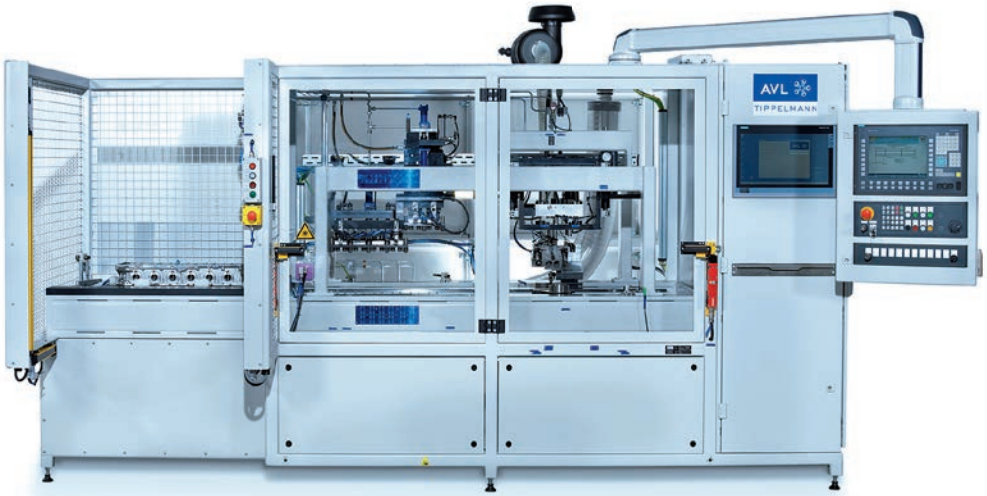
R&D Flow Test Bench

BENEFITS AT A GLANCE

- Robust construction for industrial use
- Wear-free and low maintenance
- Accurate, reproducible measurement results
- User-friendly operation due to innovative software solutions
- Exact workpiece positioning using customized mounting plate
- Multiple measuring systems installable in accordance with the customer requirements



In-cylinder Flow Characteristics: Massflow, Swirl, and Tumble



Semi-automatic Swirl Test Rig

Fully Automatic Swirl Test Rig

AVL TIPPELMANN FLOW MEASUREMENT

Flow Test Benches for Quality Control in Serial Production

AVL Tippelmann develops customer specific solutions for random sample QC …

BENEFITS AT A GLANCE

- Minimal labour utilisation due to high level of automation
- Part identification with integration into the customer's production control system
- Automated valve assembly and disassembly
- Short measuring cycles
- Testing of several engines from one family at the same test bench

… to the point of 100 % QC with full integration of the test rig in the production line.

BENEFITS AT A GLANCE

- Fully automatic operation, 24/7
- High equipment availability by means of robust, modern and proven technology
- Automated machine autoadjustment
- Integration into the production line
- 100 % quality control
- Cycle times suitable for series production

AVL TIPPELMANN FLOW MEASUREMENT

PIV Flow Test Benches

PRINCIPLE

In PIV-measurements (Particle Image Velocimetry) microscopic particles are illuminated by a laser light sheet during two closely timed pulses and simultaneously recorded photographically.

Using two cameras the spatial components of particle motion are obtained, from these the three-dimensional velocity field in the measuring plane is determined.

Velocity fields can be visualised and are well suited to the validation of computational fluid dynamics results.

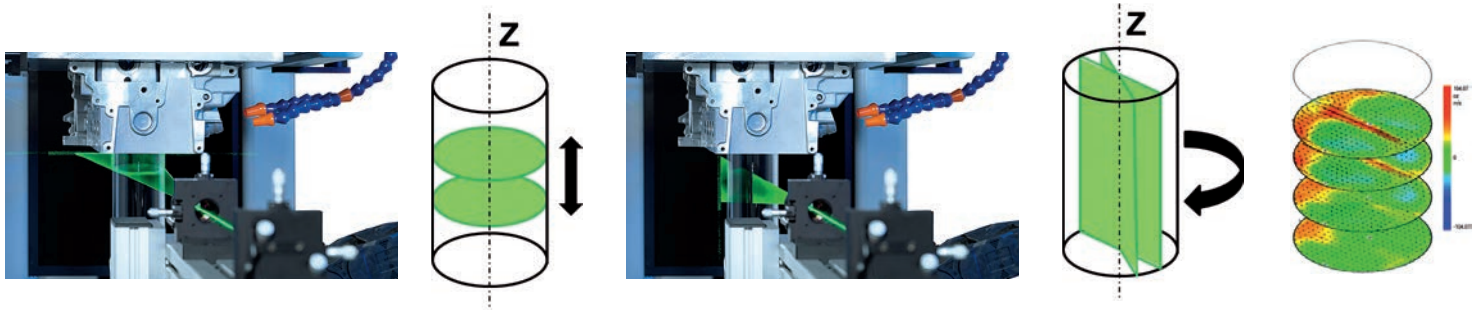
Similarly, the conventional flow characteristics (mass flow, Tippelmann swirl and tumble numbers) can be derived from the velocity fields, allowing a quick comparison with results of the integral momentum measuring technique.

In addition, other characteristics of the flow field, such as the position and orientation of the swirl and tumble axes or the omega tumble value, can be determined, further contributing to the analysis and documentation of the influences of air-conducting components.

Stereo PIV

BENEFITS AT A GLANCE

- Precise three-dimensional recording of the velocity field
- Velocity fields from different planes can be combined to visualise the spatial velocity distribution
- Measurement close to the combustion chamber surface of the cylinder head
- Automated measurement sequence
- Comparability to integral momentum measuring method according to Tippelmann
- Safety requirements for industrial use are met



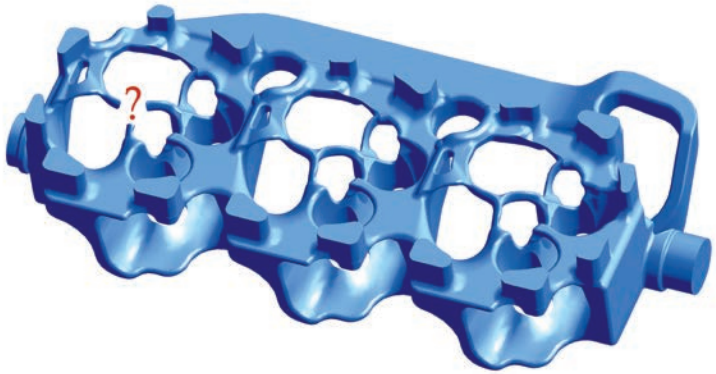
AVL TIPPELMANN

Acoustic Cavity Check System (ACCS)

PRINCIPLE

Cavities with complicated shapes can be examined efficiently using the acoustic cavity inspection system (ACCS) developed and patented by AVL Tippelmann. For this purpose a sound signal is introduced at an opening of the cavity. The transmitted signal is recorded at one or more other openings. Transmission behaviour is essentially determined by the geometry of the cavity. Deviations in phase and frequency response compared to correctly shaped cavities are thus due to geometric errors in the examined cavity. The method is, therefore, suitable for detecting inclusions and full or partial blockages in castings.

A typical application is the testing of water jackets in cylinder heads in series production featuring a complex branched and meshed structure.



BENEFITS AT A GLANCE

- Suitable for complex shaped cavities (e.g. water jackets)
- Short cycle times enable 100 % QC in serial production
- Automated measurement sequence and part evaluation
- Robust measurement instrumentation
- Low Wear and low maintenance
- Low energy consumption

A/C Testbed

The development of the qpunkt A/C testbed is based on our long-standing experience and deep understanding of the subject air conditioning. Its purpose is to provide new insights into complete A/C systems.

The modular design of the testbed allows for custom setups to fit the individual needs of each customer, and supports the efficient development of refrigerant cycles and entire A/C systems of motorcars, commercial vehicles as well as motor trucks.

APPLICATION

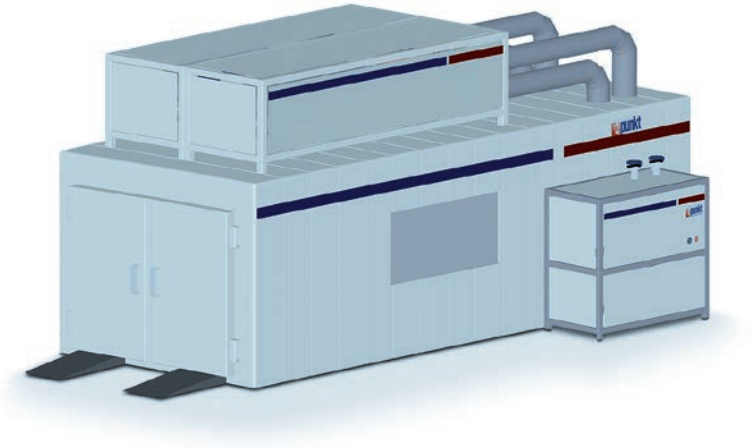
The A/C testbed has a wide range of applications. Applications range from the development of new A/C systems using R134a, 1234yf, R744 (CO_2) and alternative refrigerants, to performance evaluation studies of air conditioning units in connection with the refrigerant cycle, and even to the analysis of potential flaws and faults in the system.

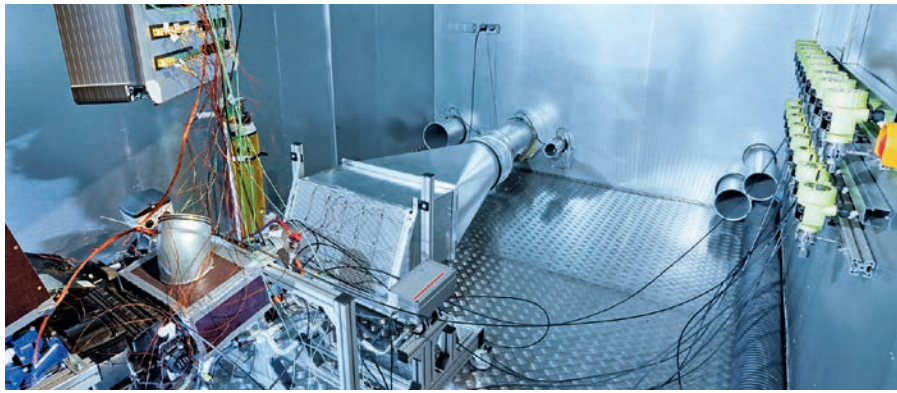
The testbed facilitates the development of one or two stage evaporator systems with the aim of: increasing overall system efficiency; tuning expansion valve performance to cycle behaviour; and analysing oil displacement and oil transportation, etc.

Refrigerant-air heat exchangers are supplied with conditioned air (temperature, volume flow, humidity), so allowing for the simulation of stationary loads as well as full driving cycles. Using this methodology it is also possible to develop entire refrigerant cycles of hybrid vehicles with integrated battery cooling.

Using the testbed as a closed climatic chamber, the refrigerant cycle can be exposed to a wide range of loads and operating conditions. If required, it is possible to generate a controlled outdoor climate with a temperature range between –25 °C and 60 °C, including control of the humidity in the test environment. It is also possible to simulate any desired weather condition, such as a rapid transition (quick cool-downs and quick heat-ups).

Another area of application for the A/C testbed is its use as a climatic chamber for measuring different test set-ups and vehicles.





Expanding the A/C testbed with dedicated conditioning modules allows for customised, dedicated setups for a wide range of specific thermal investigations. The A/C testbed can be installed in a standard ISO container for ease of transportation, or can be custom-fitted to individual customers' specifications and requirements. The test chamber can accomodate installations ranging from small refrigerant cycle set-ups to SUV-sized full vehicle set-ups.

ADVANTAGES AT A GLANCE

- Simple monitoring of the cyclic process during measurements through a precise and structured online interface
- High level of user friendliness through the use of innovative software solutions
- Cost-efficient system measurements, even for full vehicle integration cases
- No temperature situation is too extreme – be it Antarctic-cold or Sahara-heat
- Easily expandable into a fully multifunctional testbed for a wide range of specific thermal investigations

GENERAL TECHNICAL DATA

(Adjustments can be made to suit a customer's specific needs.)

Container Size L x W x H	7 m x 2,8 m x 2,7 m
Temperature Range	–25 °C to +60 °C
Volume Flow Evaporator	10 m³/h to 1400 m³/h
Volume Flow Condenser	60 m³/h to 6,000 m³/h
Humidity Control	10 % to 90 % rH
DC Voltage Connection	to 400 V/16 kW
Process Connections	–29 °C to +90 °C controllable

A/C Compressor and Component Testbed

The heart of each refrigerant cycle is the refrigerant compressor. qpunkt's A/C compressor testbed provides efficient testing capabilities regarding functionality, quality and safety for all testing conditions and requirements.

APPLICATION

The main application of the compressor testbed is the performance- and endurance testing of refrigerant compressors. An advanced testbed automation provides fully automatic determination of performance characteristic maps and corresponding compressor efficiencies. External heating of the compressor allows for the replication and study of unfavourable thermal loads. All types of refrigerant compressors, electrically as well as mechanically driven, can be measured at the testbed.

By extending the compressor testbed or integrating the compressor testbed into the A/C system testbed, all other components of a typical A/C system, such as evaporators, condensers, filters, etc. can be tested. Tests can be performed either standalone or fully integrated into a full A/C system setup. Due to the redundant setup of single components of the refrigerant cycle, each component can be replaced by the internal elements of the testbed at any time.

ADVANTAGES AT A GLANCE

- Suitable for all types of refrigerant compressors
- Simple monitoring of the cyclic process during measurements through a precise and structured online interface
- An innovative contactless measurement procedure of the piston stroke minimises measurement error rate
- Controlling the operating points with the highest stability and precision, controllable superheating and sub-cooling

GENERAL TECHNICAL DATA

(Adjustments can be made to suit a customer's specific needs.)

Compressor RPM	Up to 10,000 U/min
Refrigerant Mass Flow	0–500 kg/h
Refrigerant Pressure	40 bar, R744-performance up tp 160 bar
Driving Power	Up to 15 kW
Condenser Power	Up to 30 kW
Refrigerants*	R134a, R1234yf, R451a, R744

Measurement of refrigerant mass flow according to Coriolis principle
Continuous measurement of oil concentration
*further refrigerants on request

Filter- and Valve Testbed

The filter- and valve testbed from qpunkt was developed especially for filters in pressure-driven (hydraulic) flow, like oil and diesel filters. State-of-the-art control algorithms provide a simple, intuitive handling and thereby guarantee optimal processing times.

APPLICATION

The testbed is used in the development of new filter elements and filter components as well as during the quality assurance review within the production process.
The filter and valve testbed from qpunkt covers the following tests:

- Differential pressure of filters, according to customer specifications or to ISO 4548-1, BS 7403-1 and ISO 3968
- Flow behaviour, static as well as dynamic test conditions
- Opening pressure of bypass valves
- Leakage tests of bypass- and anti-drain valves

Due to the modular design of the testbed it can be easily adapted to meet a wide variety of customer needs, e.g. for different tests according to ISO 4548.

The test procedure can be performed manually, but also fully automatized – even an automatized creation of the test protocol is possible. Application of, or coupling with, a customer specific software is also realisable.

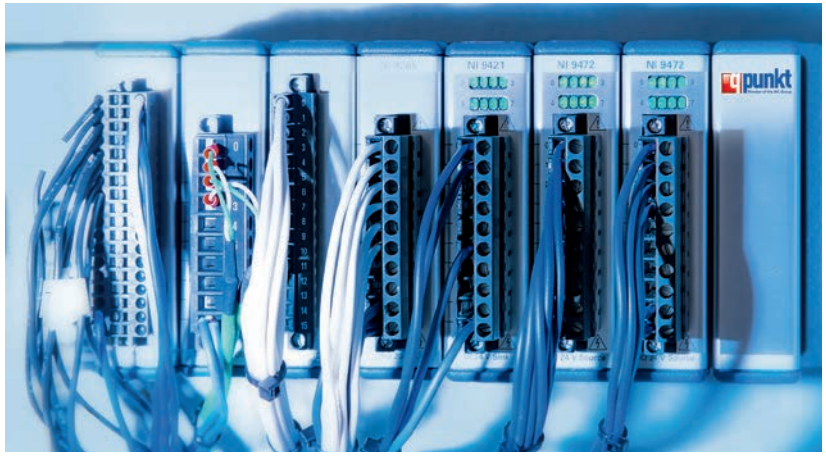
ADVANTAGES AT A GLANCE

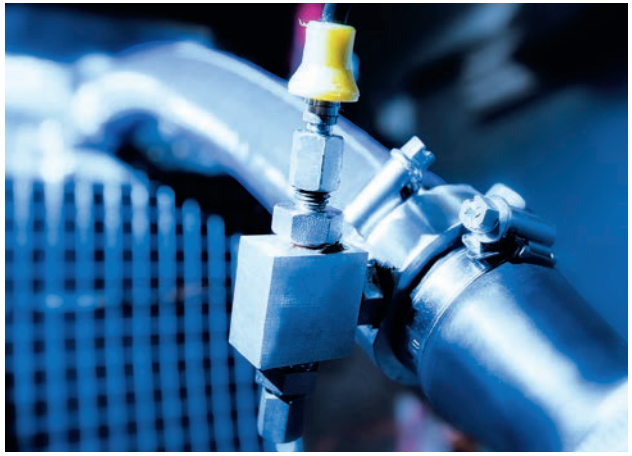
- Highest measurement accuracy through intelligent sensor wiring
- Short testing periods using a high degree of automation
- High customer value by being able to perform different tests on one testbed
- Highly flexible – due to the modular design of the testbed it can be adjusted to meet a variety of customer needs

GENERAL TECHNICAL DATA

(Adjustments can be made to suit a customer's specific needs.)

Mass Flow	0–120 l/min
Alteration Rate Flow	Up to 100 l/min/min
Temperatures	0–160 °C
Max. Pressure of Medium	18 bar
Medium	Mineral and synthetic oils, Diesel and Biodiesel
DC Voltage Connection	Up to 400 V/32 kW





Heat Exchanger Testbed

Using the heat exchanger testbed from qpunkt, measurements on different types of heat exchangers can be realised fully automatically and with high efficiency. Particular focus is placed on a high level of measurement accuracy and a high level of reproducibility of results.

APPLICATION

The modular design of the heat exchanger testbed allows for an efficient and exact measurement of the full range of heat exchangers installed in a vehicle e.g.:

- Charge-air intercoolers
- Water coolers
- Oil coolers
- Plate heat exchangers
- Evaporators – using a variety of refrigerants
- Condensers – using a variety of refrigerants
- Battery coolers – conventional cooling and direct evaporation

Centrepiece of the testbed is the cooling air conditioning unit. Volume flow, temperature range and humidity control can be individually set according to customer requirements to represent both steady state conditions as well as driving cycles. The conditioning units for charged air, coolant, oil and refrigerant can be set up modularly, thus allowing a tailored, individual assembly of the testbed.

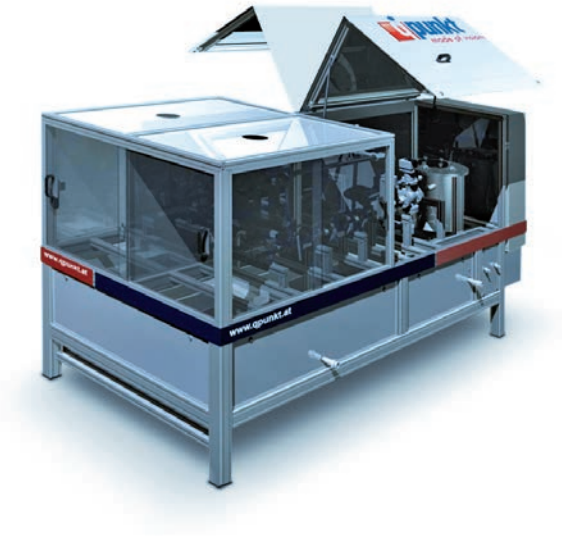
Once the input boundary conditions (measurement matrix) have been defined, the measurement procedure as well as the evaluation of the results are carried out fully automatically.

Chief among the results are the performance characteristic maps and resulting limitations of use of the heat exchanger, the pressure losses at normal operating conditions and the isothermal pressure losses.

The high level of control dynamics on the testbed also allows for the evaluation of the heat exchanger regarding its dynamic behaviour and its behaviour during real-life driving cycles.

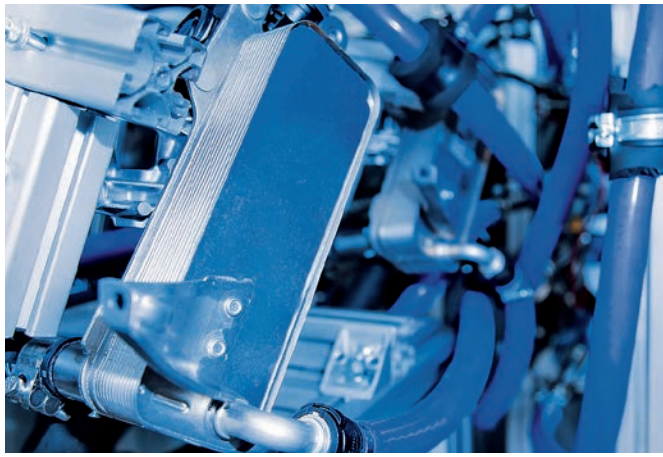
Long-standing experience with measurement technology and testing of heat exchangers in our own in-house testing facility is epitomised in the precision and user friendliness of our testbeds.

The heat exchanger testbed is also an ideal addition to the functionality of the A/C system testbed. By extending the A/C system testbed with different conditioning units, this heat exchanger testbed can be applied as a multifunctional testbed for further thermal evaluation.



ADVANTAGES AT A GLANCE

- High precision measurements of cooling performance and characteristic pressure drop curves on both sides of the media
- Measurement efficiency and highest accuracy of results is guaranteed
- Automatic measurement procedures ensure the reproducibility of results and short processing times
- The modular design allows for a later extension of the testbed functionality



GENERAL TECHNICAL DATA

(Adjustments can be made to suit a customer's specific needs.)

	Air	Charged Air	Coolant	Oil
Mass-/Volume Flow	0–4 kg/s	0–0,25 kg/s	0–210 l/min	0–100 l/min
Performance Flow	0,5 %	0,5 %	0,1 %	0,2 %
Temperatures	–25–60 °C	50–200 °C	0–120 °C	20–145 °C
Performance Temperatures	0,05 °C	0,25 °C	0,05 °C	0,05 °C

ENDURANCE TESTING OF HYDRAULIC COMPONENTS

Thermal Shock Testbed

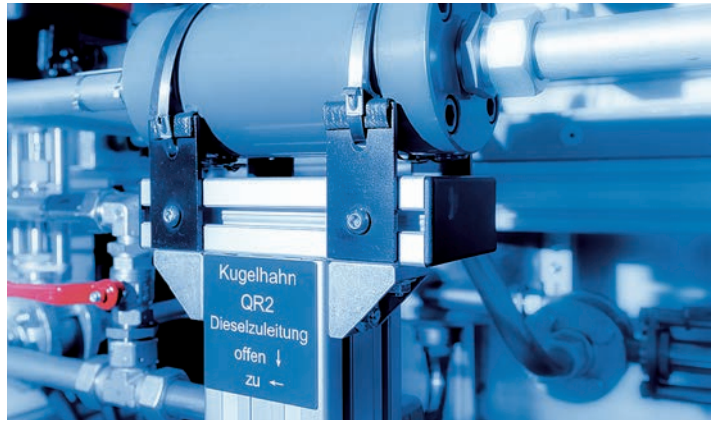
To meet manufacturer requirements / standards and for quality assurance, various hydraulic components are required to pass specific thermal shock tests. The thermal shock testbed from qpunkt provides a reliable and efficient testing method for thermal shock.

APPLICATION

Typical applications for the thermal shock testbed are endurance tests of thermostatic valves, plate heat exchangers or pipes. Very rapid switches over time are possible by using separate tanks with cold and warm testing media. A high degree of automation allows for a variety of different temperature profiles (square, trapezoid, triangle, etc.) and a precise control of heating and cooling rates. An optional design adding an additional media cycle provides testing capabilities for multifluid / multicycle components like e.g. plate heat exchangers.

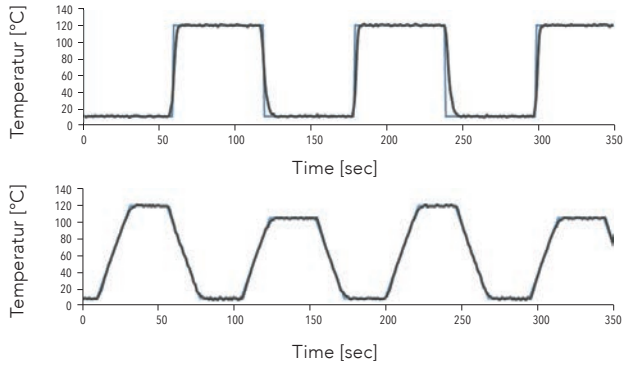
The basic version of the thermal shock testbed includes mounting points / outlets for the simultaneous testing of four test items, and can be extended far beyond that. Optionally, test items can also be placed in a conditioned chamber to minimize the influence, or study the impact, of external heating sources.

The testbed software controls the complete automated test procedure. Using remote access, intelligent disruption management of the testbed and the embedded disruption report by telephone it is possible to achieve a 24/7 operation without operating staff on-site.



ADVANTAGES AT A GLANCE

- Application of various testing media e.g. water-glycol, engine oil, gearbox oil, etc
- Highest reliability as a result of long-standing experience with endurance and thermal cycling tests at our in-house testing facility
- Covering a temperature range from –30 °C up to 150 °C



Rain Chamber

The rain chamber from qpunkt was developed to perform various vehicle specific leakage tests. In the qpunkt rain chamber entire vehicles as well as single components can be exposed to diverse rain conditions.

APPLICATION

The rain chamber is predominantly used to study full vehicles, with emphasis on:

- Tightness of the doors/claps: the vehicle is exposed entirely or partially to different water amounts. Inside the vehicle leak tightness is controlled using visual inspection, video or moisture sensors.
- Performance of the water separation in plenum chambers and/or inlet of the air conditioning unit: large amounts of water are introduced to the windshield/engine-hood area of the vehicle, or to a special construction representing a one-to-one model of the vehicle front. The fan is activated, and the amount of water inside the air conditioning unit is measured.

Another application area of the rain chamber is component testing. The tightness of different modules and car bodies can be tested.

ADVANTAGES AT A GLANCE

- Applicable to a wide range of scenarios and load cases due to customisability of size and position of the sprinkling / flush area
- Variable choice of rain groups / fields
- Precise control of water amount and pressure
- Simple tailoring of the testbed to a wide range of rain conditions through simple replacement of the nozzles
- Direct accessibility (full vehicle or fork lift)
- Visual control of the test procedure (Plexiglas walls)
- Closed cycle for the process water to minimise resource consumption

EFFICIENT CALIBRATION DEVELOPMENT ON THE VIRTUAL TESTBED™

AVL Virtual Testbed™

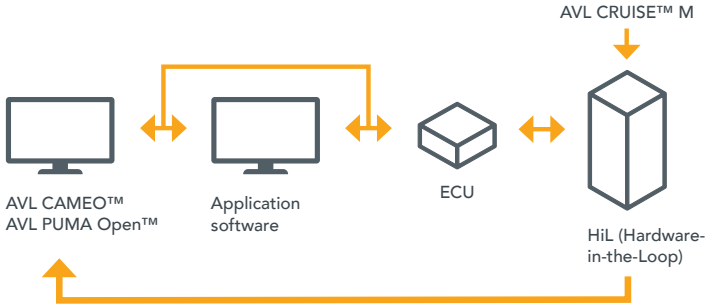
The AVL Virtual Testbed™ closes the gap between simulation and conventional engine and vehicle testing. The testing platform is common between the virtual and real environments. If offers the opportunity to significantly reduce requirements for conventional testing in terms of powertrain development.

The AVL Virtual Testbed™ successfully combines real-time powertrain models, OEM xCU's and an automated operation and optimization platform in an all-in-one solution, which is already common among calibration and testing communities.

The platform is real-time capable and offers direct access and optimization of the actual xCU parameters. The openness of the system also allows the integration of customer-built models.

An important aspect is the initial development and pre-calibration for emissions optimization over various cycles such as NEDC, FTP75 or WLTC. The AVL Virtual Testbed™ provides the ideal platform for such calibration analysis and optimization. The investigation of emissions in real driving conditions (RDE) is enabled by generating associated virtual driving routes.

VIRTUAL CALIBRATION AND TESTING MADE ACCESSIBLE



The central components of the platform between real and virtual environments

For the task of development and calibration, the AVL Virtual Testbed™ offers the engineer a well-known interface, thus providing a common platform, enabling a consistent calibration and testing approach in either the virtual or real environment.

FULL TEST FIELD INTEGRATION

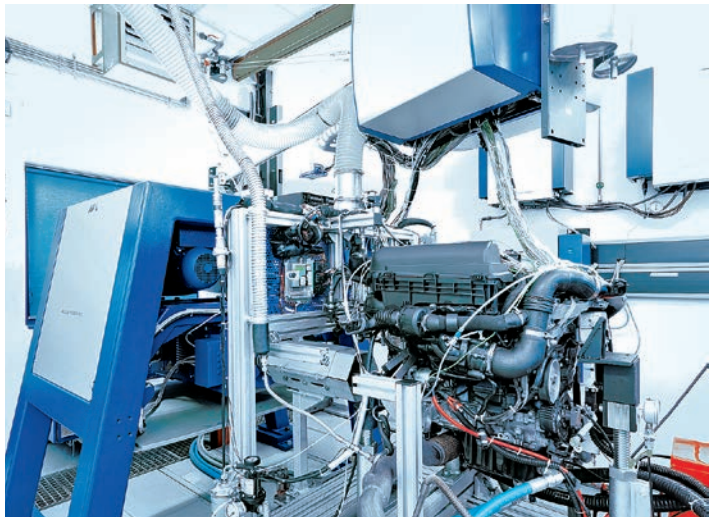
Test field operation profits from full integration of the AVL Virtual Testbed™ in the existing test field. The AVL Virtual Testbed™ joins existing data structure, and measurement results are transferred to the server system like any other testbed. Optimized xCU labels for a vehicle project can be maintained and organized using the calibration data management system AVL CRETA 4™.

BENEFITS AT A GLANCE

- Flexible calibration development process
- Shifting development from the real environment to the virtual environment
- Significant cost and time saving throughout the development process
- Improved calibration quality
- Maximum reproducibility of testing conditions
- Integrated development environment: Lab – Testbed – Road

AVL Engine Test Systems

Several thousand installations worldwide and the experience gained in doing so allows AVL to offer state-of-the-art and innovative engine testbeds for a broad field of applications. The broad spectrum ranges from the conceptual combustion development and basic research on the compact single cylinder testbed, dedicated development and calibration testbeds as well as solutions for engine homologation and production approval. There are no limitations in engine size and powertrain concept. All types, from small hand held engines to motorcycles, engines for passenger cars and commercial vehicles (off-road and on-road) up to propulsion for marine vessels and trains. An electrified powertrain can also be tested with the AVL test systems.



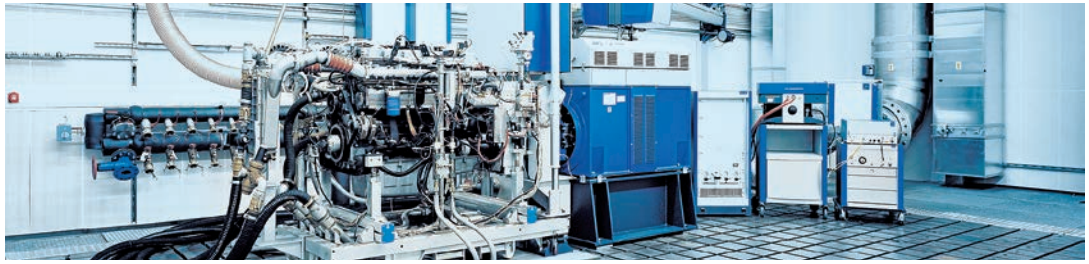
AVL successfully develops engines, transmissions and drive concepts for the automobile and transportation industries. This expertise is an integral element when designing our test systems. The testbed is designed by engine developers for engine developers. Equipped with state-of-the-art measurement, accurate control, flexible automation and smart integration of real-time simulation, AVL test systems are well prepared for all current and future development tasks. Modular design and an open-platform philosophy with the option of system extension turn the AVL testbed system into a secure investment for the future.

Typical fields of application for AVL engine and testbed technology are as follows:

- Combustion development and basic research
- Performance and emission development
- Parameterization and calibration
- Emission certification of engines for heavy-duty applications
- Endurance testing and aging of components for exhaust gas aftertreatment
- Component testing near the engine
- Mechanics and function development

MITIGATING INCREASING COMPLEXITY

The engine development process must rise to the challenge of the increasing vehicle complexity. Additional actuators, integrated support systems, more stringent emission laws with regional differences like the introduction of real driving emissions RDE requirements in Europe, new technologies and the ongoing rise in electrification – these are all have a bearing on work of the development engineer. AVL continuously searches for new solutions as well as intelligent methodologies and develops numerous state-of-the-art tools which are integrated in the test system and made available to the developer.



Testbed arrangement for calibration and optimization

HIGH LEVEL OF ACCURACY AND OPERATING POINT STABILITY

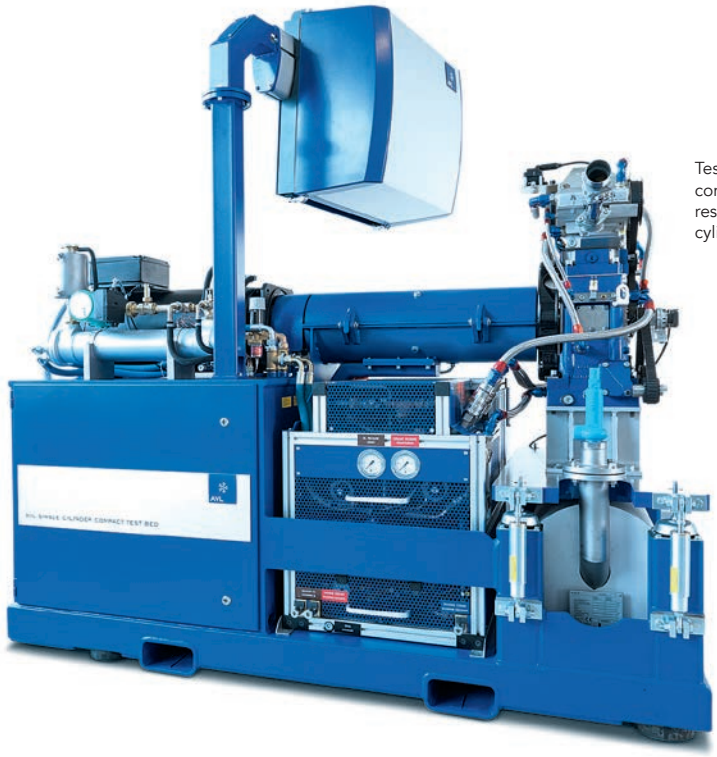
High measuring and data quality are core requirements which provide the development engineer with a suitable basis for making decisions. System components and instruments from AVL fully meet these requirements – highest stability at the stationary operating point or exact repeatability of dynamic procedures. The time required for measurements is reduced while simultaneously ensuring high data quality.

EFFICIENT DATA MANAGEMENT

The data management system located locally at the testbed allows parameters, measurements and data to be handled in a structured manner. This system can also be shifted to a host system. AVL believes that networking and ASAM compliance should be a part of all systems involved in the development process.

BENEFITS AT A GLANCE

- More than 40 years of experience in the development and design of automatic engine testbeds and test facilities
- Proven system functionality used on a day-to-day basis within AVL-operated engine development centers all over the world
- Flexibility due to modular design
- Highest data quality due to excellent system accuracy
- Continuous development and enhancement of the testbed for actual and future engineering work



Testbed arrangement for combustion and basic research with AVL single cylinder engine

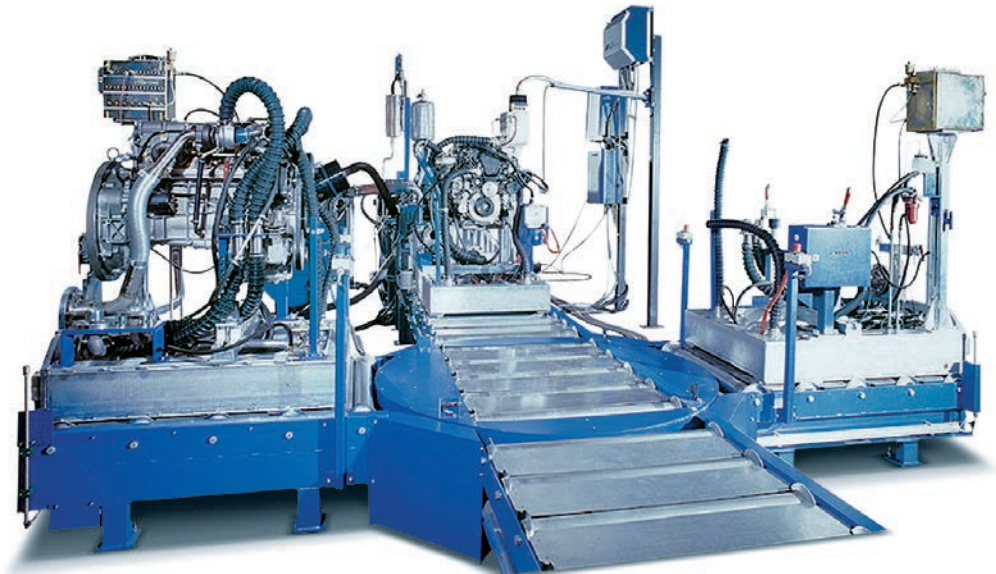
AVL End of Line Test Systems

End of line test systems for internal combustion engines are an integral and indispensable part of engine production. Within the framework of production, end-of-life test systems are used to evaluate, analyze and optimize the quality of internal combustion engines. Measurement, test and process systems are designed according to customers' requirements and are based on AVL's tested hardware and software standards.

INCREASING SYSTEM COMPLEXITY WITH ENGINES

Due to the ever increasing system complexity and diversity of variants for internal combustion engines, the challenges for end-of-line testing increases as well. This is the result of both the increasing number of sensors and the actuation system and numerous new mechatronic systems. Engine components are also increasingly purchased from third parties, meaning the quality can no longer be influenced by the OEMs. Nowadays, a simple hot test with no load is no longer sufficient to ensure the functionality and quality of a state-of-the-art engine. Today, test methodology and technology must be adapted precisely to the drives being tested and the production processes to be used. AVL solutions aim to integrate the production test facility in the production procedure in a holistic manner.

AVL end-of-line test solutions are available for light-duty, medium-duty and heavy-duty engines. The range of solutions starts with the verification of the functionality of subsystems in the manufacturing line and covers cold and hot tests and goes through to quality audit testing.



AVL offers test systems for all required test purposes

Comprehensive understanding of the test mechanism and unmatched system solution experience make AVL the ideal partner for designing and implementing state-of-the-art production testbed solutions.

AVL PROVIDES COMPLETE SOLUTIONS

The turnkey solution services – offered by AVL – range from process analysis, through planning and development, to the construction of a holistic test system integrated in production. The ready-to-operate transfer of systems is followed by AVL operational support.

AVL end-of-line test systems are best delivered as container systems and can be integrated into an existing production environment in a quick and easy manner by means of defined interfaces. Depending on the requirements, the customer is provided with anything from a manual to a fully automatic solution.

TEST SOLUTIONS FOR ALL ENGINE SEGMENTS

To suit widely varying requirements, AVL testbed solutions are divided into the following application segments:

- Light-duty, passenger vehicle engines and light-duty commercial vehicles
- Medium-duty engines
- Heavy-duty engines

AVL offers test systems for all required test purposes; in-process verification, cold and hot tests as well as COP/QA (Conformity of Production/Quality Assurance).

Depending on the engine technologies and the boundary conditions of production, different quality concepts are also selected and equipped with a suitable combination of test systems. This involves a combination of cold and hot tests. COP/QA also makes sense.

BENEFITS AT A GLANCE

- High level of technical system availability due to state-of-the-art, robust, tried and tested technology
- Highest level of flexibility for all customer requirements, modular individual systems functional within an overall solution
- Simple upgradability of hardware and software
- Turnkey systems for each application and customer application (container solutions)
- Huge experience founded on numerous turnkey projects for customers from all over the world
- Global service and support, including 24-hour service

TEST DRIVING STARTS NOW

AVL InMotion 5™

AVL InMotion 5™ is a Hardware-in-the-Loop test solution for virtual road testing with virtual/real vehicles and components: Ask questions, get answers and make high definition decisions right through the process, before massive costs arise. Rely on real-life driving scenarios for efficient powertrain development and test.

AVL InMotion 5™ generates robust and reliable engineering results through industrialized interface models between virtual and real components (testbed integration): This is the key to link up physical and virtual development environments.

For over ten years, AVL has been accumulated outstanding system and application know-how to integrate simulation and test. AVL is the global market leader in this field. Our experts assist you in implementing a tailored solution that provides quality and productivity.

MARKET REQUIREMENTS

Improved efficiency. Enhanced flexibility. Increased productivity.

Shifting from component to system-driven innovation

50 % of today's innovation is system-driven. Real and virtual worlds are converging. This leads to an approach that incorporates real-time simulation and rig-testing into an integrated development and test environment.

Leveraging integrated virtual and physical testing

Mapping the product DNA into the test process and anticipating the operational, real-life driving conditions on the testbed is becoming more and more important for intelligent and competitive powertrain development. Making the virtual and physical environments really link up significantly reduces costs, risk and time-to-market.

Creating sustainable value

System boundaries need to be overcome to create successful and complete testing-solutions. The industry recognizes that both vertical and horizontal expertise all along the test life cycle are required to guarantee long-term stability.

AVL InMotion 5™ APPROACH

Orchestrating the product-process-people continuum.

Pioneer spirit

During the last decade, AVL has been pioneering a testing solution to synthesize integrated virtual and physical virtual road testing on all types of testbeds. AVL InMotion 5™ bundles existing and established software tools for virtual road testing, such as IPG's cutting-edge CarMaker, with any type of powertrain testbed into one integrated testing solution.

Test driving starts now

The power to empower

One of our significant strengths is our ability to take over responsibility for the complete simulation/testing solution: products, processes, people. As a result, our customers reduce their risk, installation time and project complexity, while simultaneously improving system safety and reliability.

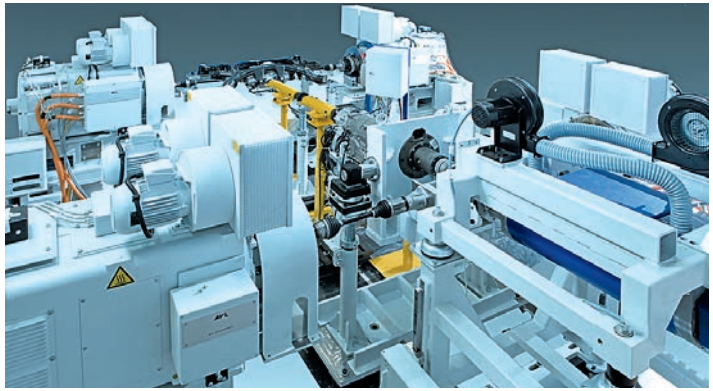
Our experts have accumulated an outstanding technological expertise about how best to realize virtual road testing on all types of powertrain testbeds.

AVL InMotion 5™ SUPPORTS GLOBAL AUTOMOTIVE DEVELOPMENT TRENDS

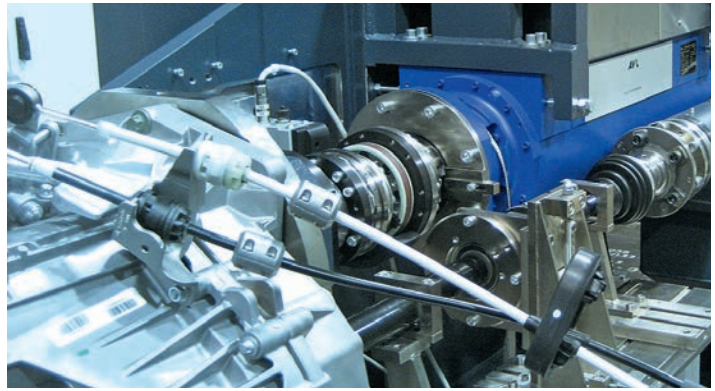
- System-driven product development and test: Test drive your real component (on the testbed) as part of a virtual vehicle environment, hybrid powertrains, interaction with chassis controls, connected powertrains (including ADAS and maps)
- Mapping the vehicle's product DNA into the test process. Test global vehicle attributes all along the process on any kind of testbed. RDE and integrated vehicle energy efficiency.
- Getting complex decision-making situated with the proper test at the right time
- Support a more continuous, progressive and pervasive test process ("agile revolution")

BENEFITS AT A GLANCE

- Brings the test drive to the testbed in an integrated environment
- Bundles the established simulation tool CarMaker for virtual road testing with any type of powertrain testbed into one integrated testing solution
- Vehicle simulation and test automation work in full harmony to qualify and ensure high performance in all test conditions throughout the development process



AVL all-wheel testbed with prime mover for vehicles with longitudinally mounted engine



AVL testbeds with prime mover as IC engine substitute for front-wheel drive vehicles with transversely mounted engine.

AVL Driveline Test Systems

The growing complexity of modern powertrains leads to higher demands on instrumentation and test systems. Validating the powertrain in an early development phase requires methods where as many system functions as possible can be tested without proving ground tests. It is, therefore, mandatory to test available components as early as possible to improve durability, functionality and performance. Vehicle comfort, NVH behavior and driveability as well as fuel consumption and exhaust emission calibration also need be considered. The great challenge of powertrain development is to achieve optimal results in a short period of time and to harmonize opposing development objectives.

Parallel development activities of key powertrain components (combustion engine, e-motor, hybrid engine, transmission, etc.) require drivetrain testing activities at the earliest possible stage without a combustion engine.

AVL's Powertrain and Drivetrain Test Systems satisfy the requirements for durability and performance validation of modern powertrains and transmissions. AVL's flexible Test System design enables the development of various transmission types in different powertrain configurations.

ENDURANCE TESTING

Durability tests determine whether the transmission, drivetrain or powertrain is properly built. These tests verify performance and are carried out 24/7. Methodologies have been introduced (high torque and power) to reduce testing time for durability testing.

SYSTEM INTEGRATION

System integration is defined as the process of bringing together component subsystems into one system and ensuring the subsystems function together. System Integration without having prototype vehicles means frontloading by introducing tools and methods which reduce costs of in-vehicle testing by running them in a virtual environment. System integration in the virtual environment must consider typical functional aspects of road tests, e.g. how a driver interacts with the vehicle (powertrain) how the vehicle reacts to changes in environmental conditions. These interactions can be evaluated during virtual driving maneuvers.

A high dynamic Powertrain in the Loop (PiL) testbed with a virtual vehicle-driver-road-infrastructure-traffic environment system generates real-world testing loads on the powertrain. The inertia of the dynamometers is key to achieving comparable loads.

BENEFITS AT A GLANCE

- Unmanned operation, 24/7
- Evaluation of specified strain limits and lifetime of the transmission case, gear teeth, bearings and clutch packs
- Evaluation and optimization of component dimensioning
- Maneuver Based Testing on a virtual proving ground with vehicle-like loads
- Advanced Calibration for Driveability in an early development stage
- Driveability Assessment without the need for a prototype vehicle
- Emission Calibration without the need for a prototype vehicle

AVL Fuel and Lube Test Systems

Fuel and Lube Testing is a specialized branch of testing in which the engine is prepared and tested in a highly prescribed way, so the potentially marginal influence of the candidate fuel or lubrication oil is determined.

For fuel and lube projects, AVL cannot only supply hardware, software and service deliverables but test engines too; i.e. the complete integrated system capable of delivering the necessary testing objectivity and descrimination.

AVL SOLUTIONS

For CEC test methods AVL can offer complete test installations with an engine prepared for test in line with the test method, mounted on a dedicated pallet. All of the necessary items of instrumentation are provided. One test system is able to support several CEC test methods by changing to pre-mounted test method pallets.

For ASTM Test Sequences AVL can offer engines prepared for test and all necessary items of instrumentation, as specified by the published Test Sequence. For such tests, a dedicated test cell is generally necessary. In addition to CEC and ASTM tests, AVL can provide systems in accordance with JASCO requirements.

