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Fahrbarkeitsuntersuchungen auf dem Rollenprüfstand

Driveability Analyses on a Chassis Dynamometer

Since introducing AVL-Drive as objective vehicle driveability assessment tool the entire system has been improved considerably. Nowadays, more driveability measurements are done on the roller chassis dynamometer to perform basic Engine and Transmission application tasks and fine adjustments much quicker with improved reproduction quality.

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1 AVL-Drive on a Chassis Dynamometer – the Basics

AVL-Drive has proven itself to be an objective analysis and evaluation system for providing an efficient driveability testing method to determine subjective driving pleasure. Vehicle developer, suppliers, and AVL itself use it as a development tool in the entire engine and vehicle development process for passenger vehicles, HDVs and busses, **Figure 1** [1-4].

The aim of AVL-Drive is to calculate and evaluate objective parameters which correspond to the human feeling of driving pleasure. Criteria like the engine response feeling which is often commented by vehicle test drivers can be evaluated objectively, based on the objective ratings and parameters aimed ECU calibration optimisation can be done to reach higher driving pleasure. Over the last few years, the system has been further developed intensively for transmission calibration to adjust higher shifting quality of automatic gearboxes.

AVL-Drive analyses up to 360 powertrain and ECU-TCU assessment criteria relevant for calibration (torque development, clutch to clutch calibration shifting gears, load change behaviour). These criteria are used to analyse up to 75 defined driving statuses (such as part load acceleration, WOT acceleration, launching, shifting gears, load change), **Figure 2**.

The driving modes are detected and the driveability is evaluated through objective evaluation in real time during driving on normal road, on test track, on the roller chassis dynamometer, as well as on the high dynamic engine test bench and transmission test bench. AVL-Drive ratings are calculated based on the familiar SAE scale from 1-10, with 10 being the highest rating.

Tests are increasingly shifted onto chassis dynamometers. AVL is currently working towards completing the development of a method for automatically driveability calibration on the chassis dynamometer. In this process, the vehicle is driven in specified driving modes, such as shifting gears at acceleration while varying selected application ECU and TCU parameters. After each ECU/TCU parameter variation, the same driving cycle is driven, AVL-Drive automatically evaluates the driven manoeuvres. Once measuring has been completed, all of the driveability ratings as well as physical parameters and corresponding variation parameters are used for an off-line DOE calibration optimisation. The best variation parameter combinations, e.g., for tuning the vehicle with an emphasis on comfort or dynamics can be chosen out of the DOE model.

2 AVL-Drive on a Chassis Dynamometer – the Configuration

For testing on the roller chassis dynamometer, the hardware components which have to be installed in the vehicle are reduced to a minimum. First of all, the AVL-Drive system itself is installed in the vehicle, but the time-consuming installation and calibration of longitudinal acceleration sensors can be omitted. The acceleration signal is provided directly by the chassis dynamometer. Thus, the preparation time is reduced to a minimum. The AVL-Drive system itself and the control of the chassis dynamometer are adjusted to suit this application using the special software of AVL Chassis Dynos.

To allow the same balance of power to be applied to vehicle positioned on the roller as on the road, a so-called coast-down test is firstly performed on the road. The vehicle is shifted to neutral and allowed to coast down from a high speed, here approximately 135 km per hour. If the road is flat and straight and there is no strong wind, the vehicle is braked simply by internal losses (friction) and by its air resistance (cw). Using the measured speed progression over time, the "driving resistance" can be calculated as a speed function. This driving resistance is typically described in the form of a 2nd degree equation with the constants F0, F1, F2. Here, factor F2 essentially represents the wind resistance due to the fact that this power percentage grows with the square of the speed.

In order to simulate the same conditions on the roller as those found on the road, the vehicle is now attached to the roller and the parameters which lead to the same coast-down curve are determined.

3 Regulation Concept

The task of the roller test bench is to simulate the road in an exact and reproducible manner from a vehicle engine viewpoint. In the two-axle dynamometer, there are three main tasks for regulating the engine torques:

- The static forces which act against the vehicle are described with the coefficients F0, F1 and F2. They are measured on the road and on the roller and their difference is specified to the regulator as the set-point value.
- On the roller, the mass of the vehicle is not accelerated to a degree worth noting. Missing mass inertia is generated by the rotating roller masses. Differences between the vehicle mass and the roller masses are compensated with the mass simulation which must be highly dynamic for vehicle acceleration jumps.
- On the road, there is no speed difference between the axles when the vehicle is travelling straight ahead. On the roller test bench, speed differences between the axles must be compensated by the regulator.

