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.

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.

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.
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
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.
Injection Nozzle Flow, Cavitation and Erosion

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.

**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.
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 correlation 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.
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-\(\varepsilon\), PANS, LES), wall treatment and heat transfer.
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.
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

CO₂ 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.

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.
REDUCING CO₂-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.
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.

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.
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 CO₂ 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.
EFFORT REDUCTION IN GEAR SHIFTING PROGRAM DEVELOPMENT

To achieve CO₂ 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.

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 3kHz. 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.
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.
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.

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-lon 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.

ENERGY EFFICIENCY IS THE FINAL GOAL
Vehicle component and sub-system 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.
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.
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.
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.
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.
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 of 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.