Dynamic oil consumption measurement

BENEFITS AT A GLANCE

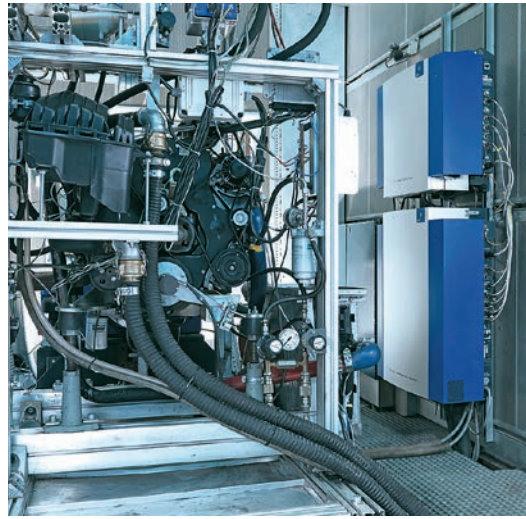
- Expert knowledge associated with specific tests
- Fully integrated solutions to comply with CEC, ASTM and JASCO
- Expert support and advice during laboratory operation
- A comprehensive delivery scope
- Scope of supply can also be extended to test engine

SYSTEM SCOPE

- Test installation – engine prepared for test, pallet mounted, if appropriate, with engine conditioning systems (coolant, oil, intercooler) and engine instrumentation rigging, all as prescribed by the specific test method/test sequence documentation)
- Engine load measuring system (dynamometer)
- Testbed mechanical hardware (pallet receiver, under frame, base frame)
- Automation system
- Post-processing software
- Instrumentation: blow-by and smoke meter, humidity measurement or as specified by the test method/test sequence
- Fuel consumption measurement and conditioning system
- Transducer box
- Engine services box
- Throttle actuator
- Combustion air system
- Engine exhaust with back pressure control
- Testbed and test facility services including ventilation, purge, plant cooling, chilled water, fire detection and suppression, fuel storage and distribution, electrical systems, acoustic attenuation
- AVL Services: engineering, project management, installation, commissioning
- Training: test system and test method
- Consumables including engines and engine parts (test dependent)
- Ongoing support

The provision of Fuel and Lube Oil Test Systems, including test installations for industry standard tests, depends on the current availability of the base engines and the specified hardware. In addition, the purchase of documentation and participation in industry working groups may be necessary.

It is suggested that initial contact is made with AVL so that the appropriate advice and support can be given. This way, up-to-date information can be provided, and the scope of projects can be determined.



Continuous fuel consumption measurement

AVL Emission Test Systems and Certification

AVL exhaust measurement systems are used for developing and certifying engines for cars, light-duty commercial vehicles and heavy-duty vehicles (on- and off-road) on the engine and chassis dynamometer testbed. Optimally integrated device and system solutions, consistent automation and data analysis provide the best possible basis for the highest possible productivity.

AVL offers cutting-edge instrumentation for standard gas emissions (CO, HC, NO_x, and CO_2) and for particle measurement. Its particle measurement technology includes devices for gravimetric measurement and for particle counting. In addition, the AVL product range includes special instrumentation for measuring ammonia emissions in SCR exhaust treatment systems, for example, or measurement systems for evaporative emissions, emissions from small off-road engines (SORE), and portable instruments for drive tests and in-use testing.

All AVL exhaust measurement systems meet the requirement of high efficiency and productivity despite the rising number of measurement parameters and the greater number of devices and subsystems involved. The testbed automation system and the device automation significantly contribute to this capability.

APPLICATIONS

AVL exhaust measurement systems fall into two categories, (1) engine testbeds and (2) chassis dynamometer testbeds. Heavy-duty vehicles for on-road and off-road use are chiefly tested and certified on the engine testbed. Light-duty vehicles and cars are developed on the engine testbed but are certified exclusively on the chassis dynamometer testbed and on the road.

PARTICLE COUNTING

Recent legislation has increased the importance of particle counting in the automotive industry.

In response to this, the highly sensitive AVL Particle Counter is able to measure the number concentration of all non-volatile particles in the exhaust and allows samples to be taken from a CVS (constant volume sampler) system, a partial flow dilution tunnel or directly from the raw exhaust. The AVL system stands out for its very high dilution factors, high accuracy and low maintenance requirements.

AVL exhaust measurement technology perfectly fits into the testbed environment

AVL M.O.V.E. GAS PEMS – portable emission measurement system.

EMISSION MEASUREMENT ON THE ROAD

Alongside the in-vehicle opacity testing, AVL offers the M.O.V.E. PEMS (portable emission measurement system) series of cutting-edge, portable systems for measuring gaseous emissions and particle mass.

AVL PEMS devices deliver high-precision measurement results and are protected against impact and vibration with damping.

Apart from being utilized during development, PEMS systems are becoming more and more important. This is the case especially due to the new European emission regulation for passenger cars and light-duty commercial vehicles coming into force in 2017, which prescribes road tests for certification.

AVL SESAM i60 FT SII for intelligent multi-component exhaust measurement

BENEFITS AT A GLANCE

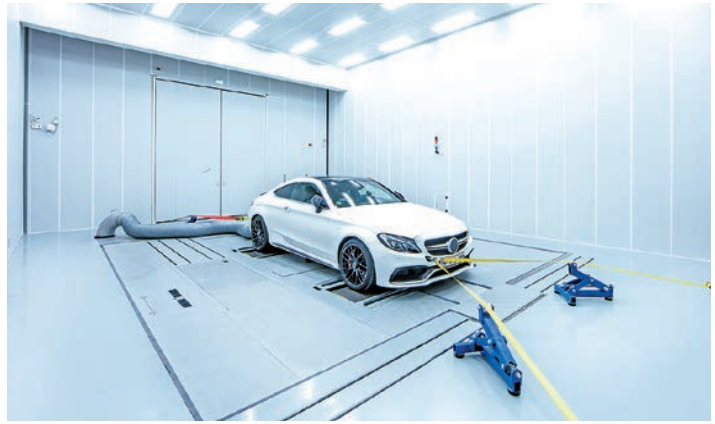
- Refined and functionally attuned complete solutions from the broad AVL product range that can be perfectly adapted to a customer's needs
- AVL covers the entire spectrum of emissions testing from development, through certification, to special instrumentation
- High quality that comes from long experience and a large number of system installations around the world
- Global service and support

AVL Vehicle Test Systems

Today's frontloading-oriented development processes with integrated and consistent use of simulation tools significantly extend the application spectrum of vehicle testbeds. Benchmarking, development and certification tasks previously reserved for road testing are increasingly relocated to vehicle testbeds. Objectification represents a major advantage of vehicle testbeds – reproducible test conditions available at any time ensure efficient tests and measurements. Thanks to highly accurate metrology, intuitive measuring, their control and automation technology (AVL PUMA Open Vehicle Testing) in combination with AVL InMotion™ powered by CarMaker and AVL CAMEO™, the tool chain ACD (Automated Calibration for Driveability) as well as the measuring system AVL M.O.V.E., AVL vehicle testbeds meet all requirements for current and future oriented R&D tasks with regard to an efficient development process. Available for all new hybrid and electric vehicles as well as for all frontloading-related tasks, these tools and features provide a seamless transition from road to testbed, where a realistic simulation is enabled.

CHARACTERISTICS

The vehicle testbed provides a realistic simulation of the road under reproducible environmental conditions. Vehicles with all types of powertrain systems can be tested. As these systems are subject to further diversification, the application fields on the vehicle testbed extend and a central development tool equally integrating all vehicle components will be necessary. Thanks to a closer connection of vehicle testbeds to engine and powertrain testbeds, significant savings can be achieved by re-using test specifications, correlating test results and standardizing test tools and methods. By shifting quality and drivability evaluations, maneuver based testing or powertrain calibration optimization, the application area of vehicle testbeds is broadened as well. The combination of road, laboratory and office, together with AVL InMotion™ powered by CarMaker and its excellent environment simulation, ensures a rational development process.



Exhaust emission measurement and optimization on a vehicle testbed

BENEFITS AT A GLANCE

- Proven solutions for development and certification of all types of vehicles with more than 800 vehicle testbeds running
- Shorter development time thanks to high levels of reproducibility and the reproduction of real driving situations
- Uniform control concept in combination with mature data management is the basis for smooth and efficient testing
- The rational development and validation of vehicles on the vehicle testbed is guaranteed by the efficient and continuous integration of the application tools (e.g. AVL InMotion™ powered by CarMaker and AVL CAMEO™ together with the tool chain ACD)

APPLICATION

Emission, endurance and R&D tests:

Excellent technical quality features and a wide range of thoroughly tested end-to-end solutions are important criteria which recommend AVL vehicle testbed systems. The increasing complexity of powertrain management systems as well as the close interaction of engine and transmission control unit in combination with emission testing often require a uniform R&D test. AVL vehicle testbeds are used in altitude chambers and Running-Loss-SHEDs for the analysis of fuel evaporation. They are also integrated in climatic chambers and climatic wind tunnels to perform component tests under extreme environmental conditions. AVL tools are increasingly used in the field of R&D for the optimization of driveability.

Climate tests of different passenger cars in the wind tunnel

Noise and vibration tests (NVH):

Worldwide, more than 70 active NVH systems are in use, demonstrating AVL's high levels of quality and flexibility regarding project planning of testbed solutions. Here, AVL is characterized by excellent phase control as well as replaceable roller surfaces.

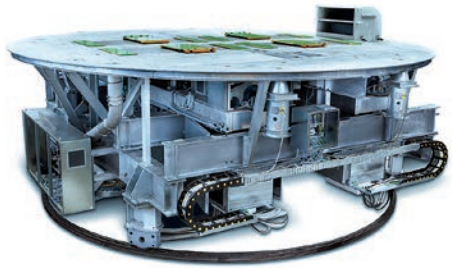
Electromagnetic compatibility tests (EMC):

AVL is the partner with unrivalled experience (> 25 years) and the most reference installations in the field of electromagnetic emission compatibility testing (EMC). Along with robust design and exact road load simulation, technical criteria such as the lowest electromagnetic emissions and high interference immunity over a wide frequency scale, up to gigahertz ranges, are the most persuasive advantages.

BENEFITS AT A GLANCE

- Future proof platform for intelligent drive concepts such as hybrid or electric drives, as well as complex powertrain functionalities (e.g. torque vectoring)
- Shorter development times due to high levels of reproducibility of vehicle tests and well integrated devices in test cells via AVL's control and engineering automation
- Tested usability and workflow design on the AVL vehicle testbed ensure reliable results
- Professional project management on-site by a local contact person

AVL ROADSIM NVH 4x4 LIGHT TRUCK vehicle testbed for noise and vibration testing



AVL ROADSIM EMC 4x4 CAR vehicle testbed for electromagnetic compatibiilty testing

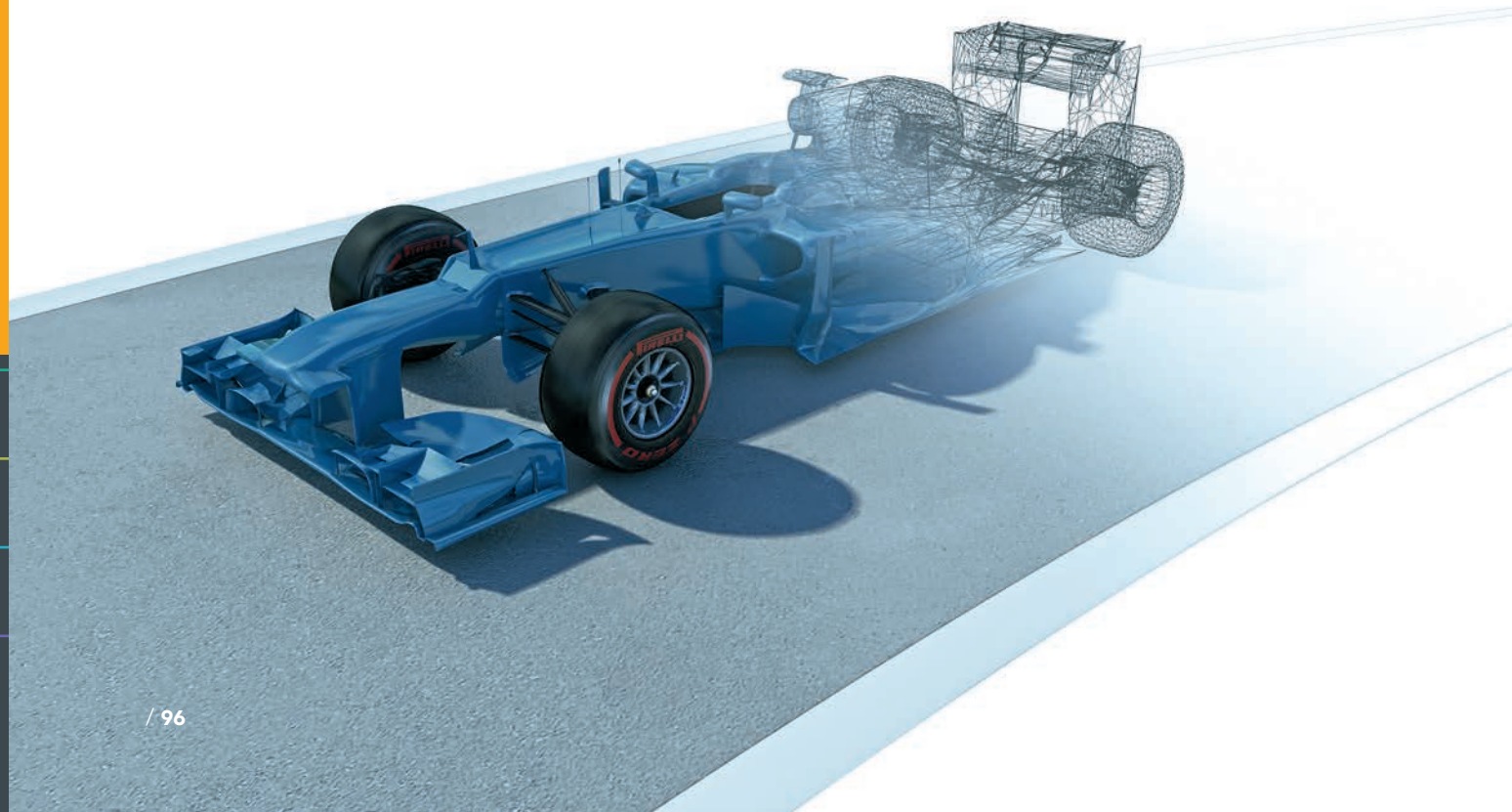
AVL Racing Test Systems

The motorsport group of AVL can quickly and competently react to the needs of motorsport customers. AVL Racing is an ideal interface between the special needs of a racing team and the wide expert knowledge of AVL: One contact person at AVL Racing manages the customer's entire project and forwards it to the respective AVL specialist.

This means racing teams have the entire instrumentation and testing technology expertise of AVL at their fingertips anywhere in the world. From simulating components to developing sensors and full testbed systems, AVL offers quality racecar development and testing solutions that have proven their worth in Formula 1, WEC, NASCAR and many other premier leagues of motorsport.

RACING ENGINE, POWERTRAIN AND COMPONENTS TESTING SYSTEMS

AVL Racing engine and powertrain testing systems stand out from the crowd with their high precision and the reliability of the hardware as well as software. AVL solutions that have been adapted to special requirements are employed for testbed hardware wherever technically possible, whereby the number of common parts can be increased. This is a major benefit to customers in terms of maintenance and the supply of spare parts. The AVL motorsport group also benefits from AVL's software expertise in this field: Special racing applications are deployed in the horizontally consistent AVL Suite, which allows all developmental steps to be performed on one software level.



CLOSE COLLABORATION AND SYNERGIES

Close collaboration between AVL Racing and the experts in series development means their extensive experience in fields such as hybridization/electrification, including battery technology, downsizing and exhaust turbocharging can be put to best use. Given certain regulation changes, in particular those limiting fuel consumption, efficiency is becoming an increasingly important factor of racecar construction in many racing series. This means racing customers benefit directly from AVL's extensive experience in developing efficient solutions for series production which are now needed just as much in racing due to higher efficiency expectations.

COMPREHENSIVE RACING SOLUTIONS

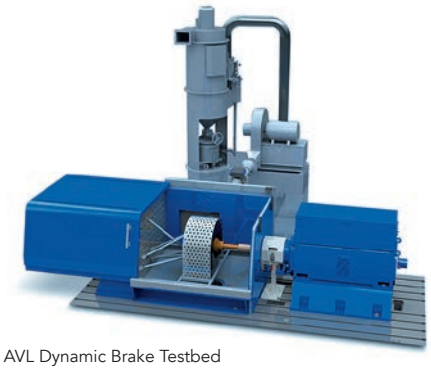
In the world of racing, AVL also provides comprehensive solutions, measurement and testing systems as well as associated services. From employee training to maintenance and parts supply with AVL eSpares, AVL Racing provides a complete solution that allows customers to focus their full attention on racing.

AVL RACING TEST SYSTEMS FOR FULL VEHICLE/COMPONENTS

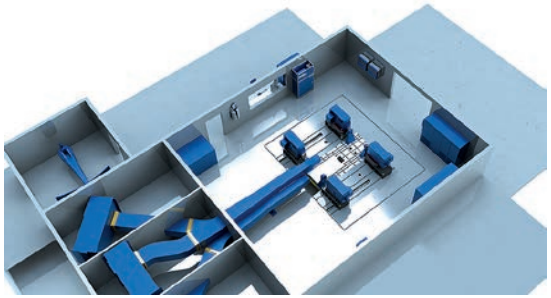
The AVL portfolio also offers test systems for full vehicles and vehicle components. Now the complex tasks from the full integration of hybrid powertrains can be shifted from the track to the testbed.

SERVICE AND SUPPORT

On request, AVL Racing will provide on-site support and resident service (with an AVL technician constantly on-site) to ensure permanent availability of the testing system. Continual updates by AVL allow system adaptations to rules as well as the integration of new functionality.



AVL Dynamic Brake Testbed



AVL Full Vehicle Testbed combines 4WD testbed with thermal simulation and driver simulator for maximum realism

BENEFITS AT A GLANCE

- Access to AVL's broad expert knowledge
- Tested hardware with many common parts
- Horizontally consistent software (AVL Suite)
- Updates to adapt to changes in rules and expand to new functionalities
- Comprehensive instruction and training program
- Maintenance program and 24-hour spare parts service

AVL Dynamometers and Actuators

APPROACH DYNAMOMETERS AND ACTUATORS

The pressure to shorten development time and increase the complexity of testing is increasing, as is the demand on test cells and dynamometers. Dynamometers are the main element in a test cell. They are the components exposed to the hardest working conditions.

The range of performance of modern engines demands dynamometers that are of the highest quality technologically, while also highly reliable and equipped with precise measurement devices. AVL dynamometers meet these requirements in an optimal way.

BENEFITS AT A GLANCE

- Dynamometers are available for different applications
- Test cell design results in a long life span and low maintenance
- Fast torque response is provided by rotorflux vector control of the stator current
- Low mass moment of inertia allows a high-speed gradient
- IGBT converters with random pulse pattern reduce the electrical noise in the machine
- Recuperation of energy especially in endurance tests saves costs and energy
- Compact and maintenance-friendly design

TASK

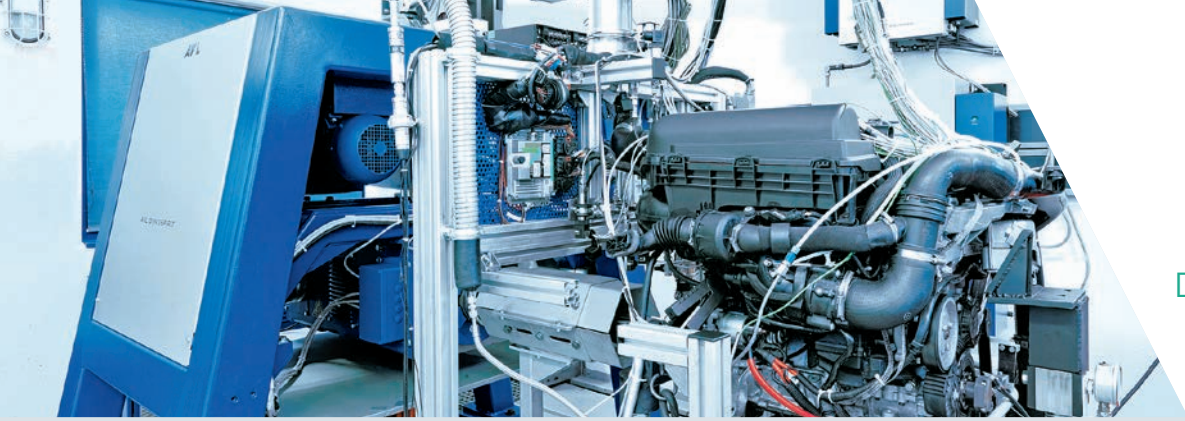
Different test procedures and different engines require different dynamometers. Engine testing with the original vehicle exhaust system requires space where the dynamometer is normally mounted.

A dynamic dynamometer is needed to run dynamic test cycles. The development of intelligent powertrain components through to hybrid systems puts a load on all components, which is comparable to the road test. Therefore, the inertia of the dynamometer should be equal to the inertia of the vehicle's wheel.

Combustion engines with high power are also calibrated and tested in low power ranges. Therefore, the requirements for torque measuring systems and their accuracy increase.

Torque peaks should not influence any technical values of the torque-measuring system. Measuring units can be changed, but the dynamometer must run with low maintenance during its whole lifetime. In case of disruption, the fast delivery of spare parts and well trained engineers must be available to support the customer.

It is also important that it is possible to upgrade dynamometers.



DIFFERENT TEST PROCEDURES AND ENGINES REQUIRE DIFFERENT DYNAMOMETERS AND FLEXIBLE ACTUATORS.

DYNAMOMETERS AND ACTUATORS

Engine test cells

AVL offers dynamometers for different engines and test procedures ranging from eddy current dynamometers, asynchronous and synchronous motors to hydraulic dynamometers for testing even the largest crosshead engines. High measuring accuracy and dynamic control are a must for AVL.

Powertrain test cells

Road to rig reduces development time. Dynamometers with the inertia of a vehicle wheel fulfil the requirements of real test conditions. Powertrain test cells are available for gearboxes, passenger cars with one or more driven axles and for Formula 1 vehicles.

Actuators

Most of AVL's test cells are equipped with the AVL throttle actuator THA. For transmission and powertrain test cells, AVL offers solutions for gear shift and clutch actuation.

AVL test systems

For research and development in the vehicle industry, AVL offers tailored solutions in test, control and measuring technology. Delivered dynamometers can be upgraded with new control systems to satisfy future demands.

LOAD UNIT FOR ENGINE TEST CELLS

AVL DynoPerform

Eddy current dynamometers in the AVL DynoPerform series are equipped with drum rotors. An adjustment of the air gap is not necessary. A DC current flows through the excitation coil. This creates a variable magnetic field that is dependent on the excitation current. The magnetic field of the rotating rotor creates eddy currents at the surface of the cooling chambers. This converts the mechanical energy of the engine into thermal energy. The energy is absorbed by the cooling water which can be retroactively cooled via a cooling tower, as it is the case for the cooling water for the combustion engine.

TORQUE MEASUREMENT

The eddy current dynamometer is a cradled dyno. The reaction force of the brake torque is measured with a strain gauge-based load cell. The measuring accuracy is influenced by the linearity of the load cell and the hysteresis of the dyno. The torque measuring system is calibrated by load beams and dead weights. The measuring error of the load cell can be compensated by the measuring amplifier.

APPLICATION

Cost-effective dynamometer for tests in R&D, quality control and endurance

- Steady-state and transient applications
- R&D for engines and components
- Tests for fuel and lubrication oil

Using the power unit LSE 410 for eddy current dynamometers, very quick load changes are achieved due to the modern IGBT technology with PWM control

BENEFITS AT A GLANCE

- Excellent full-range torque and speed control stability
- No axial forces on the shaft bearings due to drum rotor design
- No air gap adjustment required
- Very fast loading and unloading thanks to an IGBT full bridge power unit with a 4-quadrant PWM controller (substantially faster than a thyristor bridge power unit)
- High permissible coupling weights

LOAD UNIT FOR ENGINE TEST CELLS

AVL DynoDur Compact

AVL DynoDur Compact™ is optimized to the requirements of basic R&D, durability and end-of-line engine test cell applications. The system is fully regenerative and fulfils stringent EU EMC norms EN 61800-3 category C3 for operation in industrial mains environment and as an optional category C2 for operation in residential mains environments. The drive cabinet enclosure is equipped with mains switch, choke and filter as well as a 4Q IGBT power unit. It is, however, very compact and its mains requirements are less than many competitive systems.

CHARACTERISTICS

Energy is recovered on the mains with high efficiency and installation costs fully optimized. High reliability and, therefore, a high number of yearly operating hours are guaranteed by using a combination of an induction motor approved for its robustness in engine testing field together with an industry-based power drive system.

APPLICATION

The AVL DynoDur Compact™ motors are designed to minimize temperature drift on the motor drive-end-side which is equipped for the mounting of a HBM torque flange. This leads to best-in-class torque measurement accuracy and temperature stability. By using the AVL patent-pending calibration system, the calibration check can be done with higher accuracy than when using common calibration levers available on the market. The AVL DynoDur Compact™ was developed based on precise requirements and is the perfect cost-optimized solution.

BENEFITS AT A GLANCE

- Fast return on investment thanks to highly efficient energy recovery
- Fulfils stringent EMC EU norms EN 61800-3 category C3, category C2 available as an option
- Low installation costs through compact cabinet dimensions and optimized mains requirements
- High reliability due to robust motors
- Best-in-class torque measurement accuracy and temperature stability

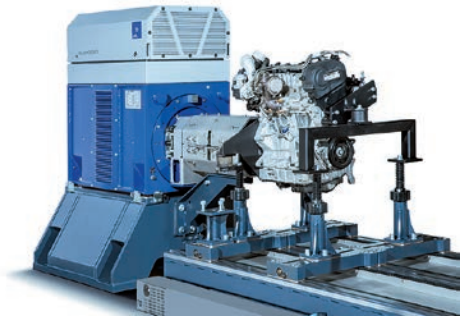
LOAD SYSTEM FOR ENGINE TESTING

AVL DynoFORCE™

The AVL DynoFORCE™ load system consists of a foot-mounted asynchronous AC-induction dynamometer combined with a 4Q-frequency converter cabinet. Together with accessories, it is a unique solution from a single source for professional testing of transient and dynamic engine applications. The series combines well-established components with innovative solutions and offers an optimized balance between TCO and performance.

PRINCIPLE

Thanks to the high power coverage of each dynamometer, a broad engine portfolio can be handled with just twelve performance classes. This ensures highest flexibility with less testbed variants. With its significantly improved torque/inertia ratio, the system is ready for testing today's and future combustion and hybrid engine generations. To achieve real vehicle load transitions, the frequency converter cabinet has a fast torque rise time and a high-speed interface to the controller. High-precision torque and speed measuring instruments ensure highest repeatability of load conditions and therefore a fast progress in engine development. Finally, designed for 24/7 operation, best testbed efficiency is guaranteed.



The new dynamometer series combines highest robustness and extraordinary dynamics. This provides a very wide application range and gives the testbed highest flexibility in various applications.

APPLICATION

The DynoFORCE™ series, designed for stationary, transient and dynamic test runs, can be used for various applications, such as vehicle simulation and exhaust emission measuring of passenger car and truck engines. In addition, other applications such as component testing and friction tests are possible.

BENEFITS AT A GLANCE

- Efficient testbed usage thanks to a flexible load system solution for transient and dynamic testing tasks.
- Easy and subsequent system upgradeability ensures futureproof solution ahead of challenges.
- Optimized Total Cost of Ownership is achieved by improved maintainability and reduction of operation cost.

The new converter cabinet combines latest industrial quality standards with high performance in order to make vehicle simulation reality.

LOAD UNIT FOR ENGINE TEST CELLS

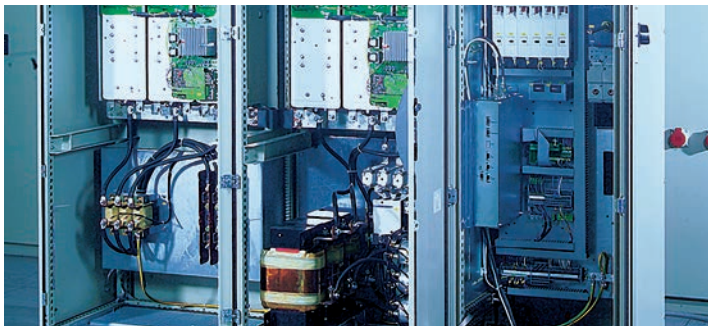
AVL DynoExact

The outstanding measuring accuracy and control dynamics offer engineers a universal tool for research and development related to engines and powertrain systems. More than 1,400 systems have already been installed. The dynamometer was developed by AVL under real test cell conditions. Existing dynos can be upgraded with new control systems.

CHARACTERISTICS

It is possible to choose between two different types of cradle bearings. The first type uses ball bearings as used in eddy current dynamometers, and the second type uses friction- and maintenance-free hydrostatic bearings. The bending beam used allows more movement than a load cell in the cradle bearings which increases the life span of the bearings. All cradle parts are covered for safety reasons.

The built-in fast torque calculator is optimized with the highly accurate actual torque signal. Therefore, a fast and accurate torque signal is created for highly dynamic control loops.



Highly precise, pendulum-mounted, robust AC drive system with a state-of-the-art 4Q-IGBT converter for speed and torque-controlled operation. A real-time torque calculator also provides the shaft torque of the machine in addition to the electric torque (air-gap torque).

APPLICATION

- R&D, quality and endurance testing for engine and components
- Precise vehicle and driver simulation as well as drivability optimization in an engine test cell
- Dynamic engine test for racing

BENEFITS AT A GLANCE

- Very high torque accuracy with hydrostatic bearings option
- Option of torque calibration check during operation
- Option to recalibrate the dyno down to half of the dynamometer nominal torque to increase the torque measurement accuracy for small engines
- Accurate high dynamic torque control
- Option of precise vehicle simulation in the test cell
- Robust industrial design for operation under extreme ambient and environmental conditions
- Easy installation and commissioning due to precommissioned components examined in a shop test

LOAD UNIT FOR ENGINE TEST CELLS

AVL DynoSpirit

New requirements for engine testing demand new types of dynamometers. Standard dynos cannot be used to test an inline engine with the original vehicle exhaust system on an engine testbed because there is no space for it. The AVL DynoSpirit hangs in a frame and the exhaust system can be installed in the available space below. The motors used for AVL DynoSpirit have a proven, robust design that has already been used in many applications.

TORQUE MEASUREMENT

The low inertia of the dynamometer allows a stiff driveshaft connection to the combustion engine. The stiff connection provides the possibility of fast torque measurement and control. The AVL permanent magnet motors have high torque linearity and high accuracy in the open torque control loop. In combination with the AVL dynamic control package (KIWI, AVL EMCON™, AVL ISAC™), the AVL DynoSpirit offers the highest level of dynamics and accuracy for torque control.

Highly dynamic, compact AC drive system for testing combustion engines consisting of state-of-the-art permanent magnet motor and IGBT frequency converter for 4Q operation with a digital real-time interface. Enables, together with a portal frame, testing of the original exhaust system.

APPLICATION

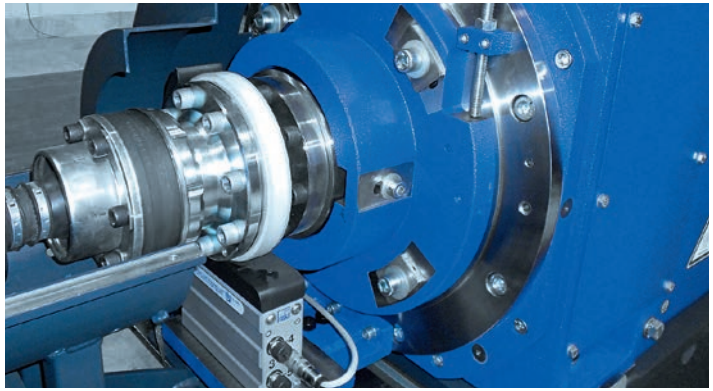
- R&D, quality and endurance testing for engine and components
- Precise simulation of vehicle load on an engine test cell
- Calibration of engine management systems
- The dyno is designed for extreme ambient conditions

BENEFITS AT A GLANCE

- Very high speed gradients thanks to an ultra low rotor inertia
- Particularly well adapted for applications where space is critical due to very small motor dimensions and weight
- Top dynamics and accurate torque control thanks to the very high motor torque linearity
- Higher torque measurement accuracy than with a foot-mounted asynchronous motor thanks to the lower temperature influence from the rotor
- Robust and compact design for operation under extreme ambient and environmental conditions

LOAD UNIT FOR POWERTRAIN TEST CELLS

AVL DynoTrain



BENEFITS AT A GLANCE

- Large choice of machines with a suitable speed and torque range selection
- Flexible and modular system of motors and inverters, with common intermediate circuit for multiple dynamometer configuration
- Robust and service-friendly design

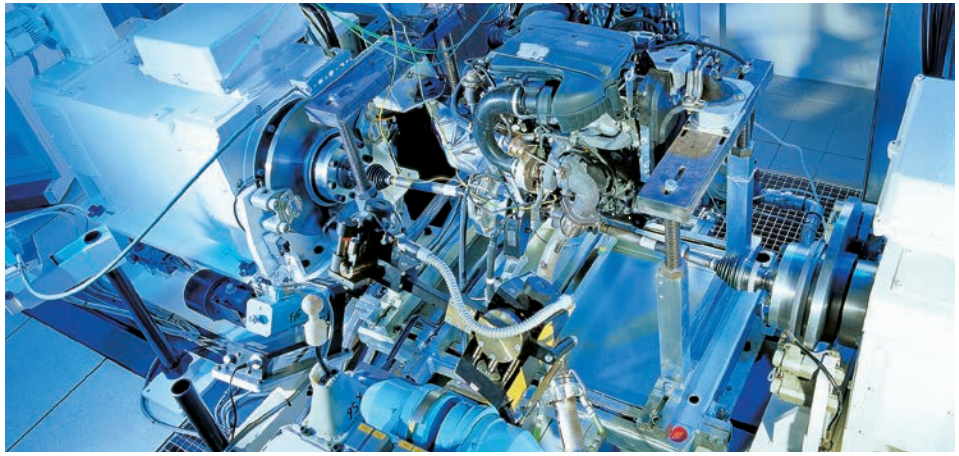
The AVL DynoTrain series is developed especially for use at gearbox and driveline test stands. All parts of the complete AVL DynoTrain family fit into different test applications. This results in a flexible system for different applications.

CHARACTERISTICS

Inline torque meters are used for torque measurement. To extend the measuring range, the inline torque meter can be adjusted to the required torque range. Together with the AVL DynoPrime, the energy runs in a loop and only the losses of the system are taken out of the grid.

APPLICATION

- R&D, quality and endurance tests for gearboxes and drivelines
- Development of drivelines for vehicles with one or more driven axles
- NVH measuring



Modular asynchronous motor and converter system, designed for application at transmission and powertrain test cells. The 4Q-IGBT converter is equipped with a digital real-time Interface.

LOAD UNIT FOR POWERTRAIN TEST CELLS

AVL DynoWheel

The AVL DynoWheel series is designed for use at gearbox test stands. Two different characteristics are provided by this dynamometer: low mass inertia and very high torque at low speed. Together with AVL DynoPrime, the energy runs in a loop and only the losses of the test system have to be supplied by the grid.

CHARACTERISTICS

The inertia of the dynamometer is equal to the mass inertia of a vehicle wheel. It is possible to simulate the same drivability as on the road as well as wheel slip. Not only the vehicle acceleration but also the driveline vibration of the vehicle is similar to reality. Fast control loops make it possible to optimize the driveline for one or two driven axles. The AVL DynoWheel drives are powertrain testing systems with features specially developed to provide the best results when the highest accuracy and control dynamics are required.

APPLICATION

- Application wherever the simulation of the dynamic vehicle values is important
- The AVL DynoWheel is directly coupled to the axle shafts
- The tire stiffness and slip is controlled by the AVL control systems

BENEFITS AT A GLANCE

- Machines with very low inertia adapted to the real vehicle wheel
- Optimized for reproduction of realistic wheel loads and torsional behavior
- Accurate test execution and excellent repeatability due to high torque control linearity
- Flexible and modular system for motors and inverters with common intermediate circuit for multiple dynamometer configuration
- Service-friendly power unit

LOAD UNIT FOR DRIVETRAIN TEST CELLS

AVL DynoPrime

The AVL DynoPrime series is designed to replace a combustion engine on gearbox and powertrain test stands.

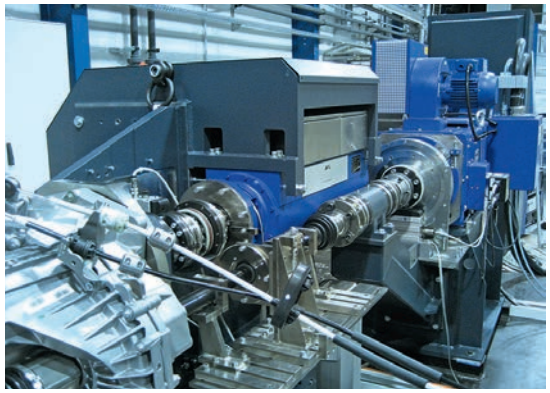
REQUIREMENTS

The mass inertia of the dynamometer has to be equal to the inertia of the combustion engine. Torque pulses of a combustion engine must be simulated. The center height must be very low. If the dyno is mounted to the bell housing of a front wheel drive vehicle, enough space must be provided to mount the axle shafts.

CHARACTERISTICS

- Very low inertia
- Low center height
- High overload capability

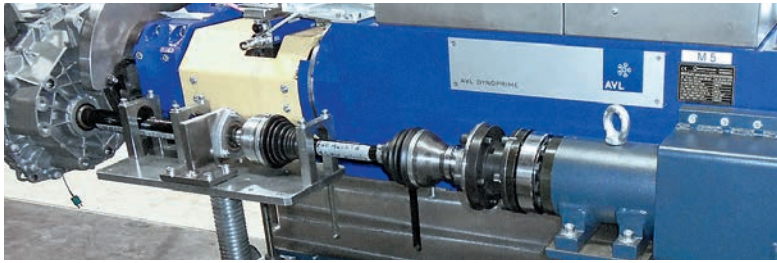
With its interfaces and dynamics, the AVL drive converter of the AVL DynoPrime corresponds to the converters of AVL DynoTrain and AVL DynoWheel dynamometers. The real vehicle behavior can be simulated in a system with one AVL DynoPrime and two or four AVL DynoWheels. The dynamometers are water jacket-cooled and supplemented by a closed air-cooling loop for the rotor. This makes noise measurements on a gearbox test stand more efficient.



AVL DynoPrime is a highly dynamic PMM drive system for the simulation of the rotational behavior of the crankshaft of combustion engines. The system is characterized by high nominal torques and a high overload capacity with the smallest moment of inertia.

APPLICATION

- Development and optimization of the driveline before the vehicle engine is available
- R&D for gearboxes, drivelines and vehicle parts that are influenced by the characteristics of the combustion engine
- Wear tests under dynamic conditions
- Noise measuring



BENEFITS AT A GLANCE

- Inertia similar to a combustion engine
- High nominal torque (larger than ICE), plus additional overload torque capability for simulation of speed oscillations
- High flexibility in the parameterization of various characteristics of engines
- Cost savings due to simpler setup of transmission and driveline testbeds
- Simple retrofitting into existing test cells is ensured by using the throttle as a demand value. Existing drive cycles can be used without modification

AVL Vehicle Testbeds

APPROACH TO VEHICLE TESTBEDS

Modern frontloading-oriented development processes with integrated and consistent use of simulation tools significantly extend the application spectrum of vehicle testbeds. Benchmarking, development and certification tasks previously reserved for road testing are more and more relocated to vehicle testbeds. Objectification represents a major advantage of vehicle testbeds providing reproducible test conditions available at any time ensuring efficient tests and measurements. Thanks to precise metrology and intuitive measuring – the control and automation technology (AVL PUMA Open Vehicle Testing) in combination with AVL InMotion™ powered by CarMaker and AVL CAMEO™ – the tool chain ACD (Advanced Calibration for Driveability) and the measuring system AVL M.O.V.E. – AVL vehicle testbeds meet all requirements for current and future oriented R&D tasks as well as those for an efficient development process. Available for all new hybrid and electric vehicles as well as for all frontloading-related tasks, these tools and features provide a seamless transition from road to testbed, where a realistic simulation is enabled.

BENEFITS AT A GLANCE

- Shorter development times due to high levels of reproducibility in vehicle tests
- Continual improvement by means of uniform tools on all testbed types
- Driveability improvement thanks to AVL PUMA Open Vehicle Testing as well as AVL InMotion™ powered by CarMaker and AVL CAMEO™ in combination with ACD and the measurement system AVL M.O.V.E.

TASK

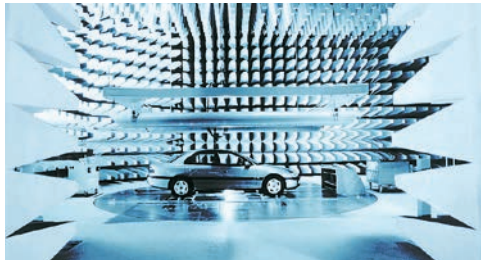
The vehicle testbed provides a realistic simulation of the road under reproducible environmental conditions. Vehicles with all types of powertrain systems can be tested. As these systems are subject to further diversification, the application fields on the vehicle testbed extend and a central development tool equally integrating all vehicle components will be necessary.

Thanks to a closer connection of vehicle testbed to engine and driveline testbed by reusing test specifications, correlating test results and standardizing testing tools and methods allows for savings. The field of use and application range of vehicle testbeds is also effectively broadened for new applications such as shifting quality and driveability, maneuver-based testing and powertrain calibration.

Since the data is collected overnight and at weekends the capacity utilisation of the vehicle testbed can be significantly increased. The subsequent data evaluation and the generation of, for example, all driveability calibration variants in the office environment makes it possible to simultaneously use vehicle prototypes for other calibration tasks.

AVL vehicle testbeds stand out because of impressive innovative characteristics such as

- Active braking support
- Implemented quality checks and service logbook
- Feed-forward type of control and innovative rolling resistance control algorithms
- Precision tractive force and speed measurement chains



APPLICATIONS

Emission, Mileage Accumulation and R&D Testing

Excellent technical quality features and a range of thoroughly tested end-to-end solutions are important criteria for AVL vehicle testbed systems. The increasing complexity of powertrain control systems and the close interaction of motor and transmission control units with emission tests often demand joint testing. AVL vehicle testbeds are applied in altitute chambers; Running-Loss-SHEDs, for the examination of hydrocarbon evaporation; as well as in climatic chambers and climatic wind tunnels.

Noise and Vibration Testing (NVH)

More than 70 active systems in use worldwide demonstrate AVL's high levels of quality and flexibility regarding the project planning of testbed solutions. In this respect, AVL testbeds are characterized by a particularly good phase control as well as replaceable roller surfaces, enabling the simulation of every possible road surface.

Electromagnetic Compatibility Testing (EMC)

Undoubtedly AVL is the partner with the most experience (over 25 years) and the most reference installations in the field of electromagnetic emission compatibility testing (EMC). Along with a robust design and an exact road load simulation, technical criteria such as lowest electromagnetic emissions and high interference immunity over a wide frequency scope up to gigahertz ranges are the most persuasive advantages.

THE TECHNICAL IMPLEMENTATION OF COMPLEX REQUIREMENTS IS A MATTER OF TRUST. WE ARE THE MOST INNOVATIVE VEHICLE TESTBED SOLUTION PROVIDER IN THE WORLD.

The intuitive and workflow oriented user interface of VECON 2016 enables efficient testbed handling

OPERATION AND CONTROL SOFTWARE FOR VEHICLE TESTBEDS

AVL VECON 2016

The immense diversity within the automotive sector in combination with tight development periods demand precise, flexible yet easy to handle vehicle testbeds. VECON 2016, the new generation of operation and control software for the regulation and closed-loop control of vehicle testbeds, has been developed especially for these requirements.

APPROACH

VECON 2016 supports the operator with its easy and intuitive workflow-oriented user interface, optimally tailored to the testbed. The specific data of testbed and UUT is sustainably managed in a database according to ASAM ODS standards. The semi-automated processes for typical tasks on the testbed in combination with integrated and standardized evaluation efficiently support the user's work.

APPLICATION

The operation and control software VECON 2016 offers various basic functions like coastdowns, loss compensations, inertia control and warm ups alongside typical control modes (velocity, force and road load simulation). The synchronous integration of measuring equipment (e.g. for fuel consumption measurement) and vehicle (e.g. for EOBD/OBDII) is ensured. Together with AVL iGEM Vehicle, VECON 2016 provides the solution for exhaust emission tests on the vehicle testbed.

BENEFITS AT A GLANCE

- Realistic road load simulation thanks to very precise synchronization control of all driven roller units and tractive force control from zero speed up
- Highly dynamic control in consideration of all relevant vehicle and road parameters in the simulation model
- Workflow oriented and structured operation concept for efficient operation
- Structured vehicle data management allows reuse and adaption to other test environments
- Customer-specific extendable user interface
- Synchronous integration of measuring equipment and vehicle data
- Automated evaluation of base functionalities with archive and history
- Integrated maintenance schedule with reminder function to display and plan regular maintenance and verification tasks
- Proven AVL-FlexiCart™ with integrated workstation and operator panel

AVL PUMA Open™ Vehicle Testing executes optimally all specific operation and control tasks on the vehicle testbeds

AUTOMATION AND CONTROL SOFTWARE FOR VEHICLE TESTBEDS

AVL PUMA Open™ Vehicle Testing

The complexity of modern vehicle systems increases the development and testing demand. Using intelligent test methods and test automation an increasing development period can be countered. AVL PUMA Open™ Vehicle Testing extends the basic functionality of VECON 2016 with the typical and proven functions of AVL PUMA Open™. This enables the automation of both testbed and vehicle.

APPROACH

AVL PUMA Open™ Vehicle Testing is different from other vehicle testing and automation systems because of its extended control modes, based on the integrated vehicle control (e.g. via accelerator pedal actuator, robot actuator, e-gas). The optional driver model "Self-learning Stähle Driver" for AVL PUMA Open™ Vehicle Testing provides a realistic simulation of the driving behavior in driving cycles. The operator is able to automate test procedures by means of the known automatic functions BSQ/SSQ.

APPLICATION

The demand for realistic tests is steadily growing. The testing effort for the calibration validation development increased by this is efficiently supported by AVL PUMA Open™ Vehicle Testing. The integrated vehicle control for driverless driving makes safe and continuous long-term tests under difficult environmental conditions possible. The parameterization is done quickly and easily in a system. Direct access to the data and the synchronous data acquisition ensures an efficient evaluation. Furthermore, other measuring devices and operation panels can be integrated flexibly.

BENEFITS AT A GLANCE

- Workflow-oriented and structured operation concept for efficient operation
- Short training times thanks to one uniform user interface for all integrated components in the software
- Customer specific extendable user interface
- Automation of complete vehicle tests (chassis dynamometer incl. uding unit under test based on BSQ/SSQ and integrated robot driver)
- Optional integrated self-learning Stähle driver for driverless vehicle testing
- Easy import of real road profiles and environmental conditions allow real-life testing on the vehicle testbed
- Consistency over several test environments (e.g. global unit parameter set)

Vehicle Testbeds for Emission and Endurance Tests

The increasing complexity of powertrain management systems and the close interaction of engine and transmission control unit, in combination with emission testing, often require a common R&D test

CHARACTERISTICS

The AVL ROADSIM 48"MIM product line covers the range from passenger cars up to light-duty vehicles. The service spectrum of this product line ranges from 150 kW to 432 kW per axle. Asynchronous pendulum motors positioned between the rollers are applied. This guarantees space savings as well as very low performance losses and high torsional stiffness. AVL ROADSIM 72"MIM is available in two roller widths (distance between outer roller edges 2,300 mm and 2,744 mm) and in the form of single-axle and twin-axle configuration for front-wheel, rear-wheel and all-wheel drive vehicles. In addition to that, the AVL ROADSIM 25"INLINE product line allows the testing of vehicles ranging from mopeds to light four-wheelers. This solution is based on an inline set-up and includes a performance range up to 150 kW. AVL ROADSIM 72"MIM is designed for the testing of state-of-the-art heavy-duty vehicles with up to 20 tonne axle load. It is equipped with a distance between outer roller edges of 3,000 mm as well as a robust 450 kW asynchronous motor-in-the-middle design for each axle. This robust and compact design combines reproducible and highly precise testing of high-performance heavy-duty vehicles.

APPLICATION

Thanks to their high accuracy and availability, these systems are used for exhaust emission testing and vehicle development all over the world. This family of products can also be used in the field of:

- Exhaust gas emission and endurance tests
- Running-Loss-SHEDs for the testing of vehicles fuel evaporation
- Climatic and altitude chambers

Planning, consultation, and implementation of system solutions for vehicle testbeds

BENEFITS AT A GLANCE

- Robust design combined with reproducible and precise measuring and control accuracy for use under laboratory conditions and in most different climate zones
- Highly precise control from zero speed for realistic road load simulation
- Comprehensive vehicle testbeds meet highest customer requirements for axle load, performance, mass simulation quality, ease of use and extensibility
- AVL ROADSIM 4x4 vehicle testbeds with their high levels of torsional rigidity allow for torque-vectoring-tests of state-of-the-art powertrain systems

Vehicle Testbeds 4x4 for Advanced Applications in R&D

The development of new drive concepts and powertrain functionalities entails new requirements for test systems. For this, AVL offers high-end solutions fulfilling these challenges.

CHARACTERISTICS

All four highly dynamic load units of the vehicle testbed can be controlled separately or synchronously. This is possible for generic analyses and also forms the basis for real-life testing in connection with AVL InMotion™ powered by CarMaker. Previously recorded 3D road profiles including curves can be modeled. Along with the conventional method (by means of coast-down coefficients), the road simulation is implemented in an advanced way on the basis of a physical multi-body simulation model linked to an environment, real road and driver model. This allows for highly varied parameters like air resistance, vehicle weight, trailer and driving style. Additionally, a comprehensive residual bus simulation can be implemented on the basis of the simulation model (e.g. simulation of acceleration or traffic for ACC systems).