A very precise map-based pilot control is used to ensure that the AVL-Zöllner roller chassis dynamometer at the vehicle axles always generates precisely those static and dynamic forces specified by the simulation model. The measured data, such as forces introduced into the roller surface by the vehicle, the speed and acceleration on the roller surface, the simulation model (F0; F1; F2 and Rw) and the roller chassis dynamometer data, e.g., the mass inertia of the testing rollers, is used to provide a precise calculation of which force must be applied by each of the dynamometers. Modern three-phase propulsion systems follow these set-point values within just a few milliseconds.

With the "ideal dynamometer", the map-based pilot control alone ensures that the dynamometer follows the static and dynamic simulation model and that, even if the vehicle forces are introduced asymmetrically, there is no speed difference between the axles. In order to compensate for inaccuracies and to reduce the rotational angle error between the rollers to below 0.2°, a superimposed controller equalises the differences between the roller speeds and roller positions. This regulation is performed symmetrically so that the complete dynamometer force is not influenced.

An additional simulation model regulator compares the forces specified by the simulation model and the mass simulation to the vehicle forces which were actually measured and reduces this difference to zero. Due to the fact that the regulators only have to correct very minor deviations, the map-based pilot control adjusts the control variables quickly and precisely to the new end value without any noteworthy tuning procedure, even if jumps occur. Thus, the regulator permanently ensures that the vehicle's roller chassis dynamometer absorbs the force, speed and energy and that this can be reproduced in real time, as would be the case on the road under the same conditions and without the vehicle being influenced any other way.

4 Comparison between Street and Chassis Dynamometer

The optimised entire system of Chassis Dynamometer AVL-Drive leads to good results. The full-load acceleration in second gear showed that the vehicle data (losses and driving resistance) was simulated very well. The fact that the indicated brake mean effective pressure (BMEP) of the engine on the roller is somewhat lower than that on the road is certainly the result of the limit before tyre slippage begins, on the one hand and on the other the result of the driving resistance indicated in the lower speed range. The deviation in the AVL-Drive road rating = 8.25 compared to 7.99 is at 3 % in an excellent range.

During WOT acceleration in third gear, it was possible to achieve an even better match between the roller values and those measured on the road (DR = 8.09 to 8.13). The AVL-Drive evaluation deviation is thus below 0.5 % which practically corresponds to a repetition accuracy under almost identical conditions. Due to the clearly lower torques, effects which point to tyre slippage are not anticipated and were not found. **Figure 3** again is an illustration showing the high conformities between the road and roller data for a gear shift at wide-open throttle (WOT).

5 Challenges

The use of the system on chassis dynamometers must of course be viewed critically as regards the general conditions and potential sources of errors. The chassis dynamometer itself represents an "environment" which has an immediate influence on the results of the driveability test. One criterion is the attachment of the vehicle, which affects the test results depending on the method used. With the conventional method of attachment using tension belts or chains, the vehicle's mobility on the chassis dynamometer is considerably restricted, which strongly influences the simulation of the driving behaviour on the open road. Alternatively, the vehicle can be attached at the rear using a special device (nicknamed a "dog sled“) either on the tow bar or a towing lug. To prevent the introduction of vertical forces into the vehicle, this attachment must move freely in the vertical axis. In dynamic operation, however, the attachment should be adequately stiff to prevent movements in the driving direction.

An ideal solution is provided by the hub attachment, which allows the rotational point of an axle - and so both hubs - to be fixed horizontally with the maximum rigidity. This fixing means that the vehicle structure is virtually free-moving on the powertrain, which is much closer to road driving conditions. Provided that the attachment itself does not exert any influence on the vehicle's natural vibration behaviour, the vibrations of the passenger compartment are also recorded and can be used for the AVL-Drive assessment.

In addition to the different means of attachment, all of the remaining boundary conditions of a roller dynamometer are also included in the test cell and, according to its design, all the variables which must be observed. Wind, sun, temperatures, or air pressure differences can be represented more accurately in a test cell and, above all, in a way which can be reproduced.

6 Outlook

With the AVL-Drive system on the chassis dynamometer, an important development step has been made by moving the tests from the road to the chassis dynamometer. Nowadays, it is possible to use the dynamometer to test all influences on the vehicle and on its ability. Objective assessments can be made at a very early stage of the vehicle development, without having to accept the disadvantages of expensive road tests.

Even in a late phase of a development process, there is potential to completely further develop individual vehicle components. An example of this is the adaptation of engine control units, their effect on the vehicle now being tested directly and objectively. A procedure which will not only result in shortened development times, but which is also accompanied by an higher degree of satisfaction on the part of the vehicle user, i.e. the customer.

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