© AVL

Testing of Modern Lubricants and Additivated Fuels

Due to current and future legislation, the fuel economy has become the most important topic for the oil industry. AVL presents two innovative technologies to meet the needs of the mentioned industries: Frisc and Dricon.

AUTHORS

Dr. techn. Vittorio Cappello
is Technical Expert for Fuels and Lubricants at AVL in Graz (Austria).

Dipl.-Ing. Hans Peter Gigerl
is Development Engineer for Vehicle Automation on Chassis Dyno and Test Track at AVL in Graz (Austria).

Dr. Dipl.-Ing. Siegfried Lösch
is Principal Engineer, Mechanical Development and Validation at AVL in Graz (Austria).

GREEN FUELS TO REDUCE VEHICLES EMISSIONS

The transport sector is a major source of air pollution and CO_2 emissions. These emissions are set to increase sharply as the global vehicle fleet is projected to grow dramatically by 2050 mostly in the developing countries. Developed countries have introduced cleaner and more efficient technologies, including green fuels, to sharply reduce vehicles emissions.

FUEL ADDITIVES

Technical innovation in the fuel additives business is a continuous process, which is often driven by legislation. Many additive suppliers are focusing their efforts in the last years to increase the vehicle fuel economy and, therefore, minimizing in this way the emission of CO_2 and of regulated exhaust pollutants. Engine and/or vehicle testing is often needed and furthermore a huge amount of laboratory tests are necessary to produce the required data. The engine developers and car-makers (OEMs), who are manufacturing constantly cleaner and more efficient motors, recognize the importance of the fuel and lube oil additives as part of this evolution to improve the performance and reduce the air pollution [1].

AVL TOOLS

In the last years the oil competence centre was founded at AVL in order to coordinate and centralize all topics related to fuel economy, friction reduction and alternative fuels. Engine and vehicle tests with new additives are costly and can take several days till months to satisfy all needed requirements. AVL developed and patented useful tools to consistently help the oil industry and additive suppliers to check the benefits of their products, saving in this way time and money. One of these tools is Frisc, which is a instrument to reliably and precisely measure the friction force in the engine cylinder. Such measurements give a correlation between friction and fuel economy.

The second tool presented is Dricon, which permits to drive vehicles on chassis dynos automatically, eliminating in this way the human factor, which itself can reduce (up to eliminate) the benefits of the additives on the fuel economy in test phase.

The following example shows the influence of the friction on the fuel economy: In a car of 1350 kg in a NEDC 10 % reduction of friction generates an improvement between 1.5 and 2.5 % of fuel economy, **FIGURE 1**.

FRICTION MEASUREMENT WITH FRISC

The basis for friction measurements under motored and fired conditions in an engine at AVL is a single cylinder engine called Frisc as short term for Friction single cylinder engine. The base part of that engine is operated over the last 10 to 15 years and known to be quite robust

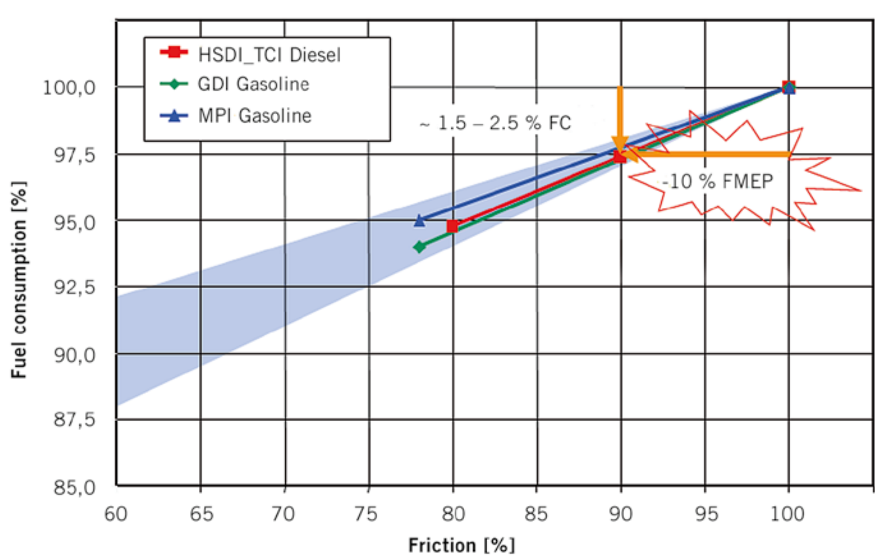

FIGURE 1 The improvement of the fuel economy due to reduced friction is shown (© AVL)