Real-life testing on the vehicle testbed

APPLICATION

The range of applications for 4x4 vehicle testbeds for advanced applications is broad:

- Real consumption and emission analyses based on customer-specific roads (e.g. Auto Motor and Sport track)
- Development of advanced driver assistance systems using free maneuver, road, and traffic definitions
- Analysis of different (virtual and reproducible) driver types linked to vehicle operating strategies

BENEFITS AT A GLANCE

- Highly dynamic four-motor vehicle testbed for modeling different pulling forces and speeds on all four wheels
- Future-proof development platform for intelligent drive concepts such as electric drives as well as complex powertrain functionalities (e.g. torque vectoring)
- Maneuver-based real-life testing on the vehicle testbed
- Parameterizable simulation models for driver, road and topology, environment and residual vehicle

Vehicle Testbeds for Advanced Calibration Applications

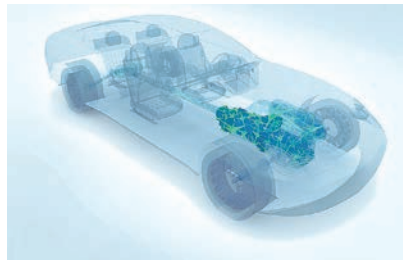
AVL offers integrated solutions for calibration tasks on vehicle testbeds. These are composed of the required testbed system, the attuned software solutions and the related methodological support.

CHARACTERISTICS

The networking of AVL ROADSIM, AVL PUMA Open Vehicle Testing, AVL CAMEO™ and AVL ACD results in a flexible and powerful overall solution. This means the vehicle testbed provides exact modeling of the road. On the one hand, the automation allows automatic operation of the test specimen and, on the other quick change-over between different reproducible operating statuses. Besides controlling the test, AVL CAMEO™ is integrated across test planning and analysis, including model formation, optimization and map calculator. An ASAP 3 interface can be used to transfer the driveability-relevant control unit variables to the application system. Ultimately, the driving maneuvers are evaluated and physical parameters and marks are determined. The signal of a load cell is, for example, designed as an indicator of longitudinal vehicle acceleration, where this load cell is integrated into a special vehicle support.

APPLICATION

This solution is used for engine, transmission and overall powertrain calibration. Time- and cost-intensive road tests can largely be relocated to the vehicle testbed. Thanks to the model-based approach, only the determined vehicle adjustment has to be verified on the road afterwards. Adjustments with different objectives, such as comfort and dynamics, can easily be implemented.



BENEFITS AT A GLANCE

- Highly precise and dynamic road load simulation to meet with the highest requirements especially in (driveability) calibration
- Integration of established tools for optimization and driveability evaluation
- High efficiency due to automated operation at night and on weekends
- Excellent reproducibility and transferability between real road and vehicle testbed
- Visualization of completely embedded driving cycles for calibration (e.g. consideration of the parameters for altitude, incline, air conditioning system and further maneuver-based factors)

Advanced Calibration for Driveability on the vehicle testbed

Vehicle Testbeds for NVH Testing

The main purpose of noise, vibration and harshness (NVH) testing is to optimize the interior and exterior noise of the vehicle, as well as to ensure the acoustic quality. It is possible to evaluate the behavior of different external or internal vehicle impulses on the excitations on the chassis dynamometer for different constructions of the drivetrain or chassis configurations.

CHARACTERISTICS

The combination of reduced noise emissions by design, high rigidity and precise road load simulation allows for highly efficient NVH development on the vehicle testbed. These combined advantages are essential for dynamic, tip-in and "pass-by-noise" tests. Motor enclosures of the water-cooled main motors reduce the acoustic emissions of the vehicle testbed. Rollers and frames are especially designed with regard to NVH applications and equipped with acoustic damping material. Exchangeable roller surfaces repicate all types of road textures. In addition to that, the vehicle testbed can be upgraded with a second axle for example for parallel hybrid and four-wheel drive vehicles. Configurations of up to four motors are possible. In this case, the vehicle testbed controller VECON monitors the vehicle and provides precise control and monitoring functions for various test modes for all NVH vehicle testbed configurations. Pit shutters or work platforms underneath the vehicle enable comfortable access to the vehicle components. This allows the quick and easy realization of modifications without changing the vehicle restraint. Therefore, the modifications can be evaluated using identical test conditions.

APPLICATION

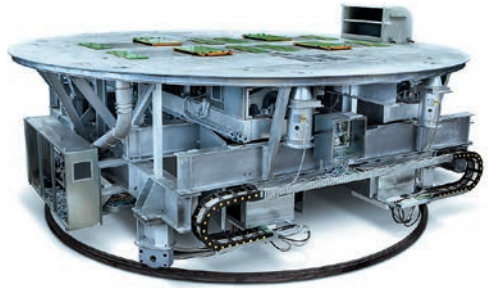
The vehicle testbed is designed to examine noise and vibration behavior as well as influences from the vehicle body, suspension or other vehicle components. The intention is mainly to check noise and vibration thresholds on the powertrain, chassis and other related components.

BENEFITS AT A GLANCE

- Scalable and "ready-to-build" hardware and software for noise and vibration tests per wheel, axle or vehicle
- Extremely low noise emissions thanks to structural measures (e.g. motor enclosures, water cooling and suitable roller design) in the testbed design
- Simulation of real road textures thanks to exchangeable roller surfaces, also for speeds over 200 kph
- Decades of experience in cooperation with planning engineers, construction and acoustic construction companies

Testing of pass-by-noise on the AVL vehicle testbed AVL ROADSIM NVH 4x4 LIGHT TRUCK

Microphone noise recording on a passenger vehicle in an NVH chamber



EMC chamber with integrated vehicle testbed on the turntable

SUV tested on the AVL vehicle testbed AVL ROADSIM EMC 4x4 LIGHT TRUCK

Vehicle Testbeds for EMC Testing

Electromagnetic compatiblity testing comprises tests of electro-magnetic emissions as well as interference immunity of the test specimen. AVL vehicle testbeds are designed for testing all types of on- and off-road vehicles.

CHARACTERISTICS

The AVL vehicle testbed is driven by motors which are specifically designed for this purpose and disposes of special EMC-compatible measuring equipment with two movable axles. It can be rotated to align the vehicle in the electromagnetic field. The turntable contains the entire mechanical configuration of the vehicle testbed. The rotation can also be executed while the vehicle testbed is in operation. Turning speeds and turntable positions can be set by the operator via control PC or remote control (position accuracy better than 0.1° possible).

APPLICATION

In addition to standard EMV tests, ABS and traction control system tests with increased slip simulation are possible. Vehicle Turning Simulation can be applied using the rotation of the turntable, a steering wheel actuator and different wheel speeds.

BENEFITS AT A GLANCE

- Reference solutions, “ready-to-build”, EMC vehicle testbeds shorten development and certification work
- Vehicle testbeds with extremely low electromagnetic emissions
- Reliable EMC-optimized components and more than 25 years of experience in the field of EMC vehicle testbed assembly and commissioning guarantee the highest immunity to interference
- Excellent cooperation with planning engineers and construction companies of EMC-buildings

Vehicle Testbeds for Special Purposes and Modernization Solutions

Besides the product lines and applications NVH, EMC and Advanced Applications mentioned above, AVL also offers special vehicle testbeds for snowmobiles, tractors or multi-axle vehicles. Customer-specific solutions can also be realized in the form of modernizations of already existing units. These are developed in intensive cooperation with the customer before the start of the project and are planned in detail and built in our factory. AVL update packages provide up-to-date system components for mechanics, measuring and control techniques as well as the current software for installed AVL and external testbeds.

CHARACTERISTICS

The AVL portfolio ranges from hardware and software upgrades of control unit components for double-roller sets right up to large single rollers. The testbeds are designed as single- or multiple-axle testbeds (e.g. per wheel or per axle equipped with a motor). Vehicles, from motorcycles up to heavy-duty vehicles, can be tested. In addition to control and closed-loop control, the flexible automation system of AVL PUMA Open Vehicle Testing allows for the integration of measurement technology. Upgrades via an accuracy package enable a more precise force and speed measurement chain to achieve increased measuring and control accuracy.

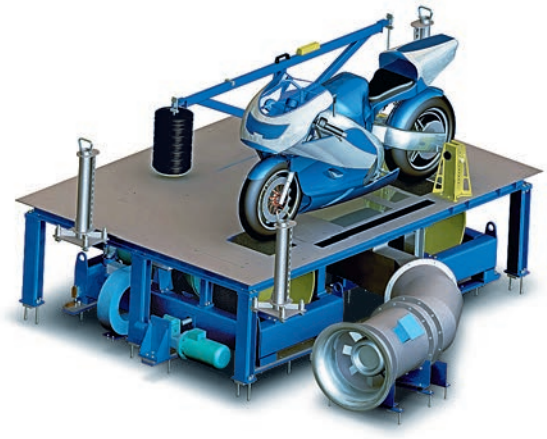
APPLICATION

Mechanical design, performance electronics and automation systems are needed to meet the requirements. However, the focus is on the application. AVL offers solutions for exhaust emission testing, vehicle aging, environment simulation, maneuver-based testing, acoustic testing, electromagnetic compatibility testing and much more. All types of AVL and third-party testbeds can be upgraded with AVL update packs. Furthermore, it is possible to complement and extend the basic application of vehicle testbeds to be updated with additional applications.

BENEFITS AT A GLANCE

- Individual system design complies with customer-specific requirements for vehicles of any type (e.g. special vehicles such as tractors or snowmobiles)
- Adaptation to local conditions and local standards
- Robust industrial design extends the usage period of vehicle testbeds
- Long-term experience and successful implementations in plant engineering and with vehicle testbed renewal
- Improved availability of service and spare parts

Full range of services from motorcycles to truck vehicle testbeds



Renewal of control unit components and integration of existing AVL and third-party vehicle testbeds into the AVL VECON controller

AVL Modular Test Cell Mechanics and Control Rooms

APPROACH

A prerequisite for smooth test processes is sophisticated testbed mechanics in combination with ergonomically designed control room equipment. Based on lengthy experience through all kinds of realized projects, AVL provides systems designed for the customer's specific application – for engine, powertrain, hybrid, racing and component testbeds.

AVL's modular concepts allow a high degree of scalability from simple durability testbeds to highly sophisticated and complex powertrain development testbeds.

BENEFITS AT A GLANCE

- Reduced setup times due to mounting of the test specimens onto pallet systems
- Quick and easy fixing of the pallets on the testbed
- Wide range of standardised drive shaft systems, with automatic docking function if required
- Easy adaptation to changing requirements due to modular and ergonomic design of control room equipment
- Shifting test run preparation and evaluation from the test cell to the office by using the AVL PUMA Open FlexiCart™ as simulator

TASK

The demands for more productivity in modern test facilities are constantly increasing. Besides intelligent measuring techniques and automation, the mechanical automation of testbeds can increase productivity by minimising the setup and testbed downtimes and enhancing the quality of test results due to an appropriate design. The pursuit of increased productivity also affects the testbed control rooms in the form of constantly changing requirements and work situations. Consequently, highly process-oriented design and functionality are required for control room equipment.

Quick installations and a simple setup of the testbed equipment require drive shaft systems with standardised mounting possibilities. Unproductive duties like engine commissioning and decommissioning, rigging, media conditioning, system checks, calibration, service, maintenance and repair tasks have to be shifted out of the test cell to ensure optimal test cell utilization.

Support of the test facility's processes via Test Lab Management Software capable of planning test execution tasks and resources (test cells, personnel, pallets, sensors etc.) is another area in which demands for increased productivity are on the rise. Preparation and checking of test runs without utilizing the testbed are also required to improve the testbed's availability.

REFERENCES

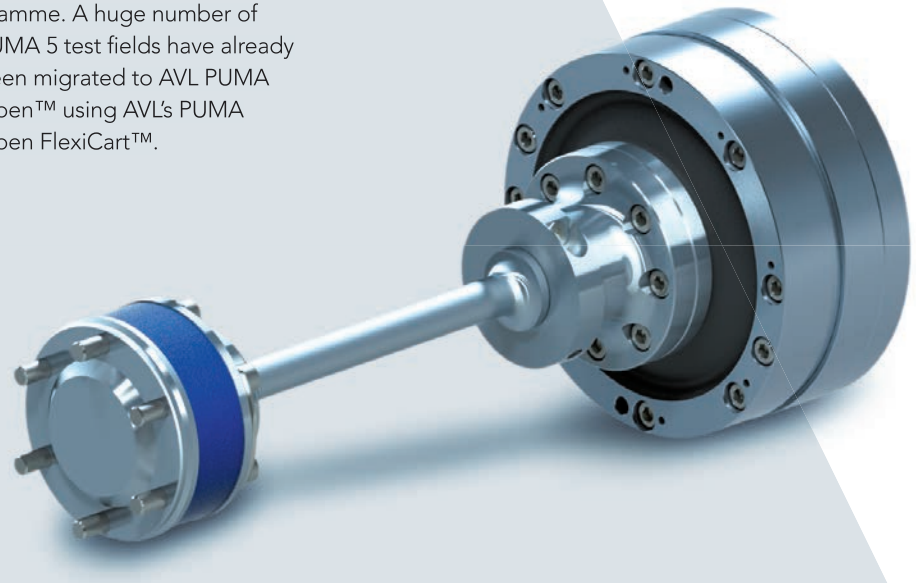
AVL Pallet Systems
As a supplier of various testbeds for premium car manufacturers worldwide as well as internal testbeds, AVL has first-hand knowledge of engine and powertrain developers.

AVL Drive Shaft Systems
Having delivered more than 1,000 drive shaft systems, AVL has acquired extensive experience in shaft dimensioning.

AVL Test Station
Process-oriented design which has received a famous design award fulfils ergonomic as well as functional requirements. By combining control room components with office furniture, a flowing transition between test stand operation and the office area is no longer a problem.

AVL Flexi Cart™
The functions of the AVL PUMA Open FlexiCart™ range from a simulator in the office to real test operation at an existing testbed with the AVL PUMA Open™ "Migration" programme. A huge number of PUMA 5 test fields have already been migrated to AVL PUMA Open™ using AVL's PUMA Open FlexiCart™.

BY USING MODULAR TESTBED MECHANICS, AVL'S TEST FACTORY HAS BEEN ABLE TO DOUBLE THE NUMBER OF TESTED PROJECTS PER YEAR (FROM 70 TO 150 UNITS) WITHOUT INCREASING RESOURCES.



THE WAY TO HIGH TEST FIELD EFFICIENCY

AVL Pallet & Drive Shaft Systems

AVL pallet systems meet customer demands for reduced test specimen changing and mounting times, thereby shortening testbed downtimes and lowering costs through automation. AVL pallet systems enable simple and easy pre-mounting and aligning of the test specimen and instrumentation in a separate setup room. Even pre-testing of the test specimen outside the testbed is possible with an appropriate level of automation.

AVL DRIVE SHAFT SYSTEMS

Drive shaft systems not only serve for the mechanical power transfer between the test specimen and the dynamometer on steady-state or dynamic testbeds, they also influence the vibration behavior of the entire system.

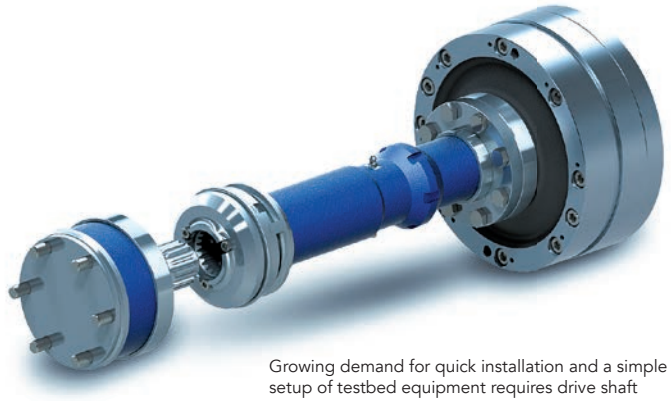
APPLICATION

AVL pallet and drive shaft systems cover the whole range of operating requirements for passenger car, commercial vehicle and racing engines. Different sizes, scopes and specific characteristics of the test specimen or the test application result in different standard drive shaft dimensions suitable for:

- PC and LD diesel and gasoline engines < 250 kW
- HD diesel engines < 600 kW

AVL standard pallet systems can be used for the following applications:

- PC & LD engines: engine-only and powerpack applications
- HD engines: engine-only applications



Growing demand for quick installation and a simple setup of testbed equipment requires drive shaft systems with standardized mounting possibilities

BENEFITS AT A GLANCE

- Convenient preassembly and alignment of the test specimen and the measuring equipment in separate setup rooms
- Quicker connection of the media supply by quick couplings or docking plate systems
- Qualified engineering partners for complex drive shaft demands
- Wide range of standardized drive shaft systems

THE FLEXIBLE SYSTEM HOUSING AND SIMULATOR SOLUTION

AVL Test Station & AVL PUMA Open FlexiCart™

AVL TEST STATION

The new operating-room concept of AVL takes into account the constantly changing requirements and work situations when executing engine and powertrain tests. The modular and variable system can also be easily adapted to new workflows or spatial requirements at any time.

In addition, compact and intelligent solutions are available particularly for cramped space conditions (e.g. container testbeds).

AVL PUMA OPEN FLEXICART™

The functions of the AVL PUMA Open FlexiCart™ range from use as a simulator in the office to real test operation on an existing testbed with the AVL PUMA Open™ "Migration" program.

When using the AVL PUMA Open FlexiCart™ as a simulator, the customer is able to prepare sets of parameters and test runs for real test operation in the office.

The customer can easily carry out a AVL PUMA Open™ Training for personnel on the AVL PUMA Open FlexiCart™ within an ideal office environment.

BENEFITS AT A GLANCE

AVL Test Station

- Ergonomic accessibility and optimal use of space
- Industrial and EMC compliant design
- Patented modular design for easy extension

AVL PUMA Open FlexiCart™

- Parameter and test run preparation in the office
- Training of customer's personnel in the office
- AVL PUMA Open™ test operation on a real testbed during the "Migration" test phase

Ready to go: The PUMA Open FlexiCart™ is delivered with all required hardware components to start simulation/migration operation right away

AVL Media Conditioning Systems

APPROACH

The performance of combustion engines strongly depends on media conditions. For better reproducibility under almost real conditions, highly dynamic control of the media conditioning units is necessary. For 30 years, AVL has intensively developed different compact conditioning systems and technologies used in high-end engine test cells. Where standard systems are not sufficient, AVL designs customer-specific units.

BENEFITS AT A GLANCE

- The Modular design ensures applicability in a wide range of testing. Various modules are available for different applications
- High control accuracy in steady state and dynamic mode ensures exact data from the test procedure and increases the testbed efficiency
- Extreme temperature and pressure ranges for simulating conditions at the test bench, which are hard to achieve on the road
- Easy integration with the automation system enables quick initialisation (Plug & Play using AVL ActiveLink™)
- Good repeatability allows rapid achievement of the development goal
- Minimized downtime with robust and reliable design
- Short commissioning time
- Flexible use due to mobile design
- Less maintenance work required

TASK

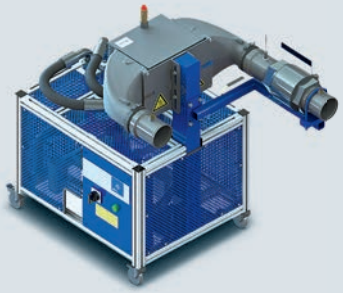
The thermodynamic and mechanical behavior of a combustion engine is influenced by the combustion of air and the engine fluids.

The relationship between temperature and pressure in fluids and gases offers great potential for the development of different applications. Test consistency and reproducible conditions are in high demand, particularly for exhaust emissions.

Compared to application on the road, there are normally constant ambient conditions in a test cell. To prepare the engines for these real situations (see RDE), it is necessary to simulate different conditions such as altitude or climatic conditions in the test cell.

High reliability and reproducibility of control and measurement results over a wider range of applications is needed to achieve high testing efficiency.

MORE THAN 1,500 SYSTEMS ALL OVER THE WORLD IN DIFFERENT APPLICATIONS UNDERLINE THE PERFORMANCE AND RELIABILITY OF THE AVL MEDIA CONDITIONING DEVICES.



REFERENCES

ConsysAir applications

The combustion air conditioning system has been delivered 600 times around the world. There has also been a large number of customized systems for extreme conditions. Pressure ranges from –400 to +200 mbar and temperatures from –40 to +90 °C.

ConsysBoost applications

The boost air conditioning system is designed as a secondary cooled heat exchanger or as a spray version for pressures up to 5 bar and temperatures of 200 °C or more. Units with a cooling power of up to 250 kW have already been delivered.

ConsysCool applications

AVL coolant conditioning systems are installed at 1,000 test cells worldwide. The application is used in end-of-line, research and high dynamic racing test cells.

ConsysLube applications

The oil conditioning system is installed in engine test cells, single cylinder research engines and gearbox test cells.

INTAKE AIR CONDITIONING

AVL ConsysAir

The intake air conditioning AVL ConsysAir is a conditioning system to control the main parameter of the combustion air. Independent of the engine speed and torque, temperature and humidity are kept within small tolerances. To control the pressure under dynamic conditions, AVL offers the "Dynamic Package" with a very short delay time (< 3 sec.).

CONTROL PRINCIPLE

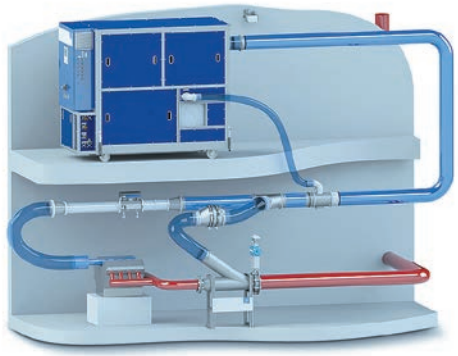
The intake air temperature is adjusted by cooling and heating and the humidity by cooling and moistening. The desired pressure is increased by the blower or decreased with throttle valves. An internal air re-circulation system also provides high control response at low air flow rates.

APPLICATION

There is broad range of applications covered by the five standard units. For special applications, tailored systems can be delivered. The customer can choose between THP stationary (ACS-Mode – closed air inlet to the engine) or TH dynamic (TCS-Mode – open air inlet to the engine). Climate chambers and altitude simulations of several thousand meters enable simulation of extreme conditions on the testbed.

BENEFITS AT A GLANCE

- The dynamic package allows high dynamic test runs with a near-zero delay time
- Optimized investment costs through parallel operation of two-or-three testbeds with one ConsysAir
- The high repeatability of the measuring values increases the efficiency of the test cell
- Wheels allow a flexible usage on different testbeds
- A tested interface to the AVL PUMA Open™ system ensures short commissioning time



Installation example of an AVL ConsysAir together with an Air Mass Flow Meter (AVL FLOWSONIX™) and with the Dynamic Option. A short connection line improves the performance of the whole system. A maximum length of 12 m should not be exceeded.

COOLANT CONDITIONING

AVL ConsysCool

The coolant conditioning system AVL ConsysCool with combined primary and secondary circuit control is used to bring the coolant of the Unit Under Test (UUT) to a freely definable temperature and keep it within tight limits. Integrated electrical heating supports the pre-heating and improves the control stability.

CONTROL

Integrated control loops and algorithms are optimized for various requirements on steady-state and dynamic/transient testbed tasks. Besides temperature control, the unit further enables exact simulation of coolant pressure and flow behavior (e.g. radiator, cooling pump).

APPLICATION

The wide range of configurations of the AVL ConsysCool meets the requirements of nearly all automotive testbed applications. In end-of-line tests, friction tests, high-dynamic racing engines and all kind of cooling loops in electrification components, the AVL ConsysCool supports the engineers to solve their development and certification tasks efficiently.

BENEFITS AT A GLANCE

- One system for a wide application range due to its modular design and several options
- Easy integration into the automation system (AVL PUMA Open™) with a comfortable device user interface (ActiveLink™)
- Integrated controllers ensure flexibility in operation
- High reproducibility due to great control accuracy for steady-state and dynamic operation, ensures short development time
- Robust design in stainless steel piping for a long lifetime and, therefore, lower operating costs
- Compact build and easy installation in the test cell or false floor due to its very compact design

The main components are installed in the bottom part of the system CC-200/450. This allows the separation from the upper part (electric panel, expansion tank) and the placement in the intermediate floor. More space in the test cell is the benefit.

OIL CONDITIONING

AVL ConsysLube

The oil conditioning system AVL ConsysLube conditions the engine or transmission lube oil temperature and oil supply pressure to a pre-definable set value and keeps it within a certain tolerance at steady state and dynamic operation of the unit under test (UUT). The effective temperature value can be taken at the device or preferably at the UUT.

The effective pressure value must be taken at the UUT. Electrical heating is incorporated for preheating the lube oil and better control dynamics in transient operation.

CONTROL PRINCIPLE

The PID control is carried out by an external system (e.g. AVL PUMA Open™). The temperature control is performed by a mixing valve (heat exchanger/electrical heating). The supply pressure control is handled by a control valve in the bypass between the supply and return lines to and from the unit.

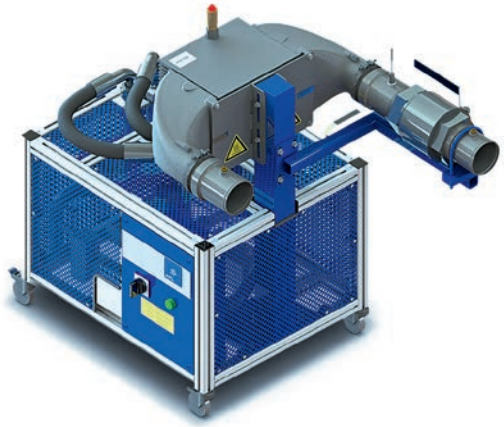
APPLICATION

The main applications for ConsysLube are engines up to 400 kW, with customized solutions for larger engines. Several connection modes and unit options allow different applications like oil pan conditioning, oil pressure control and pre-heating. For oil conditioning on gear boxes, the AVL ConsysLube can also be used.

All components are installed in a compact frame with wheels and covers. This allows a flexible use in different test cells. The arrangement of the components at the bottom of the unit ensures that the oil level in the oil pan is always higher than in the conditioning unit. Oil backflow to the oil pan is therefore prevented.

BENEFITS AT GLANCE

- Stainless steel tubing avoids dissociation of rust particles and guarantees long service life
- High control accuracy and dynamics increase the testbed efficiency
- Faster control response thanks to primary controlled oil circuit
- The compact design enables installation close to the unit under test (engine or transmission) and, therefore, keeps the external oil volume small
- Flexible in applications due to several connection modes, such as connection to the oil sump or to the oil pressure circuit



BOOST AIR CONDITIONING

AVL ConsysBoost

The boost air conditioning system AVL ConsysBoost conditions the boost air temperature to a pre-definable value and keeps it within a tight tolerance range mainly for steady state applications, or at least those with constant demand values. The boost air from the turbo charger is indirectly conditioned by controlling the cooling water flow on the secondary side of the heat exchanger.

CONTROL PRINCIPLE

The boost air temperature control is performed indirectly by controlling the cooling water flow through the heat exchanger. A circulation pump ensures an adequate flow of cooling water in the heat exchanger even for low-power applications. In addition, this pump improves control behavior by returning the heated cooling water to the heat exchanger inlet.

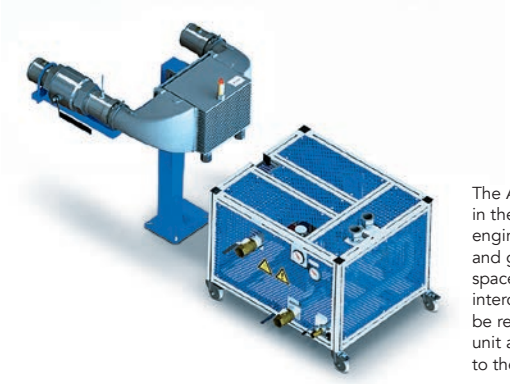
For simulating the pressure drop of different engine intercoolers, a valve is installed between the AVL ConsysBoost and the engine intake duct.

APPLICATION

The standard ConsysBoost 1200 or 3000 units are basically designed for stable temperature control during a steady state or dynamic engine operation. Alternative solutions, such as spray variants or intermediate circuits, are available for simulating dynamic temperature profiles.

BENEFITS AT GLANCE

- The precise adherence to a pre-defined boost air temperature significantly improves the reproducibility of measurements on turbo-charged combustion engines and, therefore, increases the testbed efficiency
- The ability to simulate different pressure losses for different vehicle intercoolers allows use on a wide range of engines
- The compact and mobile unit can be moved to different testbeds, saving investment costs by eliminating the need for extra units
- Space-saving installation close to the engine by separating the conditioning part from the heat exchanger



The AVL ConsysBoost is installed in the test room, close to the engine for a fast response time and good control stability. To save space around the engine, the intercooler and stand can easily be removed from the conditioning unit and located separately, close to the engine.

AVL Fuel Consumption Measurement on Engine Testbeds and in the Vehicle

APPROACH

AVL has long understood the increasing importance of fuel consumption as a reference value for the development of state-of-the-art, low-consumption combustion engines, and this understanding is reflected in its in-house engine development department, as elsewhere. More than 45 years of concentrated know-how in the field of fuel consumption measurement technology, technological diversity and clever modular product concepts, in combination with a global presence and sophisticated service and system competence, make AVL the clear leader in the field of consumption measurement technology the world over.

BENEFITS AT A GLANCE

- Shorter time to achieve development objectives due to reliable AVL fuel consumption measurement systems, ensuring high levels of engine testbed availablity and significantly reduced test effort thanks to shorter measurement times and high levels of measurement accuracy, one example being the reduction of the measurement effort during automatic engine calibration
- Protection of investments through modular design, subsequent expandability and adaptation to new injection systems and applications
- Supporting bio fuel such as bio diesel and bio ethanol
- Increased productivity of the engine test facility due to lower product lifecycle costs: simple and projectable maintenance and service as well as quick availability of spare parts via AVL eSpares™

TASK

Stricter laws and regulations with regard to CO_2 and fuel consumption reductions increase the pressure to develop engines even faster, coupled with rapidly increasing measurement expenditures. Engineers developing diesel and gasoline engines are increasingly forced to implement measurements in automatic operation with ever shorter measurement times or in transient modes.

In addition to accelerated test procedures, new combustion and injection technologies require instrumentation devices delivering precise measurements even for efficient engines with low consumption levels during cyclic tests under partial load. And this is all the more true if fuel is a target variable in automated optimization and calibration procedures.

The call for higher testbed efficiency does not only mean an easy installation and quick commissioning procedure for the measurement system; it also means a reliable fuel supply for the engine with preselected parameters, such as fuel temperature and pressure. Precision fuel temperature control is required to achieve high- measurement accuracy in the overall system on the engine testbed, even in case of low fuel consumption values.

The layout of the fuel consumption measurement system, for example having fuel lines which adapt to different mixture preparation systems, has a decisive influence on the quality of the measurement results. Engines for alternative fuels also require the compatibility with bio diesel or alcohol admixtures of up to 100 %.

REFERENCES

Emissions Development in the Field of Commercial Vehicles

AVL has equipped engine test facilities of renowned manufacturers of commercial vehicles with the AVL Fuel Mass Flow Meter and Fuel Temperature Control. These fuel consumption measurement systems measure the transient fuel curve in a continuous, fast and precise manner.

AVL Fuel Exact™ PLU/ AVL Fuelexact Mass Flow

This covers a wide range of different engines and modern applications. Passenger car engine test facilities with up to 60 testbeds, from the single-cylinder, gear, climate and multi-cylinder engine testbed up to 500 kW, have been equipped with AVL Fuel Exact™.

Bio Fuels

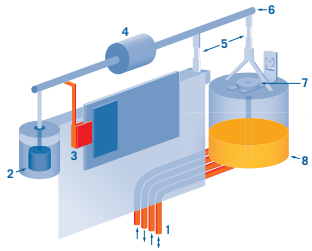
AVL has had many years of experience with the application of biofuels, such as methanol in racing and ethanol in Brazil. AVL fuel consumption measurement systems are suitable as FlexFuel designs for Otto cycles and diesel fuels, as well as for the admixtures of up to 100 % bio fuels.

Installed Base

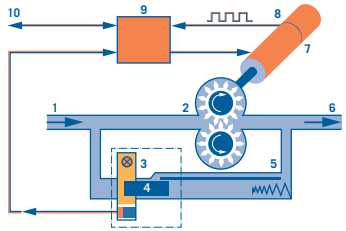
45 years of competence in the field of development and production of fuel consumption measurement systems. Already more than 15,000 systems have been delivered worldwide by AVL to be used in engine research, development, quality assurance and production as well as for road testing.

THE SUPPLY OF MORE THAN 15,000 FUEL CONSUMPTION MEASUREMENT SYSTEMS CONFIRMS OUR EXPERIENCE AND COMPETENCE IN THE FIELD OF FUEL CONSUMPTION MEASUREMENT.

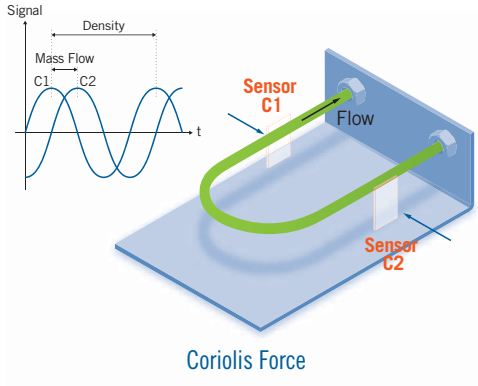
Unique Variety of Measurement Principles



1 Fuel supply connections (4)
2 Damping device
3 Capacitive sensor
4 Tara weight
5 Blade spring
6 Measurement beam
7 Calibrating weight
8 Measuring vessel



1 Inlet
2 Gear meter
3 Piston sensor
4 Piston
5 Bypass
6 Outlet
7 Servo motor
8 Encoder
9 Controller
10 Signal Output



Coriolis Force

GRAVIMETRIC (FUEL BALANCE)

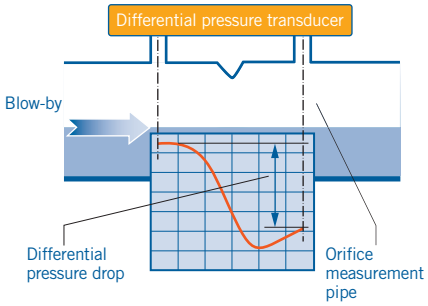
The fuel consumed by the engine is taken from a continuously weighted measurement vessel which has the same properties as the vehicle tank. The detection of the weight of the fuel is carried out with a capacitive displacement sensor connected to the measurement vessel by means of a beam. A calibration weight is used to perform the accuracy testing and calibration procedures in accordance with ISO 9001. Calibration takes place in a fully automatic manner within a few minutes and is integrated by default into the AVL Fuel Balance.

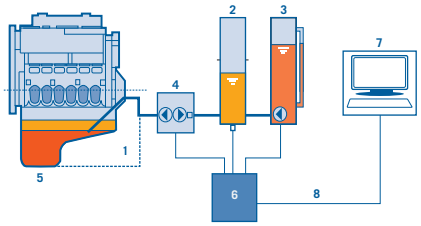
PLU MEASUREMENT PRINCIPLE

The PLU positive displacement meter combines a servo-controlled gear counter with a dynamic piston sensor. A gear meter (2) driven by a servo motor (7) with encoder (8) defines a geometric volume to pulse frequency ratio when gear rotation is adjusted to media flow. A bypass (5) ensures zero pressure difference ($\Delta p = 0$) between inlet and outlet, preventing leakage flow. Flow changes immediately displace a zero-friction piston (4) in either direction. A piston position sensor (3) and a servo controller (9) provide a fast gear speed control loop keeping the piston centered.

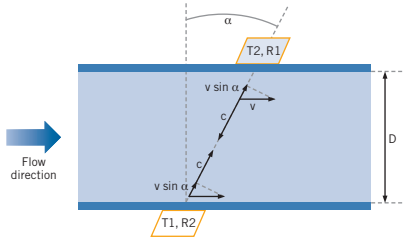
CORIOLIS

Fuel passes through a U-shaped tube which vibrates at its natural frequency. This frequency is proportional to the fuel density which, in addition to the mass flow, is a separate measurement variable and, thus, allows for the output of volumetric measurement values. The time lag of the vibration frequency C1 to C2 is proportional to the mass flow.





1 Oil dip stick
2 Measuring tank
3 Refilling tank
4 Pump
5 Drain plug
6 Electronics
7 PUMA CDH – Task
8 Hybrid interface or serial interface via RS232



T Transmitter
R Receiver
c speed of sound
v flow media velocity
α inclination angle

DIFFERENTIAL PRESSURE

For the determination of blow-by flow the orifice measurement principle (differential pressure measurement procedure) is used. A neck (orifice) in the tube cross-section provokes a pressure drop that is measured by means of a differential pressure sensor. The shape of the orifice of the AVL Blow By Meter means that it, on the one hand, ensures the accuracy in both flow directions and, on the other, prevents condensation at the orifice that might modify the cross-section. The selected shape of the orifice allows for a broad dynamic range of 1:50.

GRAVIMETRIC (OIL CONSUMPTION METER)

This measurement is based on the gravimetric principle. This means that oil is always sucked to a defined level or completely into a measurement tank with modified dip stick or an oil drain plug. Afterwards, the weight is determined with the help of a precision pressure sensor. After the weight has been determined, the oil is pumped back into the oil pan of the engine. This measurement cycle consists of three steps: pumping (out), weighing and pumping (back). The difference between two subsequent measurement cycles results in the oil consumption.

ULTRASONIC TRANSIT DIFFERENTIAL TIME

The measuring principle is based on the ultrasonic transit-time differential method. Two ultrasonic pulses are sent simultaneously through the flowing medium from Transmitter 1 (T1) and Transmitter 2 (T2). One pulse is propagating into the flow and the other one against it. The interaction between the speed of sound c and the velocity of flow v accelerates the pulse on one of the paths and decelerates the pulse on the other path. This effective propagation velocity results in different transit times through the medium: The signal at Receiver 1 (R1) arrives faster than the signal arriving at Receiver 2 (R2). The device measures the speed of sound traveling either way, corresponding to t1 and t2.

ACCREDITED ACCORDING TO ISO17025

AVL Calibration Laboratory

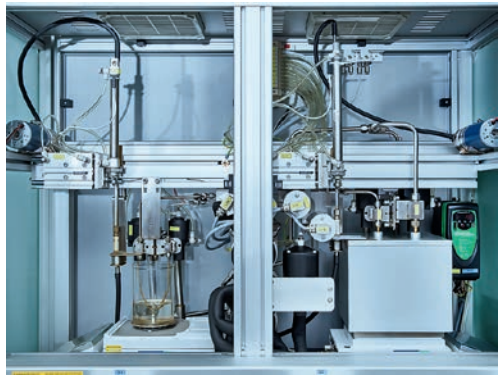
The globalization of the automotive industry requires measurement values which are comparable worldwide. Legislation covering CO_2 and fuel consumption reduction are imminent, with stricter requirements concerning the measurement uncertainty of fuel consumption.

QUALITY STANDARDS

The traceability required by the established quality assurance standards, such as ISO 9001 for measuring instruments in production and development requires measurement equipment to be calibrated on a regular basis.

ACCREDITATION

Measurement uncertainty and the evidence of traceability can now be established in the best way by the manufacturers of measurement equipment in the form of so-called factory calibrations, or in the context of tests, in accredited laboratories.



In this case state accreditation offices initially audit and accredit laboratories for their quality assurance processes and their actual measurement quality. Regular post audits, ensure that the measurement uncertainty stated by the laboratory is complied with. These audits are performed in accordance with ISO 17025. Besides such audits, the measurement quality is also checked in regular round-robin tests carried out among the laboratories.

AVL FUEL MEASUREMENT DEVICES

AVL has been accredited for the calibration of "liquid media". Standard calibrations for AVL Fuel Measurement Devices such as FuelExact or Fuel Reference are performed on an accredited AVL calibration bench, whereby the traceability to international measurement standards are assured and the specified measurement uncertainty is met.

DYNAMIC FUEL CONSUMPTION MEASUREMENT UP TO 2 MW ENGINES

AVL FuelExact™

The AVL FuelExact™ is a high-precision fuel consumption measurement system with harmonized fuel temperature control and fuel consumption measurement capable of detecting the volumetric and gravimetric fuel flow values in a highly precise manner and with shortest measurement times. The focus is on transient measurement and on the advanced field of application for measuring engines of up to 2,000 kW. The AVL PLUtron™ sensor with onboard intelligence provides unique robustness and Plug & Play usability.

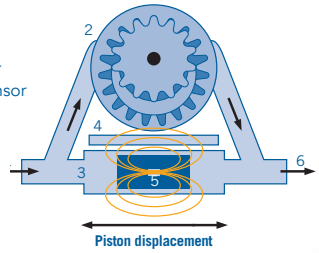
MEASUREMENT PRINCIPLE

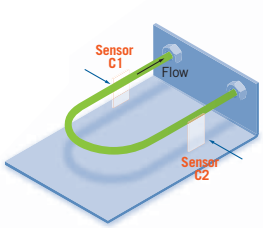
The FuelExact™ exists in two versions: one based on the PLUtron measuring principle and one based on the Coriolis measuring principle. For further information, please refer to page 130/131.

APPLICATION

AVL FuelExact™ covers applications from single-cylinder up to 2,000 kW engines in the field of engine research and development. Due to the high data rate of 100 Hz and the "Zero" step response (with AVL PLUtron™ sensor), the system is ideally suited for transient calibration methods that are increasingly being applied in the field of engine development. The AVL PLUtron™ sensor expands the application range towards development tasks with highest dynamic for close to engine measurements in returnless fuel injection systems. New and improved features consistently protect your investment.

1 Inlet
2 Gear meter
3 Piston sensor
4 Magnetic sensor array
5 High-power magnet
6 Outlet





Coriolis Force

BENEFITS AT A GLANCE

- Ideal for use in transient and dynamic fuel consumption optimization
- Unique data quality due to maximum temperature control accuracy and the application-oriented design of the measuring system
- Fast and easy setup on the testbed – AVL ActiveLink™
- AVL PLUtron™: self-diagnostic functions monitor operation conditions, optimize measurement analysis and protect the device
- Unmatched dynamics for close to engine measurement (with AVL PLUtron™ sensor)

HIGH PERFORMANCE IN FUEL CONSUMPTION MEASUREMENT

AVL Fuelsystem PLU

The AVL FuelSystem PLU is a high precision fuel consumption measurement system with integrated fuel conditioning and optional heating for continuous fuel consumption measurement in the range of 0.05 l/h to 300 l/h. The implementation of the newest AVL PLUtron sensor allows the fastest step response combined with a data-rate of 100 Hz.

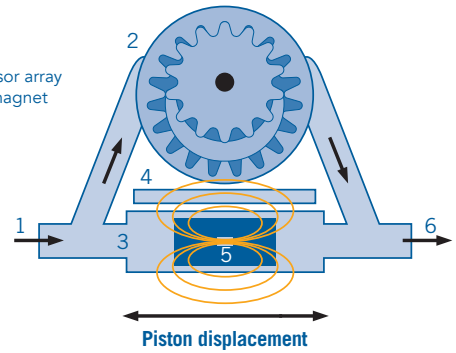
MEASUREMENT PRINCIPLE

The AVL FuelSystem PLU is based on the PLUtron principle. For further information, please refer to page 130/131.

APPLICATION

The FuelSystem PLU is used for fuel consumption measurements on engine testbeds in the development of passenger car engines. The integrated automatic venting and filling procedures make the highly scalable measurement device ideal for applications on testbeds where engines are changed frequently. The internal vacuum pressure regulator allows to generate negative relative pressure in the return fuel line. This measurement device is designed for Flex Fuel, covering all fuel types from gasoline (EN228) with up to 100 % alcohol (M100 or E100) and diesel (EN590) with up to 100 % biodiesel (EN14214).

1 Inlet
2 Gear meter
3 Piston sensor
4 Magnetic sensor array
5 High-power magnet
6 Outlet



BENEFITS AT A GLANCE

- Enhanced testbed efficiency through integrated functional check and online plausibility to prove the state of the hydraulic installation.
- High reliability and short installation and commissioning time enable long operational testbed availability.
- Low switching costs for the AVL KMA4000 installed base thanks to the 100 % backward compatibility (hydraulic and electrical).

FUEL CONSUMPTION MEASUREMENT

AVL Fuel Mass Flow Meter and Fuel Temperature Control

Regarding fuel consumption measurement, the mass flow measurement system AVL Fuel Mass Flow Meter and Fuel Temperature Control uses a Coriolis sensor optimized by AVL and supplies the engine testbed with fuel of the highest temperature stability. A pressure control system patented by AVL provides constant, adjustable fuel pressures and allows reliable and easy utilization with state-of-the-art mixture preparation systems. The FlexFuel version is applicable to bio fuels and, thus, provides investment safeguarding for future development tasks.

MEASUREMENT PRINCIPLE

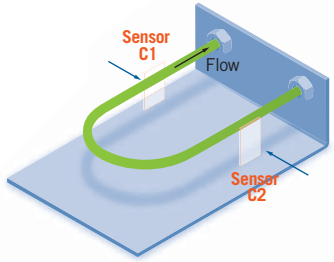
The fuel passes through a U-shaped tube which vibrates at its natural frequency. This frequency is proportional to the fuel density which, in addition to the mass flow, is a separate measurement variable and, thus, allows for the output of volumetric measurement values. The time lag of the vibration frequency C1 to C2 is proportional to the mass flow.

APPLICATION

Given its precision of 0.12 % and direct mass flow measurement capability, the AVL Fuel Mass Flow Meter with Fuel Temperature Control can be used on all engine and chassis dynamometer testbeds in the fields of research, development and production. The measurement system can be used universally for different engine sizes from single-cylinder engines up to 600 kW large-scale engines and for state-of-the-art mixture preparation systems and test cycles.

BENEFITS AT A GLANCE

- Shorter measurement and testing times due to precise fuel temperature control within +/– 0.02 °C
- The patented AVL pressure control allows for a universal application, in line with the requirements of state-of-the-art measurement methods and injection systems
- Increased testbed efficiency due to reliable measurement operation, integrated maintenance displays and detailed diagnosis functions
- With numerous options, a broad spectrum of applications is covered



Coriolis Force

BENEFITS AT A GLANCE

- Minimization of testbed times due to high levels of reliability and long maintenance intervals
- Time-saving ISO 9001 testing due to calibration within a few minutes
- Fast and low-cost integration in the engine testbed due to the presence of compatible interfaces
- Fast application with different injection systems

FUEL CONSUMPTION MEASUREMENT

AVL Fuel Balance and Fuel Temperature Control

The AVL Fuel Balance, based on the gravimetric measurement principle, is the fuel consumption meter used most commonly on engine testbeds. Providing advantages such as reliable operation, measurement accuracy of 0.12 % as well as very low maintenance expenses, it is the uncontested leader.

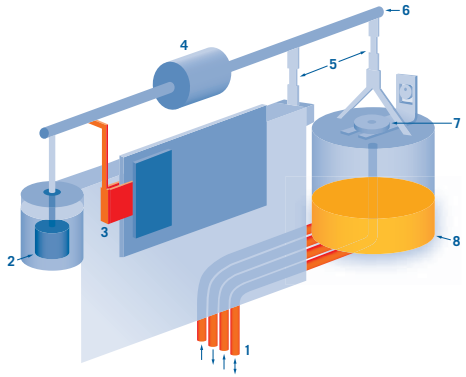
MEASUREMENT PRINCIPLE

The fuel consumed by the engine is taken from a continuously weighted measurement vessel with all the properties of the vehicle tank.

The detection of the weight of the fuel is implemented with a capacitive displacement sensor that is connected to the measurement vessel by means of a beam. A calibration weight is used to perform the accuracy testing and calibration procedures in accordance with ISO 9001. The calibration is implemented in a fully automatic manner within a few minutes and is integrated by default in the AVL Fuel Balance.

APPLICATION

In combination with the AVL Fuel Temperature Control or the AVL Cooling System, it is the ideal solution and industrial standard when equipping research, development, quality and endurance testbeds. It is used for single-cylinder and large diesel engines up to an output of 1,000 kW. The whole range of applications is covered by one AVL Fuel Balance using measurement range switching. Compatible interfaces, allow it to be easily be integrated into different testbed automation systems.



1 Fuel supply connections (4)
2 Damping device
3 Capacitive sensor
4 Tara weight
5 Blade spring
6 Measurement beam
7 Calibrating weight
8 Measuring vessel

FUEL MEASUREMENT SYSTEM CALIBRATION

AVL Fuel Reference

AVL Fuel Reference is an efficient calibration system that provides you with a simple way to check various types of fuel consumption measurement devices, including the way they are set up on the test-bed. Quality assurance, ISO calibration, periodic verification, and calibration according to UN ECE R49 and US EPA 40 C.F.R. part 1065. Depending on your requirements, it is capable of reducing time and effort for calibration (including testbed installation) to as little as 60 minutes. In order to increase the efficiency of the engine test field, it is also important that results from different testbeds are comparable.

MEASUREMENT PRINCIPLE

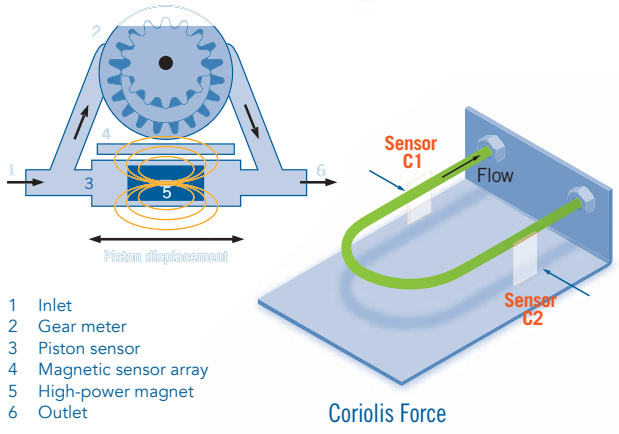
The Fuel Reference exists in two versions: one based on the PLUtron measuring principle and one based on the Coriolis measuring principle. For further information, please refer to page 130/131.

APPLICATION

An AVL Fuel Reference unit is typically connected to a fuel measurement system instead of an engine. It compares the fuel consumption value of the fuel measurement system with the sensor value of the AVL Fuel Reference. Within the software of the AVL Fuel Reference, various test runs with different flow rates and measurement times can be parameterized. For performing the test run, the operator is guided by the software to manually or automatically adjust different flow rates for the calibration points. The result: high accuracy down to low flow rates due to massively increased measurement resolution of the AVL PLUtron™ sensor.

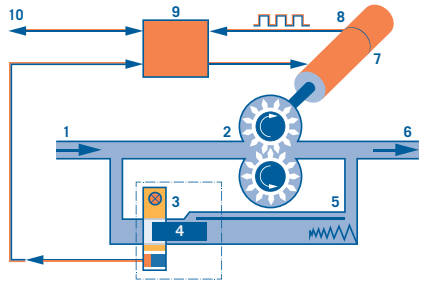
BENEFITS AT A GLANCE

- Applicable to the entire AVL fuel consumption portfolio
- High resolution at low flow rates with the AVL PLUtron™ sensor
- Calibration of the entire fuel consumption measurement chain (measurement device and testbed installation)
- Compliance with all statutory guidelines and standards (ISO, US EPA 40 C.F.R. Part 1065 and UN ECE R49)
- Overall calibration effort is reduced to as little as 60 minutes
- By returning fuel to the measurement device or fuel supply system, the calibration of measurement devices is done without wasting fuel



1 Inlet
2 Gear meter
3 Piston sensor
4 Magnetic sensor array
5 High-power magnet
6 Outlet

1 Inlet
2 Gear meter
3 Piston sensor
4 Piston
5 Bypass
6 Outlet
7 Servo motor
8 Encoder
9 Controller
10 Signal output



END-OF-LINE-TEST OF SMALL OFF-ROAD ENGINES

AVL SORE PLU 110 Fuel Consumption Measurement Unit

The AVL SORE PLU 110 fuel consumption measuring unit is especially useful in the testing of handheld small off-road engines (SORE). The unit is designed to measure even extremely small fuel flow rates and very low supply pressure on carburetor gasoline engines without return flow. The PLU measuring principle avoids interference with engine performance (Δp = 0) in a very large flow range. Installation close to the engine gives the PLU 110T flow meter a unique dynamic measurement capability and minimizes temperature influences. As a stand-alone flow measuring unit, AVL SORE includes a density meter, a data acquisition module and flexible interfaces.

MEASUREMENT PRINCIPLE

The PLU positive displacement meter combines a servo-controlled gear counter with a dynamic piston sensor. A gear meter (2) driven by a servo motor (7) with encoder (8) defines a geometric volume to pulse frequency ratio when gear rotation is adjusted to media flow. A bypass (5) ensures zero pressure difference (Δp = 0) between inlet and outlet, preventing leakage flow. Flow changes immediately displace a zero-friction piston (4) in either direction. A piston position sensor (3) and a servo controller (9) provide a fast gear speed control loop keeping the piston centered.

APPLICATION

AVL SORE PLU 110 is used in R&D, production and engine testing. End-of-line tests for two-stroke SI engines include carburetor adjustment for performance optimization and emission standards compliance. Test time minimization is a primary target of EOL test design. Due to its dynamic measurement capability, the AVL SORE PLU 110 accelerates adjustment of power limits significantly, so contributing to efficient engine testing.

BENEFITS AT A GLANCE

- Dynamic flow measurement due to high resolution and high accuracy even at extremely low fuel flow
- Cycle time reduction and quality improvement in end-of-line testing
- No influence on engine performance (no pressure drop; Δp = 0)
- Fast testbed integration, flexible use and convenient stand-alone functionality

MOBILE FUEL CONSUMPTION MEASUREMENT

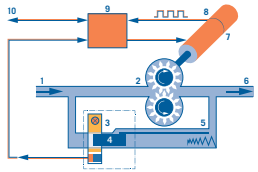
AVL KMA Mobile

The AVL KMA Mobile is an in-vehicle fuel consumption measurement system that sets standards regarding reliability, flexibility and precision. Due to the modular design, the measurement system can be adapted to the different requirements. For example, engines without return flow require only the measuring module while engines with return flow to the tank require the measuring and the conditioning module. Thanks to the three measurement ranges each system covers a large range of vehicles and engine types, from two-wheelers to large construction vehicles. Dynamic measurements combined with high measurement quality (accuracy, reproducibility) can be achieved due to very short response time (100 ms) and very short measurement time.

MEASUREMENT PRINCIPLE

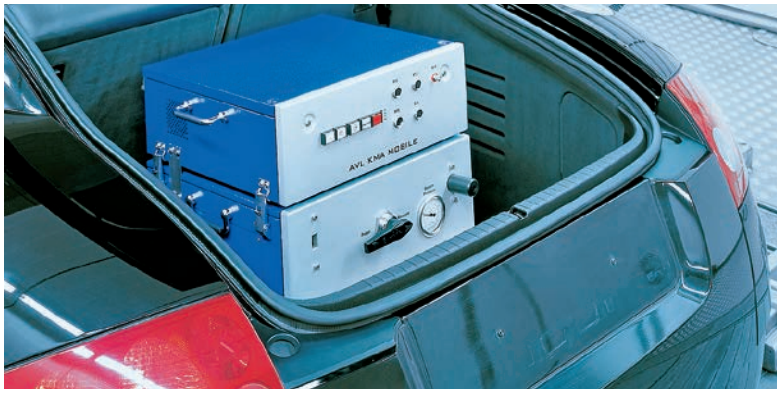
The AVL KMA Mobile measurement system uses the worldwide approved PLU measurement principle of the servo-controlled positive displacement meter ($\Delta p = 0$). The positive displacement meter is driven by a servo motor (7) so that the differential pressure across the meter is controlled to "zero". This differential pressure of zero between sensor inlet (1) and outlet (6) results in an absence of leakage flows within the PLU sensor that could affect the measurement result. As the sensor does not cause a pressure drop, wear and tear on the sensor are minimized.

1 Inlet
2 Gear meter
3 Piston sensor
4 Piston
5 Bypass
6 Outlet
7 Servo motor
8 Encoder
9 Controller
10 Signal output



APPLICATION

The universal fuel measurement system AVL KMA Mobile is used for fuel consumption measurement in vehicle road testing and at chassis dynamometer testbeds. The AVL KMA Mobile is available with different PLU sensors and, thus, allows for measuring flows between 0.16 l/h and 300 l/h. Hence, all applications from passenger cars to heavy commercial vehicles are covered.



BENEFITS AT A GLANCE

- Due to its universal applicability, the AVL KMA Mobile can be used with all common vehicle fuel delivery systems
- Reliable road test results are guaranteed by high measurement accuracy, reproducibility and robustness
- Due to engine supply and return pressure adjustment capability, the measurement system does not have any influences on the engine fuel system
- Simple handling due to modular design and the application of self-sealing quick couplers facilitates integration in the vehicle

PLUTRONIZE BEYOND LIMITS

AVL PLUtron™ CLASSIC

As a universal flowmeter AVL PLUtron™ CLASSIC is suitable for a very wide range of applications in the automotive sector. It impresses with a true "Plug & Play" usability in setup and operation, based on integrated sensors and onboard intelligence, enabling self-diagnostic functions. It simplifies all those flow measurement applications where experts are not available, yet reliable results must be produced quickly in changing or unknown environments. Users benefit from the advanced PLU measuring principle by a much larger dynamic range, no influence on the tested circuit ($\Delta p = 0$) and extreme robustness against vibration and shock. An optional integrated density meter also allows the direct measurement of mass flow with the PLU.

MEASUREMENT PRINCIPLE

PLUtron extends the traditional PLU dual sensor measurement principle. The gear head accurately measures the net flow rate, and flow rate variations are sensed by the piston sensor instantaneously. With PLUtron, this highly dynamic flow contribution is now added to the averaged flow signal of the gear head. Therefore, the response time of the electro-mechanical control loop of the servo drive is eliminated from the flow signal.

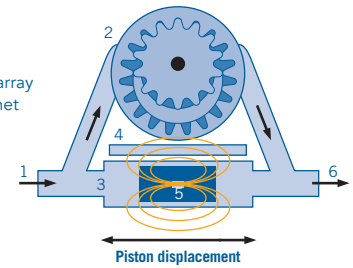
APPLICATION

AVL PLUtron™ CLASSIC is an ideal solution for in-vehicle testing on gasoline vehicles as passenger cars or motor cycles, where robustness against pressure pulsation and vibration is an increasingly important feature for achieving reliable results. Flow measurement in component production testing is another demanding field of application. The higher PLUtron resolution offers faster stabilization and shorter measurement time than all other devices. AVL PLUtron™ CLASSIC is an outstanding solution for many more applications on testbeds as well as in the lab, which focus on flexible use, simple setup and robustness. Please consult us for a detailed analysis of your needs and requirements. Optionally, mobile display and an integrated density meter are available.

BENEFITS AT A GLANCE

- Unique Plug & Play usability for optimized workflow
- Reliable results under rough conditions due to robust design and long-term stable calibration
- Higher flexibility due to large measuring ranges with highest resolution and accuracy
- Up to 15 % shorter test time in component production at affordable cost of ownership
- No influence on engine performance

1 Inlet
2 Gear meter
3 Piston sensor
4 Magnetic sensor array
5 High-power magnet
6 Outlet



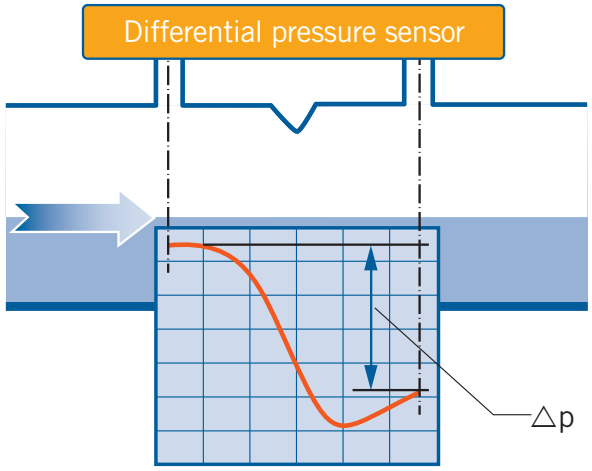
ENGINE CRANKCASE VENTILATION FLOW MEASUREMENT

AVL Blow by Meter

Blow-by measurement nowadays is standard on engine testbeds. To be able to comply with the emission legislation for new combustion engines today and in the future, the requirements for crankcase ventilation systems will continue to increase. In order to design these systems, knowledge of engine blow-by mapping is also required. This and the possibility of continuous measurement of the blow-by flow to monitor the engine condition make the AVL Blow By Meter an indispensable instrument for engine testing.

MEASUREMENT PRINCIPLE

For the determination of blow-by flow the orifice measurement principle (differential pressure measurement procedure) is used. A neck (orifice) in the tube cross-section provokes a pressure drop that is measured by means of a differential pressure sensor. The shape of the orifice of the AVL Blow By Meter means that it, on the one hand, ensures the accuracy in both flow directions and, on the other, prevents condensation at the orifice that might modify the cross-section. The selected shape of the orifice allows a broad dynamic range of 1:50.



Orifice Principle

APPLICATION

On the basis of the interchangeable measurement ranges between 0.2 and 2,400 l/min, the AVL Blow by Meter can be used from small-scale and single-cylinder engines to ships' diesel engines. The areas of application cover engine research and the optimization of the piston cylinder assembly. Furthermore, this system is used when designing crankcase ventilation systems and on quality and endurance testbeds.

BENEFITS AT A GLANCE

- The accuracy of 1 % FSO (optional) and the reproducibility of 0.1 % comply with the strict requirements of engine measurement technology
- Due to the minimum pressure drop, the blow-by behavior of the engine is hardly affected
- High reliability and constant measurement readiness are realized by low dirt sensitivity
- Correct detection even of reverse blow-by flows
- Simple integration and installation on the testbed

AIR CONSUMPTION MEASUREMENT

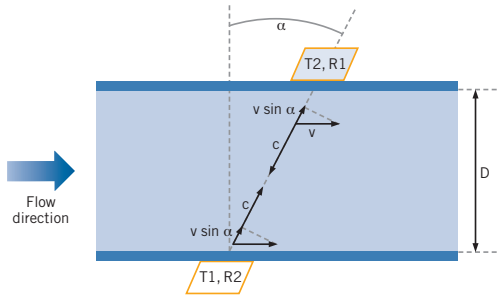
AVL FLOWSONIX™ Air

Along with fuel consumption, air consumption is another important parameter when developing combustion engines. In emission certification, air consumption is taken as a reference value. Consequently, air consumption is an integral part of AVL testbed solutions.

The AVL FLOWSONIX™ Air components are the measuring head, the evaluation unit and two very short inlet- and outlet pipes (< 5* DN each). Due to the large measuring span of 1:70, only two different pipe diameters are needed (DN 100, DN 150) to cover the full application range of up to ± 2,900 kg/h.

MEASUREMENT PRINCIPLE

The measurement principle is based on the ultrasonic transit-time differential method. Two ultrasonic pulses are sent simultaneously through the flowing medium from Transmitter 1 (T1) and Transmitter 2 (T2). One pulse is propagating into the flow and the other one against it. The interaction between the speed of sound c and the velocity of flow v accelerates the pulse on one of the paths and decelerates the pulse on the other path. This effective propagation velocity results in different transit times through the medium: The signal at Receiver 1 (R1) arrives faster than the signal arriving at Receiver 2 (R2). The device measures the speed of sound traveling either way, corresponding to t1 and t2.



T Transmitter
R Receiver
c Speed of Sound
v Flow Media Velocity
α Inclination Angle

APPLICATION

The combination of high levels of measurement accuracy, a large measurement range and short response time enables applicability of the air mass measurement in the following fields (of application): engine development, quality assurance, emissions development and emissions certification.

BENEFITS AT A GLANCE

- The unique AVL FLOWSONIX™ Air is impervious to contamination, which enables long maintenance intervals
- Marginal influence on the combustion engine due to small pressure drop in the measurement head
- Quick and easy installation for any engine type
- High availability of the measurement device due to extended calibration interval of one year
- One size fits all. Due to the wide measurement range, only two different instrument versions are required: light duty or heavy duty
- Little space required – just < 5*DN up-stream and down-stream tubing

Different measurement tubes up to 4,000 kg/h.

AIR CONSUMPTION MEASUREMENT

AVL Air Consumption Meter

Along with the fuel consumption, air consumption is another important parameter when developing combustion engines. In emission certification, air consumption is taken as a reference value. So the air consumption is an integral part of AVL testbed solutions.

The air consumption measurement system consists of the components of flow meter sensor (measuring tube), supply/evaluation unit and measuring section. The measuring tube is available in six different nominal widths of NW 25 up to NW 200 and is installed in the measuring section using quick release connections.

MEASUREMENT PRINCIPLE

The system works in accordance with the principle of the hot film anemometer. This measurement procedure is based on the fact that heat is withdrawn from a heated body by the air flowing around it. In the relevant measurement range, this flow-dependent cooling does not depend on pressure and temperature but on the type and number of air particles making contact with the heated surface. The procedure, then, directly represents the mass flow of the suction air. With this procedure, the measurement value is provided directly in the units of kg/h or the standard m^3/h.

APPLICATION

The combination of high levels of measurement accuracy, a large measurement range and short response times result in the use of air mass measurement in the following fields of application: engine development, quality assurance, emissions development and emissions certification.

BENEFITS AT A GLANCE

- The high levels of measurement accuracy across a large measurement range comply with the requirements of automatic engine calibration
- The short response time is a precondition for detecting quick engine load changes in the transient measurement range
- Simple handling due to modular design and the use of quick release connections facilitates the integration into the test facility

UREA CONSUMPTION MEASUREMENT

AVL PLUrea™

AVL PLUrea™ serves the specific requirements of SCR system applications in diesel engine exhaust after-treatment. Compliance with the challengingly low limits of future exhaust emission legislation requires maximum NO_x conversion ratios while avoiding ammonia slip. Successful urea dosing strategy development for a specific engine/SCR system/catalyst combination includes accurate dosing calibration over the entire engine map and comprehensive emission cycle testing. Enabling AVL measurement technology allows fast setup, easy handling, robustness and durability in addition to accurate and reliable measurement data.

MEASUREMENT PRINCIPLE

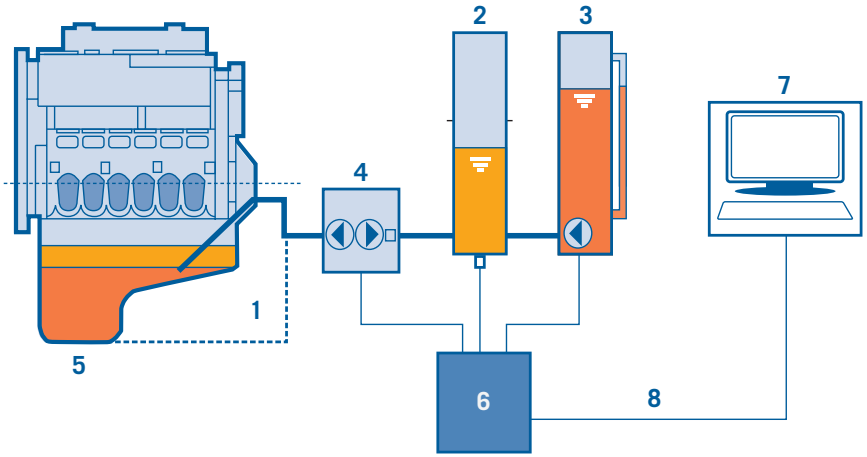
Extremely small flow quantities and high levels of flow dynamics require a measurement position in the direct vicinity of the injector to minimize temperature's influence on the results. Robustness to pressure pulsations resulting from the injection is, of course, an important precondition in this position. With their dual measurement principle PLU sensors are ideally suited to these measurement conditions.

APPLICATION

AVL PLUrea™ provides stationary urea flow metering as well as highly dynamic consumption measurement during transient test cycles. The system solution is used on engine or chassis dynamo testbeds as well as in vehicle testing. With accurate online measurement, AVL PLUrea™ contributes to efficient SCR system testing in all development stages of SCR system application and verification.

BENEFITS AT A GLANCE

- Efficient urea dosing strategy development due to dynamic correlation
- Optimized system solution for SCR-specific operational conditions
- Immediate detection of dosing deviations or SCR system malfunction and exact identification of corresponding operational conditions
- Fast testbed integration, flexible use and comfortable stand-alone functionality



1 Oil dip stick
2 Measuring tank
3 Refilling tank
4 Pump
5 Drain plug
6 Electronics
7 PUMA CDH – Task
8 Hybrid interface or serial interface via RS232

OIL CONSUMPTION MEASUREMENT

AVL Oil Consumption Meter

The determination of the lubrication oil consumption of state-of-the-art combustion engines is as important as ever because of stricter emissions regulations. These exhaust gas and particulate matter emissions limited by law confront the engine developers with a difficult task that can only be solved in the combination of combustion, exhaust gas after-treatment and oil consumption development.

MEASUREMENT PRINCIPLE

The measurement works using gravimetric principle. This means drawing the oil into a measurement tank, either completely or up to a defined level, using a modified dip stick or the oil drain plug. Afterwards, the weight is determined with the help of a high-precision pressure sensor. After the weight has been determined, the oil is pumped back into the oil pan of the engine. A measurement cycle consists of the three steps: pumping out, weighing and pumping back. The difference between two subsequent measurement cycles indicates the oil consumption.

APPLICATION

Thanks to the compact and mobile design, the measurement unit can be used in many applications. The areas of application in the field of engine development and research are the optimization of cylinder head seals, piston rings, the valve guides, as well as inspection of oil dilution or the reasons for oil consumption. In durability testing, the AVL Oil Consumption Meter can also be used for monitoring or refilling the consumed quantity of oil. On production testbeds the meter can be used to check the production quality of engines.

BENEFITS AT A GLANCE

- Up to 50 % time savings compared to traditional methods
- The integrated oil refilling unit allows extended test cycles
- The simple installation and testbed integration minimizes downtime
- The integrated operating panel on the device allows stand-alone operation
- Due to the fully-automated measurement procedure, there is no need to handle the oil

Dynamic Injection Measurement Technology

APPROACH

With the introduction of the diesel CR and DGI technologies, the requirements on flow measurement for engine development have changed over the course of the last two decades. In both research and development and in production, continuous fuel consumption measurement has been complemented by cycle-related injection quantity measurements and the analysis of the corresponding rate curve. Driven by the goals of reducing fuel consumption and emissions, we are currently experiencing a new spurt of innovation in the field of combustion development with a major impact on injection technology and injection measurement technology. As a pioneer in applications for common rail and GDI technologies, AVL remains the market leader in dynamic injection measurement systems thanks to the Shot-to-Shot™ measurement technology.

BENEFITS AT A GLANCE

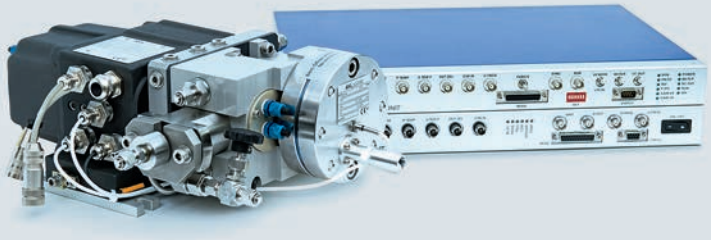
- Shorter development times: cycle-synchronous correlation of injection quantities and time behavior with the relevant system and engine parameters
- Reduction of measurement times: high measurement accuracy reduces the measurement period on the testbed and on the production line
- Protection of development steps: precise analysis, for example, of minimal quantities and multiple-injections as components of the indicating data collection
- Robust development tool: efficiency due to universal applicability and high long-term stability of calibration

TASK

Decreasing exhaust gas emission limits and the requirements for continuously lower fuel consumption are currently the primary driving forces behind the further development of engine technology. The strategy and precise control of the fuel combustion play a central role. These different focuses require the detailed analysis of the injection rate curve related to the engine cycle:

- The development and production of capable injectors and injection systems requires the accurate analysis of opening and closing behavior. Testing the injector during production requires high precision and long-term reproducibility of injection quantity measurement.
- Today, combustion strategies with layer loading and multiple-injection sequences play an important role in the development of GDI internal combustion engines. The highest measurement resolution of low separation times at low injection quantities pose extreme challenges for the measurement technology.
- The exact optimization of performance, consumption and exhaust gas emissions on diesel engines has become an extremely complex task due to the application of different components for exhaust gas aftertreatment. The precise quantity measurement of multiple-injections, down to the smallest partial injections, has to be implemented in the overall engine map in realistic conditions.

The Shot-to-Shot™ measurement technology is used in all examples mentioned above and, thanks to its superior characteristics, it plays a part in ensuring our customers' products have competitive advantage.



THE COMPETENCE AND EXPERIENCE OF AVL HELPS CUSTOMERS KEEP UP WITH THE RAPID PROGRESS IN INJECTOR TECHNOLOGY AND TO MASTER THE HIGH-TECH PRODUCTS OF TODAY AS EVERYDAY TECHNOLOGIES OF TOMORROW.

REFERENCES

Combustion development on single-cylinder engines

STS is an important contribution to the correlation of characteristic combustion and injector parameters in realistic conditions. The research departments of the most renowned German automobile manufacturers and suppliers are among our customers.

Production testing of injectors

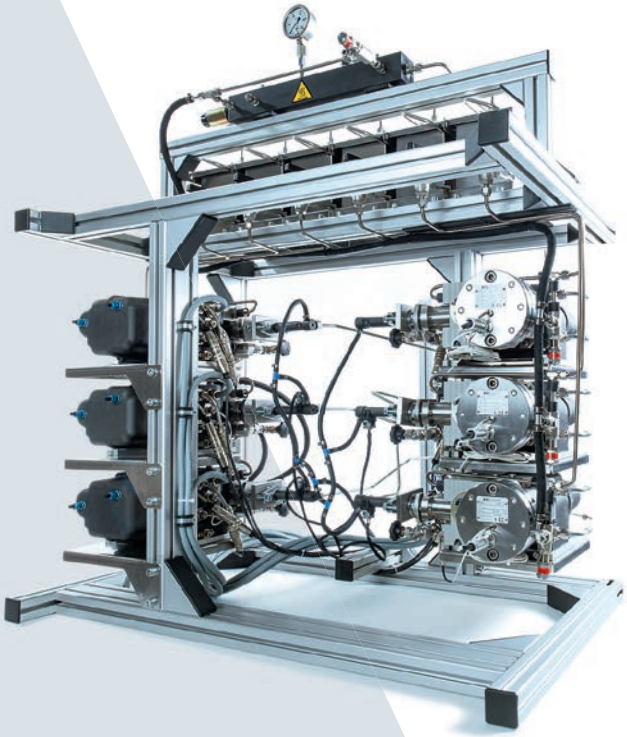
The current challenges with 100% testing of injection quantities are measurement time reduction, minimal injection quantities and achieving the required measurement accuracy. STS serves as the only practical means of production measurement for the market leader in SCR systems.

Engine calibration

The parameterization of the engine controller with map data on the system testbed equipped with STS significantly reduces calibration expenditure on multicylinder engines. As a standard tool, STS has been ensuring the timely and economical implementation of development projects at AVL for years.

Installed base

More than three decades of competence in the field of flow sensory systems. More than two decades of experience in the field of injector testing and more than three years of successful applications of STS measurement systems in a variety of customer-specific applications with widely varying requirements.



GASOLINE INJECTION QUANTITY MEASUREMENT

AVL STS PLU 131 Gasoline

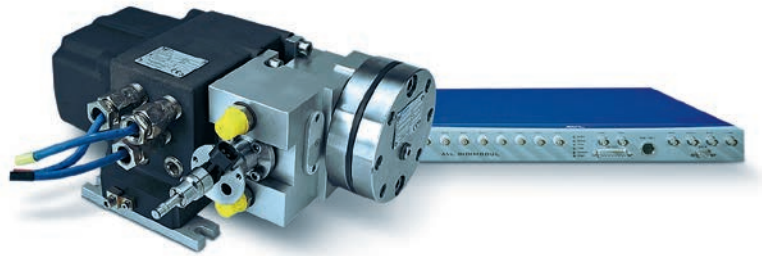
Research and development are two application focuses in the field of internal combustion engines for the AVL Shot-to-Shot™ PLU 131 flow measurement system. In the course of such work, the shot quantity measurement and the details of the chronological rate curve for fuel injection provide valuable findings for the optimization of combustion behavior. Furthermore, shot quantity measurement has become increasingly widespread as part of production testing for fuel injectors.

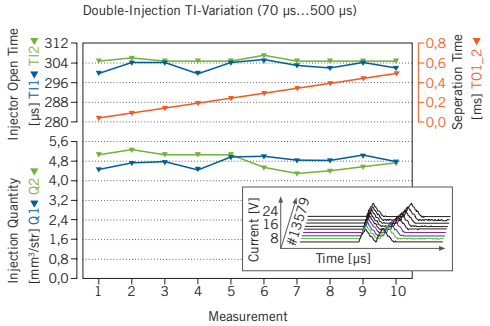
MEASUREMENT PRINCIPLE

The dual PLU measurement principle provides STS with a very flexible hydraulic configuration of the measurement design due to the combination of a rotatory and a translatory positive displacement meter. As a result, the STS measurement system can be used on the high-pressure side of the injector (upstream) and in the low-pressure area (downstream).

APPLICATION

The versatility of STS provides an additional option of a dynamic injection quantity measurement at the operating single-cylinder engine and at the spray chamber, turning the AVL Shot-to-Shot™ PLU 131 flow measurement system into an indispensable measurement tool when characterizing injectors and developing spray image and combustion behavior.
When looking at the example of stratified charge combustion with its cascades of subsequent injections, the importance of these measurement values becomes particularly clear.
However, STS is now also used for 100 % series testing purposes in the manufacturing of injectors for homogenous operation.





Gasoline Upstream – Multiple-Injection Analysis: injection quantity and injector open time measurement of a double injection profile with variable separation time (TI = 70 … 500 µs)

BENEFITS AT A GLANCE

- Flexibility: Applications are possible on both the high-pressure side of the injector (upstream) and low-pressure side (downstream)
- Versatility: Large measurement ranges between flow and injection quantities combined with high measurement accuracy for even minimal quantities
- Shorter development times: quick characterization of prototypes due to shot measurement at the operating engine or spray chamber
- Relevant results: No influence on the injection system due to the instrumentation device principle (Δp = 0)

DIESEL INJECTION QUANTITY MEASUREMENT

AVL STS PLU 131 Diesel

For diesel applications, the AVL Shot-to-Shot™ PLU 131 flow measurement system is used for the research, development and production of injectors, injection systems and corresponding combustion engines.

The connection with the AVL indicating technology family IndiAdvanced offers convenient options for rate curve analysis as part of the indicating data collection. The timing analysis and the minimal quantity measurement in particular are very important measurement variables for multiple-injections during diesel combustion.

MEASUREMENT PRINCIPLE

In diesel applications, the system is used in downstream configuration on the low-pressure side of the injectors at up to 200 bar of counter pressure. The dual PLU measurement principle entails the combination of a rotatory and a translatory positive displacement meter. Using STS, you can determine the injection quantities precisely and also record the rate curves in high resolution.

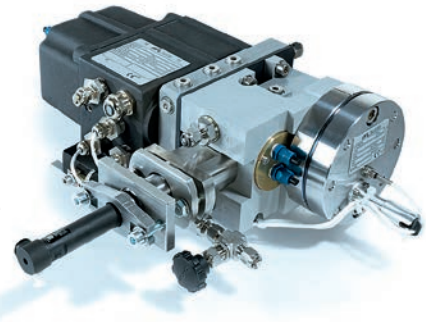
APPLICATION

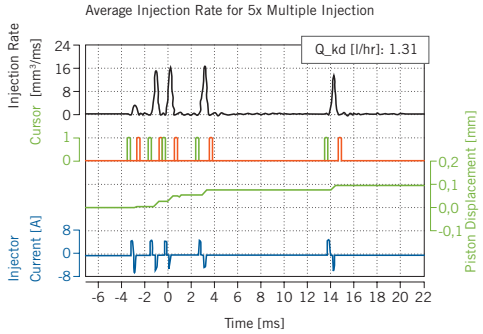
Diesel CR injectors are characterized on component benches regarding injection rate, injection quantity as well as open and closing delay times. Complete injection systems are pre-calibrated during the engine development procedure on the fully instrumented multiple-cylinder system testbed to save valuable development time and costs on the engine testbed at a later point in time.

Renowned heavy duty vehicle manufacturers use STS to optimize their unit-injector fuel injection systems on full HD engine testbeds, for example. Within the framework of 100 % testing of the injector series production, STS satisfies the extreme requirements of a robust, fast shot quantity measurement with high accuracy.

BENEFITS AT A GLANCE

- Compliance with the emission limits through reliable characterization of the relevant parameters to control multiple-injection systems
- Reduction of engine testbed development time for the calibration of injection systems due to pre-mapping of injection parameters on the injection system testbed
- Cost efficiency of the production test due to short measurement times and robust measurement systems
- High relevance due to large operating ranges for pressure and temperature which allow different loads and speeds to be measured under realistic conditions





Diesel Downstream – Multiple-Injection Analysis: injection rate measurement of a typical CR diesel multiple-injection sequence with pilot, main and post injections. Piezo injector current, piston sensor displacement and cursors for quantity measurement are seen below.

UREA INJECTION QUANTITY MEASUREMENT

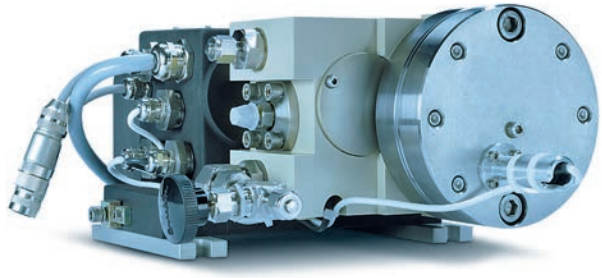
AVL STS PLU 131 Urea

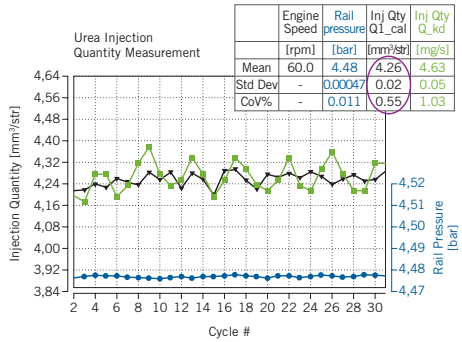
The development and production of SCR injection systems requires precise shot quantity measurement of the urea dosage in the exhaust gas system. In doing so, the characterization and testing of curves and functionality are implemented in an advantageous manner and under realistic conditions for both injectors and complete injection systems.

MEASUREMENT PRINCIPLE

Just like in low-pressure fuel injection, a precise consumption measurement on the undisturbed SCR system can only be implemented at the feed side (upstream) of the injector. The most important difference compared to fuel is the extremely low level of urea consumption, which amounts to only five percent of diesel consumption.

With these extreme requirements, the AVL Shot-to-Shot™ PLU 131 is the only flow measurement system that also satisfies the requirements for measurement accuracy. This is achieved through the dual PLU measurement principle with two complementing sensors for dynamics and injection quantities.





Urea Upstream Injection Quantity Measurement: Injection quantity statistics over 30 injections of an injector characteristic test down to extremely low flow rates of 10 g/h

APPLICATION

To measure the minimal quantities of urea injectors, component testbeds for SCR system development comply with stringent requirements on stability of pressure and temperature conditions as well as the precision of flow measurement. This is the only way to ensure actual injector properties are characterized without interference from error sources. The high level of measurement accuracy at extremely low flow rates as low as 0.01 l/h is also the reason AVL Shot-to-Shot™ PLU 131 Urea has been the only approved means of measurement in the production system of the world market leader for SCR systems since 2006.

BENEFITS AT A GLANCE

- Relevant results: application on high-pressure side of injector (upstream) for shot quantity measurement on low-pressure injectors
- Development safety: high level of measurement accuracy on a broad measurement range with minimal influence on the system
- Production quality: fast and precise measurements at the full range of operating parameters when testing injectors with the 100% test

FLOW MEASUREMENT FOR COMPONENT TESTING

AVL PLU 131F, PLU 131S, PLU 131U

The AVL product line PLU 131 offers a wide range of high precision flow meters for all kinds of applications in various fields of combustion engines. In addition to standard flow meter versions for all kinds of fuels and test fluids, specialized models for water or urea solution are available. Other device types have been designed for high media pressure up to 200 bar and high media temperature up to 150 °C.

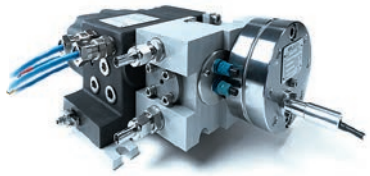
The different measuring ranges cover everything from small quantity measurement of 0.05 l/h to high flow rates of 300 l/h. The measurement accuracy is 0.1 % of the measured value over the complete measuring range of the individual device types of up to 1:500.

MEASUREMENT PRINCIPLE

The dual PLU measuring principle entails the combination of a rotatory and a translatory positive displacement meter. The servo-controlled gear counter determines the flow volume from the rotation. The dynamic piston sensor controls the engine speed and ensures zero pressure difference (Δp = 0) between inlet and outlet. This prevents internal leakage flow in the sensor. Over the complete measuring range, the measuring device generates no pressure difference in the hydraulic system being measured.

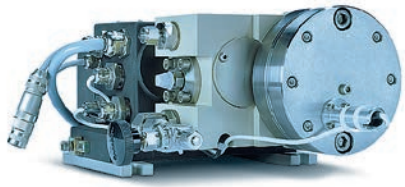
APPLICATION

The main fields of application of the PLU 131 are test benches and production lines for automotive fuel supply components. The PLU measurement principle is suitable for pulsating flows and can be applied in direct hydraulic adaptation for the testing of pumps, injectors and control valves on the inlet (upstream) side as well as on the outlet (downstream) side. AVL PLU 131 sensors increase measurement accuracy and reduce measuring time for continuous flow measurement.



BENEFITS AT A GLANCE

- Reduced measurement time due to high-precision flow rate measurement
- High flexibility due to broad range of media compatibility and extremely large measuring ranges
- Reliable results with upstream measurement (high-pressure side) and non-interference between meter and hydraulic system (Δp = 0)
- Low cost of ownership due to outstanding robustness and long-term stability of calibration



Combustion Measurement Technology

APPROACH

Based on detailed knowledge and experience in the methodology of combustion analysis, AVL has developed practical tools and devices to make the complex thermodynamic processes of an engine visible and understandable. To support all phases of development, AVL offers different solutions for different tasks in combustion development, application and calibration.

Perfectly integrated and matched components are the benefits offered to customers by the only complete combustion analysis measurement solution available worldwide.

BENEFITS AT A GLANCE

- Complete indicating measurement chain with consistent communication, the only one of its kind
- Flexible solutions for multiple applications
- Perfect integration and communication with testbed and application systems
- Data security through integration into the testbed data management system
- High precision measurement through inbuilt plausibility checks
- Open, homogeneous solutions for user-specific adaptations

TASK

Today, legislation acts as a major driving force in the automotive market and is largely responsible for current development needs and trends.

In the future effective drive systems with the lowest pollutant emission possible at moderate costs will be in high demand for all engines sizes. At the same time, the market is changing rapidly as a result of new manufacturers of engines/models appearing on the market and intensifying the competitive pressure on all OEMs.

All these circumstances lead to a general trend of radically shortened development cycles. Combustion analysis will increasingly become a central test focus again, because future engines will have to incorporate several combustion concepts in parallel. Therefore, all test engineers, calibration engineers and development engineers, as well as test-field managers, are facing increasing complexity.

Engineers also face new challenges in the need for stronger interaction and correlation between combustion analysis results in engine automation and control systems faster than ever before.

REFERENCES

All Application Fields
For basic engine calibration, optimizing fuel consumption or emissions, combustion noise and mechanical diagnostics, optimizing engine performance or developing new combustion methods: AVL equipment is used worldwide whenever detailed information about the combustion process is needed.

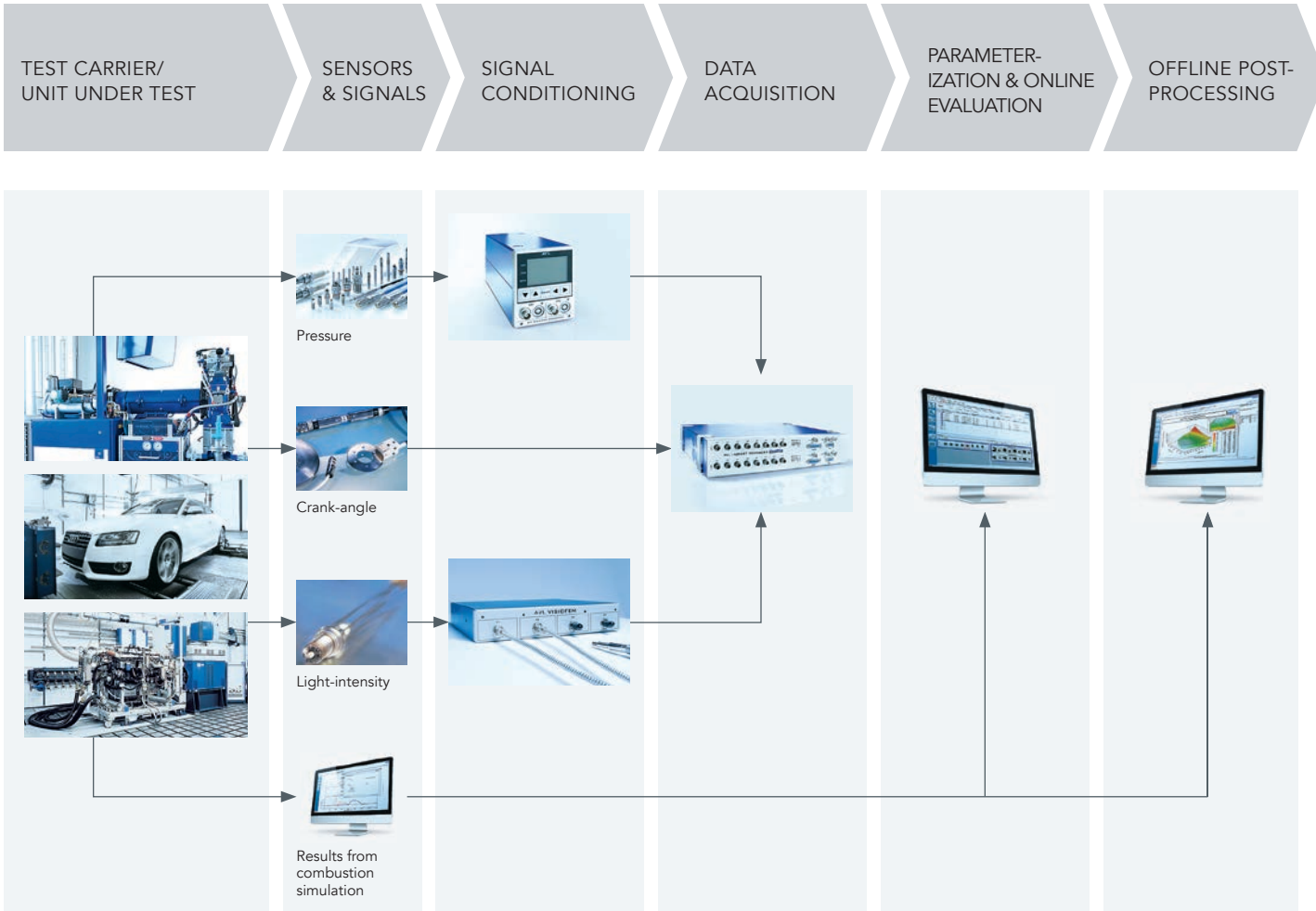
Certified Product Development Process
The AVL combustion analysis software AVL IndiCom™ is developed using the certified software development process CMMI. CMMI monitors the development in terms of time, budget and, most importantly, achieved quality.

In-House Powertrain Engineering Experience
All AVL combustion analysis tools are practically tested and optimized in close cooperation with our in-house powertrain engineering teams. This is the key to offering products of the highest quality and reliability, another unique benefit for our customers.

Installed Base
Problem-solving competency based on AVL's extensive experience in combustion analysis and the fact that AVL is the only manufacturer of a fully indicating measuring chain make AVL the customer's preferred choice and the market and technology leader for high-end combustion analysis.

DUE TO COMBINED USE OF INDICATING AND VISUAL METHODS, I NOW UNDERSTAND THE PROCESSES INSIDE THE COMBUSTION CHAMBER.

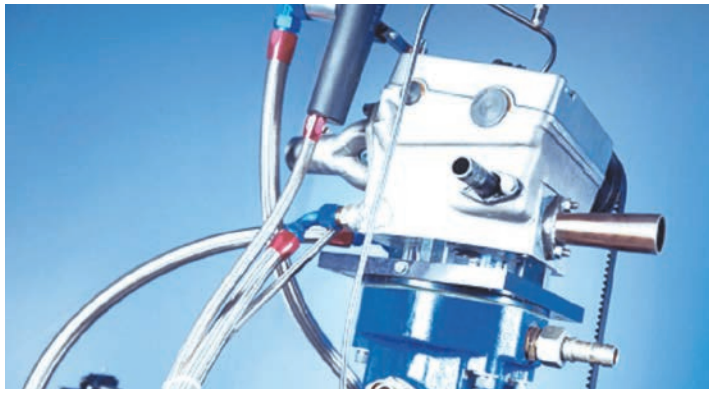
Complete Measuring Chain for Combustion Analysis

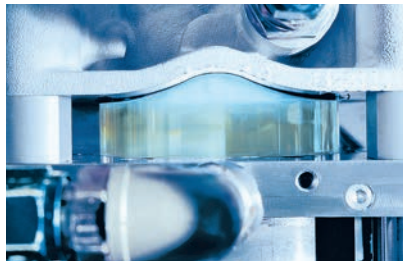


Single Cylinder Research Engines and Testbeds

AVL single cylinder engines and AVL single cylinder testbeds are used for combustion and basic research as well as for visualizing fuel injection and combustion phenomena with transparent access to the combustion chamber (via a glass liner fitted to the cylinder head). The benefit is that the prospects of success are tested under realistic engine conditions long before the concept is applied to the full engine.

Single cylinder engines cover a range from small passenger car engines up to heavy duty truck engines. Given their modular structure, they are suitable for standardized, fully-equipped engines as well as one-off, customized solutions for all scales.





APPLICATION

Typical applications for single cylinder research engines and testbeds are: combustion development, injection development, flow studies with laser measuring methods (basic research), lube oil development, fuel development, alternative fuel research and investigations on gas engines and heavy fuel engines, as well as friction evaluation of the piston-liner-group.

OVERVIEW OF RESEARCH ENGINES

VARIANT	BORE	STROKE	DISPLACE-MENT	REV. SPEED	PEAK PRESSURE
Series 540 Car Size	65 mm to 100 mm	60 mm to 95 mm	0.2 l to 0.75 l	8,000 rpm	200 bar
Series 580 Light Duty Size	80 mm to 110 mm	90 mm to 130 mm	0.45 l to 1.2 l	5,000 rpm	200 bar
Heavy Duty Size	110 mm to 145 mm	120 mm to 170 mm	1.2 l to 2.8 l	3,000 rpm	300 bar

BENEFITS AT A GLANCE

- Single cylinder compact testbeds (including dyno and more) as cost-efficient compact systems and turnkey solutions
- Ideal combination of testbed and research engine for professional operation of single cylinder engines
- Robust design of engines for peak demands under extreme conditions
- Exact replication of customer-specific multi-cylinder engines ensure excellent correlation to the production engine
- Possibility of extensive combustion R&D projects at AVL's internal transparent engine laser laboratory and application support from AVL experts

Sensors for Combustion Analysis

AVL offers piezoelectric pressure sensors in all typical dimensions from M5 to M14 for a wide range of applications at the engine. AVL uses the unique piezoelectric crystal $GaPO_4$ for uncooled and most water cooled sensors with its outstanding thermodynamic properties. The AVL sensor portfolio includes solutions for absolute and low pressure measurement as well as needle and valve lift measurement. Manifold crank angle encoder solutions specifically designed for specific types of application are used to make a precise measurement of crank angle signals.

APPLICATION

- The precise AVL pressure sensors are most often used for the thermodynamic analysis of combustion engines
- The robust AVL pressure sensors are most often used for calibration or endurance test of combustion engines
- The new AVL spark plug solutions, available in sizes M10x1, M12x1.25 and M14×1.25, with a broad range of heat values and spark protrusions, are easily adaptable and fulfil the requirements for high measurement precision and highest ignition voltage demands. They are, therefore, best suited for in-vehicle applications as well.

AVL crank angle encoders of the 365 series are available in different designs: The 365C for standard mounting at the free crankshaft end, the 365X for mounting at the shaft between engine and dyno; or the 365R ("massfree marker trace") especially designed for racing applications, small engines or engines with limited direct access to the crank shaft.

In addition to pressure signals robust and highly accurate crank angle signals are a basic requirement for high quality combustion analysis. Therefore, AVL offers solutions for simple and flexible installation with angle encoders of the series 365.

BENEFITS AT A GLANCE

- Maximum precision and outstanding thermodynamic properties due to the unique piezoelectric crystal $GaPO_4$, Double Shell sensor housing
- Integration of all piezoelectric pressure sensors in AVL SensorDataManagement SDM™
- Flexible sensor solutions for manifold applications
- For highly demanding applications like super charged engines, special sensor types are offered with extremely high robustness and durability

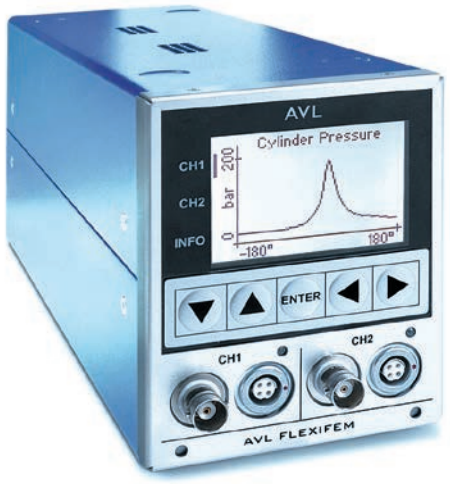
Indicating Amplifier Solutions

The FI Piezo and FlexIFEM product families enlarge AVL's indicating amplifier product range to include an additional intelligent amplifier concept. FI Piezo and FlexIFEM are able to provide the first indicating results cycle by cycle in addition to the measured signals, so offering a wider range of applications for the engine engineer.

APPLICATION

The applications of the MicroIFEM range from cylinder pressure to the measurement of piezo-resistive signals (e.g. low pressure indicating). The FI Piezo and FlexIFEM can additionally be operated on a stand-alone basis (integrated front display). Furthermore, all variants of all indicating amplifier families can be operated stand-alone (via stand-alone parameterization software) or optionally remotely controlled (via AVL IndiCom™).

Typical application fields for all three product families are research, light-duty development, heavy-duty development, large engines and racing applications. In addition, the FI Piezo and FlexIFEM are



The AVL MicroIFEM is the reliable, modular and advanced amplifier concept and is best suited to applications directly at the testbed and in-vehicle

suitable for endurance testing (engine monitoring on the testbed and in-vehicle), for in-vehicle performance testing (engine protection) and for use on large engines for on-board measurement.

The FlexIFEM Noise is a stand-alone device for combustion noise analysis, best suited to benchmark activities or as a reference noise meter through the complete development process. The new Flex-IFEM Knock is the stand-alone knock monitoring device, which can be used for durability tests or as a reliable engine protection for R&D activities.

BENEFITS AT A GLANCE

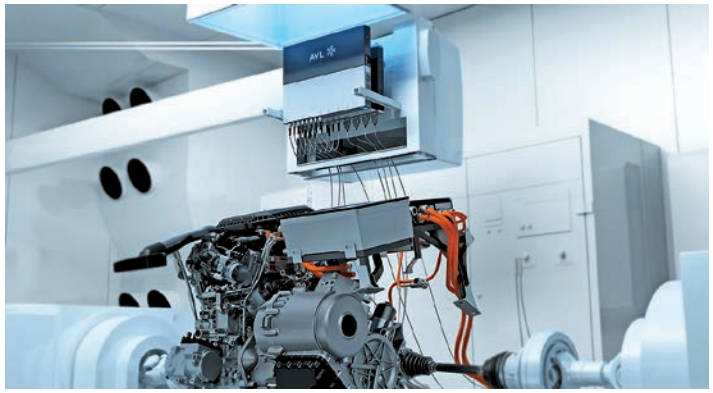
- Peak pressure monitoring without indicating system (calculation results at stand-alone FI Piezo or FlexIFEM)
- Best suited for stand-alone usage due to integrated parameterization, front display and monitoring functionality (including limit detection and alarm signals)
- Maximum data quality due to full support of AVL SensorData Management SDM™ in all amplifier families
- Cost effective, as a result of scaleable channel configurations for single FI Piezo, FlexIFEM, MicroIFEM or cascaded systems

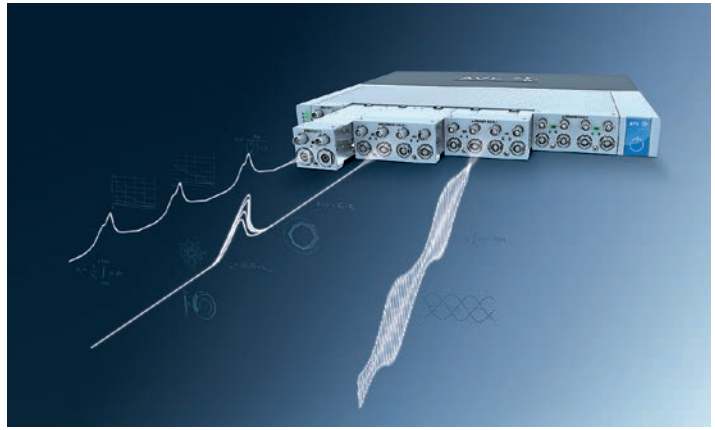
ADAPTS. ACQUIRES. INSPIRES.

AVL X-ion™

THE MODULAR DATA ACQUISITION PLATFORM FOR HIGH-SPEED APPLICATIONS

AVL X-ion™ is the new high-speed data acquisition platform dedicated to powertrain development. AVL X-ion™ is a modular acquisition system that can be easily adapted to different units under test and test environments. It combines AVL's know-how and expertise in several application areas, such as indicating, optical combustion analysis, and e-Power analysis.





Powered by the well-known software AVL IndiCom™, which can be used for crank-angle and time-based acquisition tasks, AVL X-ion™ helps reduce the number of tools in the test environment and in the office, which strongly increases testing and post-processing efficiency.

Its unique modular concept – it can host up to 8 application-oriented "X-FEM" front-end modules combining analog-digital converters and signal conditioning – enables time reduction for changeover and retooling on the testbed. The possibility to deeply investigate not only combustion engines, but also e-motors or hybrid powertrains, also means stress-free transition to electrification.

THE ADDED VALUE

- Increased efficiency based on reduced number of tools in the test facility and in the office
- Enables testbed versatility, reduces changeover and retooling times
- Stress-free transition to electrified powertrains
- Future-proof investment thanks to evolutionary module concept

Decreasing emission limits and increasing demands on driveability cause information for verifying and optimizing combustion processes in vehicle application that make new demands on combustion measurement technology

Mobile Indicating Systems

The AVL IndiMicro sets a new benchmark with regard to compact combustion measurement technology. Due to a high level of flexibility, there are unprecedented mounting possibilities for a broad range of mobile applications. This device can also be used in stand-alone operation for the output of indicating parameters via real-time CAN interfaces.

The AVL FlexIFEM Indi is a one or two channel indicating system with integrated charge amplifier and, therefore, a scaleable solution for testbed applications, upgraded by default with software and hardware settings for the best acquisition and calculation capacities. The device can be used in stand-alone operation by its integrated display enables permanent monitoring of the pressure signal. Cascading of devices lead to a compact solution, optimized for multichannel in-vehicle applications.

YOUR BENEFITS AT A GLANCE

- Ideal for base calibration of the engine, engine monitoring and development
- Flexible use due to application packages for gasoline and diesel engines
- Compact design for in vehicle use
- Direct integration into the application system (INCA)
- Functionally expandable for the measuring tasks of tomorrow

COMBUSTION EXCELLENCE

AVL IndiCom 2™

Combustion engine and drivetrain development is quickly increasing in complexity. At the same time, development cost and time pressure are escalating. Understanding the combustion processes and the influences of the many engine parameters are the key to optimizing modern engines and using their full potential. The current product generation AVL IndiCom 2™ is the answer to these increasing demands for even more flexibility and performance where powerful calculation tools, measurement automation and professional visualization are combined with an easy-to-use interface.

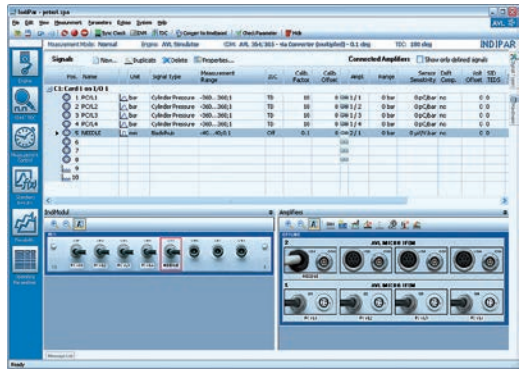
APPLICATION

Measurements for all applications, ranging from standard combustion measurements to continuous monitoring, model-based calibration (with AVL CAMEO 3™), cold start and vehicle testing, optical flame evaluation and more, are possible with AVL IndiCom 2™. It is built to cover even future applications due to powerful real-time calculations and flexible and customizeable online calculations (based on CalcGraf). The integration in any test cell automation environment is supported by tailored and generic interfaces. In addition, the full compatibility with generic post-processing tools like AVL CONCERTO 4™) also increases the range of possible applications.

The specific software extension AVL GCA (gas exchange and combustion analysis) is used online at the testbed for indicating purposes with AVL IndiCom 2™. Results provided by "GCA online" are immediately available in order to perform automated calibration e.g. at low-end torque. AVL GCA is also used offline in conjunction with AVL CONCERTO 4™ in the office and is designed for the detailed analysis of the combustion process and gas exchange, delivering additional results that cannot be measured on the testbed (e.g. air fuel ratio inside the combustion chamber or residual gas). The calculation can also be carried out for dynamic operation. AVL GCA is seen as a virtual sensor based on the proven calculation kernels of AVL BOOST.

BENEFITS AT A GLANCE

- Reduced measurement preparation time and easy-to-use advanced functionalities via the workflow-oriented user interface
- Supports the engineer to make fast and informed decisions based on professional evaluations and clear presentations
- Fast and efficient problem-solving in development and calibration through the unique combination of conventional pressure-based and new optical-based combustion analysis
- Seamless combination of measurement and simulation with AVL IndiCom 2™ and AVL GCA (gas exchange and combustion analysis)
- Integration in any test cell automation environment supported by tailored and generic interfaces



AVL Visiolution Systems
Optical Access to the Engine

With the help of optical measuring methods, a detailed insight into the complex processes of fuel mixture and combustion beyond the findings of the pressure indicating method can be achieved. AVL Visiolution technology helps users understand the whole process in detail and, therefore, provides the right tool for improving performance in terms of fuel consumption, mixture formation, exhaust emission and engine power.

The system is based on indexing in the combustion chamber. AVL Visiolution technology provides the perfect tool for flame evaluation, thermal radiation and injection monitoring, making complex processes clearer.

The formation of pollutant emission in transient operation becomes understandable. Engineering duties are finished in record time and with utmost precision.

MEASURING PRINCIPLE

Visioknock/VisioFlame/VisioTomo: Special spark plugs or head gaskets equipped with glass fibers allow optical access to the combustion chamber. This allows observation of flame propagation, localisation of knocking sounds and access to combustion patterns.

VisioFEM: cycle-precise, cylinder-specific recording of phenomena that contribute significantly to pollutant emissions

VisioScope: carburetion, fuel injection, soot formation and temperature distribution are recorded by endoscope and camera

BENEFITS AT A GLANCE

- Measurement in highly transient operation
- Best suited for exploring injection strategies
- Finding critical emission cycles
- Engineering mixture formation
- Evaluation of flame propagation
- Evaluation of thermal risk
- Detect potential for knock limit improvement
- Detection of root causes of irregular combustion
- Cold start/tip-in/tip-out emission evaluation
- Services covering the whole Visiolution range
- Perfect interface to existing AVL indicating chain

AVL EPOS™ – Main Window GUI

PREDICTABLY POWERFUL

AVL EPOS™

AVL EPOS™ (Engine Performance Optimization System) is AVL's condition monitoring platform for large engines. The AVL EPOS™ system has a winning pedigree: it combines class-leading R&D measurement technology developed by AVL with expertise from large engine and combustion engineers from the world's leading independent powertrain engineering and measurement company, AVL.

AVL EPOS™ and related services are designed to support engine operators by

- Increasing engine efficiency and reducing fuel consumption
- Preventing engine damage and downtime by continuously monitoring the condition of your engine
- Reducing maintenance and service costs
- Monitoring engine emissions (AVL EPOS™ NO_x Module)

AVL EPOS™ – THE PLATFORM

AVL EPOS™ provides expert condition monitoring based on automated engine diagnosis for large combustion engines and their auxiliaries. This condition monitoring platform is unique – by using expert algorithms, AVL EPOS™ provides valuable information at a glance, regarding imminent malfunctions or failures of the engine.

In comparison to other engine condition monitoring systems on the market, AVL EPOS™ does not leave the evaluation and analysis of data solely to the engine operator. The 'traffic light' indicators will tell you the condition and efficiency of your engine, and the system provides explicit root cause information. Further screens show measurement data and diagnosis results in different detail and depth.

AVL MEASUREMENT HARDWARE – THE BACKBONE

The primary source of information of the system is the cylinder pressure measurement. However, any other source of information can be used and integrated into the system.

AVL provides cylinder pressure sensors for continuous monitoring (GO series) connected to a smart indicating unit (SIU) for efficient data acquisition. Sensor lifetimes of more than 50,000 h for HFO and 25,000 h for gas operation have been reliably achieved until now.

AVL EPOS™ is designed as an open diagnosis platform by being able to accept the systematic integration of third part sensors, systems, or information.

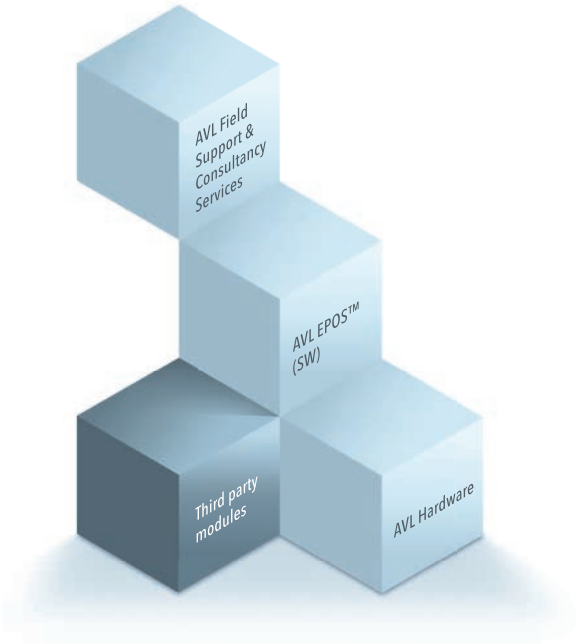
AVL EPOS™ NO_x MODULE

AVL EPOS™ NO_x Module is the world's first model based expert system for emission monitoring (currently covering NO_x, SO_x and CO_2) for large-bore engines in all applications.

Since current emission analyzers are expensive, sensible and often (under long–term perspective) unreliable in the difficult environment they need to operate, AVL's approach is to determine the NO_x emission with the help of a physical model based on the cylinder pressure measurements and the derived combustion analysis. This model can be integrated as part of AVL EPOS™ or installed as a standalone system.

The system is suitable for continuous monitoring of NO_x emissions to comply with the requirements of MARPOL Annex VI and NTC 2008 (confirmation of compliance by DNV GL).

AVL Smart Indicating Unit and AVL Cylinder Pressure Sensor for Continuous Monitoring (type approved by GL)



AVL SERVICES – THE DIFFERENTIATOR

In addition to software and hardware, AVL also offers extended engineering and consultancy services on a regular basis for continuous system optimization and for trouble shooting:

- Tuning recommendations based on detailed analysis of engine measurement data from field operation
- Training on AVL EPOS™ to get the maximum benefit out of the system
- On-site engine inspection (e.g. analysis of engine damage)
- Advanced engine analysis including simulation investigations (CFD, gas exchange, FE analysis etc.)

AVL Emissions Measurement Solutions

APPROACH

AVL offers the complete range of emission test systems for certification, development and conformity of production on engine and chassis dynamometer testbeds. The latest requirements of global emissions regulations are complied with by the new iGeneration Series II product line. AVL is able to offer products with the highest quality available on the market. Testbed solutions with permanent automation and data analysis integrated in the best possible manner provide the basis for the highest possible productivity. AVL particulate measurement technology comprises a wide range of applications. AVL offers test devices for measuring the lowest soot concentrations, for gravimetric measurements and for particle number counting as well as portable devices for in-vehicle testing during R&D and in-use compliance testing. Special conditioning units allow for measurements at high temperatures and pressures in front of filter systems (DPF). These special conditioning units also enable test cycles during high altitude simulations.

TASK

The dramatically decreasing emission limits and the increased use of alternative fuels pose significant challenges for engine and vehicle developers. Due to more complex engine and exhaust gas aftertreatment strategies and new requirements, such as the limitation of the particle number and the concentration of NH_3, the complexity of testbeds and the requirements for automation systems are dramatically increasing. Along with the currently limited emission components, more and more substances need to be measured. These include, for example, nitrogen compounds such as NO, NO_2, NH_3, N_2O, HNCO and aldehydes such as formaldehyde and acetaldehyde.

Further requirements result from the "In-Use" and "Real Driving Emissions" legislation, which requires checking vehicles in real operation with portable emission measurement systems.

The requirements for sampling are increasing as well, for example due to higher emission pressures on filter systems and because of the need to avoid chemical reactions and deposits during gas sampling in emission measurements of SCR systems.

The requirements placed on operators and for the automation systems are increasing because of the rising number of measurement parameters and device subsystems needed. At the same time, the demand for an increase in productivity has to be met. AVL has optimized its emission measurement technology for these challenges and offers futureproof system solutions combined with an integrated testbed automation system.

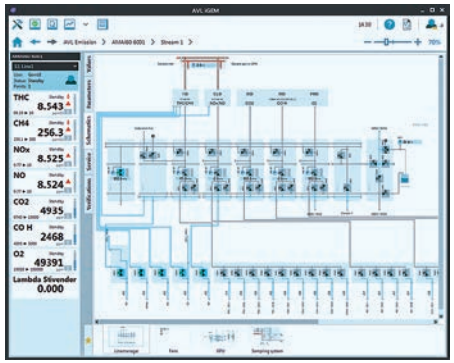
ONLY AVL COMBINES A COMPREHENSIVE AND HIGH-QUALITY EMISSION TESTING PRODUCT RANGE WITH THE IN-HOUSE KNOW-HOW OF AN ENGINE DEVELOPER AND TESTBED OPERATOR.

BENEFITS AT A GLANCE

- All-in-one solutions from a single source
- Tailored systems for certification, development and COP (conformity of production)
- Future-proofing with maximum flexibility of automation systems and the latest analyzer technologies
- High quality products due to decades of expertise and comprehensive know-how, proven by a broad installed base
- Global service support

REFERENCES

AVL has years of experience in the field of emission and particulate measurement:
All leading OEMs and suppliers as well as institutes and authorities like EPA, CARB and TUEV use AVL exhaust gas measurement technology.



The iGEM AMA software allows for easy, intuitive operation of the AMA i60 via a touchscreen. It provides a quick overview of the bench status, including all streams and analyzers. The control software offers diagnostic functions to be performed automatically via the integrated calendar function.

MEMBER OF AVL iGENERATION SII

EXHAUST MEASUREMENT SYSTEM

AVL AMA i60 SII

The AMA i60 SII exhaust measurement system has an extended portfolio of gas analyzers (QCL, HOT CLD, FID/PMD-COMBI) and a compact, modular design. The revised, intuitive and interactive user interface supports all essential service and diagnosis functions and issues warnings in case of pending maintenance intervals. The Quality Center iQ makes it possible to monitor freely selectable variables (e.g. pressures) and visualizes the statistical evaluations of calibration check data.

MEASUREMENT PRINCIPLE

Integrated pumps draw in the measurement gas from sample points, which can be located at a distance of up to 20 m. Depending on the application, heated lines, overflow valves and pre-filters or sample point selection units located in the vicinity of the sample are used. The analysis of the measurement gas is performed using high-end analyzers – FID for THC and CH_4, CLD and HOT CLD (180 °C) for NO/NO_x, IRD for CO, CO_2, QCL for N_2O, and PMD for O_2. After several correction steps, the raw values of the analyzers provide concentration values that can be transmitted to a test cell automation system along with other information like pressure, temperature and device status. The AMA i60 SII can also be controlled by means of an AK interface.

APPLICATION

The AMA i60 SII contains analyzers with a broad dynamic measurement range for THC, NO/NO_2/NO_x, CO, CO_2, O_2, CH_4, N_2O, NH_3 and SO_2, which can be adapted to the application (diluted/undiluted exhaust gas or gasoline/diesel/hydrogen/etc). Due to the combination with different sampling systems, the AMA i60 SII is ideally suited for the development and certification of combustion engines according to EPA (including EPA 40 CFR part 1065 and 1066), ECE (including GTR 4 and 15), Japanese and other emission regulations. Special versions and mobile remote or stand-alone units are available with optimized system designs for SULEV, SCR and other applications.

BENEFITS AT A GLANCE

- Best-in-class footprint with up to two streams plus EGR/ Tracer in one 19" cabinet
- Safe investment in state-of-the-art, intelligent technology of the highest flexibility and retrofitability
- First-class measurement results with regard to accuracy, reproducibility and response times for all applications
- Substantially reduced expenses for installation, operation, service and total cost of ownership
- Graphical user interface with interactive flow diagram of the system
- Innovative remote diagnosis down to sensor and valve level

MOBILE EXHAUST MEASUREMENT SYSTEM

AVL AMA i60 Remote/Stand-Alone Units

The AMA i60 Remote and Stand-Alone-Units have been designed to serve as an extension to an existing AMA i60 analyzer bench (Remote Unit) or as a separate small analyzer bench (Stand Alone Unit). The Remote Unit is controlled by the AMA i60, the Stand-Alone Unit by the iGEM AMA bench control software on a separate computer.

MEASUREMENT PRINCIPLE

Depending on the application, various analyzer types can be used with the AMA i60 Remote/Stand-Alone Unit. Integrated pumps draw in the measurement gas from the sample point. Heated lines and pre-filters or sample point selection units are used in the vicinity of the sample point. The analysis of the sample gas is performed using high-end gas analyzers – FID for THC and CH_4, CLD for NO/NO_x, IRD for CO, CO_2, QCL (quantum cascade laser) for N_2O and/or NH_3 measurements and a UVD analyzer for SO_2 measurements.

The iGEM AMA bench control software allows for easy and intuitive operation of the AMA i60 Remote/Stand Alone Unit. It provides essential information on the status of an integrated gas analyzer.

APPLICATION

The AMA i60 Remote/Stand-Alone exhaust measurement system is available in the folllowing variations:

- For THC (and CH_4) and/or NO/NO_x measurements
- For CO, CO_2 and N_2O (IRD) measurements
- For NH_3 or NH_3 and N_2O measurements
- For N_2O measurements with a QCL analyzer
- For SO_2 (UVD) measurements
- For measurements of oxygenated components using an Innova analyzer

The system is ideally suited for the development and certification of combustion engines in accordance with emissions regulations worldwide, as well as SCR exhaust aftertreatment systems in accordance with European heavy-duty regulations.

BENEFITS AT A GLANCE

- Compact mobile unit which is easy to move around and to use at different sampling points
- Allows for short sample transfer lines resulting in fast response with high accuracy
- Optimized packages for applications like heated THC/NO_x measurements or EGR-CO_2 determination or SCR ammonia measurements, SHED THC or EPA greenhouse gas (GHG) measurements
- Substantially reduced setup time and total cost of ownership thanks to the use of proven i60 technology, the well-known iGEM AMA user interface and diagnosis functions

COMBINED EXHAUST MEASUREMENT AND DILUTION SYSTEM

AVL AMA i60 COMBI

The AMA i60 COMBI combines the proven AMA i60 exhaust measurement system with components of the CVS i60 dilution system, resulting in a very compact and modular design. The system is best suited for certification/audit and R&D testing of small off-road engines, motorcycles and all-terrain vehicles (ATV). The revised, intuitive and interactive user interface with interactive flow diagram supports all essential operation, service and diagnostic functions and issues warnings in case of pending maintenance intervals. The new Quality Center iQ makes it possible to monitor freely selectable variables (e.g. pressures) and visualizes the statistical evaluations of calibration and check data.

The CVS valve matrix is integrated in the AMA i60 COMBI cabinet. The compact dilution unit is prepared for wall- or ceiling-mounting to perfectly fit testbed conditions.

MEASUREMENT PRINCIPLE

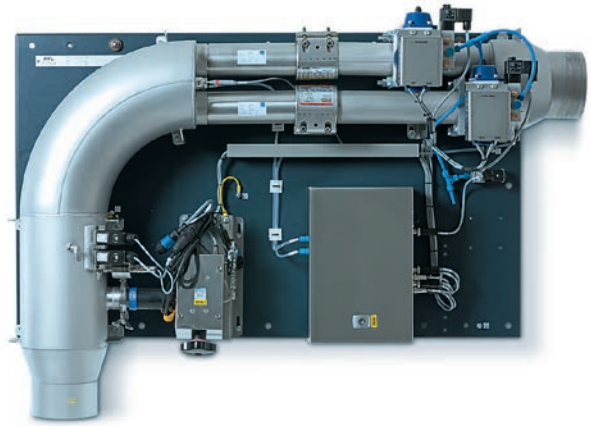
The AMA i60 COMBI comprises a gas analyzer bench for diluted modal and bag exhaust gas analysis combined with a constant volume flow dilution system (CVS). The concentration readings from the analyzer bench together with the volume flow measured with the sonic venturi of the CVS system are used to calculate the exhaust mass emissions in a very simple, reliable and accurate way. The analysis of the diluted sample gas is performed by means of NDIR, FID and CLD gas analyzers.

APPLICATION

The AMA i60 COMBI contains analyzers with a wide dynamic measurement range for THC, CH_4, NO/NO_x, CO, CO_2 and N_2O, depending on the configuration. It is ideally suited for the certification of gasoline small off-road engines (SORE) with less than 19 kW, in accordance with EPA (US Environmental Protection Agency) 40 CFR part 1054/1065. A special configuration for the development and certification of motorcycles and ATVs on chassis dynamometer testbeds is also available. To comply with the EPA greenhouse gas regulations (GHG), the AMA i60 COMBI is designed to easily integrate the corresponding gas analyzer for CH_4 measurements.

BENEFITS AT A GLANCE

- Integrates analyzer bench and bag sampling system in one 19" cabinet
- Very compact CVS venturi unit for flexible installation
- Fits easily onto the exhaust system of small combustion engines
- Optimized solution for SORE, motorcycle and ATV applications
- Sophisticated diagnosis functions with the support of interactive flow diagrams
- Complies with EPA 40 CFR part 1054 and 1065 as well as other worldwide exhaust emission regulations



MULTI-COMPONENT EXHAUST MEASUREMENT SYSTEM

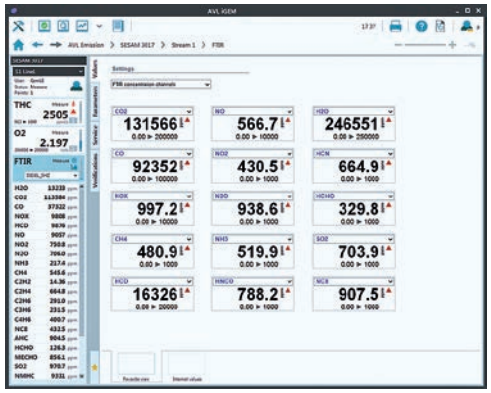
AVL SESAM i60 FT SII

The SESAM i60 FT SII provides accurate and fast measurement of the most important exhaust gas components for all automotive applications within one system. The revised, intuitive and interactive user interface supports all essential operation, service and diagnostic functions and issues warnings in case of pending maintenance intervals. The Quality Center iQ makes it possible to monitor freely selectable variables (e.g. pressures) and visualizes the statistical evaluations of calibration and check data.

MEASUREMENT PRINCIPLE

The system is available in two cabinet versions, which allow for various standard setups and the integration of different extensions. The small cabinet includes the FTIR i60 spectrometer and optionally an FID analyzer for THC measurements. The large cabinet may also contain an additional PMD analyzer for O_2 and/or an IRD analyzer for EGR (CO_2) measurements. Alternatively, the large cabinet can be equipped with two FTIR i60 spectrometers for dual stream applications providing simultaneous pre- and post-exhaust aftertreatment measurements.

The sophisticated control software iGEM SESAM is based on the iGEM software platform. The iGEM SESAM software allows for easy, intuitive operation via a touch-screen and provides a quick overview of the system status. It includes diagnostic functions and checks to be performed automatically via the integrated calendar function.

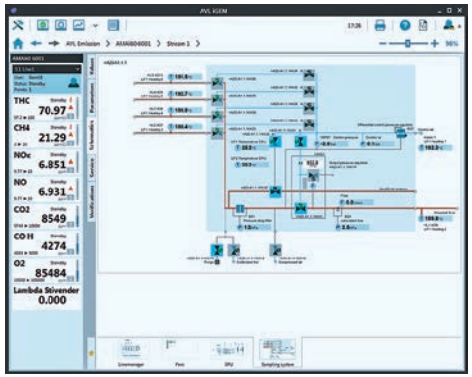


APPLICATION

Today's exhaust gas aftertreatment systems for combustion engines are getting more and more complex, especially since the introduction of SCR catalysts and the increased use of alternative fuels. Understanding the detailed chemical reactions in engine exhaust and aftertreatment systems is critical for the efficient development of new engines and powertrains. The SESAM i60 FT SII guarantees best quality measurement results and complies with legislative requirements such as Euro VI and EPA 40 CFR part 1065 and 1066 for measurements allowing FTIR.

BENEFITS AT A GLANCE

- Optimized evaluation methods and gas cell for up to three times better detection limits of 5 Hz (e.g. NH_3, N_2O)
- 35 % faster response times at lower sample flow rates (≤ 1.5 s at 8 l/min)
- Extended life time of key components like detector and laser (over 4 years)
- Self-aligned gas cell with robust and service optimized design
- Reduction and ease of maintenance and repairs



The iGEM device control SW provides full control of the heated sampling system down to valve and sensor level

HEATED SAMPLING SYSTEMS

AVL HSS i60

The HSS i60 product line consists of pre-filters, heated sample selection modules and a heated boost pump for raw exhaust measurements.

BENEFITS AT A GLANCE

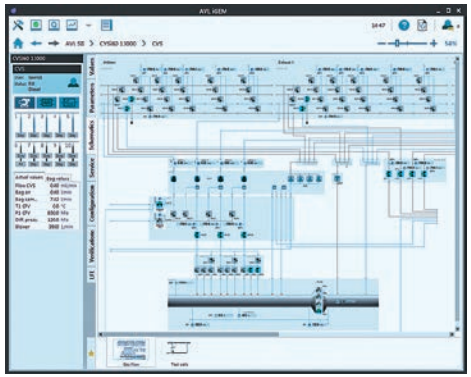
- Extendable with e.g. pressure drop sensor, pressure regulation
- Minimized delay time for transient measurements due to innovative valve manifold layout
- Optimized design to minimize wall effects (hang-up)
- Modular setup for sample point and line switching (≤ 10 inlets)
- Boost pump with controlled recirculation circuit – no bypass required
- Stand-alone pre-filter to be connected to third-party equipment

MEASUREMENT PRINCIPLE

Pre-filters remove particulates from the exhaust gas and prevent contamination of sample lines and emission measuring systems. Heated sample selection modules offer the option to switch an AMA i60 or a SESAM i60 FT to different sample points or lines. Depending on the specific model, extensions like additional inlet filters and flame traps, calibration gas inlets, backflush functionality, turbo pressure regulators, pressure drop and flow sensors are available.

APPLICATION

Different applications, like test cell sharing or large test cells, support the demand for increasingly modular and reliable heated sampling systems. The HSS i60 product line offers a broad range of applications and customized configurations. Depending on the engine and fuel type as well as on the sample point (e.g. pre-cat, post-cat, post-DPF), AVL provides different filter materials such as ceramic, fiber glass or stainless steel. To overcome the pressure drop, caused either by very long sample lines or altitude (simulation), AVL's solution is the Heated Boost Pump.



It is easy and intuitive to perform all functions in the standard operation of the CVS i60 SII. Remote operation concept and interactive self diagnosis functions to sensor and valve level allow for increased productivity as well as reduced and simplified maintenance and service work.

EXHAUST GAS DILUTION SYSTEM

AVL CVS i60 SII

The CVS i60 SII is the most compact full flow dilution system on the market. With a total flow rate of up to 30 m³, all system components fit into one 19"-cabinet. The sophisticated gas flow system guarantees fast response times and the best reproducibility for gas analysis. The extended valve manifold with increased numbers of phases (max. five) and simultaneous analyzing, purging, evacuating and filling optimizes the running of test cycles, e.g. with regard to HEV/ PHEV applications. The modular design – with up to four main flow venturis, three bag sample venturis or, alternatively, with mass flow controllers – supports all possible applications on chassis dyno and engine testbeds. The patented angulated inlet tube allows particulate measurement in accordance with ECE, EPA and Japanese exhaust emission regulations with one dilution tunnel.

MEASUREMENT PRINCIPLE

The exhaust gas is diluted with filtered ambient air close to the tailpipe outlet and then homogeneously mixed in the dilution tunnel for particulate measurement. During each phase of a test cycle, the exhaust gas bags are filled proportionally to the main flow rate of the CVS. The integrated mass emissions are calculated using the background gas concentrations in the bag and the accumulated flow rate of the diluted exhaust.

APPLICATION

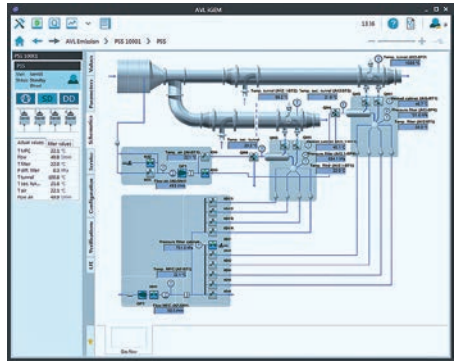
The CVS i60 SII is used for the certification of all kinds of combustion engines and fully complies with the latest emission legislation for passenger cars and commercial vehicles, such as Euro 5/6 or EPA 40 CFR part 1065 and 1066. The CVS i60 SII supports all modern drive technologies like hybrid and gas engines as well as alternative fuels including hydrogen. The CVS i60 SII is available for flow rates up to 20 m³ or 30 m³ (LD), up to 60 m³ (MD) or up to 90 m³ or 160 m³ (HD).

BENEFITS AT A GLANCE

- Simultaneous bag valve functionality, separated sampling lines or backflushable bag venturis for most accurate HEV/PHEV emission testing
- Easy serviceability by front access for venturi calibration and pull-out drawer for maintenance of pumps, MFCs, etc.
- Particulate mass and particle number measurement of GDI and diesel vehicles via one dilution tunnel
- Semi- or fully-automated LFE for venturi calibration
- Minimized total cost of ownership and less power consumption through frequency-controlled blower and alternative operation without heat exchanger

PARTICULATE SAMPLER

AVL PSS i60 SII



All functions in the standard operation of the PSS i60 SII are easy and intuitive to perform. Intelligent self-diagnosis functions and fully automated MFC calibration simplifies and reduces maintenance and service work.

The PSS i60 SII particulate sampler for gravimetric particle measurement is characterized by its innovative and compact system design for exhaust certification testing. Optimized gas flow rates combined with an enhanced mass flow control and direct electronic signal processing increase the accuracy and reproducibility of measurements, especially with regard to the extremely low PM emissions of today. The new particle filter holder design and temperature controlled sampling provide the best conditions for detecting very small particles in minute quantities. Finally, the particle filter holder is designed to be able to integrate RFID-filter trays for automated filter weighing via the AVL Filter Weighing Robot (FWR).

MEASUREMENT PRINCIPLE

The PSS i60 SII is a full-flow particulate sampling system used to collect particulates from the diluted exhaust gas on a filter during a test cycle. At the beginning and end of the test cycle, the filter is weighed and the particulate mass is calculated and the background application is considered (gravimetric-measurement).

APPLICATION

The CVS full-flow dilution based particulate mass determination is also the reference for partial flow determinations. The PSS i60 SII single dilution (SD) is used for light duty and passenger car chassis dynos. For heavy-duty and off-road engine testbeds the double dilution version PSS i60 SII DD is used. Applications for engine performance and emission development, certification and conformity of production (COP) are fully covered with the PSS i60 SII. The system is used on transient and stationary engine testbeds for R&D, certification and quality control, as well as on chassis dynos for HD vehicles.

BENEFITS AT A GLANCE

- Compact design enables the installation of a heated FID, particle background measurement and an AVL Particle Counter APC 489 in one 19 " cabinet
- Compatible with AVL FWR for automated filter weighing and management.
- Fulfills the latest emission legislations up to Euro 6, JASIC and EPA 40 CFR part 1065 and 1066
- Improved measurement accuracy and repeatability adequate for extreme low PM emission due to optimized gas flow and new sensor technology
- iGEM PSS provides operation, high-grade diagnostics and intelligent interfaces with easy upgradability
- Fully-automated calibration of mass flow controller (MFC)

GRAVIMETRIC PARTICULATE MATTER MEASUREMENT
WITH PARTIAL FLOW DILUTION

AVL Smart Sampler

The AVL Smart Sampler is a partial flow dilution system used in gravimetric particulate matter sampling from internal combustion engines in accordance with ISO 16183, 40-CFR 1065 , 1066 and all other relevant global regulations.

MEASUREMENT PRINCIPLE

A partial flow dilution system such as the AVL Smart Sampler mixes and dilutes a small sample of the exhaust flow with air under controlled conditions. This allows particulates to form in a repeatable manner simulating reactions in the atmosphere. The system samples the diluted exhaust over a filter medium where the particulates are captured and can subsequently be weighed. The flexible design also allows the AVL Smart Sampler to be used as a diluter for particle counting according to ECE regulation No 49 and Global Technical Regulation No 4. For particle counting, the system operates as it does for gravimetric measurement with a proportional sample of the diluted exhaust diverted to an optional particle counting device. A new field is the certification of passenger cars on chassis dynamometers according to US 40-CFR part 1066.

APPLICATION

The Smart Sampler can be used instead of a CVS for Euro III to VI certification, and, with the addition of the "add-on sampling" option, it also provides other testing devices like particle counters with diluted exhaust samples. The option of high pressure testing allows the Smart Sampler to be used at pressures as high as 1,000 millibar (gauge), and this makes it the perfect tool for efficiency evaluations and the optimization of DPF systems. The Smart Sampler can also be used for analyzing the influence of different fuels on PM emissions. The same Smart Sampler is suitable for sampling everything from small portable engines to the largest engines and can easily be moved between test cells for maximum flexibility.

Above: Due to the small and modular design of the Smart Sampler, it can be placed even in smallest test cells

Left: The Smart Sampler's software is intuitive and easy to use

BENEFITS AT A GLANCE

- Fulfills all relevant regulations
- Fast warm up time: Smart Sampler is ready for operation in 15 minutes from a cold start.
- With the optional add-on sampling, the Smart Sampler acts as a diluter for particle counting applications.
- Modularity of components allows for simple structuring of options; future upgrades are simple and can be done at the customer's site.
- Rapid set up time for quick test cell changeovers
- Automatic Filter Changer for up to 20 PM filters.

AVL Filter Weighing Chamber (FWC) for conditioning and weighing of particle filters

AVL Filter Weighing Robot (FWR) for fully automated filter weighing and management

PARTICULATE FILTER WEIGHING

AVL Filter Weighing Chamber and Robot

New legal demands for climate control during the weighing process require an optimized and enhanced weighing environment. Drastically reduced emission limits call for increased measurement accuracy of particulate mass results. AVL's solution to these new challenges is the Filter Weighing Chamber (FWC). It is a cost- and space-saving alternative to a separately conditioned clean room and offers maximum user friendliness, ergonomics and functionality. The AVL Filter Weighing Robot (FWR) automates the weighing process from conditioning to filter disposal and archiving (from 160 to 640 filters). Thus, it reduces measurement inaccuracy and increases the efficiency of the entire weighing process.

MEASUREMENT PRINCIPLE

A laminar flow with a precise monitoring of temperature and dew point is assured within the working area. In addition, the atmospheric pressure is monitored and is ready to be used for the required buoyancy correction. The ambient air inserted into the working area is prepared to achieve the clean room standard 5 according to ISO 14644-1. A vibration-decoupled weighing stone is situated in the weighing section. The high-precision scale is place on this stone. Throughout the whole weighing process, automated by the AVL FWR, the filter stays in a RFID transport ring with integrated RFID chip. Thereby, any filter data can be stored and read anytime. No moving of the filters or handling with foreceps is necessary.

APPLICATION

The AVL FWC is ideally suited for installation in laboratory and testbed environments for particle filter weighing. The working area offers sufficient space for handling and storage of the particle filters. The AVL FWR is used and controlled by means of AVL ParticleScale for the measurement of very low particulate masses.

BENEFITS AT A GLANCE

- Precise control of constant climatic conditions regarding temperature, pressure and dew point in the weighing area to comply with e.g. EPA 40 CFR Part 1065 and 1066, EURO 5/6 (LD) and EURO V/VI (HD)
- Unique and smooth integration of the AVL FWR into the existing PM weighing process
- Fully-automated, movement path and time-optimized weighing process via AVL FWR
- Intelligent storage management with four filter magazine towers and max. 640 filter storage capacity

PARTICLE FILTER MANAGEMENT IN THE WEIGHING PROCESS

AVL ParticleScale

The constant demand for increasing efficiency in the exhaust test field inevitably leads to new challenges for central management and administration of sample filters. Moreover, the many tighter regulations require a lot of effort to ensure the corresponding measurement quality. With AVL ParticleScale, AVL presents a universal solution for managing sample filters as used for particle measurement in emission tests. The intelligent particle filter management supports the user in the weighing process and offers easy handling of test and reference filters as well as reference weights throughout the whole filter life cycle.

SOLUTION

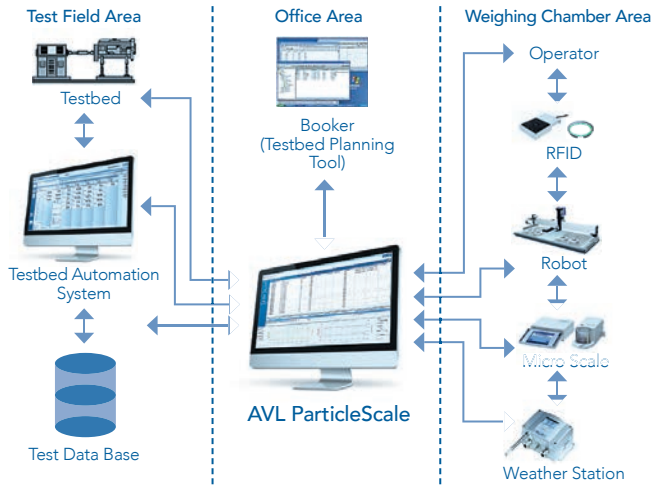
AVL ParticleScale fits ideally into the existing AVL automation system environment and leads the operator through the whole weighing process. Corresponding to the selected test cycle and/or number, size and configuration of the required sample filters as well as the compulsory conditioning time are automatically pre-defined and used in the flow control. Every filter runs through different states controlled by the program, beginning with pre-conditioning and ending with the weighing of the loaded filter and its disposal.

APPLICATION

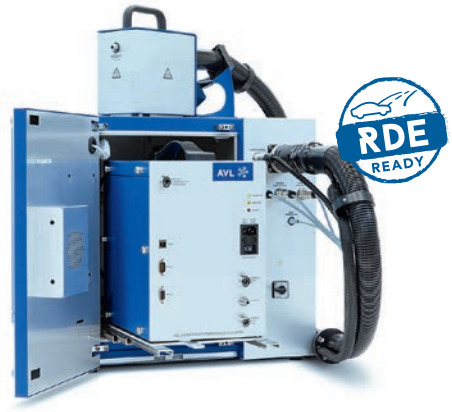
Even for a small number of weighings, AVL ParticleScale enhances the measurement quality of the particle weighing process. On large exhaust test fields, it also increases the efficiency. For further automation of the particle weighing, AVL ParticleScale can serve as an interface between the user and the AVL Filter Weighing Robot (FWR).

BENEFITS AT A GLANCE

- Increased efficiency and quality assurance thanks to intelligent particle filter management
- Central administration of all used test and reference filters as well as weights in the test facility
- Climate data monitoring as well as calculation and storing of the exhaust test measurement results according to current legislation
- Clearly structured and intuitive graphical user interface with extensive configuration and customization options
- Secure identification of filter sets by RFID or barcode labeling
- Easy integration into an external system based on a flexible .NET architecture



Robot control and climate data monitoring, AVL ParticleScale graphical user interface with filter list (active/history)



COUNT ON IT

APC^{plus} – now AVL CPC inside

The APC^{plus} – AVL Particle Counter measures the transient particle number concentration of solid particles in combustion engine exhaust. The new core sensor AVL CPC of enhanced functionality further improves the APC^{plus} performance by both optimizing service and calibration costs. It complies with the legal requirements of UN-ECE R83 and R49 and is the ideal tool for specific R&D applications to be ahead of the RDE challenge.

MEASUREMENT PRINCIPLE

The exhaust sampling is carried out, conducted either directly at a CVS tunnel or a partial flow dilution system (PFDS), or, for R&D applications, directly at the tailpipe of an engine testbed with a heated sample line. Legislation (UN-ECE R83 and R49) requires a complex conditioning system for removing the volatile fraction of engine exhaust. It consists of:

- a hot primary dilution (PND1),
- an evaporation tube (ET) and
- a cold secondary dilution (PND2).

AVL has developed a patented chopper diluter to ensure a very high, size-independent dilution that also allows to use the system to sample from raw exhaust gas during R&D. The particle number concentration is measured by a particle counter (CPC) with a cut-off characteristic specially adapted for automotive applications. The extended measurement and operating temperature range of the AVL CPC guarantees a maximum of test results even under toughest conditions on the engine testbed.

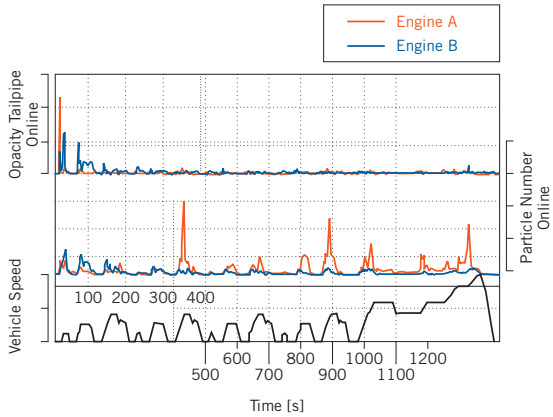
APPLICATION

- Certification according to UN-ECE R83 and UN-ECE R49 procedure
- Applications in research and development
- Applicable on engine and chassis dynos
- Sampling from CVS systems, partial flow dilution tunnels or directly from raw exhaust
- Suitable for diesel and gasoline engines

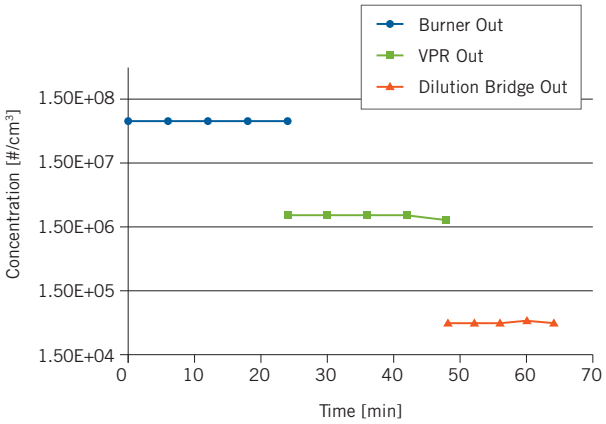
BENEFITS AT A GLANCE

The brand-new combination of APC^{plus} with built-in AVL CPC allows:

- Highest application flexibility due to a three times higher sensor concentration range and best in class dilution accuracy and stability
- Maximum test utilization even under harshest testbed conditions due to a 60 % higher temperature operating range of the AVL CPC
- Unique combination of APC^{plus} and AVL Smart Sampler for highest data quality combined with minimum test effort
- Reduction of service and calibration costs by up to 20 % and throughput times by up to 25 %
- AVL ActiveLink™ for a more efficient and flexible use of AVL measurement instruments, especially in combination with AVL PUMA Open 2™ testbed automation systems



The figure shows the results from an NEDC test on two different vehicles. The number of particles for vehicle A has significant peaks in comparison to vehicle B. Despite concentrations being very low, the differences in emissions can be measured with the AVL Particle Counter.



The figure shows the aerosol stability of the three available sample outlets

ON-SITE CHECKS FOR PARTICLE MEASUREMENT DEVICES

AVL Particle Generator

Particle number measurement is the new requirement for certification measurements according to Euro 5/6 and EURO VI. In addition to the legal requirements of an annual device calibration, on-site quality checks of critical components such as the dilution system and the particle number counter are highly recommended. Apart from particle number checks, there is also a demand for on-site verification of other particle measurement devices. Those requirements necessitate a particle generator with:

- Adjustable dilution over a wide dilution range
- Adjustable particle sizes

FUNCTIONAL PRINCIPLE

The AVL Particle Generator is a stand-alone device for generating a pre-conditioned combustion aerosol. Aerosol particles are first formed during combustion of propane and then pre-treated and diluted in an integrated Volatile Particle Remover system. The pre-treatment process stabilizes particle size and number concentration while ensuring reduction of volatile and semi-volatile particles. A further dilution stage with a dilution bridge can decrease the concentration to very low levels. The three dilution stages etrations and size distributions. An integrated touch-screen display and four pre-adjusted operating points ensure straightforward and fast operation. The pre-adjusted operating points and the recommended applications are based on many years of AVL expertise in the field of particulate measurements.

APPLICATIONS

- On-site quality checks of particle counting devices
  - Particle Concentration Reduction Factor check
  - Particle Number Counter linearity check
  - Particle Number Counter cut-off check
- Comparison measurement of Micro Soot Sensors and PM-PEMS devices

BENEFITS AT A GLANCE

- Generation of a highly stable combustion aerosol
- Wide range of applications due to integrated dilution stages
- Calibrated operating points for a convenient verification of particle measurement devices
- Straightforward on-site quality checks of particle measurement devices
- Utilization as stand-alone device
- Integrated touch-screen for simplified operation

TRANSIENT SOOT MEASUREMENT

MSS^{plus} – AVL Micro Soot Sensor

The continuous lowering of emission limits requires increased development efforts and maximum precision during exhaust aftertreatment and combustion system development. In engine development, soot emission has always been measured as the first parameter because it is an important indicator of combustion quality and generally a main contributor to particulate emissions. Soot is also the main parameter when evaluating the efficiency of DPF systems.

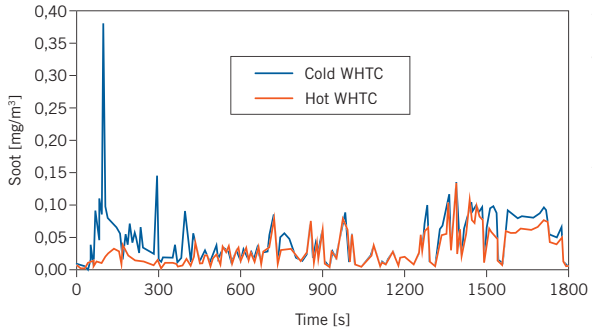
MEASUREMENT PRINCIPLE

The AVL Micro Soot Sensor is based on the photo-acoustic principle. In this method, an absorbing substance – in our case the black carbon particles – is irradiated with modulated light. The periodic warming and cooling and the resulting expansion and contraction of the carrier gas produce a sound wave which is detected with a microphone. With soot-loaded air or exhaust gas, the signal increases proportionally to the concentration of soot in the measured volume.

APPLICATION

Due to its high sensitivity and wide measurement range, the Micro Soot Sensor can be used for measuring at the point where exhaust leaves the engine and also at the end of the tailpipe. With the optional conditioning unit, which provides dilution and pressure reduction, the instrument can also withstand the high pressures and temperatures upstream of a DPF, making it a perfect tool for the evaluation and development of DPF systems. The Micro Soot Sensor is likely to be used also as a soot monitor in dilution tunnels. The instrument can be used as a stand-alone device, and thanks to its various interfaces (including RS232 with AK protocol, digital/analog interface, TCP-IP), it can also be easily integrated into testbed automation systems.

MSS AVL 483 – Cold and hot WHTC



The figure shows the MSS soot signals of two WHTC tests. One was done with warm and the other with cold engine conditions. Especially at the beginning of the test, big differences in concentrations can be observed.

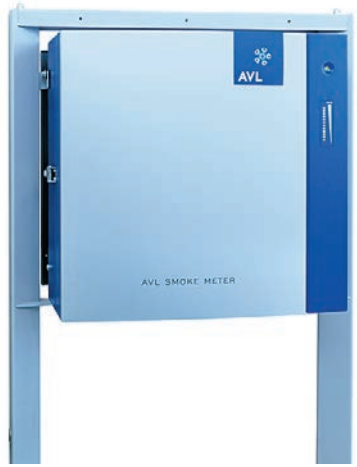
BENEFITS AT A GLANCE

- Transient measurement of soot concentration [mg/m³]
- Measures soot – no cross sensitivity to other components
- High sensitivity (resolution 0,01 µg/m³, detection limit 1 µg/m³)
- Wide measurement range of 1 µg/m³ to 1,000 mg/m³ (with conditioning unit)
- Exhaust back pressures up to 2,000 mbar, temperatures up to 1,000 °C (with conditioning unit)
- Can be used on chassis dyno, engine test cell and for on-board measurements
- Automated thermophoretic loss compensation, providing automatic calculation and display of the loss corrected soot signal

SMOKE MEASUREMENT WITH FILTER PAPER METHOD

AVL Smoke Meter

The AVL Smoke Meter is a filter-type smoke meter for measuring the soot content in the exhaust of diesel and GDI (gasoline direct injection) engines. The device has become the proven and tested standard in the automotive industry. The variable sampling volume and thermal exhaust conditioning ensure a wide range of applications, from combustion optimization at prototype engines to production monitoring.



The measuring principle of the Smoke Meter makes it highly versatile. The variable sampling volume allows measurements on any generation of large engine or car engine, independent of the soot content in the exhaust.

MEASUREMENT PRINCIPLE

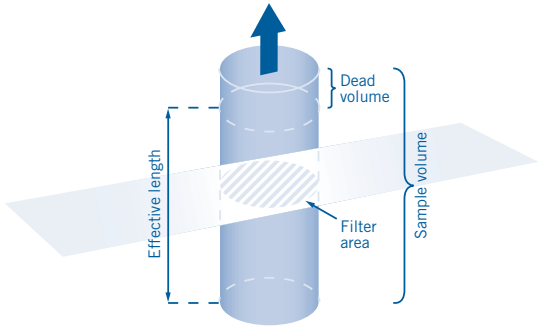
A defined flow rate is sampled from the engine's exhaust pipe through a clean filter paper in the instrument. The filtered soot causes blackening on the filter paper which is detected by a photoelectric measuring head and evaluated in the microprocessor to calculate the result in FSN and mg/m³. The extremely high reproducibility of the AVL Smoke Meter is guaranteed by its variable sampling volume method and thermal heating. The sampling volume can be set automatically depending on the exhaust soot concentration. This enables measuring low soot levels of modern CI engines.

APPLICATION

Due to the easy installation and variable sampling volume, the AVL Smoke Meter can be used on engine testbeds as well as on chassis dynamometers. The smoke measurement comprises the whole range from modern diesel engines with aftertreatment systems to GDI engines. The many possible applications make it a perfect all-round system. The standardized measurement values can be compared all over the world, offering an additional benefit to globally operating companies. Thanks to the high repeatability, the system can also be used for testing at the end of the production line, enabling the detection of very small tolerance deviations.

BENEFITS AT A GLANCE

- High measurement resolution (0.001 FSN or 10 µg/m³) and low detection limit (0.002 FSN or 20 µg/m³)
- Timely paper change due to remaining filter paper indicator
- Altitude measurements up to 5,000 m above sea level and altitude simulation up to 5,000 m
- High reproducibility, improved cleaning efficiency and increased robustness against wet exhaust gas due to shop air purging of the gas path – optional
- Extended application range up to three bars exhaust back pressure for engines with exhaust aftertreatment systems – optional
- Remote-control service with intuitive user interface – optional

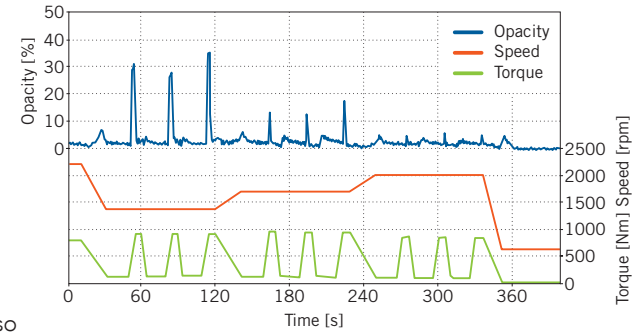


$$\text{Effective length} = \frac{\text{Sample volume} - \text{Dead volume} - \text{Leak volume}}{\text{Filter area}}$$

OPACITY MEASUREMENT

AVL Opacimeter

Recent emissions legislation is increasing requirements for transient test procedures. To comply with tough future emission limits, it is also necessary to monitor an engine's particulate emissions during transient operation even in the early stages of the engine R&D process. The development of modern diesel and gasoline engines requires a dynamic measurement instrument with high resolution.



Example: opacity as a percentage during a prescribed test cycle (ELR – European Load Response test)

MEASUREMENT PRINCIPLE

The AVL Opacimeter measures the opacity of contaminated air, in particular of diesel exhaust emissions. A measuring chamber with a defined measuring length and non-reflecting surface is filled homogeneously with exhaust gas. The loss of light intensity between a light source and a receiver is measured, and the opacity of the exhaust gas is calculated based on this. The very fast response time of 0.1 sec, the easy-to-use data evaluation and the ability to use the device upstream and downstream of a DPF (diesel particulate filter) make the AVL Opacimeter a perfect tool for development tasks where extremely fast measurement is the key.

APPLICATION

The AVL Opacimeter can be used on engine testbeds and on chassis dynamometers. The device is already preconfigured to automatically run the legally required tests ECE-R 24 – EEC 72/306, HD Euro III, Euro IV and Euro V ELR test, ISO 8178, and SAE J 1667. As a partial-flow system for the online measurement of the exhaust gas opacity of diesel engines, the AVL Opacimeter is a unique system that satisfies not only legal standards but is also a perfect tool for meeting the demands of engine development and production.

BENEFITS AT A GLANCE

- High measurement dynamics for transient test runs
- Pre-programmed test cycles, such as ELR or ECE-R24
- High measurement value resolution and signal stability thanks to the conditioning of all essential parts (N = 0.01 %, k = 0.001 m^{-1})
- Also suitable for exhaust gas back pressure of up to +3,000 mbar relative pressure (with high pressure option)
- Low maintenance costs due to the robust design

EMISSION CALIBRATION DEVICES

AVL iCAL

The accuracy of exhaust measurement systems is highly dependent on the quality and precision of the calibration devices used. The AVL iCAL calibration devices guarantee excellent accuracy and reliability and minimize operating costs through fully automated routines. This substantially reduces the time required by the operator. The AVL iCAL calibration devices allow for manual or fully-automated verifications of analyzers (linearity and NO_x converter check) and system leak checks (CFO test).

MEASUREMENT PRINCIPLE UND APPLICATION

The gas divider iCAL GDU is a highly accurate device for the calibration of gas analyzers. The underlying physical principle is based on the combination of calibrated, critical nozzles allowing for the accurate dilution of the test gases. The pressures of the calibration and dilution gases are controlled by means of a precise pressure controller with extraordinary long-term stability.

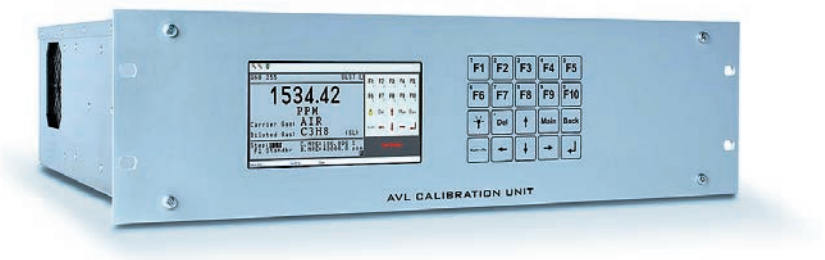
The NO_x converter tester iCAL NGU is used to check the efficiency of the NO_x converter of CLD analyzers. The technology is based on the gas phase titration between NO and O_3 and provides known concentrations of nitrogen dioxide (NO_2). The ozone (O_3) is generated by means of corona discharge in an atmosphere consisting of pure oxygen (O_2).

The iCAL CFO (critical flow orifice) propane injection tester is used to inject a precise quantity (e.g. of propane) into the CVS dilution system or into a SHED chamber. The injected quantity is compared to the mass measurement of the CVS dilution system or the SHED chamber. For improved accuracy, the iCAL CFO is temperature-stabilized at 50 °C. Most regulations require the regular implementation of this CFO test.

The iCAL HBU heated bubbler unit is used to humidify air or test gases for execution of automated quality checks on the exhaust gas measurement systems. The gases are led through two heated water tanks. The water content is measured via a high precision chilled mirror hygrometer. The iCAL HBU supports the sample dryer verification as well as the CLD quench verification according to EPA 40 CFR part 1065.

BENEFITS AT A GLANCE

- High level of precision (< 0.4 % of the selected step)
- Pressure-independent flow stability
- Plug & Play integration
- Simple use and operation
- Excellent long-term stability
- Remote diagnosis down to valve and sensor level
- Factory-calibrated and individually certified, NIST traceable



The iCAL calibration devices allow manual or fully automatic verifications of analyzers (linearity, NO_x converter check) and system leak checks (CFO test). These devices can be connected to the exhaust measurement system by plug & play and are visualized in the iGEM software.

EVAPORATIVE EMISSIONS DETERMINATION SYSTEM

AVL VT/VV-SHED

VT/VV-SHED systems incorporate state-of-the-art technology responding optimally to clients needs. Long-term experience in the field of analytics and in-house analyzer development as well as automation expertise form the foundation of this homogeneously adjusted complete system. Integrated interfaces to fuel and canister conditioning devices make this a complete solution for the entire area of application.

MEASUREMENT PRINCIPLE

A one-bag system is used for volume compensation which can be configured as an active or passive regulating module. A dynamic PID controller guarantees ideal temperature control within the chamber.

The SHED AMA i60 is available as an analysis unit equipped in different configurations for the specific measurement tasks (e.g. ethanol, methanol, aldehydes etc.). Fully integrated interfaces for the required calibration devices (such as gas dividers, CFO propane injection testers and sensor calibration references) are standard.

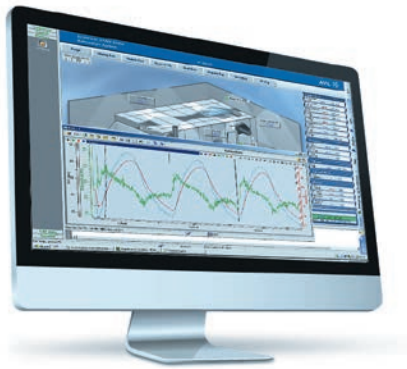
APPLICATION

SHED systems are designed for the evaporative emission measurements of vehicle components (e.g. tank systems) as well as entire vehicles. AVL SHED systems cover both certification and R&D purposes and offer a broad range of applications:

- Available chamber sizes of 1 m³ – 110 m³ (Micro–Magnum)
- Passive-SHED: measurement of bleed emissions
- Running-Loss: chamber with integrated chassis dyno
- ORVR for fuel tank filling tests
- Point-Source solutions
- Temperature control system for motor vehicle tanks (heated pad extension)

BENEFITS AT A GLANCE

- Uniform and analytically optimized system for minimum background measurements
- Flexible modular design
- Integrated standard test procedures and checks (Diurnal, HotSoak, DBLT, Background, etc.) meeting the latest worldwide emission requirements (e.g. EPA, CARB, EU)
- Automated test procedures with an extensive safety concept
- Software extension (e.g. Hybrid)
- CE conform / ATEX certified equipment



SHEDCon automation: Intuitive and easy to use graphical user interface with integrated service and diagnostic functions

CANISTER CONDITIONING UNIT

AVL CANLOAD

Current trends and future demands concerning alternative fuels and various drive concepts require adequate and flexible test systems. AVL CANLOAD systems show themselves to be state-of-the-art by providing a wide range of test solutions and supporting standard certification, individual R&D and durability testing.

MEASUREMENT PRINCIPLE AND SOLUTION

The CANLOAD pneumatic unit is designed for all standard applications based on butane/nitrogen or fuel vapor handling. It provides all required functions including individual valve matrix control, canister interface and mass-flow regulation. The elimination of volumes between valves and canister, combined with intelligent software functions, e.g. delay time evaluation and time-based purge routines, etc. increases accuracy and repeatability. Specially designed mass-flow controllers provide freely adjustable mass flow rates.

The CANLOAD enables the conditioning of activated carbon filters (ACF), which are used in the tank systems of vehicles. During this procedure, the ACF is loaded with butane- and fuel-vapor up to full saturation and is flushed again afterwards. This test verifies the ACF's correct functioning and is compulsory for further evaporative emission measurements (SHED) and fuel tank filling tests (FUELLOAD) of vehicles. The modern system design enables flexible alignment with constantly increasing requirements in the field of fuel mixtures and powertrains (hybrid).

BENEFITS AT A GLANCE

- Modularly extendable design for up to four lines simultaneously
- ORVR simulation modules supporting R&D
- Hybrid vehicle canister testing, e.g. dynamic purge functions
- Fully-automated, unmanned operation
- Continuously variable fuel loading rate and scavenging airflow rate
- Gravimetric control function (use of two balances)
- CE conform / ATEX certified equipment

CANLOAD device automation: improved graphical look and feel operation interface for manual operation, specific diagnostics and services

NEW CHALLENGES FOR ENGINES AND VEHICLE DEVELOPMENT

REAL DRIVING EMISSIONS (RDE)

The Real Driving Emissions (RDE) legislation is adding the road as a new environment for emission testing and certification. Compared to the current test environments, which are designed and optimized for perfect reproducibility and a removal of external influences, driving a vehicle on the road under "real-life" conditions will never be 100 % reproducible. The influence of the road profile, the ambient conditions, the traffic situation as well as the behavior of the driver will significantly influence the results. One-to-one comparison of test results will not be possible; instead it is nessecary to handle and evaluate the test data using statistical methods. The RDE legislation will require the engines to be clean under all operating conditions. This will impose significant challenges on the design and calibration of engines. Here RDE can become a door opener for alternative technologies as well as for alternative development processes.

AVL OFFERS SIMULATION AND TESTING TOOLS FROM INSPIRATION TO OPEN ROAD

RDE is imposing new challenges and complexity on today's approach for the development of vehicles and engines. There is certainly no magic bullet to battle the increasing complexity, but AVL's complete solution portfolio makes a difference. AVL can support any development project for RDE at all levels:

INSTRUMENTS AND DEVICES

Leading the market in various fields, AVL is committed to providing best in class performance, certified compliance with legislations as well as easy integration in test systems.

TEST SYSTEMS

AVL covers the full range of test environments, from first ideas in the office to the open road. Consistent operation across all test environments is ensured. AVL M.O.V.E iS is a tailored testing solution for the RDE on-road application.

PROCESS SUPPORT

AVL software supports the test operation, calibration, model based development and data management through the entire development process.

PORTABLE MEASURING SYSTEM FOR GASEOUS EMISSIONS

AVL M.O.V.E GAS PEMS iS

The AVL M.O.V.E GAS PEMS iS is a compact, lightweight and easy-to-install Portable Emission Measurement System (PEMS) for measuring the NO/NO_2 and CO/CO_2 exhaust gas emissions of diesel and gasoline vehicles. It is especially optimized for the Passenger Car "Real Driving Emissions" (RDE) application where low power consumption, compact dimensions, low weight and safe operation are extremely important. The new solution is based on the proven GAS PEMS and, therefore, provides the same high measurement accuracy.

MEASUREMENT PRINCIPLE

The system can flexibly be installed inside and outside the vehicle on a standard trailer hook mounting system to avoid any exhaust making its way into the vehicle, so protecting the test driver. The system is rain proof and additionally protected by a cover. The protective cover is designed to also optimize the wind drag coefficient to avoid influence to the test vehicle performance. The power distribution, including the batteries, can be mounted on top of the measuring module and are protected by the cover. With an optional trailer hook the GAS PEMS iS system does not need any modification to the test vehicle. The GAS PEMS iS system can be preinstalled on the carrier, warmed up and is ready to use. Then you simply install it on the trailer hook and connect the sample lines to your exhaust system with the quick clamps provided. A ready-to-go installation can be achieved in less than three minutes!

AVL GAS PEMS iS installed on a trailer hook mounting system

APPLICATION

Due to its compact, lightweight and smart design, the AVL M.O.V.E GAS PEMS iS is an efficient solution for the upcoming EU Real Driving Emission (RDE) and Chinese NO_x regulations for HD vehicles. It is also an efficient solution for "on-the-road" engine and vehicle development and vehicle surveillance testing.

BENEFITS AT A GLANCE

- Optimized and complete solution for RDE application
- Compact and lightweight
- Fast and safe installation
- Flexible installation in or outside the car and with or without exhaust flow meter
- No additional damping plates needed for passenger car application
- Wide operating range from –30 °C to +45 °C
- High measurement accuracy
- Y-type heated line is available in the case of dual exhaust pipe configurations

PORTABLE MEASUREMENT SYSTEM FOR PARTICLE NUMBER EMISSIONS

AVL M.O.V.E PN PEMS iS

The AVL M.O.V.E PN PEMS iS is a compact and robust continuous particle number [#/cm³] measurement device for on-road applications. This low weight and low power PN PEMS solution is especially designed to meet the Real Driving Emissions (RDE) requirements for gasoline and diesel vehicles. The modular concept enables the smart integration into the M.O.V.E iS platform and completes the AVL RDE solution for passenger cars. The PN PEMS iS incorporates AVL's broad expertise in particle number measurement methodology.

MEASUREMENT PRINCIPLE

The sample probe is located at the tailpipe of the vehicle and has been optimized to keep particle losses as low as possible and achieve maximum reproducibility.

The exhaust treatment unit includes a temperature controlled and diluted exhaust sampling unit and a volatile particle remover (VPR) to minimize particle losses and enables an optimum correlation to existing particle number (PN) instruments on the testbed which is compliant to UN-ECE R83. To fulfil the legislative requirements despite challenging limitations regarding size and weight, a patented Catalytic Stripper was introduced to remove the volatile fraction of the engine exhaust with high efficiency.

The Advanced Diffusion Charger technology is a further enhancement of the well-known corona discharge principle and has a directly proportional correlation with particle number [#/ccm]. Due to its robustness and low maintenance effort, the progressive sensor technology fulfills perfectly the challenging requirements of real world measurements.

APPLICATION

The modular design enables high flexibility for different applications:

- Standalone PN PEMS configuration with independent power supply
- Complete setup (Gas + PN PEMS) with combined sample probe

BENEFITS AT A GLANCE

- Compact, lightweight and robust solution optimized for RDE
- Innovative exhaust sample treatment to reduce particle losses and to reduce particle losses for best correlation to UN-ECE-R83 PN instruments.
- Modular concept: The PN PEMS iS can be operated both as a standalone device or integrated into the iS platform in combination with the Gas PEMS iS module

AVL M.O.V.E PN PEMS iS

PORTABLE MEASURING SYSTEM FOR GASEOUS EMISSIONS

AVL M.O.V.E GAS PEMS / GAS PEMS iX

Measurements with portable emission measurement systems (PEMS) on the road are an efficient way to keep the development effort at a reasonable level even as the requirements for fuel economy, emissions and customer expectations increase. PEMS systems are also needed for in-use compliance testing where heavy duty vehicle manufacturers have to report compliance with emission standards. Such measurements require robust and compact devices which can withstand rough testing conditions and provide reliable and accurate measurements over long test durations and under changing ambient conditions.

MEASUREMENT PRINCIPLE

The AVL GAS PEMS/ GAS PEMS iX are compact and robust PEMS devices for obtaining the emissions of vehicles during real life operation on the road. The GAS PEMS measures the THC, NO/NO_2 and CO/CO_2 concentrations in the exhaust gas of Diesel and Gasoline Vehicles. The GAS PEMS iX also allows the measurement of CH_4 concentrations. Reliable test cell analyzers, which are optimized for mobile application, ensure high measurement accuracy. All analyzers are temperature conditioned to achieve reliable measurements even in changing ambient conditions. The GAS PEMS/ GAS PEMS iX is controlled via AVL M.O.V.E System Control, which stores all data and provides interfaces to access e.g. ECU/CAN bus data and additional sensors.

APPLICATION

- Internal climate concept for accurate measurements in a wide ambient temperature range and under changing ambient conditions
- Protected from vibration by internal dampers and external damping options
- High measurement accuracy even in a low measurement range
- Low span and zero drift for long measurement intervals
- Special “Hybernate” mode to reduce warm-up time

BENEFITS AT A GLANCE

- Wide operating temperature range and high accuracy even in changing ambient conditions
- Robust against vibration through internal dampers and external damping options
- High measurement accuracy even in the low measurement range
- Low span and zero drift for long measurement intervals
- The GAS PEMS iX allows in addition to measure the CH_4 concentrations

AVL M.O.V.E GAS PEMS and AVL CONCERTO PEMS result screen

PORTABLE MEASUREMENT SYSTEM FOR PARTICULATE EMISSIONS

AVL M.O.V.E PM PEMS

In 2010 particulate matter (PM) limits were added to the US EPA Heavy Duty In-Use (HDIUT) rules. This requires manufacturers to prove their vehicles meet the PM limits even after many years of operation. A corresponding European In-Service Conformity legislation is already in preparation as well as regulations for off-road machinery, both in the US and in the EU. Soot and PM measurements are also important during development: Soot is an indicator of combustion system quality and the efficiency of a filter system (DPF). PM is limited by legislation and needs to be checked during development. Measurements on board a vehicle require compact, easy-to-install and robust devices which correlate to test cell equipment.

MEASUREMENT PRINCIPLE

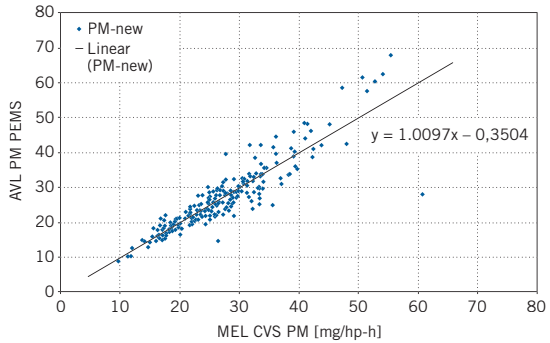
The PM PEMS is a combination of two measurement principles and consists of two units: the photo-acoustic measuring unit for the continuous measurement of soot concentrations and a gravimetric filter module which conditions the exhaust gas and measures PM using the gravimetric filter method. At the end of the test, the loaded PM filter is weighed with a microbalance. By using the transient soot signal and the filter weight as inputs, a time resolved PM signal is calculated as required by the in-use legislation. The calculations are available in AVL CONCERTO PEMS.

APPLICATION

The AVL PM PEMS is fully integrated into the AVL M.O.V.E in-vehicle testing platform. AVL System Control is the central device that integrates the exhaust flow meter, the PM PEMS, the AVL GAS PEMS and additional signals required for mass emission calculations. The PM PEMS can also be easily integrated into existing portable systems. In this case, the device can be operated independently as it does not need any external input signals. Control, data storage and operation are performed via notebook. The data integration is done with AVL CONCERTO PEMS.

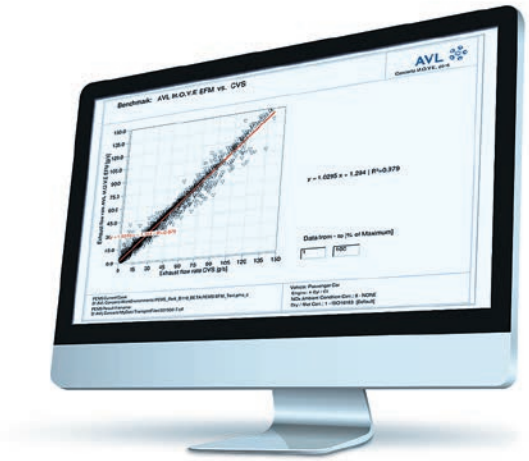
BENEFITS AT A GLANCE

- Ready for Euro VI HD in-service conformity (ISC) testing due to proportional sampling
- US EPA approval for Heavy-Duty in-use testing (HDIUT)
- Short installation time and easy to operate
- High measurement accuracy
- Easy integration into existing PEMS systems
- Robustness proven in multiple evaluation projects and with customers
- Based on proven AVL measurement technology



Correlation of PM PEMS with CVS

Correlation of MSS/GFB with Mobile CVS



Benchmark result for a 4-cylinder diesel engine

DEVICE FOR MEASURING THE EXHAUST MASS FLOW RATE OF INTERNAL COMBUSTION ENGINES

AVL M.O.V.E EXHAUST FLOW METER (EFM)

The AVL M.O.V.E EFM is a cost effective, accurate and robust exhaust mass flow measuring device with a special focus on the In-Use/ Real Driving Emissions (RDE) testing applications. The AVL EFM is fully integrated into the comprehensive AVL M.O.V.E in-vehicle measurement systems and can also be used as a "standalone device" e. g. on chassis dynos or engine test cells. Different interfaces allow for a flexible integration into automation and data acquisition systems.

MEASUREMENT PRINCIPLE

The AVL M.O.V.E EFM is based on the proven and robust "differential pressure" measurement principle. It consists of the EFM tube which is installed on the tail-pipe of the vehicle and the EFM control box which includes the electronics and the pressure transducers. The EFM tube and the EFM control box is separated for the most flexible installation. The EFM box is temperature conditioned to achieve high accuracy at changing ambient conditions.

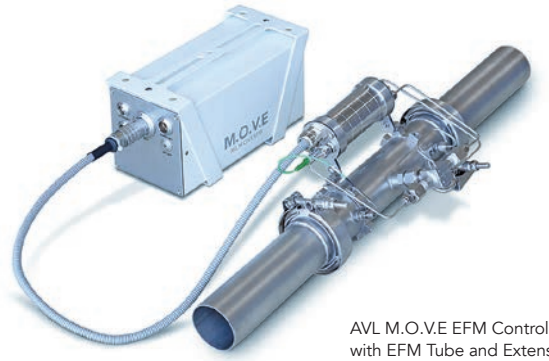
The usage of high-speed pressure transducers ensure accurate measurements at dynamic flow conditions in the exhaust duct. The EFM Control Box is water and dust protected (IP Protection Class 65) for the most reliable operation under harsh ambient conditions.

APPLICATION

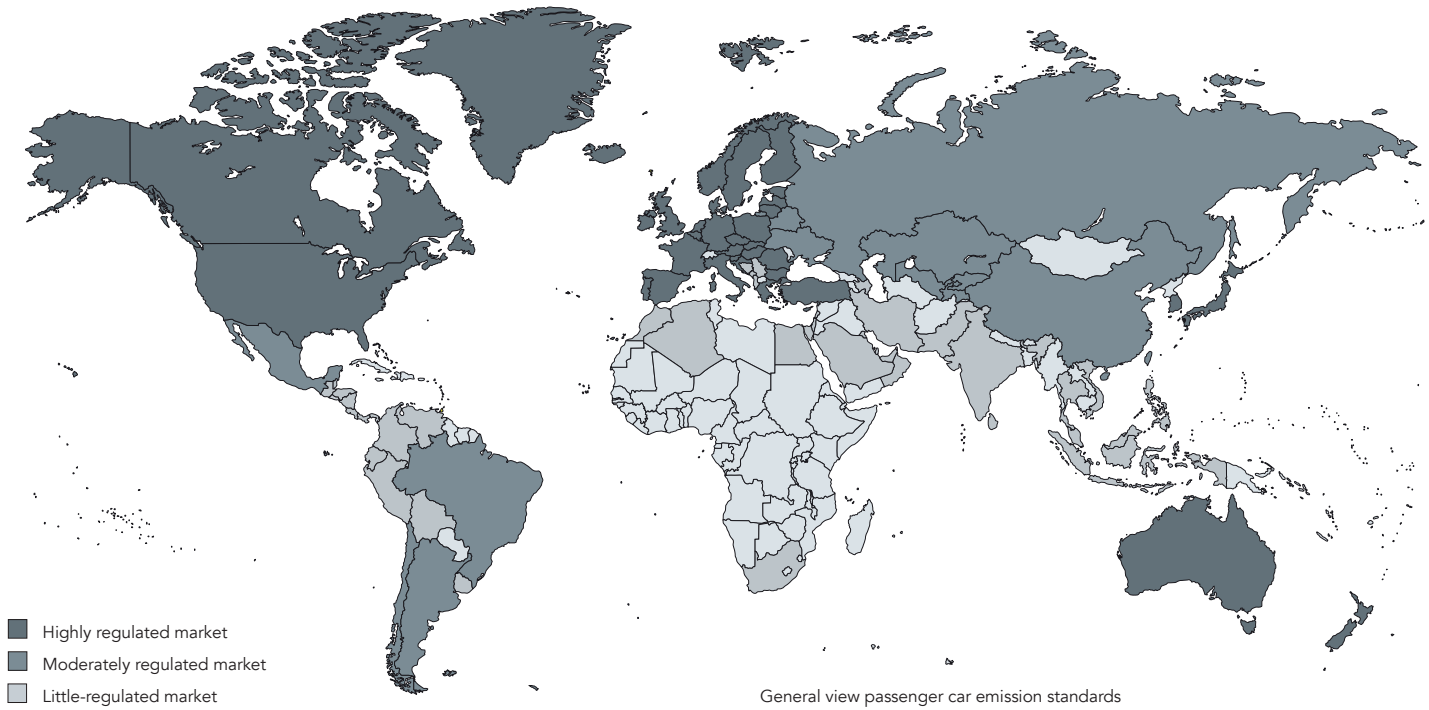
Due to its robust design, high measurement accuracy and flexibility in installation and operation, the AVL M.O.V. E EFM is a perfect solution for the In-Use/ RDE testing application or use on engine test cell or chassis dyno. It can be flexibly used either in combination with AVL M.O.V.E or as a standalone device.

BENEFITS AT A GLANCE

- Wide range of supported applications: From small passenger car up to heavy-duty truck engine, operation either in combination with AVL M.O.V.E or standalone e. g. on test cell
- High measurement accuracy even at changing ambient and highly dynamic conditions in the exhaust
- Fulfills all relevant legal requirements
- Flexibility in installation to allow for the most easy and safe mounting
- Quick and easy integration into AVL M.O.V.E and other automation and data acquisition systems



AVL M.O.V.E EFM Control Box with EFM Tube and Extensions



General view passenger car emission standards

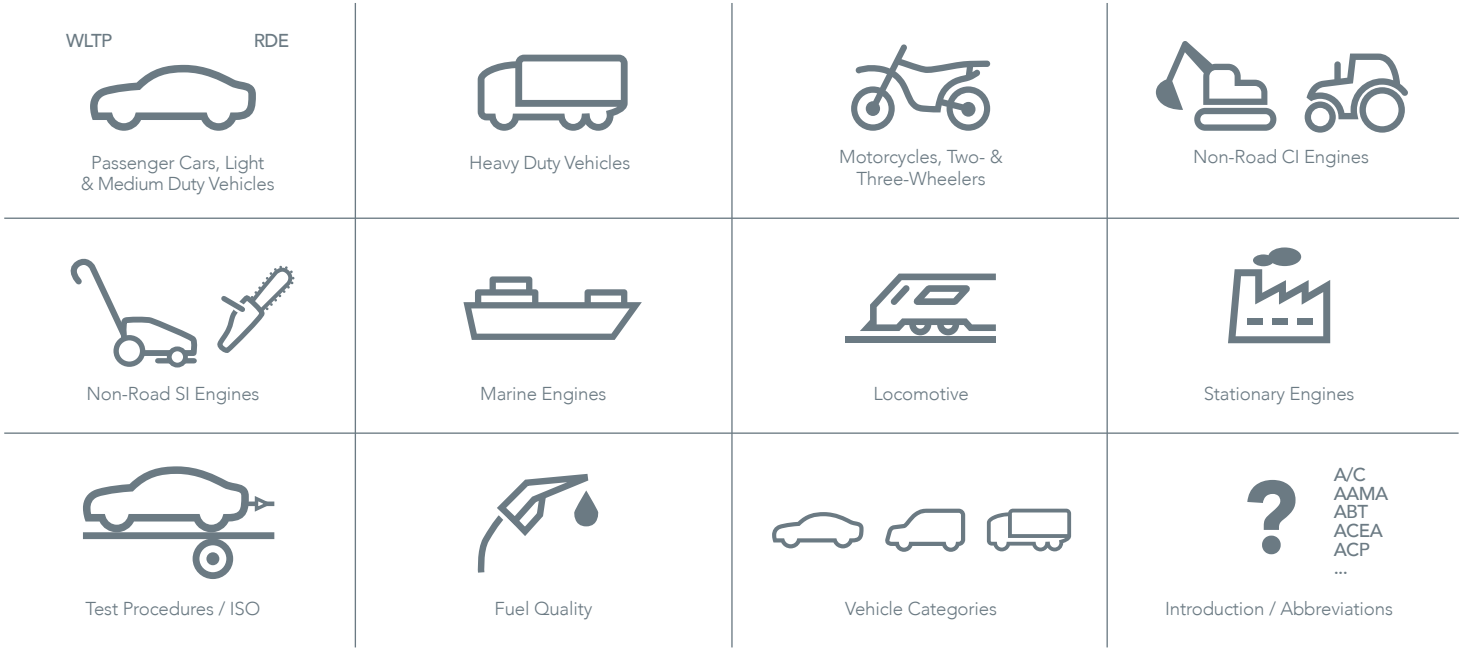
AVL Emission Regulation Report (AVL EmRep)

Increasingly stringent regulation of tailpipe emission and CO_2 is one of the major drivers for the technologies of future powertrains and test systems. AVL offers a well established tool to monitor the global developments: the continually updated AVL EmRep.

AVL EMREP KEEPS YOU UP-TO-DATE WITH EVER CHANGING REGULATIONS!

It offers a comprehensive summary of current and future regulations and covers trends in law-making for a broad range of internal combustion engines, motor vehicles, hybrid and electric vehicles, non-road equipment and many more.

Long experience and global presence ensure high quality data and the latest information.



AVL EmRep is your single source for:

- Highlights and view-at-a-glance information
- Detailed regulation requirements and specifications for development engineers and experts, serving as a reliable reference
- Future regulatory trends, to keep you informed on the evolution of standards and requirements in your fields of applications

AVL EmRep contains clear, structured and condensed information on regulations, proposals and forecasts regarding rule making for

- Tailpipe emissions
- OBD
- CO_2 emissions
- Fuel and electrical energy consumption
- Electric and alternative fueled vehicles
- Fuel quality
- Test procedures

A demonstration version is available at www.avl.com/legislation-services.

AVL M.O.V.E
Integrative Mobile Vehicle Evaluation

APPROACH

Based on strong powertrain and vehicle development know-how, AVL has created a new in-vehicle measurement platform.

AVL M.O.V.E is a compact and robust product line for a wide range of in-vehicle applications. It provides results for in-use conformity tests, vehicle calibration and vehicle benchmarking.

AVL M.O.V.E offers tailored solutions for different applications based on a modular device concept controlled by a central integration unit which takes over the device handling, data storage and post-processing. The package is rounded off by a universal mounting concept and a common power supply.

BENEFITS AT A GLANCE

- Complete measurement solution for integrated consumption, emission and driveability calibration
- Central device handling, data acquisition and post-processing
- Modular plug-in solution for fast installation
- Compact and robust design for use in harsh environments

TASK

High market demands for minimum emissions, optimized fuel consumption as well as maximum driving fun within complex system environments, which leads to an increasing number of vehicle tests.

Main application areas

- "In-Use" Testing according the US EPA Heavy Duty In-Use and the European EURO VI In-Service Conformity rules
- Light Duty "Real Driving Emissions" testing
- Vehicle and engine optimization on the road

In Vehicle measurement

Nowadays, in-vehicle testing challenges the application engineer with a wide variety of different measurement systems. The market demands integrated solutions with central device control, data handling and post-processing.

Electrification and combined systems (hybrid)

The trends of electrification and hybridization lead to more complex drivetrain systems that require more detailed analyses of xCU interactions in the vehicle. The component integration and system optimization increase the workload in the vehicle. Here, a seamless measurement platform is the key factor for further increases in efficiency.

PARALLEL OPTIMIZATION OF MULTIPLE DESIGN PARAMETERS INCREASES PROJECT EFFICIENCY AND SUPPORTS A BETTER UNDERSTANDING OF INTERACTIONS.

REFERENCES

All applications

AVL Instruments are used all over the world for the reduction of emissions and consumption as well as the optimization of combustion systems.The derived know-how in these fields was the cornerstone for the development of AVL M.O.V.E. The system's flexibility and robustness facilitate its use in different environments.

Powertrain engineering know-how

Powertrain and vehicle development know-how is a fundamental aspect for all AVL Instrumentation Test Systems product developments. A continuous process of sharing information and defining new functional requirements guarantees the technical leadership position of AVL in this application field.

Data consistency

The use of uniform measurement principles and methods guarantees the consistency between AVL M.O.V.E and AVL testbeds. This simplifies development and increases the efficiency of our customers due to a consistent philosophy. In addition, new testing methods can easily be developed based on this new approach.

Uniform data post-processing

The comparison of test data within different development environments is a key factor. AVL CONCERTO™ is a generic post-processing tool with open interfaces which supports efficient post-processing and data handling.

SYSTEM INTEGRATION

AVL M.O.V.E System Control

Current in-vehicle measurement set-ups consist of a multitude of different measuring devices. Devices are not connected to a central data acquisition system and measurements cannot be automated comprehensively.

SOLUTION

AVL M.O.V.E System Control meets this challenge and offers a robust and compact integration platform for in-vehicle measurement technologies that centrally collects all relevant measuring data such as

- Exhaust gas components
- Combustion data
- Fuel consumption
- Driveability

and processes them in an efficient data post-processing and evaluation tool.

System Control for central device integration and data acquisition

Calculation: Based on the available values, further results can be defined and calculated as required.
Data recording: All measuring channels as well as all calculated channels are recorded and saved in a single file (AVL I file format.)
Visualization: The graphical user interface provides all typical visualization objects (e.g table, X/Y-Plot, bar chart, single values etc.), which the user can freely configure.

Automated measurements: Control sequences, calculations, measurement processes and even evaluations and report generation can be automated by means of a script function.
Reporting: Data post-processing and visualization are based on the powerful tool AVL CONCERTO™.

BENEFITS AT A GLANCE

- Robust design for mobile operation in the vehicle
- Central operation and control of devices
- Central data acquisition and seamless data evaluation
- Easy and flexible integration sensors and measuring devices

MEASUREMENT OF GENERAL SIGNALS

AVL M.O.V.E SMART-FEM

In addition to the measurement of vehicle parameters, general signals (e.g. temperature, voltage etc.) are becoming more and more important in many in-vehicle applications. Such signals have to be measured depending on the application. Modern powertrain concepts demand new signal types and increased acquisition rates.

SOLUTION

AVL M.O.V.E SMART-FEM is a configurable I/O measurement system consisting of two components. The central unit (called Smart Box) is indented for attaching different conditioning modules. The Smart Box is connected to the M.O.V.E System Control via a CAN bus interface.

The following input types can be measured:

- Temperatures (thermocouples, RTDs)
- Voltages
- Currents
- Resistances
- Strain gages

Further modules are under development.

BENEFITS AT A GLANCE

- Modularity: the Smart Box can be equipped with different smart devices
- Expandability: designed for further demands (e.g. high voltage)
- Flexibility: measurement of temperatures, voltages, currents, measurement bridges in one device

Flexible I/O system for mobile applications

VEHICLE INSTALLATION

AVL M.O.V.E Mounting Concept

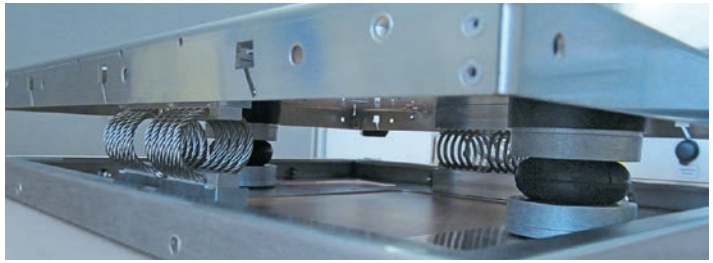
Different environments and various mounting situations require high flexibility with regard to safe device installation. The area of in-vehicle applications ranges from motorcycles to excavators.

SOLUTION

The AVL M.O.V.E mounting concept is designed to fulfill all requirements regarding the safe and secure installation of devices. Each device features a robust design and is optimized for operation under rugged environmental conditions.

However, some applications (e.g. off-road applications) require additional protection against shock and vibrations. For these particular conditions, AVL M.O.V.E offers a dedicated mounting plate for off-road testing.

GAS PEMS iS with Exhaust Flow Meter (EFM) installed on trailer hitch



Mounting plate for heavy duty and off-road applications

BENEFITS AT A GLANCE

- Secure fixation of devices
- Simple system extension
- Quick and easy installation

VEHICLE INSTALLATION

AVL M.O.V.E Power Supply

In addition to device installation, power supply strongly depends on different usages and customer philosophies. Customers today follow a broad range of power supply strategies including mains power (for system heat-up), generators (long-term independent operation), batteries (short-term independent operation) and/or vehicle power supply.

SOLUTION

All AVL M.O.V.E devices operate on 24 VDC power. The power supply concept is designed for operation of the M.O.V.E devices independently of the vehicle power supply. The E-Box provides the following features:

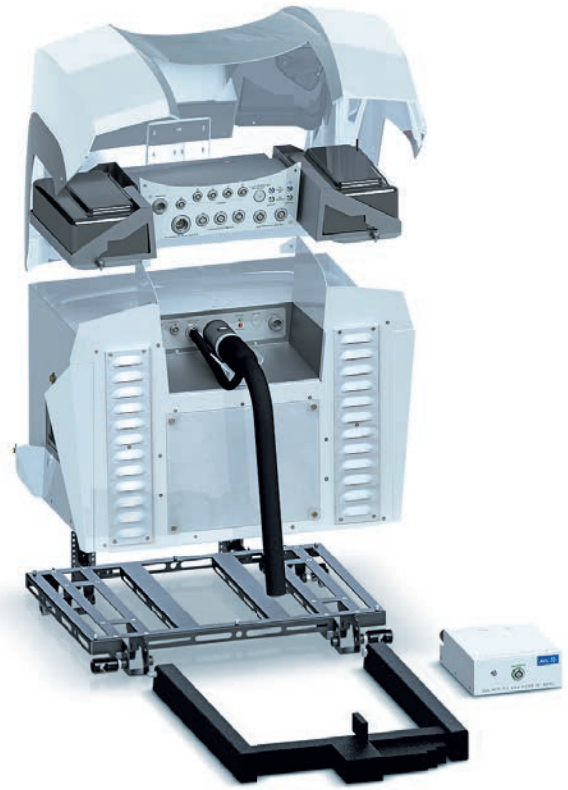
Handling of power sources: The E-Box enables the user to seamlessly switch between different power sources such as mains/generator power during system heat-up and batteries for back-up power supply.

Power distribution: The E-Box distributes the power to the M.O.V.E devices and at the same time ensures safe battery loading (different battery types and sizes are supported). The system monitors the energy flows and shows the remaining battery power on a display.

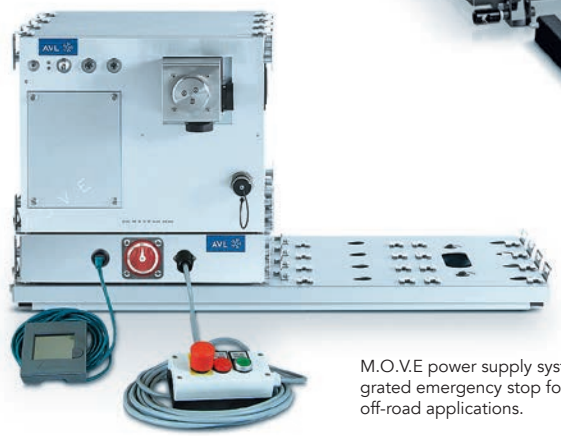
In the case of AVL M.O.V.E GAS PEMS iS System. The E-Box is mounted together with the battery packs between GAS PEMS iS and the outer cover. This new concept allows for quick installation because there is no need to plug in or unplug the devices when e.g. switching from one car to another.

BENEFITS AT A GLANCE

- Different supply strategies
- Integrated emergency stop circuit
- Central power distribution



M.O.V.E iS System overview



M.O.V.E power supply system with integrated emergency stop for heavy duty and off-road applications.

A Kaleidoscope of Simulation Possibilities

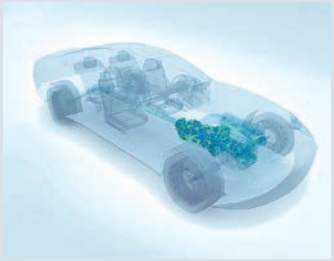
INCREASING SIMULATION DEMAND

The challenge of reducing time and costs along the product development cycle creates a growing demand to replace physical prototypes with virtual prototypes applying frontloading. The vast range of variables in modern powertrain systems and the increasingly considered interaction of all vehicle components need to be mastered in the most efficient manner. Engineers are facing a great number of challenging development and simulation tasks which need more than just 'good software'.

The unique power of AVL Advanced Simulation Technologies is derived from the systemic linking of single simulation results to integrated, multidimensional simulation platforms on the basis of AVL's sound knowledge of engineering. These simulation platforms address the key tasks of the powertrain development process. A closed measurement loop enables a very early verification of testing data and a significant reduction in test attempts.

OUR STRENGTHS HELP CUT DEVELOPMENT COSTS AND TIME

- Robustness, ease of use and the completeness of physical models enable simulation as a "frontloading" development tool
- Exceptionally reliable and practical simulation solutions which solve development problems with a high level of accuracy and confidence
- Simulation solutions focus on powertrain engineering and therefore provide problem-tailored capabilities for model set-up and result presentation to the powertrain development teams
- Experienced local support and powertrain simulation teams support global development activities



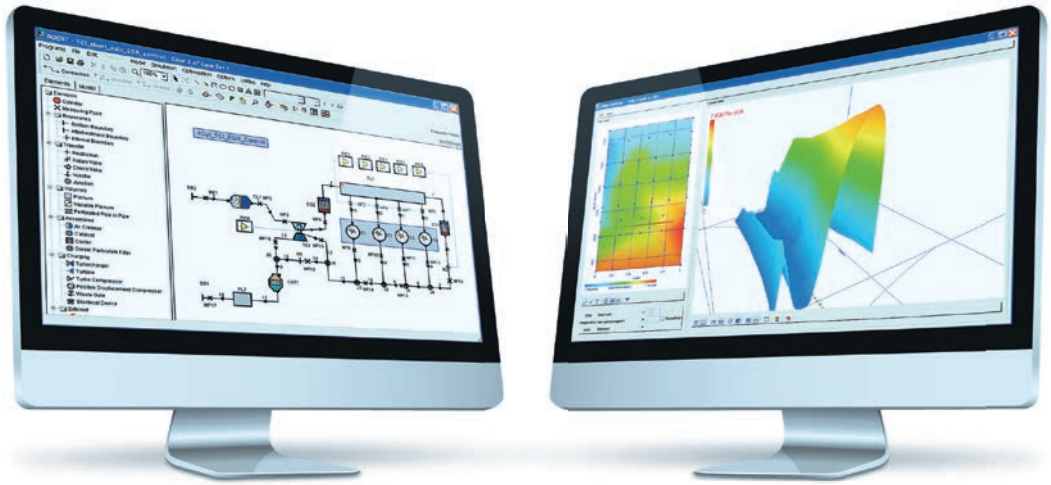
POWERTRAIN ENGINEERING INSIDE / CLOSE LINK TO TESTING

AVL SIMULATION WORK FLOWS THROUGHOUT...

AVL's unique simulation power is the combination and integration of AVL software tools, third-party tools, testing and analysis methods with seamless simulation workflows which guide the user to practical solutions.

...THE PRODUCT CREATION PROCESS

AVL's simulation workflows address application tasks which cover all aspects of the product creation process. The huge complexity of these tasks is bundled into multidimensional simulation platforms on the basis of AVL's sound engineering know-how.



AVL BOOST™

AVL BOOST™

MARKET DRIVERS

Automotive marketplace demands, such as fuel efficiency, passenger comfort and emissions, places limits on today's vehicle designs. The ability to meet the majority of these demands is highly influenced by the combustion engine.

These idealized targets often conflict, as shown by the constant trade-off between high performance and fuel efficiency, for example. To meet core specifications required by the vehicle team, engine designers must balance dozens, if not hundreds, of engine parameters. The use of simulation tools, whether pure simulation or a combination of hardware in testbed environments (hardware-in-the-loop), is essential.

AVL BOOST™ is an advanced and fully-integrated "Virtual Engine Simulation Tool" with advanced models for accurately predicting engine performance, acoustics, and the effectiveness of exhaust gas aftertreatment devices. It supports engine development in such a way that, for a given vehicle concept, the required torque and power can be delivered in combination with optimized emissions, fuel consumption and passenger comfort (acoustics and transient behavior).

AVL APPROACH

AVL BOOST™ – the well established "Virtual Engine Simulation Tool" with high fidelity simulation models for

- Combustion and pollutant formation in the cylinder
- Exhaust gas aftertreatment
- Acoustic analysis

AVL BOOST STRENGTHS

- Powertrain expertise drives software development
- Specialized user interface designed for engine engineers
- Consistent 1D and 3D aftertreatment simulation in AVL BOOST™, AVL FIRE™ and AVL CRUISE™
- Engineering, testing, and software under one roof
- Support provided by experienced engineers from local AVL offices around the world

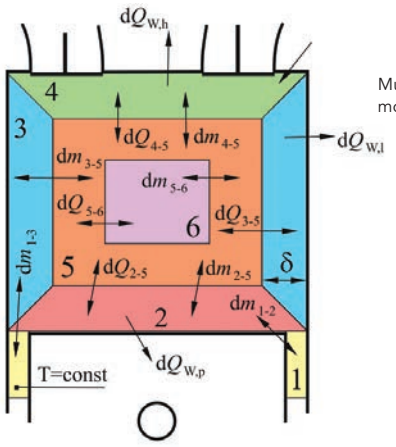
INTEGRATED SOLUTIONS WITH AVL BOOST™

AVL BOOST™ – AVL FIRE™

AVL BOOST allows to model any part of the intake or exhaust manifold in full 3D by coupling the 1D flow solution with the 3D CFD Software AVL FIRE™. This includes time as well as cost effective optimization of key elements such as the intake plenum (EGR mixing) or the close-coupled catalyst (uniformity, heat-up and conversion).

AVL BOOST™ – AVL CRUISE™

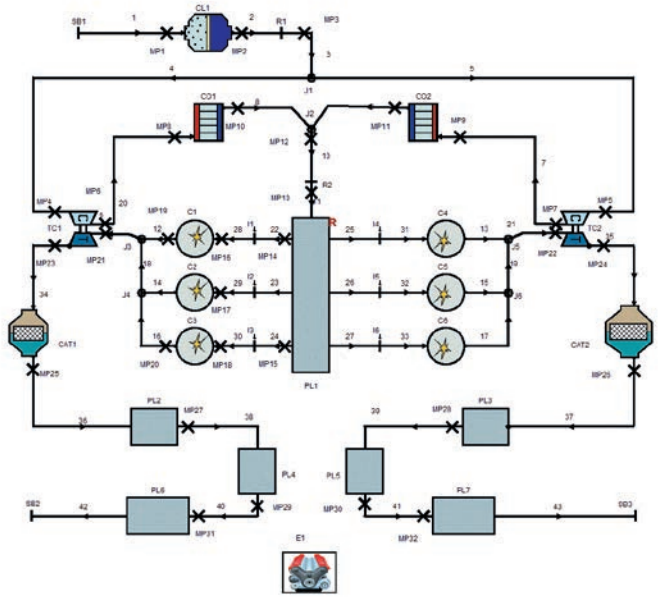
AVL CRUISE™ is a software package developed for vehicle simulation. Typically, AVL CRUISE™ uses engine maps for performance and emission data. However, a direct coupling to an AVL BOOST™ engine model can be selected for even greater accuracy, especially for transient analysis.



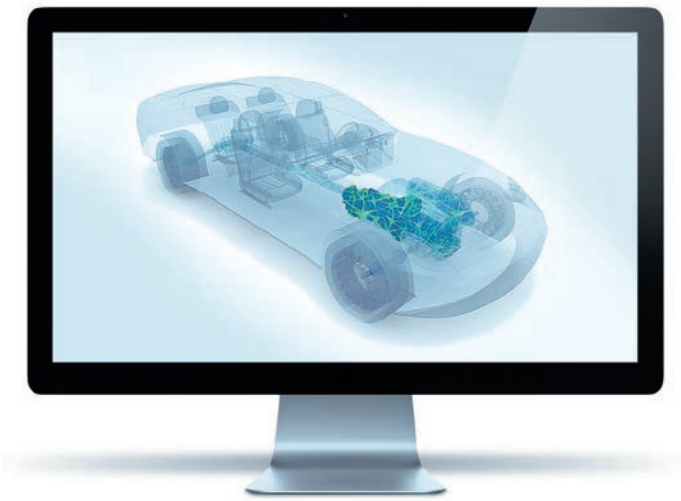
Multi-zone combustion modeling in AVL BOOST™

GCA – GAS EXCHANGE AND COMBUSTION ANALYSIS

Although today's engine testbeds are equipped with a variety of sensors, certain important performance and combustion parameters (for example residual gas concentration, volumetric efficiency, scavenging efficiency, and trapped mass) cannot be measured directly. This limitation is overcome by GCA, an integration of AVL BOOST™ into AVL's testbed environments AVL IndiCom™ and AVL CONCERTO™. This integration provides engine engineers with access to crucial results for their development tasks.



AVL BOOST™ model: 6 cylinder bi-turbo Ottomotor

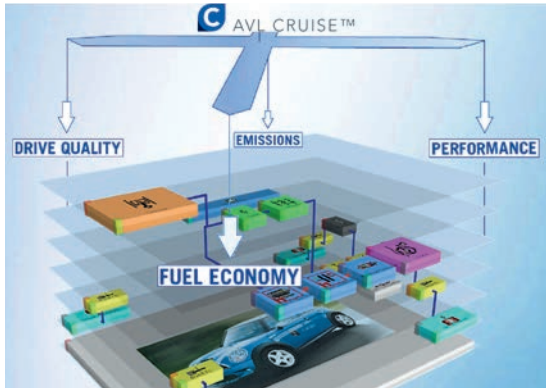


AVL CRUISE™

AVL CRUISE™

MARKET DRIVERS

Cost reduction and time pressure in vehicle development demand highly flexible simulation systems. The models produced by these tools need to be able to fulfill their functions throughout the product development workflow to prevent the initial concept from being lost under the weight of conflicting engineering demands and compromises regardless of driveline topologies. The increased complexity of advanced vehicle concepts requires interdisciplinary cooperation of teams, because vehicle-level simulation tools need to be able to leverage the communication between different teams and ensure consistency in model and data management. Resources for the time- and cost-intensive development are hard to justify as are validation and maintenance of vehicle-level simulation tools. But comprehensive tools are required to create product-defining attributes such as fuel economy, emissions, performance and drivability with an optimized costbenefit ratio.



Finding the perfect trade-off to achieve given targets

CONSISTENT SIMULATION MODELS AND APPLICATION-FOCUSED WORKFLOWS

AVL CRUISE™ supports everyday tasks in vehicle system and driveline analysis throughout all development phases from concept planning to launch and beyond. Its area of application spans from conventional vehicle powertrains to highly-advanced HEV systems.

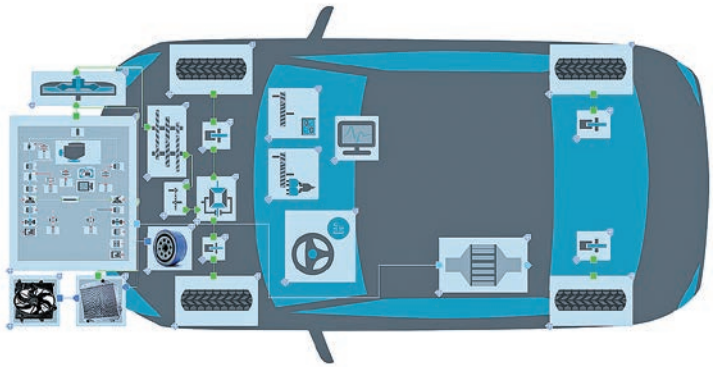
AVL CRUISE™ offers a streamlined workflow for all kinds of parameter optimization and component matching – guiding the user along the way to practical and attainable solutions. Due to its structured interfaces and advanced data management AVL CRUISE™ has established itself as a data communication and integration tool for various teams within world-leading OEMs and their suppliers. This facilitates consistent target definition and traceability of decisions made in reaching the best overall results for the developed product.

AVL CRUISE™ STRENGTHS

- Realistic vehicle system modeling of any topology with complete vehicle component models and scaleable fidelity
- Inclusion of all simulation vehicle system analysis tasks and workflows
- Intelligent and consistent management of data throughout teams, applications and workflows
- Developed with OEMs engaged in leading-edge vehicle and powertrain design – AVL CRUISE™ incorporates the expertise of these companies

YOUR BENEFITS

- Simulate driveline structures efficiently, from standard to the most complex
- Perform all fuel economy, emissions and performance tests in a single run with the same vehicle model
- Hybridize conventional vehicles with only a few mouse clicks
- Explore new transmission concepts such as automated manual transmissions and dual clutch transmissions
- Execute very large parameter optimization and component matching tasks with DoE functions
- View the energy and power flows graphically in the entire powertrain



Multi-disciplinary vehicle system model

AVL CRUISE™ M

AVL CRUISE™ M

INTRODUCTION

The multi-disciplinary vehicle system simulation platform AVL CRUISE™ M is designed for model-based system development, seamlessly integrating high-quality, realtime-capable subsystem models of engine, driveline, 1d fluid flow, aftertreatment, electrical and control system domains.

The numerical solver, tailored for efficient multi-physics vehicle system simulation is combined with a highly flexible, multi-detail level modeling approach, open to third-party tools and interface standards (FMI).

This allows for AVL CRUISE™ M subsystem and overall vehicle models to be re-used in the powertrain development process anywhere from traditional fuel efficiency, emissions and performance analysis to entire vehicle thermal and energy management assessment in the office as well as validation and calibration on realtime HiL and test systems.

FUNCTION DEVELOPMENT AND CALIBRATION

AVL CRUISE™ M Engine is one of the essential parts of the entire AVL CRUISE™ M multi-disciplinary model-based development solution, focusing on system level realtime engine simulation which can be used throughout vehicle development cycle. Scaleable engine modeling depths from empirical to semi-empirical, and then the physical level, using a crank-angle resolved cylinder and a gas path approach provide a unique solution to create and execute models which meet the requirements of model-based calibration.

This ensures consistent, comparable, and reproducible tests which can be performed even before the hardware is available to lower the risk

of missing critical operating conditions in early development phases and increase development efficiency. Integrating AVL CRUISE™ M MOBEO's semi-physical modules for the simulation of cylinder and exhaust aftertreatment system in AVL CRUISE™ M, enables an automated engine calibration process for all vehicle types, backed up by powertrain engineering know-how.

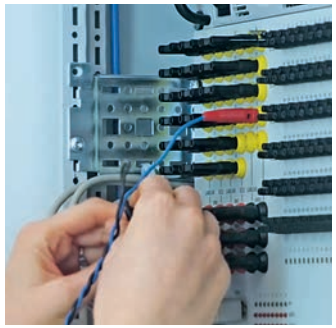
The open concept of AVL CRUISE™ M supports calibration and test tasks from MiL to SiL to HiL which can be applied to a wide range of globally leading RT platforms, achieving real-world conditions without any actual risk to the driver or equipment.

VEHICLE ENERGY MANAGEMENT SYSTEMS DEVELOPMENT

AVL CRUISE™ M provides a simulation environment for the development of an effective thermal management system and its control strategy which require a comprehensive consideration of the entire powertrain.
It works as the thermal link between the powertrain subsystems, covering integration tasks such as cooling and heating of all relevant components, reduction of thermal losses and optimization of the overall efficiency, detecting critical thermal conditions, so preventing damage to the vital parts of the engine and driveline. In addition to the subsystem components, there is a fully-integrated property database extendable by the user containing numerous solids, oils, and coolant media.

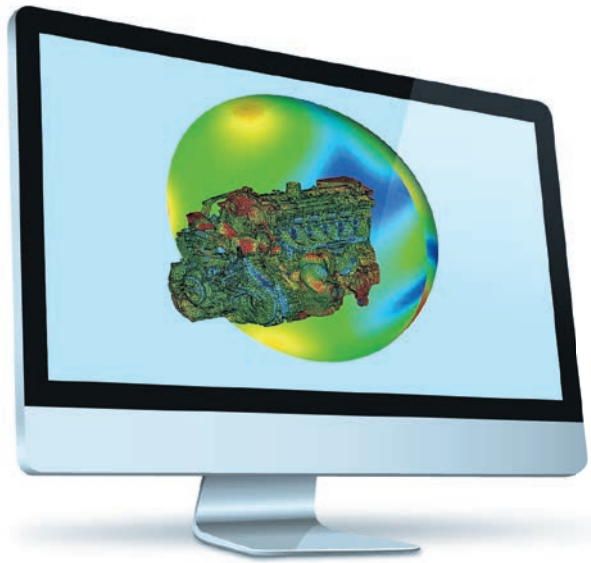
The modular system integration with other AVL CRUISE™ M domains extends capabilities for realistic interaction and development of complete vehicle energy management.

In the office…



…on HiL…

…on the testbed. Simulate Anywhere. AVL CRUISE™ M



AVL EXCITE™

AVL EXCITE™

MARKET DRIVERS

AVL EXCITE™'s family of products are the leading market simulation tools for powertrain NVH and durability assessment. The powertrain development process is increasingly subject to opposing pressures. As the requirements for strength, durability and noise reduction rise, so do associated time and cost pressures. This challenge can only be met through the use of efficient simulation and calculation tools.

These tools must be as realistic as possible during the concept phase with increasing precision throughout the later development stages. Math-based models assist engineers in producing higher quality products while achieving shorter development times and lower costs.

AVL APPROACH

AVL has developed complementing tools for simulating and calculating individual components, submodels and entire system.

HIGH FIDELITY SYSTEM SIMULATION

Complete systems and individual components with various modeling depth levels can be built or scaled for each stage of the development process. Models can be adapted to meet requirements ensuring the optimum balance between simulation effort and accuracy.

POWERTRAIN ENGINEERING INSIDE

With many years of experience in the field of engine development, AVL's software uses accurate and validated mathematical models to provide calculation results which are as realistic as possible. AVL simulation solutions are highly application-oriented.

CLOSE LINK TO TESTING

The AVL EXCITE™ Designer tool provides results in a format which enables an electric motor to reproduce the torsional vibrations of a combustion engine on the transmission testbed. In this way, AVL EXCITE™ enables customers to save time and costs during the testing phase of a project.

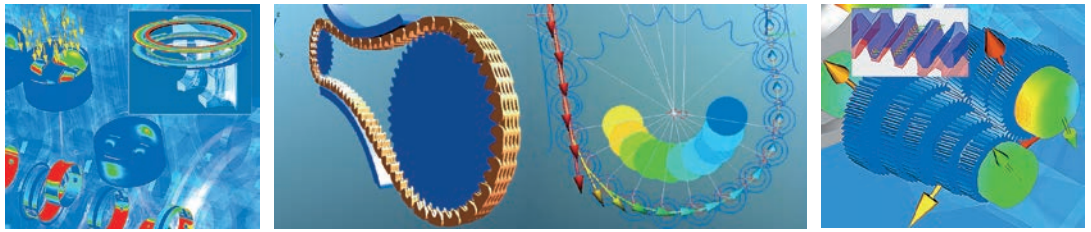
AVL TOOLS FOR STRENGTH, DURABILITY AND NVH SIMULATIONS

AVL EXCITE™ POWER UNIT

is the industry's leading tool for calculating the dynamics, strength and acoustics of combustion engines, transmissions and powertrains. It is also used for the detailed analysis of local hydrodynamic effects in oil-lubricated contacts (slider bearings, piston-liner contacts).

AVL EXCITE™ DESIGNER

uses analytical methods to enable the fast and realistic dimensioning of crankshafts and powertrains at an early stage in the development process.



AVL EXCITE™ – dynamics, durability and NVH of engines and powertrains

AVL EXCITE™ TIMING DRIVE

ensures reliable results for all kinds of valve trains and timing drives. It covers the entire work-flow, from the kinematic designing of cam profiles and the dynamic behavior of individual components, to entire timing drives driven by gears, chains or belts.

AVL EXCITE™ PISTON & RINGS

is an efficient tool for sizing piston assemblies. The piston ring module can be used to calculate absolute values for inter-ring pressures, piston ring movements and blow-by as well as the reliable trend prediction of lube oil consumption.

AVL EXCITE™ ACOUSTICS

is a new tool for calculating the noise radiation of vibrating structures such as power units. Using a unique automated procedure to generate the acoustic mesh within minutes, starting from the unmodified structural FE mesh and a wave-based technique solver, it enables the calculation of airborne noise results with significant short analysis lead time.

AVL EXCITE™ STRENGTHS

- Robust and optimized solver for short calculation times
- Parameter-based simulation models – easy variation of design parameters
- Hybrid modeling approach (2D workspace with a 3D view capability) for easy and fast model generation
- Customizable GUI – user definable for template definition
- Integrated standard workflows for crankshaft dynamics and NVH analysis, extendable by user-defined workflows
- Automated application-oriented and user-extendable 2D post-processing (standard reports)
- Design explorer – integrated tool for DoE and optimization
- Interfaces to third-party CAE software (FE, optimization) and application programming interface for smooth integration into the existing CAE environment

CUSTOMER BENEFITS

- One simulation environment for all phases of the engine development process and for all structural dynamics analysis
- Based on AVL's 60+ years of leadership in engine and powertrain engineering consultancy
- Dedicated user support and guidance teams around the world with AVL engineers who are highly experienced in engine analysis

AVL FIRE™

AVL FIRE™

MARKET DRIVERS

The automotive industry continues to focus on delivering products with improved quality, balancing driving comfort, performance and fuel consumption while continuously reducing tail pipe out emissions. To meet these requirements, automotive engineers demand development tools which provide accurate representations of complex systems in the virtual world. A rapidly growing number of design parameters for both traditional and alternative powertrain systems increases the importance of predictive simulations which can be deployed during all phases of the product development process. AVL FIRE™ 3D Computational Fluid Dynamics (CFD) Software, with a particular focus on accurate modeling of physics and chemistry related to IC Engines and powertrains, meets the demands of the development engineers during all stages of their work. AVL FIRE™ is used every day by hundreds of engineers to accurately predict results on a robust basis, quickly and reliably. AVL FIRE™ users optimize designs more quickly and with greater confidence.

AVL FIRE™ is primarily used by researchers and developers working in internal combustion engine and powertrain engineering. The software is integrated into their specific processes. This way the quality and performance of new concepts and products can be tested, well before the hardware is available. Development cycles are shortened and costs are reduced, even though the number and complexity of the tasks performed are significantly higher.

AVL APPROACH

As the leading simulation program in the field of combustion engine analysis, AVL FIRE™ specializes in the accurate prediction of engine gas exchange, fuel injection, mixture formation, combustion and emission as well as exhaust gas aftertreatment.

1. HIGH FIDELITY COMPONENT SIMULATION

The overall environment and individual components of AVL FIRE™ allow it to be applied in any phase of the development process. The wide range of available models allows users to properly balance simulation effort and accuracy.

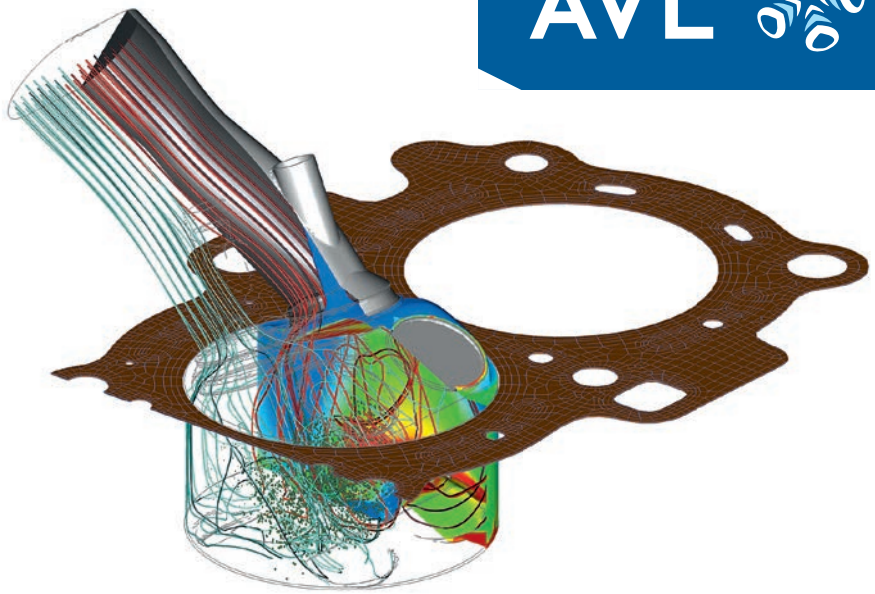
2. POWERTRAIN ENGINEERING INSIDE

The development of AVL's simulation tools is in a unique way supported by over six decades of engine engineering experience

collected in our powertrain engineering division. While our customers as well as our own consulting and service business can directly profit from this know-how, our software development team gains invaluable insight into current and future requirements.

3. CLOSE LINK TO TESTING

The virtual inspection of engine-related phenomena with AVL FIRE™ allows shorter development times and cost reductions. New techniques – such as coupling with optimization tools – allow for the investigation of more design variations. The results are: a more robust prototype on the testbed; shorter test periods; lower costs; higher product maturity and quality.



AVL FIRE™ STRENGTHS

- AVL FIRE™ is a full-scale 3D CFD Solution with an embedded chemistry solver, complemented by pre- and post-processing tools, all embedded in an intuitive graphical user interface; there is no need to purchase third-party tools, even for the most complex tasks
- AVL FIRE™ is based on tested state-of-the-art solver technology capable of handling general polyhedral computational elements and offering a robust platform for continuous enhancement
- AVL FIRE™ offers automated meshing technology for arbitrarily complex geometries, including multiple moving parts; this helps to drastically reduce setup times for complex models
- AVL FIRE™ offers a consistent set of physical and chemical models to cover various types of fluid flow simulation tasks – in particular those related to internal combustion engines – at different stages in the development process
- AVL FIRE™ development effort is complemented by AVL's internal R&D activities as well as by extensive industrial and academic partnerships
- AVL FIRE™ provides an open code structure enabling researchers to extend the software's capabilities to meet specific requirements
- AVL FIRE™ offers unique models and capabilities to simulate flow and chemistry in exhaust gas aftertreatment

CUSTOMER BENEFITS

- AVL FIRE™ is specifically tailored to meet the requirements of automotive research and development engineers
- AVL FIRE™ is flexible to allow users to adjust modeling complexity and integrate the software into their CAx framework
- AVL FIRE™ is a tested tool, used daily in AVL's engine development process and by hundreds of customers worldwide
- AVL FIRE™ is easy to use thanks to automated pre- and post-processing, integrated application-specific workflows and pre-defined solution control files
- AVL FIRE™ provides reliable and accurate simulation results. Its models are extensively validated
- AVL FIRE™ computational models are being continuously developed and enhanced via in-house research activities and partnerships with leading technology centers world-wide
- Customer support is provided by engineers who know powertrains and powertrain development

AVL FIRE™ M

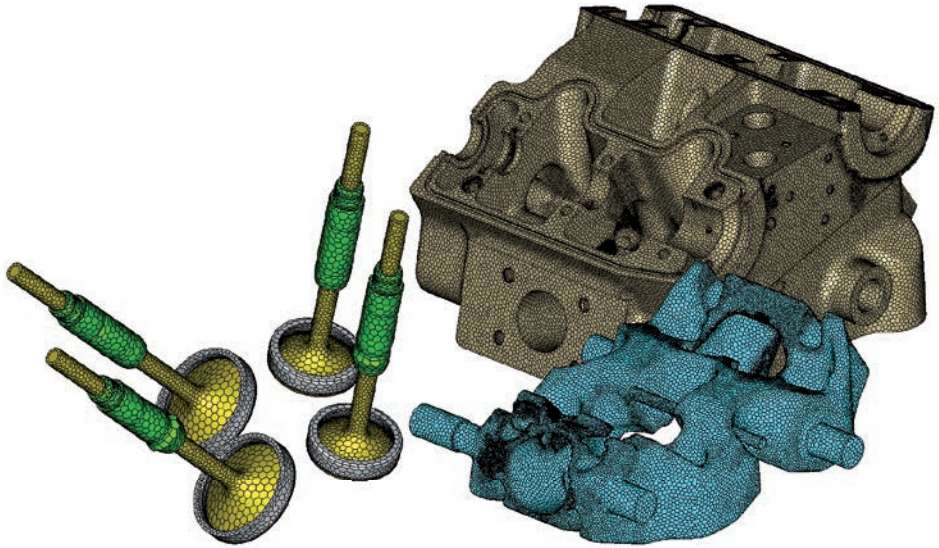
AVL FIRE™ M

TURNING PROBLEMS INTO SUCCESS STORIES

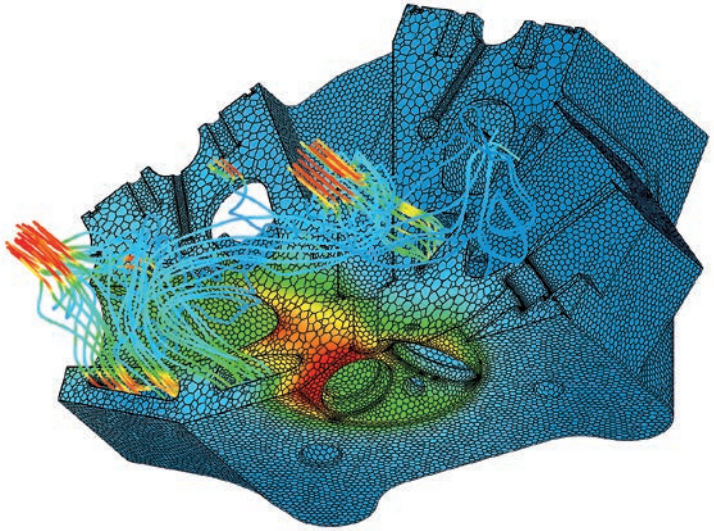
AVL FIRE™ M is a novel solution for generating, executing and analyzing standard CFD models. It offers a comprehensive set of new capabilities for pre-processing, main program and post-processing, and is the first FIRE™ version integrated in the AVL Simulation Desktop – a highly functional Graphical User Interface (GUI) also providing common project and data management for all CAE tools developed at AVL Advanced Simulation Technologies. This enables easy information sharing and supports inter-disciplinary simulation tasks.

AVL FIRE™ M offers automated modeling of arbitrary complex geometries deploying polyhedral cells. Additionally, tools for interactive generation block-structured grids are provided.

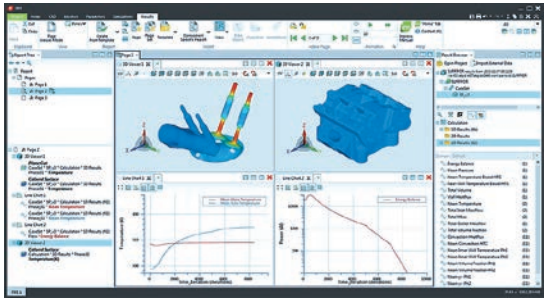
Extended solver capabilities allow setting up multi-domain models. This is essential if classical fluid flow problems and heat transfer into adjacent structures need to be solved simultaneously.



Multiple domains discretized in a single meshing step



Coolant flow through the thermally loaded cylinder head



Highly functional GUI

The easy and fast assignment of material properties to individual domains with the help of the extensive AST Property Database is another highlight of the new AVL FIRE™ version.

Simulation results are assessed in the new AST Post-Processor, supporting interactive and template-based visualization and analysis of two- and three-dimensional calculation data. The post-processor also allows the creation of animations, movies and 3D PDF, allowing engineers to easily recognize and interprete the causes and effects of transient fluid flow phenomena. An in-built report generator creates application-specific documentation.

This results in significantly shorter model turn-around times, helping to investigate more design variants more efficiently in the product development process.

TYPICAL APPLICATIONS

Typical simulations frequently executed by AVL FIRE™ M *standard* to support the development and optimization of powertrain components include:

- Intake and exhaust ports
- Manifolds and lines
- Ventilation and air conditioning equipment
- Internal and external aerodynamics
- Cooling systems
- Turbocharger
- Heat transfer and thermal load of structural parts

CUSTOMER BENEFITS

The software's user-friendliness and the high degree of automation provide easy access to CFD to a large number of people, enabling them to take advantage of a simulation-driven design process.

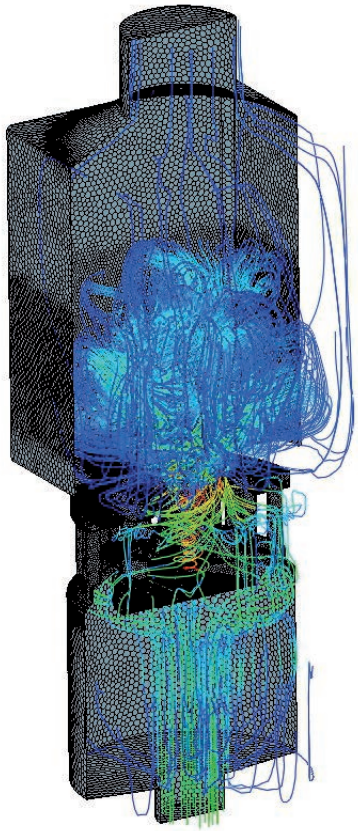
AVL TABKIN™

AVL TABKIN™

MARKET DRIVERS

For internal combustion engines, one of the major market challenges is to optimize engine-out emissions without sacrificing thermal efficiency. Higher predictivity from combustion CFD simulations, at reduced CPU time, will enable the industry to elaborate the best specification of engine soft- and hardware in a shorter time frame. A more detailed description of fuel and emissions chemistry is key to achieve improved CFD predictivity. However, with traditional approaches, the description process leads to a significant increase in CPU time, often exceeding project lead times.

Diesel combustion in the early phase

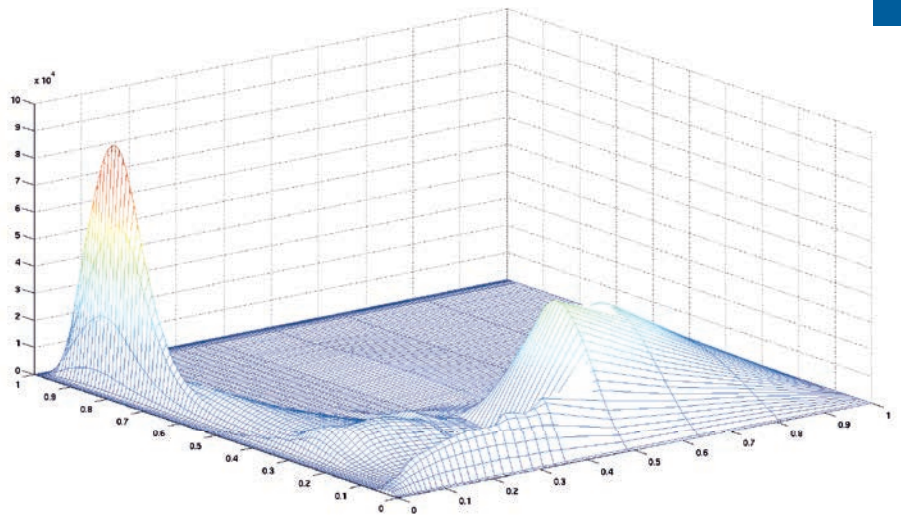


Swirling flow in gas turbine combustor

AVL APPROACH

AVL TABKIN™ pre-calculates combustion chemistry and efficiently maps the results to the flow field computed with CFD. This chemistry tabulation technology allows to include the most detailed fuel chemistry available today directly in CFD simulations, while still meeting engineering project lead times. AVL TABKIN™ is natively coupled to AVL FIRE™. Interfaces to AVL TABKIN™ exist for all common CFD codes.

Sample from AVL TABKIN™ look-up table



AVL TABKIN™ STRENGTHS

AVL TABKIN™ embodies more than a decade of experience with chemistry tabulation technology for combustion applications. The modeling approach has been successfully applied to diesel and gasoline engines. Advanced concepts such as Low Temperature Combustion (LTC) and Premixed Charge Compression Ignition (PCCI), as well as dual-fuel concepts such as Reactivity-Controlled Compression Ignition (RCCI) or diesel-ignited gas, which are all strongly driven by chemical kinetics, are accurately modeled with AVL TABKIN™:

- AVL TABKIN™ substantially reduces the computation time for CFD simulations with detailed reaction schemes.
- AVL TABKIN™ significantly enhances the predictivity of combustion CFD simulations through an improved physical description of the turbulent combustion process and the use of state-of-the art fuel chemistry.

AVL TABKIN™ INTERFACES

AVL TABKIN™ Interfaces link the look-up table generated with TABKIN™ to the CFD code of the user's choice in two different ways:

- Through the AVL TABKIN™ FGM combustion model, implemented in the latest AVL FIRE™ release and available through User-Defined Functions (UDFs) for other supported CFD codes.
- By using tabulated chemistry data, generated with AVL TABKIN™, for other combustion models in a native format of the CFD of the user's choice.

CUSTOMER BENEFITS

- Improved speed and predictivity of combustion CFD simulations
- 50 % reduction of cost-per-useful-answer (est.)
- Reduced number of hardware prototypes and shorter time-to-market

AVL Testbed Automation

APPROACH

AVL's testbed automation system guarantees the highest productivity, quality assurance and efficiency in test operation. Thanks to its many years of successful use by all notable automotive manufacturers and by AVL's own powertrain engineering competence. The new generation, AVL PUMA Open™, is the only automation system suitable for all testbed types which can be easily extended by modern testing methods. The continuous development of the automation platform is driven by a permanent dialogue with our customers and in direct collaboration with selected pilot customers. Whether destined for use with global OEMs or local SMEs, AVL PUMA Open™ has been verifiably proven to increase efficiency in test operation.

BENEFITS AT A GLANCE

- State-of-the-art user interface and unique design
- All testbed configurations and applications on one common platform reduce operational, maintenance and training costs
- Integrated concepts for the frontloading of development tasks minimize total development time and time-to-market
- A high degree of system automation provides optimal basis for unmanned test operation
- AVL ActiveLink™: automatic and fast integration of measurement devices

TASK

Our customers want total solutions that provide the most efficient solution to the problems they are confronted with. The generation of "Digital Natives" has a completely new understanding of collaboration, connectivity and the sharing of data, knowledge and results. New demands are placed upon the operability of our products. AVL acknowledges this with intuitive operation, cutting edge design and consistent operational style across a range of software products. The availability of information for smart devices has become a given for users.

Apart from product features, factors that are decisive for the competitiveness within the automotive industry are: costs, time-to-market and product quality. Testbed automation contributes significantly to the generation of test results with the highest possible quality and reproducibility. Powerful search functions enable the rapid location and further processing of data.

The best automation system is of no help, if it cannot be relied upon. Short product life cycles in the IT sector and the need to support numerous testing applications require the ability to simply and regularly update software. Investment security is constantly in focus.

AVL PUMA Open 2™ – A SYNONYM FOR PLEASURE AT WORK!

REFERENCES

All Testbed Types, all Applications

What do testbeds for Hardware-in-the-Loop (HiL), engines, fuel cells, electric motors, powertrains and vehicles have in common? What can be found in the R&D testbed, at the certification testbed and end of line? Answer: Modular solutions on the basis of the AVL automation platform.

Certified Quality, Reliable and Stable

AVL PUMA Open is tested intensively in a modern and large-scale test center in a real customer test environment. Source code quality is validated automatically with more than 1,000 test cases.

Holistic Approaches for Increased Efficiency

Many factors have to be right to increase efficiency. Accordingly, AVL automation systems support pallet-compliant IO modules, intelligent pallet handling, workflow support and plausibility checks on results.

Installed Base

AVL PUMA Open™ is the global industry standard for testbed automation with over 4,200 active systems in use at more than 150 customers worldwide.

THE EASE OF AUTOMATION

AVL PUMA Open 2™

VALIDATION IN THE OFFICE

AVL PUMA Open 2™ enables test runs and parameter sets to be prepared in the office, together with the administration of projects, results and operator rights. The acquisition of measurement values, calculation of a range of quantities and the execution of automated test runs is done on the testbed.

PRINCIPLE

The creation of test tasks is done in the office. Modern and intuitive tools are available to the user. A graphical test run editor facilitates and accelerates the creation of test runs. The test run parameter library, with integrated version administration for all parameter types, makes standardisation and effortless distribution possible within the test field. The validation of individual parameters and multiple parameter sets is no longer done on the testbed, as was the convention, but is now done entirely in the office. This saves valuable testbed time.

APPLICATION

Testbed automation on a common platform:

- HiL-testbeds: virtual environment AVL Virtual Testbed™ for validation and preparation of complex test methods
- E-motor testbeds: Coverage of the full four-quadrant operation
- Engine testbeds: From endurance testing to high-end racing applications
- Powertrain testbeds: From transmission durability testing to optimisation of the complete powertrain
- Component testbeds

BENEFITS AT A GLANCE

- Pleasure while working thanks to the new Intellisense (“Auto-complete“) based parameter concept combined with immediate check for correctness
- Increase in productivity by re-use of test parameters through to complete configurations
- Reduction of maintenance effort and training costs through a common operability concept for the AVL Team SUITE™ products

Save valuable testbed time by transferring parameterization and analysis tasks to the office workplace

EXECUTION ON THE TESTBED

AVL PUMA Open 2™ guarantees the easy interplay of all testing tools and testbed components. It coordinates the data flow, beginning with the testbed control and test definition, through to the acquisition, processing and archiving of the data.

PRINCIPLE

AVL PUMA Open 2™ supports the user with all work processes on the testbed, with the aim of achieving maximum efficiency. Apart from standard functions, such as fully automatic and manual operation, AVL PUMA Open 2™ reliably and accurately controls and monitors measurement devices, test equipment and the unit under test. The new possibility of signal flow analysis permits errors to be recognised immediately and test repetition to be avoided.

TEAMPLAY INTERFACES

Innovative interface technology enables a more efficient and more flexible use of AVL measurement instruments and permits the execution of state-of-the-art calibration methods.

AVL ActiveLink™ enhances with:

- Intelligent measurement instrument recognition
- Complete measurement data availability

Powerful interfaces between AVL CAMEO™ – AVL PUMA Open™ – AVL IndiCOM™ set a new level in xCU calibration work.

BENEFTIS AT A GLANCE

- Reduced downtimes on the testbed thanks to intelligent diagnostic functions and AVL ActiveLink™ technology
- Simple upgrades of existing AVL PUMA Open™ testbeds through the use of migration tools
- Reliable results due to test execution, control and simulation fully synchronized and in hard real time

AVL PUMA Open 2™ – The ease of automation

NAVIGATION & SEARCH WITH AVL PUMA Open 2™

The seamless integration of all test field data, from test parameters via global data to result data, is one of the most important new features of AVL PUMA Open 2™. The navigation tool Navigator is the main entry and exit point for all specific activities.

PRINCIPLE

The relevant features of Navigator are the unified approach to the processing of parameters, the clear and concise administration of projects and user rights, and the management of values and files. A powerful search function enables the rapid location and further processing of data.

APPLICATION

The level of support provided by Navigator significantly reduces the workload for test engineers, test field managers and IT administrators. The Navigator: a tool for all activities!

BENEFITS AT A GLANCE

- Cutting edge user experience for new and experienced users
- Task-oriented operator interface
- Maximum flexibility due to centralised parameter management

The Navigator permits access to all parameters, global data and results from a testbed or from a networked test field

THE EASE OF AUTOMATION

AVL PUMA Open 2™

EMISSION TESTING, SIMPLIFIED

AVL iGEM 2™

AVL iGEM 2™ responds to the growing demands for flexibility regarding R&D tasks and legal compliance in the field of emission certification of e.g. heavy-duty vehicles and off-road engines. The test procedures, test data evaluation as well as the test conditions for such emission tests are specified by regulations and are subject to strict limits. During engine development for passenger cars, legal test cycles are increasingly being simulated on engine testbeds and often require additional emission devices and evaluation methods. AVL iGEM 2™'s high degree of automation most efficiently utilizes the equipment on emission engine testbeds to produce reliable data, while its powerful toolbox enables a very flexible way of reacting to new test requirements.

SOLUTION

Pre-configured and tested legal cycles, intelligent device control and calculation as well as reporting of test results are the core components of AVL iGEM 2™. A unique, easy-to-use parameterization concept allows the creation of project specific test cycles or engineering targets without any need for programming skills. The seamless interaction with its platform products AVL PUMA Open 2™ and AVL CONCERTO 5™ leads to an easy integration of AVL iGEM 2™ into the user's workflow and test environment.

APPLICATION

The emission automation software AVL iGEM 2™ is designed for the development and certification of heavy-duty and off-road engines as well as the development testing of light-duty and passenger car engines on dynamic and stationary engine testbeds. Software packages for further applications are currently being devised.

BENEFITS AT A GLANCE

- Intuitive user interface based on AVL PUMA Open 2™
- Simple measurement device integration via standardized interfaces
- Easy-to-use development kit to create your own test cycles and result evaluation
- Transparent and extendable test reporting based on AVL CONCERTO 5™
- Visualization of calculations and automated formula documentation
- Efficient testbed utilization by means of innovative parameterization
- Easy extensibility for enhanced R&D requirements with the powerful AVL PUMA Open 2™ testbed automation platform

AUTOMATION SYSTEM FOR EMISSION TESTING ON CHASSIS DYNAMOMETER TESTBEDS

AVL iGEM Vehicle

Continually changing international emission legislation as well as new engine designs and measurement methods create a market demand for innovative solutions in the automation of emission testbeds. AVL iGEM Vehicle is the answer to these challenges. Based on decades' experience in the automation of emission testbeds, AVL iGEM Vehicle was created with state-of-the-art software. This software features future-oriented design, which makes it a sound investment.

SOLUTION

Based on the proven success of AVL PUMA Open™, AVL iGEM Vehicle offers a high degree of scalability. It also allows simple adjustments for different testbed configurations based on individual user needs. This means it offers the highest level of flexibility and independence to the user. This flexibility guarantees the fulfillment of both present and future legal requirements.

APPLICATION

The AVL iGEM Vehicle is used for certification, research and development, and also for production compliance purposes. AVL iGEM Vehicle offers the best solution for passenger car, medium duty and heavy duty truck and motorcycle emission automation. It also provides a variety of customized application packages.

BENEFITS AT A GLANCE

- Valid emission test certification packages covering all current standards, including electrification and RDE
- Fully-automated procedures in the preparation of common devices for testing, calibration and checks
- Simple and flexible integration of new measurement devices using device abstraction as well as an extensive driver library
- Efficient tools to create custom test cycles and test applications
- AVL iGEM Offline – a powerful data evaluation tool with a central formula database

Easy operation thanks to a dynamic and intuitive graphical user interface. The entire test cycle is run fully automatically.

Powertrain Calibration

APPROACH

Modern powertrain development creates significant challenges for the automotive industry. Essential vehicle attributes – performance, dynamics, fuel consumption, emissions and acoustics – depend on an optimized tuning of control units. Those calibration tasks are becoming more complex, while optimal results are required more quickly. To master the wide range of tasks in everyday work, calibration engineers need efficient tools that put new methods into practice.

BENEFITS AT A GLANCE

- Software tools to support development engineers during the entire calibration workflow
- Models can be reused throughout the different stages of the development process
- Full utilization of the test facility due to intelligent test runs – even in unmanned 24-hour operation
- Tools are supported and maintained on a global scale (roll-out capability for test facilities and different locations)
- Development focus on calibration tasks rather than the development of calibration tools

TASK

More than ever, completing calibration tasks reliably requires modern software tools that can manage complex tasks and applications.

Those tools have to meet requirements such as data quality, reproducibility, stability and safety when used in the development process. This is the only way to solve tasks, such as the dynamic operation of modern powertrains in combination with low emission requirements, in a satisfactory way.

To be able to meet the increasing calibration requirements, constant and continual development of methods is the key. AVL has years of experience and is leading in the development of high-performance tools and methods in xCU calibration. Our aim is to provide a complete workflow for each single calibration task. AVL calibration software has delivered significant increases in efficiency for implementations worldwide.

REFERENCES

AVL CRETA 4™ – Calibration Lifecycle Management

As Calibration Lifecycle Management, AVL CRETA 4™ supports a traceable application process that is indispensable for series projects. Short access times, high levels of stability and safety as well as easy operation are key criteria. More than 10,000 installations prove the high quality of AVL CRETA 4™.

AVL CAMEO 4™ – With intelligent automation to calibration results

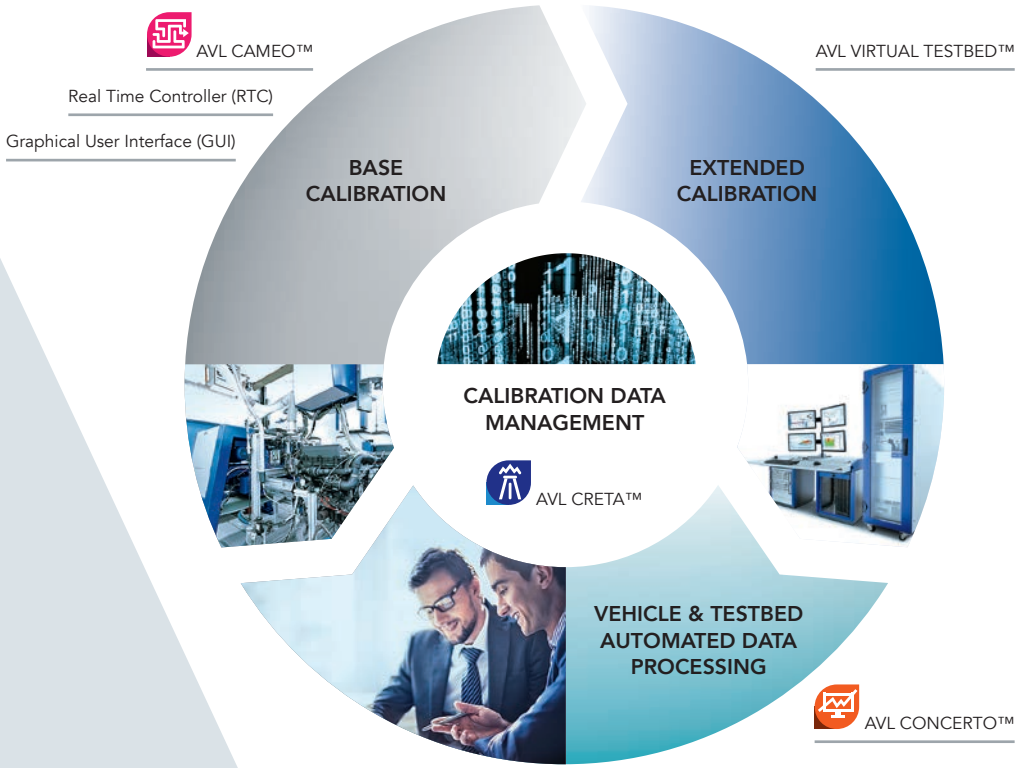
With almost 800 licenses in use worldwide, AVL CAMEO 4™ is the leading tool for efficient, automated test procedures in calibration. The complexity of calibration is visualized in the software, and therefore allows easy handling.

AVL Virtual Testbed™ – Modelbased Development

AVL Virtual Testbed™ combines models, a Hardware-in-the-Loop system and a testbed to create an integrated system. Significant cost reduction in testing and enhanced calibration have already convinced users from different fields.

AVL CONCERTO 5™ – Data processing platform

The brand new generation of AVL CONCERTO 5™, the generic data processing platform, specializes on visualization, analysis and reporting of simulation and measurement data. For specific applications, AVL CONCERTO 5™ provides individual solutions: Pro Apps and toolboxes.



TRUST YOUR CALIBRATION POWER

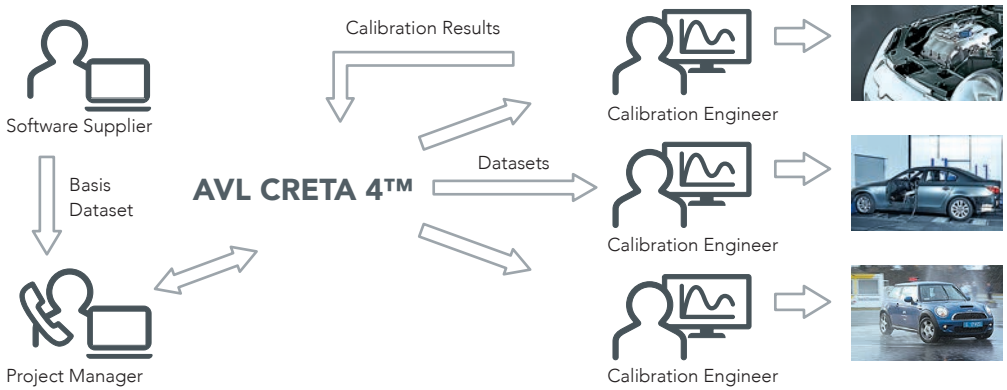
AVL CRETA 4™

Given the increased number of mechatronic systems in today's vehicles, an increase in the complexity of engine, transmission and hybrid control functions is inevitable. With calibration for steering, suspension and ADAS-Systems, the number of factors to be calibrated for a single vehicle has increased significantly. The large number of parameters add a new level of complexity to modern calibration projects and generate a need for new methods to maintain a clear overview and enhance standardization where possible.

APPLICATION

AVL CRETA 4™ enables the simple handling of calibration data throughout the vehicle development process and ensures conflict-free and traceable integration of xCU parameters throughout the calibration project. Clearly assigned parameter responsibilities avoid conflicts when merging calibration data from different sources and guarantee consistent results. A common data repository forms the backbone of AVL CRETA 4™ and helps calibration teams around the world to share project relevant information easily and ensure a smooth collaboration with partners. Standardized methods for pre-calibration of new projects, monitoring of calibration projects and reuse of calibration knowledge guarantees high efficiency.

AVL CRETA 4™ APPLICATION PROCESS EXAMPLE



AVL CRETA 4™ helps meeting today's challenges in calibration projects while reducing data management costs by more than 50 percent and is a highly intuitive and easy-to-use software with a strong focus on the application

BENEFITS AT A GLANCE

- Traceable, secure and simple administration and documentation of control unit data
- Worldwide collaboration and data exchange between team members, partners, suppliers and customers
- Quick pre-calibration of initial datasets and re-use of data
- Plausibility check of datasets using data-mining algorithms
- Easy project and quality monitoring through integrated reporting mechanisms

KEY FEATURES OF

AVL CRETA 4™

PROCESS WORKFLOW SUPPORT

AVL CRETA 4™ supports your calibration process by reducing time for every step of your workflow.

REPORTING & DOCUMENTATION

Simple creation and reuse of reports help you save time when reporting to the management or customer.

COLLABORATION

Work together anytime from anywhere with alerts, notification subscriptions and team information.

PROJECT STATUS CONTROL

Find the status of every calibration task easily and check if your project is on track.

RESPONSIBILITY MANAGEMENT

Clear responsibilities safeguard the complete process and overlapping work is eliminated.

KNOW-HOW MANAGEMENT

Ensure that your calibration knowledge is reused and does not disappear due to changes in staff.

CONFLICT-FREE DATA MERGING

Clear responsibilities enable a simple and easy creation of new merged datasets without conflicts.

QUALITATIVE METRICS

Monitor your quality and processes and optimize them where potential is identified.

TRACEABILITY & VERSIONING

Understand the “who, what, when and why” of any change during the calibration process.

EXTENSIBILITY

Open, pre-defined APIs let you connect to your in-house systems and apps.

MAKES COMPLEXITY EASY

AVL CAMEO 4™

AVL CAMEO 4™ – much more than DoE! With the new generation of AVL CAMEO™ the road for the future is set and prepared. AVL CAMEO 4™ offers a complete solution for powertrain testing and optimization demanded by the RDE legislation.

WHAT DOES AVL CAMEO 4™ OFFER?

Transient calibration is supported in combination with the integrated data processing platform AVL CONCERTO 5™. Enhanced usability and a new software user interface allow users a faster parametrization and execution of their tasks. AVL CAMEO 4™ offers a standardization concept to handle the data needed to deliver world-class engine calibration. A standard test in AVL CAMEO 4™ made for multiple use cases and users, is easy to set up for the individual needs, also for the testbed operator themselves, leaving room for the engineering team to concentrate on innovation. A test sequencer allows to start different test runs in an automated sequence to utilize the test facility 24 hours, 7 days a week. Furthermore, an advanced interface to AVL PUMA Open 2™ offers outstanding integration and performance of daily automated calibration work.

APPLICATIONS

AVL CAMEO 4™ offers a wide range of applications:

- Gasoline engine calibration (e.g. charge or torque calibration)
- Diesel engine calibration (e.g. torque structure, base calibration, emissions calibration)
- Exhaust aftertreatment calibration (e.g. LNT, SCR)
- Drivability calibration (e.g. power on/off, tip in/out)
- E-motor calibration
- Battery management calibration
- Inverter calibration
- Fuel cell calibration

- Steering calibration
- Chassis calibration
- ADAS calibration
- Simulation model parametrization
- Vehicle concept selection and optimization

BENEFITS AT A GLANCE

- One software environment to cover the whole calibration workflow
- Fully automated and self-adaptive test runs to ensure highest efficiency
- Test sequencer and standardized tests ensure high utilization and efficiency
- Optional programming interfaces for user-specific solutions and adaptions
- Real-time controllers for faster and more efficient calibration

TEST & MEASURE
AVL CAMEO 4™

AVL CAMEO 4™ Test & Measure is much more than a DoE tool. Artificial intelligence is used through online global modeling to shorten the testing time while increasing the quality of the results. Little prior knowledge is needed to achieve the desired results. Standardized tests for multiple use cases and users ensure highest utilization in the test facility by means of exchangeable parameters and profiles reducing the parametrization effort.

KEY FUNCTIONS

- Active DoE with online global modeling
- Intelligent test sequencer
- Central test configurations and layouts
- Real-time controllers
- Programming interfaces
- Central data storage
- Scripting interfaces (e.g. iDoE, Matlab, .net)
- Vehicle and traffic simulation system (e.g. CarMaker, AVL VSM 4™)
- Model.CONNECT™ interface
- AVL CONCERTO 5™ interface

MODEL & MAP
AVL CAMEO 4™

AVL CAMEO 4™ Model & Map supports to calibrate xCU labels based on all kind of measured or simulated data, using efficient behavior models and powerful optimization technology. By intuitive parametrization, best-in-class label calculation and easy-to-use result analysis, complex multidimensional calibration tasks can be solved in very little time and at highest quality. The results are achieved right first time thanks to the integrated data and process flow.

KEY FUNCTIONS

- Data analysis with graphical support
- Outlier detection
- Global and local models
- Model export
- Interactive model graphics
- Global optimization
- Map calculation
- Real driving prediction

AVL Testbed Control and Simulation on Engine and Powertrain Testbeds

APPROACH

Decades of experience in the field of testbed control as well as detailed knowledge of the development processes of our customers have significantly influenced the development of AVL testbed controllers. The need for precise real-time simulation models is increasing with the "road to rig" approach. The major challenge in today's vehicle development is to rapidly shorten vehicle development cycles. Vehicle simulation which is more than just vehicle inertia simulation enables significant progress in vehicle optimization and calibration, e.g. driveability as well as real world emission and fuel consumption optimization. AVL provides a stable and robust virtual vehicle model for engine testbeds which enables the simulation of real-world shaft oscillation phenomena (e.g. jerk). The counterpart for powertrain testbeds is a patented solution for the vehicle dynamics with wheel slip simulation. These requirements led to the creation of a modular and scalable controller with integrated simulation environment which ideally covers all requirements from individual testbeds up to applications in large-scale test facilities.

BENEFITS AT A GLANCE

- Approved safety concept for unmanned operation, 24/7
- Central administration of parameterization in test facilities
- Fast road to rig due to highly accurate real-time simulation
- Open simulation environment for the modular integration of customer real-time models
- Central administration and distribution of real-time applications in a test field

TASK

Parameterizing engines and their variants for different vehicles and countries constitutes the highest expenditure of time in the development cycle today. To accomplish this on testbeds in an automated manner, it is essential to have precise control over test subjects and the load facility.

Increased efficiency

To increase efficiency, it is necessary for control parameters to be managed centrally in the test facilities, and it must be possible to unambiguously associate these parameters with the test results.

Operational simplicity

During the operation of the testbed control system, the operator requires only minimal expert knowledge. Uniform, graphically supported, online-compatible parameterization that is also continuous across different testbed types reduces training costs as well as errors.

Consistent usability

The option of adding functionality when specifically required allows for targeted investments. Here, the modular structure of the control system offers ideal adaptability to the current requirements with regard to measurement value collection, control functions and real-time platform.

REFERENCES

All manner of applications have been successfully equipped with AVL EMCON™: from simple testbeds for continuous operation, development testbeds with vehicle simulation, powertrain testbeds and component testbeds, all the way to racing testbeds. Globally, several large-scale test facilities with more than 30 testbeds profit from complete integration into the testbed automation system. AVL ISAC™ offers a scalable and robust simulation solution from road load, vehicle inertia and powertrain oscillations to wheel slip. The flexibility and open character of the system allow the customer-specific adaptations and the direct integration of MATLAB®/Simulink® control algorithms which can be created by the user. This makes the AVL ARTE.Lab™ real-time simulation environment the ideal extension for specific simulation needs at the testbed.

Driveability Evaluation and Simulation

Over 10 years of experience in driveability evaluation and simulation. More than 50 % of all OEM's and transmission manufacturers successfully use AVL-DRIVE™ and AVL VSM™ in engine and powertrain development and for quality assurance.

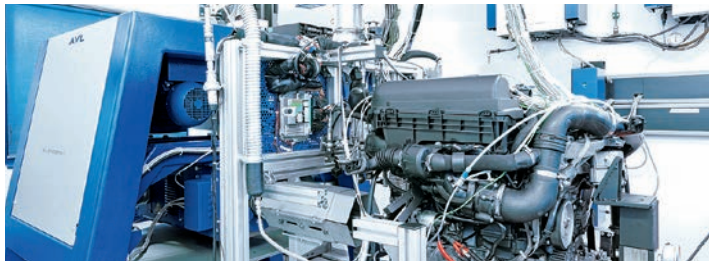
Installed Base

More than 3,400 testbed control systems of the current generation, including stand-alone ones, are in successful use, proving their capabilities around the clock.

A CONTINUOUS CONCEPT FOR ALL TEST JOBS – EASY TO OPERATE, SCALABLE, APPROVED ON MORE THAN 3,400 TESTBEDS.

Dynamometer Control Stand-Alone BME 400

The operating panel P400 is integrated in the Stand-Alone controller case. The F-FEM-CON Advanced provides the controller with I/O for control and monitoring of the dynamometer. The F-FEM-DIO provides 16 additional digital inputs and outputs.



The AVL Stand-Alone digital dynamometer control systems consist of hardware and software for controlling a variety of dynamometers. The system uses proven algorithms to control the dynamometer and, depending on the configuration, also combustion engines. The dynamometer conditions are monitored with predefined and definable responses. The control system has an ergonomically designed operating panel. Incremental pulse wheels permit the exact setting of demand values while the bumpless change of control modes is ensured. The LCD shows demand and actual values as well as parameter settings and operating menus. Alarm and warning messages are also displayed. Function buttons with LED status are available for selecting operating modes and control functions.

TECHNICAL FEATURES

The control software operates on powerful INTEL™ hardware with an INtime® real-time operating system. The input and output of signals to the dyno and to the throttle actuator happens via the F-FEM-CON Advanced and F-FEM-DIO modules which are connected via an IEEE1394 interface. The operating panel allows the operation of the dyno using push-buttons and incremental pulse wheels. Different control modes are used to control the torque or speed of the dynamometer and the throttle position of the unit under test.

APPLICATION

AVL Stand-Alone dynamometer control systems have multiple interfaces to connect to all types of testbed automation systems. To use the parameterization capabilities of AVL PUMA Open™, the Stand-Alone control system can be upgraded to be operated via the AVL automation system.

BENEFITS AT A GLANCE

- Precise operation through excellent torque and speed control stability over the whole performance range
- User-friendly handling through the ergonomic design of operating elements and flexible parameter adjustment via the display
- Stand-alone operation
- Bumpless change of control modes
- Upgrade of control system to be integrated in the AVL testbed automation system AVL PUMA Open™
- Communication with a host system by means of hybrid or digital interfaces like CAN, Ethernet, RS232
- Reliable and approved safety concept

Engine & Dyno Controller EMCON Stand-Alone Advanced

The AVL EMCON 400 Stand-Alone Advanced is a complete digital testbed control and monitoring system for a combustion engine and dynamometer on an engine testbed. Like the BME 400, it has an ergonomically designed operating panel and the same control I/O. AVL EMCON 400 Stand-Alone Advanced includes a runtime environment to execute MATLAB®/Simulink®-based real-time applications created with AVL ARTE.Lab™ on the same controller HW. Real-time applications can be started individually or automatically with AVL EMCON 400 Stand-Alone. An AVL EMCON Stand-Alone Advanced web client enables the parameterization of the controller by using the standard browser on the office PC or directly on the controller workstation. The Web Client provides a number of intuitive and user-friendly GUIs to edit some of the most frequently used AVL EMCON database arrays.

TECHNICAL FEATURES

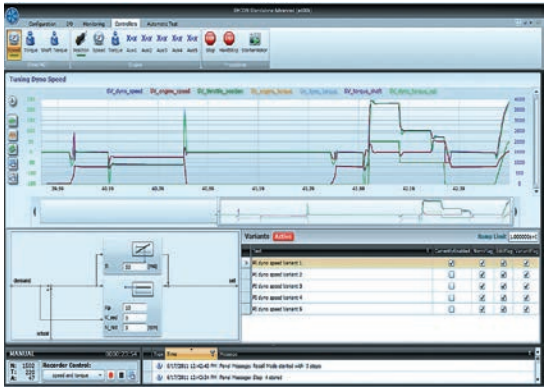
The control software operates on a powerful INTEL™ hardware with an INtime® real-time operating system. It uses the same control I/O as the BME 400 and the AVL automation system AVL PUMA Open™. As the same hardware is used, a direct upgrade path to AVL PUMA Open™ is available.

APPLICATION

Like the BME 400, the AVL EMCON Stand-Alone Advanced can be connected to all types of testbed automation systems by means of different hybrid or digital interfaces. At the same time, parameterization of the controller is possible by using the standard web browser on the office PC connected via Ethernet. The MATLAB®/Simulink®-based real-time applications can automatically be integrated while model start/stop and online parameterization is managed via a common application desktop.

BENEFITS AT A GLANCE

- Features as of Stand-Alone BME 400
- Additionally full support of combustion engine control
- Fast controller parameterization due to user-friendly GUI
- Online graph for support of controller tuning
- Execution of customer-specific MATLAB®/Simulink®-based real-time models on the same AVL EMCON Stand-Alone Advanced HW
- Automatic real-time model integration on the AVL EMCON Stand-Alone Advanced HW
- Upgrade of control system to be integrated in AVL PUMA Open™



Access to the parameters of the controller I/O, dyno and engine via the standard web browser. An online graph supports controller tuning.

EXPERIENCE THE PERFORMANCE

AVL EMCON 6™

MARKET REQUIREMENTS

Better comparison of vehicle components

In series production the quality of produced parts needs to remain on the highest level to fulfill the end customer's expectations. Decreasing quality produces serious damage to a company's reputation and leads to expensive product recalls.

Safety for expensive prototypes

Prototypes of newly-developed vehicle parts are rare and expensive. When testing the prototypes' limits – for example, their performance or longterm durability – a reliable safety net is important.

AVL SOLUTION

AVL EMCON 6™ is the leading control and monitoring system for engine, e-motor, powertrain and chassis dyno testbeds. Based on proven control algorithms, it provides an accurate reproduction of test cycles.

ETC FEM FIO in operation

AVL EMCON 6™ is fully integrated into the AVL PUMA Open 2™ automation system. AVL EMCON 6™ fully supports the AVL Integrated Open Development Platform.

BENEFITS AT A GLANCE

- Bundling of know-how gained from engineering and testing
- EtherCAT® dyno interface for fast control of up to 10 kHz
- Very low latency time in control loops
- Reliable and approved safety concept
- Worldwide racing experience
- Future-proof due to application-specific solutions

ENRICH YOUR TESTING

AVL ARTE.Lab 4™

AVL ARTE.Lab 4™ is an open simulation environment for the integration of real-time applications into AVL PUMA Open 2™ and AVL EMCON Stand-Alone Advanced. AVL ARTE.Lab 4™ uses MATLAB®/Simulink® for modeling of engine and powertrain components and systems as well as other real-time applications. It consists of the development environment AVL ARTE.Lab 4™ Studio SDK and the run-time environment for the execution of real-time models AVL ARTE.Lab 4™ RTE. A generic Model Parameter Editor (MPE) allowing the smooth management of the model parameters at run-time is provided.

AVL ARTE.Lab 4™ Explorer is an extension to visualize internal processes of the MATLAB®/Simulink® based real-time applications. The model development is done on a development PC where the model behavior can be analyzed and the real-time capabilities of the application can be tested before the model deployment on the testbed which saves testbed time. The model integration in the AVL automation system AVL PUMA Open 2™ or in the controller AVL EMCON Stand-Alone Advanced is automated while the same real-time application can be used on both systems without model adaptions.

APPLICATION

Customers can develop and execute their own real-time applications on different testbed types. Common applications are:

- Simulation of transmission models, vehicle models, engine models, testbed simulation and driver models or extended AVL standard simulation models
- Formulas: e.g. map-based feed-forward path of controllers
- Controllers: e.g. combustion controllers, media controller
- Filters: e.g. filters of higher magnitude
- On-line analysis of measured values

BENEFITS AT A GLANCE

- Seamless integration of customer-specific Simulink® models
- Fast changes to the real-time applications at run-time
- Online parameterization of models with Model Parameter Editor
- Update/calculation frequency of models up to 1 kHz
- Automated model integration in AVL PUMA Open 2™ and AVL EMCON Stand-Alone Advanced
- Central administration and distribution of real-time applications in a test field
- Rapid prototyping by model analysis at run-time with AVL ARTE.Lab 4™ Explorer

THE QUICK ENTRY TO SIMULATION

AVL ISAC 6™

MARKET REQUIREMENTS

The need for a standardized look and feel

Different systems and software products currently require a significant training period. Therefore, a lot of unused time is lost before being able to reach a smooth operation mode.

Quick entry to simulation

Simulation for non-existing hardware needs to be available but not visible. Furthermore, it is required to ensure an immediate use of the simulation on the testbed.

Robust operation on the testbed

Simulation is integrated increasingly into day-to-day tasks. This increases the demand for tools that are easy to handle and able to guarantee a robust and stable simulation.

AVL APPROACH

With AVL ISAC 6™, real-time simulation is just one click away. It allows simulation of vehicle, transmission, driver and road load.

Unified user experience

With the unified user experience of automation, control and simulation, operation of the software becomes easier. Training effort decreases, which allows an immediate productive use of the tools.

Embedded simulation

The AVL ISAC 6™ simulation is a well-integrated part of the automation system AVL PUMA Open 2™. Starting and operating the simulation needs no additional action nor effort.

BENEFITS AT A GLANCE

- Open for customer simulation models connected internally or externally
- Reproducible drive cycles
- Highly accurate and dynamic AVL ISAC 6™ driver
- Realistic gear shifting simulation for shift behavior analysis

AVL ISAC 6™ – REAL-TIME SIMULATION TRANSMISSION MODELS

The AVL models for automatic transmission, CVT (continuously variable transmission) and DCT (double clutch transmission), allow the realistic and reproducible simulation of the expected load on the combustion engine in the vehicle. Standard AVL simulation models for the driver, the vehicle and the drive train are also used for this purpose.

INTEGRATION OF OPERATING MODES

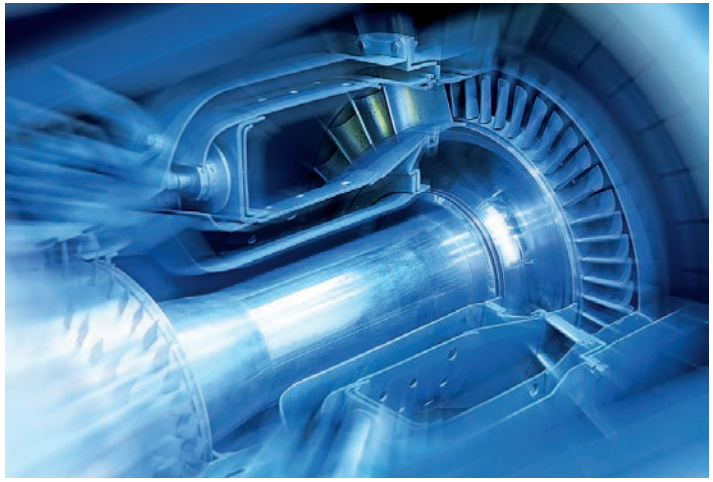
To obtain realistic measurement results of legal emission test cycles, e.g. FTP75, the AVL ISAC 6™ simulation integrates all important operating modes of the engine in the vehicle. This includes the vehicle speed control via accelerator pedal and vehicle brake as well as the simulation of realistic starting from rest and coast down.

USER-FRIENDLY PARAMETER HANDLING

All model parameters are standard transmission parameters and can be obtained from the manufacturer. Thanks to a Model Parameter Editor, they are included in a complete package. This user-friendly graphical interface makes it easy to change and store the model parameters. Additionally, the parameters can still be changed online while the test is running.

BENEFITS AT A GLANCE

- Cost saving by transferring tests from the road to the dynamic engine testbed
- No external hardware required to enable online simulation
- Reproducible results
- Models can be fully parameterized
- Integration of customer components by using AVL ARTE.Lab 4™



EFFICIENT DRIVING PLEASURE

AVL VSM 4™

Due to the constant reduction of CO_2 limits, it is necessary to find the right balance between affordable CO_2-reduction measures and a positive driving experience. Additionally, in order to save time and cost, crucial tasks have to be shifted to an earlier stage in the development process. One important aspect, in this context, is the end customer satisfaction that can be achieved by class-leading and brand-related driveability.

Therefore, the OEM's objectives are:

- Initial definition of vehicle attributes: driveability, handling, ride comfort, performance, lap time
- Early target definition & chassis development
- Early prediction and optimization of the technology required
- Forecasts of the behavior of engine/powertrain and vehicle with specific components and the effects of single component changes
- Early identification of design and calibration issues to avoid design changes
- Fast and easy calibration and validation without vehicle prototypes

AVL VSM 4™ is a comprehensive vehicle dynamics simulation package that precisely predicts vehicle behavior and enables improvement of various vehicle attributes, from the initial concept to the testing phase.

APPLICATIONS

- Driveability calibration and development in office, HiL and engine/powertrain testbeds
- Performance simulation
- Lap time optimization
- Balancing vehicle CO_2 and driving pleasure
- Handling and vehicle stability
- Steering development and testing
- Optimization of primary ride comfort on virtual shaker rig
- Active chassis and suspension development

BENEFITS AT A GLANCE

- Enhancement of vehicle driving pleasure
- Maintaining vehicle brand driving characteristics while fulfilling CO_2 legislation limits
- Reduction of development time thanks to targeted frontloading
- Significant reduction of development costs
- Surpassing competition in driving performance
- Increase of product quality

DRIVE YOUR BRAND-DNA

AVL-DRIVE 4™

Increasingly stringent emission legislation on a global level as well as cost pressure have strong effects on vehicle design and characteristics. The choice of CO_2 and efficiency measures from the powertrain to the vehicle is all about balancing cost and positive driving attributes such as driveability, handling and ride comfort, thus creating the vehicle's "DNA".

These driving attributes describe the qualitative assessment of the vehicle's response to the driver's input and are important factors of brand identification. An outstanding level of these attributes greatly enhances the overall driving experience while an acceptable level is an essential prerequisite for driving pleasure and purchase decision.

AVL supports customers to:

- Provide a high driveability quality level for vehicles with all powertrain configurations
- Handle the trade-off between emissions, fuel economy, high performance and driveability
- Guarantee an agreed vehicle character (branding)
- Manage increased vehicle complexity
- Increase efficiency (target-driven development)
- Reduce time-to-market
- Reduce development costs

APPLICATION

AVL-DRIVE 4™ allows vehicle and powertrain development engineers to objectively assess, analyze and optimize subjectively perceived powertrain and vehicle attributes such as driveability and performance, ride comfort and handling, perceived safety and driving comfort of ADAS systems.

AVL PRODUCTS FOR OBJECTIVE DRIVING ATTRIBUTES ASSESSMENT

- AVL-DRIVE 4™ – Driveability
- AVL-DRIVE 4™ – Handling
- AVL-DRIVE 4™ – Ride Comfort
- AVL-DRIVE 4™ – ADAS

BENEFITS AT A GLANCE

- Objective real-time assessment provides instant feedback on driving attributes' quality issues
- Automated driving attributes assessment, data management and reporting support efficient and target-driven development
- Common language between development areas and within the supply chain
- Reproducible assessment of driving attributes based on measured physical values
- AVL-DRIVE 4™ is designed for all phases of the development process, from pure math to lab or on-road vehicle testing

Test Information Management

APPROACH

Since the beginning of networking testbeds in the early eighties, AVL has been working on optimized solutions to support specialists in the fields of planning and preparation of test jobs, including support at the testbed and further processing of test results. The continuity between individual components form a highly efficient information chain from development to test facilities, making an important contribution to increasing the efficiency of the overall development process.

A significant productivity gain in testbed utilization can be achieved by integrating all test systems in a central data management system, minimising delays and downtimes at the testbed. An unique balancing of standardization and flexibility is the key to increased productivity.

BENEFITS AT A GLANCE

- Enhanced utilization of testbeds (according to an AVL study, an average potential increase of 20 percentage points)
- Optimization of the productive test time
- Reduced time and costs for administrative activities due to central data management
- Fast response times due to remote monitoring of the entire test facility

PORTFOLIO

Central Data Storage for Testbeds

Using the AVL SANTORIN HOST™ system (more than 300 installations worldwide), all data is organized centrally within the test facility in a shared database and provided to testbeds across several applications, from engine tests and transmission systems to component tests.

Testfield Management

AVL TFMS 1™ enables standardization and automation of core processes within the test field. The central tasks of the system are to manage all data in an efficient manner and handle all activities related to test jobs, test equipment and units under test.

Remote Monitoring of Testbeds

AVL TESTGATE™ provides users within a test facility with efficient remote access to the online data of the testbeds and HOST systems via a web browser, offering a real-time overview of the status of all testbeds.

Global Data Management

AVL SANTORIN MX 2™ is an intelligent central data management system that meets today's and future challenges of OEMs. No matter where data come from, the system stores heterogeneous data in a consistent and synchronized way. It logically connects data from various sources and enables a harmonized data view. The unique combination with AVL CONCERTO 5™ offers the possibility for detailed result visualization and reporting.

CENTRAL DATA STORAGE FOR TESTBEDS

AVL SANTORIN HOST™

Individual automation systems are networked with a productive test facility in an ideal manner. Parameters and results are centrally stored in a database, standardized in accordance with the ASAM-ODS standard, and the data is available for all users at any time. AVL HOST systems are designed for test facilities with between 1 and 70 automation systems.

APPLICATION

To achieve continuous utilization of testbeds, all activities impairing continuous test operation have to be kept away from the testbed. These activities include, for example, the definition of the test run parameters and the analysis of the result data.

Furthermore, efficient test facility operation is only guaranteed when the data can be applied and compared to several testbeds. For this, all data, such as variables, units, dimensions, fuel data, calibration data, formulae, etc., are stored on the central data server and made available to the testbeds. As a result, centrally created test runs can be executed on different testbeds and the result data can be compared between different testbeds. The results are analyzed either locally at the testbed or at the office workstation.

The integrated interfaces, standardized in accordance with ASAM-ODS, provide many third-party suppliers with access to information within the test facility by means of open, defined programming interfaces and file formats.

BENEFITS AT A GLANCE

- Comparable measurement data throughout the test facility thanks to a central database containing all measurement data and variables for testbeds from AVL and other suppliers
- Shorter setup times with parameterization from the office
- Shorter downtimes with data analysis in the office
- Reduced costs and time for administrative activities due to central data management for parameters and result data
- Efficient user management due to centrally managed access rights for testbeds and analysis
- Simple data exchange with external systems through open interfaces standardized in accordance with ASAM-ODS

UNLEASH DATA POWER

AVL SANTORIN MX 2™

AVL SANTORIN MX 2™ is an intelligent central data management platform. No matter where the data comes from, MX stores heterogeneous data in a harmonized, unified and synchronized way. It shows logical connections between the contents as well as providing a uniform access mechanism. With AVL SANTORIN MX 2™ the processing task is given a new dimension: users can trigger one or more real time processing. AVL SANTORIN MX 2™ is a unified and all time accessible data platform for users complying with the globally-approved ASAM-ODS standard.

AVL SANTORIN MX 2™ represents a new dimension of data management

APPLICATION

Within the framework of the engine and powertrain development process, there is an increasing need to link information between different test applications. The sources of this information are test facilities of different generations and manufacturers. The testbeds for applications such as engine development, transmission testing, endurance tests, noise and vibration tests or crash tests provide non-compatible results in different file formats. Therefore, a significant gain in terms of testing productivity can be achieved by integrating all the systems into one single platform.

BENEFITS AT A GLANCE

- Central data storage of heterogeneous data from different test facilities or locations (AVL or 3rd party testbeds)
- Easy, fast and secure data access within AVL Navigator
- Reduction of time and cost of administrative activities due to standardization and centralization of test data
- Easy integration of data analysis platforms such as AVL CONCERTO 5™
- Intelligent and high quality data integration

EXPERIENCE THE HARMONY

AVL CONCERTO 5™

AVL CONCERTO 5™ is the generic data processing platform for visualizing, analyzing and reporting many measured and simulated data types. Its open interfaces and integrated comparison mechanisms empower it to be the data correlation tool for automation, simulation and measurement systems. What is more, the platform offers toolboxes with application-specific functionalities and Pro Apps for complete data pre- and post-processing solutions. This makes AVL CONCERTO 5™ the smartest way to turn data into decision-relevant information.

APPLICATION

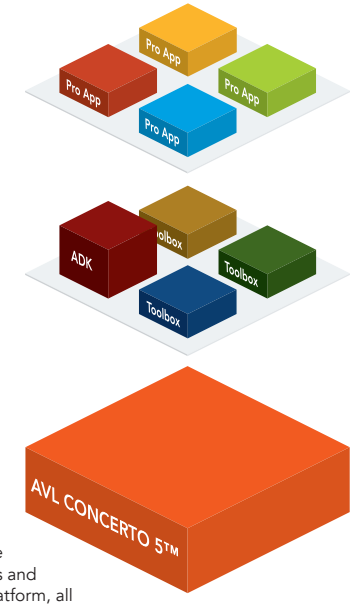
Due to its modular concept consisting of toolboxes and Pro Apps, AVL CONCERTO 5™ ideally supports dedicated application fields such as evaluation of testbed data, detailed combustion analysis, evaluation of emission data, reporting of engine calibration data, visualization of hybrid testbed data and much more.

AVL CONCERTO 5™ builds a common platform for all data processing tasks within one tool:

- From generic data management (including search, filtering and navigation options)
- Through interactive analysis (e.g. advanced cursor functionalities)
- And calculation possibilities (integrated calculation tools from simple calculator to advanced programming environment and formula editor, including pre-defined libraries for application-specific calculations)
- To sophisticated reporting functions (from simple diagrams to reduction of data evaluation time due to fully automated advanced reports)

BENEFITS AT A GLANCE

- One platform for harmonization, standardization and applications
- Highest data performance, intuitive data search and interactive calculations
- Consistent pre- and post-processing
- What-You-See-Is-What-You-Get reporting
- Fully automated evaluations and integration of third-party algorithms



AVL CONCERTO 5™ as software platform meets today's and future challenges for toolboxes and Pro Apps. Within the platform, all standard file types as well as a broad range of graphical diagrams for different visualization needs and styles are available.

LEADING EFFICIENCY

AVL TFMS 1™

AVL TFMS 1™ is the first modular system to standardize and automate the core processes within the test facility. The core tasks of the system is to manage all data in an efficient manner and activities related to test jobs, test equipment and units under test. Traditionally, this is implemented by different people with the help of different systems.

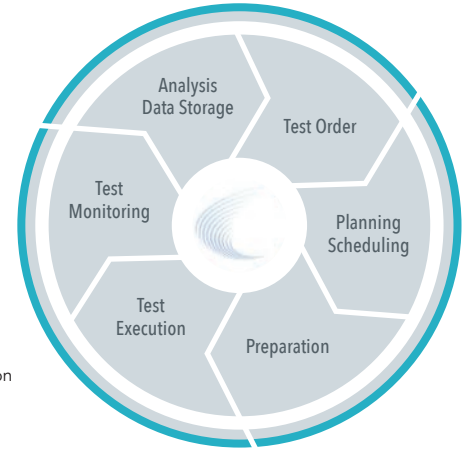
APPLICATION

While there is a trend towards increasing the complexity of the processes and diversity of systems in test facilities, the test costs must be dramatically reduced. Simultaneously, the reliability, reproducibility and quality of the process need to be improved. AVL TFMS 1™ supports users in achieving these seemingly contradictory objectives.

To support the seamless implementation of test processes, the system controls the work steps and provides all data and documents that are relevant in the corresponding step. In this way, the planning, definition and implementation of test jobs, as well as inventorying, maintenance, and calibration of test equipment are managed and optimized with the help of the AVL TFMS 1™. The existing system environment within the test facility is not replaced, but the AVL TFMS 1™ integrates and interacts with the existing systems, such as project management, unit under test and calibration data management. Thus, the system taps into the unused productivity potential of a test facility through cross-networking and providing the corresponding information at the right time and place.

BENEFITS AT A GLANCE

- Higher utilization of testbeds (typically an increase of 20 percentage points, according to an AVL study)
- Reduction of non-productive time (e.g. test repetition due to incorrect methodology or erroneous parameters)
- Reduction of the time and costs of administrative activities and redundant, manual data transfers
- Continuous utilization optimization through comparison of planned and actual utilization
- IT-supported standardization and continuous optimization of the workflow



AVL TFMS 1™, our modular test facility management system, can be configured for many applications (engines, gears, components, rollers etc.). Open, standardized interfaces make AVL TFMS 1™ easy to integrate into existing IT infrastructures, guaranteeing automated information flow from job order to the conclusion of a test.

FAST REMOTE TESTBED ACCESS

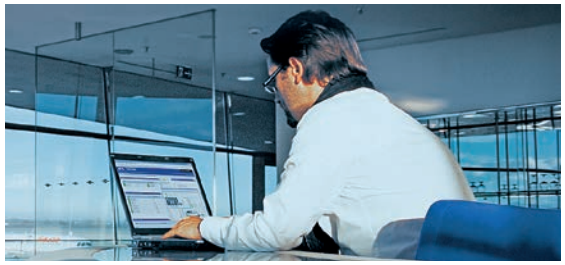
AVL TESTGATE 1™

You can easily gain an overview of the status of the entire test facility through the internet and web browser from your office, while traveling or from any other location with internet access. You can retrieve the current status of all testbeds, loaded parameters and online measurement values at any time.

APPLICATION

Within the test facility, AVL TESTGATE 1™ supports users of different fields in monitoring, managing and diagnosing testbeds.

- The testbed operator can retrieve data from AVL PUMA testbeds (PUMA 5.5, PUMA 5.6 or AVL PUMA Open 2™), from 3rd party testbeds and from HOST systems to obtain a detailed status overview
- Testbed administrators receive an overview of the entire test facility and can determine the status of the overall test facility in a very efficient manner. Thus, they can quickly diagnose malfunctions by navigating to a certain testbed from the overview and retrieving details
- The development engineers can use AVL TESTGATE 1™ to observe the status of their testbed. Furthermore, they can support testbed operators from their office or home office by means of internet connection



Furthermore, AVL TESTGATE 1™ makes use of the existing security mechanisms of the test facility, thus avoiding additional user management tasks within AVL TESTGATE 1™.

BENEFITS AT A GLANCE

- Fast and safe remote access to testbeds with any internet connection
- Clear, graphical status representation of all testbeds within the test facility
- Reduced response times for support activities
- Improved and simple access to test information and administrative information
- Simple company-wide roll-out without software installation on the office computer: AVL TESTGATE 1™ requires a standard web browser

AVL Customer Services

APPROACH

We at AVL Customer Services have designed a portfolio to "serve our customers anywhere, any time, with everything necessary to achieve their testing objectives".

Total Cost of Ownership

Through our services the value of your test equipment will be maintained and even increased while keeping the total costs of ownership down to a minimum.

Maximized Utilization

New technology provides new functions and features. AVL Customer Services helps you maximize the use of your equipment. Combining premium AVL testing technology with the best possible services ensures an optimized product and service package.

Comprehensive Service Portfolio

Our smart portfolio of Service Modules and Service Solutions meets all your requirements, from basic and everyday service needs to fully tailored service packages for complete test fields.

Global Solution Competence

AVL's global service network of highly qualified experts in more than 50 locations provides the know-how, proximity and responsiveness that is essential in today's globalized, fast-paced world.

BENEFITS AT A GLANCE

- Short ramp-up phase
- Maximized long-term availability of test equipment
- Optimized investment protection through tailored Service Solutions
- Safe and reliable operation due to knowledge transfer from AVL's experts
- Application-specific solutions for individual testing tasks

TASK

Running a test system is an extremely challenging task both technically and economically.

AVL's Service Solutions safeguard the availability and usability of your testing equipment and measurement devices in all phases of the product lifecycle, avoiding the high cost of operational downtime and the risk of inaccurate test results.

In case the unexpected happens, AVL Customer Services has highly qualified service personnel ready to be at your site in the shortest possible time. AVL Customer Services can share its expertise with your experts in the form of professional training and support. This is what we call the "fast track to comprehensive skills and results."

Leading edge technology needs innovative Service Solutions. AVL Customer Services provides the best possible solutions as a partner to many of the industry's leading companies – every single day.

EXPERIENCE THE ADDED VALUE.

FIX
Hotline Support
Hardware Repair
Spare Parts Management

MAINTAIN
Equipment Calibration
Hardware Maintenance
Software Maintenance
Device Overhaul

USE
Training
Start-up & Operation Support
Testbed Operations

OPTIMIZE
CAREline Support
Software Subscription
Application Support

SERVICE MODULES + **SERVICE SOLUTIONS**

INTEGRATED RESIDENT SERVICES
Make or buy

APPLICATION SERVICES
Doing the right things right

AVL CARE™
Connecting with Customer Objectives

Our Service Modules are structured according to customer usages: Fix. Maintain. Use. Optimize.They are focused to support everyday service needs.

Our Service Solutions are comprehensive and tailored service packages which are developed for individual customer needs in their specific testing environments. Service Solutions combine relevant service modules with additional skills, knowledge and methodologies. The aim is to improve the overall productivity of test fields beyond the optimization of individual systems.

Fix

COMPETENT AND FAST SYSTEM RECOVERY

Get systems up and running again as quickly as possible.

HOTLINE SUPPORT

The AVL Hotline Support service provides fast telephone and email support for any technical issue or question related to the usage of AVL equipment. All requests will be handled in a professional manner and answers and advice provided where possible.

HARDWARE REPAIR

In the case of unexpected equipment breakdown, AVL has a range of professional repair and rental services to minimize downtimes by restoring the equipment to full functionality as quickly as possible and providing alternative solutions in the meantime. If possible, the equipment is repaired on site. If this is not possible, for example if special technical facilities are needed or calibration is necessary subsequent to repair, AVL offers off-site Factory Repair at certified repair centers as well as rental equipment.

SPARE PARTS MANAGEMENT

AVL Spare Parts Management covers a range of services that makes procurement and supply of critical and non-critical spare parts as smooth and efficient as possible. The services ensure that you receive the right spare part at the right time, in the right place, thus avoiding unplanned downtimes, minimizing process costs and reducing fixed capital.

AVL eSpares plus™ is an easy-to-use web shop with all AVL's standard spare parts. The online shop is the heart of AVL's Spare Part Management platform and has been redesigned for easier part identification, more detailed information including online availability checks, simplified automated part ordering and fast delivery.

Quick response and recovery of your system functionality

Maintain

PROFESSIONAL PREVENTATIVE MAINTENANCE

Reduce risk of unexpected breakdowns.

EQUIPMENT CALIBRATION

AVL provides on-site and factory calibration & adjustment services to ensure that your AVL equipment is properly and regularly calibrated, according to defined quality and/or legislative standards and that your measuring results are accurate, consistent and plausible.

HARDWARE MAINTENANCE

The AVL Hardware Maintenance program consists of preventative measures to ensure the longevity of your equipment and to avoid unexpected breakdowns. The service is carried out on site by certified AVL Service Engineers. The quality and availability of the service are guaranteed by exclusive use of original AVL parts and by compliance to fixed maintenance procedures.

SOFTWARE MAINTENANCE

AVL Software Maintenance is a special service designed to provide you with fast software solutions and to keep your software running (low technical downtime). AVL Software Maintenance is available only in combination with the AVL CAREline Support Service.

DEVICE OVERHAUL

AVL Device Overhaul is a service we offer for older test devices where we carry out an in-depth maintenance operation and replace those parts that we know from experience may cause problems in the near future. Device Overhaul is both a preventative step, to avoid breakdown, and also an opportunity to considerably extend the lifetime of the device. The Device Overhaul takes place off-site at one of our Repair Centers.

For entire test systems we offer on-site health checks. Findings are summarized in a report and any necessary action proposed.

Securing the value of your test systems

Use

SAFE AND EFFECTIVE OPERATION

Ensure equipment is being used productively.

TRAINING

AVL Training consists of a comprehensive range of training courses to ensure your staff can safely and effectively operate AVL equipment and competently perform a wide range of testing tasks. An investment in training is an investment in employee motivation and skills that in turn will have a positive effect on competitiveness. Correctly trained system operators can also extend the lifetime of your equipment.

START-UP & OPERATION SUPPORT

AVL Start-Up & Operation Support is a service we offer to customers who have either newly installed AVL test systems or new staff members. For this initial period of getting used to the new system,

Fast track to comprehensive skills and usage of your test systems

AVL provides one or more technical engineers to show staff how to set up and use the system, how to solve problems, and generally answer any questions that may arise.

The advantage of this approach is that you can use your system productively within a very short period, as operators have learnt the most important operational steps, test procedures have been defined and tests configured.

TESTBED OPERATIONS

With the AVL Testbed Operations service, you can hire one or more fully-qualified test engineers for a certain time. This service is particularly useful if you are short of staff or during periods of heavy workload.

AVL takes care of specific and agreed tasks and jobs embedded in your primary value creation chain. In line with a defined work split, AVL will help you focus on your core competencies. Agreed KPIs will ensure a seamless interaction within teams and responsibilities.

Optimize

MAXIMIZE EQUIPMENT VALUE AND USE

Get the most out of your investment.

CAREline SUPPORT

AVL CAREline Support is a contract-based service that provides you with specialized support for your AVL test equipment and AVL software – at any time. We provide fast assistance when you have any problems operating or using your test system, taking full ownership of the issue until it is resolved. AVL CAREline Support is provided to customers in combination with AVL Software Maintenance and/or Hardware Maintenance in the context with an AVL CARE™ contract.

SOFTWARE SUBSCRIPTION

The AVL Software Subscription is an extension to the AVL Software Maintenance and AVL CAREline Support service and guarantees you upgrades of your AVL software products to the latest release within the contract runtime. The service ensures you are up to date with the latest features and fixes and can benefit from any new functionality.

APPLICATION SUPPORT

AVL Application Support is the service we offer to assist you "on the job" in using AVL testing equipment for a specific application. This is particularly helpful for challenges caused by new testing tasks as well as upcoming changes in legislation. Application Support is a highly practical and targeted service that helps you reach and maintain a high level of productive operation within a short period of time.

Specialized assistance for efficent testing

AVL CARE™

CONNECTING WITH CUSTOMER OBJECTIVES.

Benefit from more time for your core competence

The content and level of services in an AVL CARE™ agreement are defined between AVL and our customers according to specific objectives. The agreed services are easily accessible and their performance can be monitored using measurement indicators, showing objectives are achieved. This makes planning easy and reduces costs.

The focus of the agreement is on the support by the AVL CAREline. CARE customers have clearly assigned contact persons with guaranteed expertise and defined response times, resulting in quick solutions in case of problems.

SOFTWARE CARE

Software-related service level agreements typically include software maintenance and software subscription, guaranteeing access to the latest software and functionality. Upon customer request, the agreement also includes installation services as well as the required services for performing software upgrades.

HARDWARE CARE

Hardware-focused service level agreements contain the maintenance and repair of measurement devices and testbeds, as well as customer-specific spare parts solutions. High technical availability of the systems, best measurement result quality as well as continual and professional support of the installed testing equipment are ensured. Scalable commercial frame conditions (ranging from delivery-related billing to all-inclusive solutions also including unplannable service visits and spare part needs) provide a high degree of flexibility in designing service level agreements.

BENEFITS

- Efficient use of software and devices thanks to quick and solution-oriented support by product experts (AVL CAREline)
- Uniform software levels ensure that test operation is optimized for the application
- Hardware and software value protection through regular maintenance work
- Reduced ongoing operating costs through plannable services, product experts and high-volume scaling effects

Application Services

DOING THE RIGHT THINGS RIGHT.

OEMs have to adopt the latest methodologies and tools to fulfill today's demands and future targets in calibration and powertrain vehicle testing. An organization must have:

- Correctly specified, reliable facilities (testbeds, instrumentation and tools)
- People with the appropriate skills to get the most out of available tools and methodologies

AVL provides Application Services by assigning application experts who are temporarily or permanently on site and work at the customer's facility together with the customer's personnel. Examples:

APPLICATION SERVICES FOR ENGINE TESTBEDS

AVL experts provide extensive knowledge, e.g. in the use of AVL CAMEO and AVL PUMA Open in xCU diesel or gasoline calibration tasks. Post-processing, for example in the form of model-based approaches, can also be part of these services. Application Services lead to the productive use of new methodologies, e.g. "Design of Experiment" (DoE) and tools in ECU calibration.

APPLICATION SERVICES FOR POWERTRAIN TESTBEDS

There are different combinations of configurations and testing targets for powertrain testbeds: This could be for a transmission with electrical drive unit or for complete hybrid powertrain with 4WD. To meet this broad range of goals, AVL experts help answer the following questions: How can durability in relation to a specific load profile be investigated? What is the best approach to evaluate shifting behavior of an automatic transmission, or to pre-calibrate a TCU? How can a specific test from the road be brought into the test cell? AVL provides the competence to show the possibilities and limitations of new approaches.

BENEFITS

- Reliable and optimized application of test systems
- Reduced development time due to less test and measuring effort, e.g. through high testbed automation rate
- Improved quality of development processes through consistent, standardized processes
- Higher quality of results, e.g. through use of online data plausibility checks, statistical raw data evaluation and model-based approaches
- Sustainable use through know-how transfer from AVL

Optimized quality and efficiency in testing and development

Integrated Resident Services

MAKE OR BUY.

Integrated Resident Services (IRS) are customer-specific partnership models. These models comprise servicing the test equipment and the implementation and execution of test programs. IRS means that customers can concentrate on core competences, reduce their costs and optimize productivity.

The partnership model for test field productivity

MAINTENANCE/REPAIR SERVICES

The partnership model comprises all activities in the field of maintenance, repair and device calibration, including the coordination of sub-contractors and other suppliers.

SUPPORT SERVICES

Support services include user support and/or test procedure configuration, problem/case analysis and solutions, data post-processing and result analysis. Possible objectives are an accelerated start-up, system optimization, continuous process enhancement and knowledge transfer to customer personnel.

OPERATING TESTBEDS

AVL can provide operating services or even take over full responsibility for the operation of a test facility. This typically includes mounting the unit under test, implementing the test program, monitoring the test procedure, checking the data for plausibility, managing the resources and documentation.

BENEFITS AT A GLANCE

- Maximum efficiency in test operation thanks to the know-how and experience of the testing staff
- Secured functionality and guaranteed technical availability of testbed systems
- Optimum deployment of personnel according to the actual work load
- Reduced costs due to well-defined processes and responsibilities, allowing the focus on core competences

AVL Customer Services – Experience the Added Value.

REFERENCES

Global Presence and Service Quality

AVL operates a worldwide network of service experts. More than 700 service employees in the field are ready to assist our customers at more than 50 locations. Fourteen hotlines also guarantee our customers access to professional support.

AVL CARE™

AVL CARE™ controls services for more than 1,600 testbeds globally. A CARE agreement with clearly defined performance criteria guarantees the efficient operation and maintenance of software and hardware. Our AVL CAREline team offers you fast and direct access to expert support.

Integrated Resident Services

More than 75 customers worldwide benefit from a permanent on-site AVL team at their test facilities. Maintenance, support and operation of more than 1,500 testbeds (customer and AVL internal) is carried out by AVL teams.

Application Services

AVL supports you in increasing efficiency and testing effectiveness. Using the right calibration methodology and infrastructure can reduce testing time by more than 70 %. A tailored service concept can boost utilization rates to over 80 % and technical availability to over 97 % due to AVL's combined know-how in testing and engineering.

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