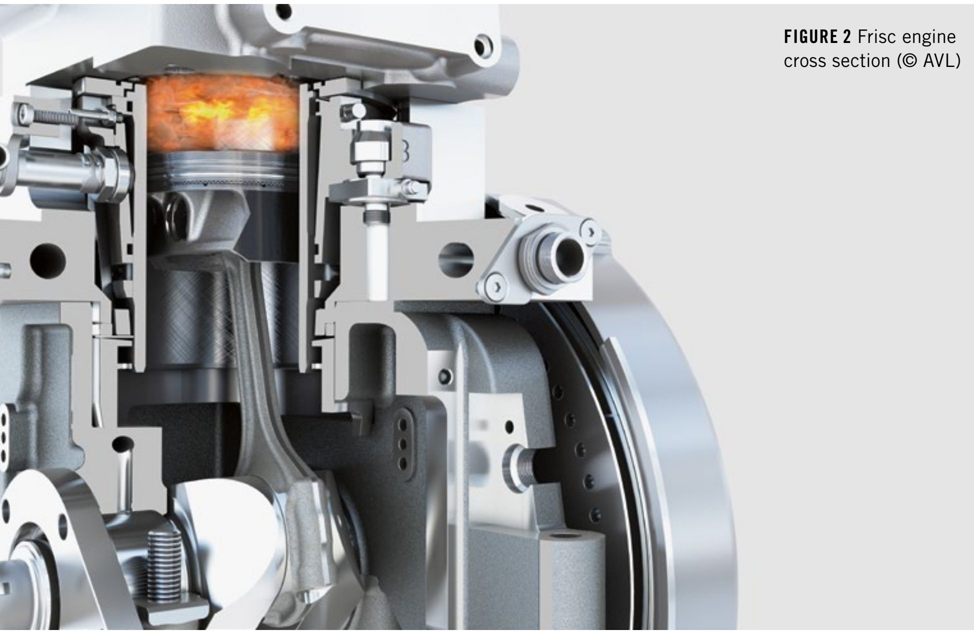

FIGURE 2 Frisc engine cross section (© AVL)

and stable. Features like mass balancing up to second order and different combustions were continually added.

In between cylinder head and crankcase we implemented a so called floating liner system, which is connected to the crankcase over force sensors, **FIGURE 2**. There is no fixed connection between liner and cylinder head but a special sealing ring which is located inside on top of the liner and works like a piston ring. A ring carrier is mounted on the cylinder head. The floating liner system consist of a so called liner carrier, which has liner with water jacket inside.

The floating liner assembly is moveable into liner axis direction according the elasticity of the force sensors. The displacement values we are talking about are in the range of some µm. Thus if there is a force acting at the inner surface of the liner which has a component into liner axis direction this effect is transferred to the force sensors and measured.

The liner has contact to the piston skirt and the piston ring pack. Depending on the current velocity there is more or less lube oil in between what results in time varying friction force signals. On the other hand during fired engine runs we are concerned with pressures that modify the friction force accordingly also over time.

In that way it is possible to measure friction forces in the engine (motored and/or fired) for different part combinations and also for different lube oils. Of most interest here are distinct surface coatings on the piston skirt and piston rings and different honings on the liner.

In addition, the Frisc also enables us to test the friction behavior of different lube oils like 0W20 and 0W30 and also effects coming from added friction modifiers.

After mounting the engine the Frisc is put onto a test bed and some calibration work has to be done before the real test procedure starts, **FIGURE 3**. To reach friction stable conditions a break-in run is carried out at defined measurement points. A certain number of cycles that have all the same peak pressure (within defined tolerance) are taken as measurement values and mean values of them are calculated. From raw data to final data dedicated low and high band filters are used and influences like resonance points and crankcase pressure influence are considered as well.

The following figures show some results of a comparison of a defined lube oil with the same lube oil added with a special friction modifier. In general, all figures show in the top placed diagram the friction force FR in [N] over 720 °CA, **FIGURE 4**. The combustion process is gasoline and one can realize from the friction force the four strokes in that order: suction, compression, firing and exhaust.

FIGURE 5, displays the cylinder pressure over the crank angle. There as the table in the top left corner describes Oil specification, indicated mean pressure and maximum cylinder pressure for the two different lubes. The last row of the

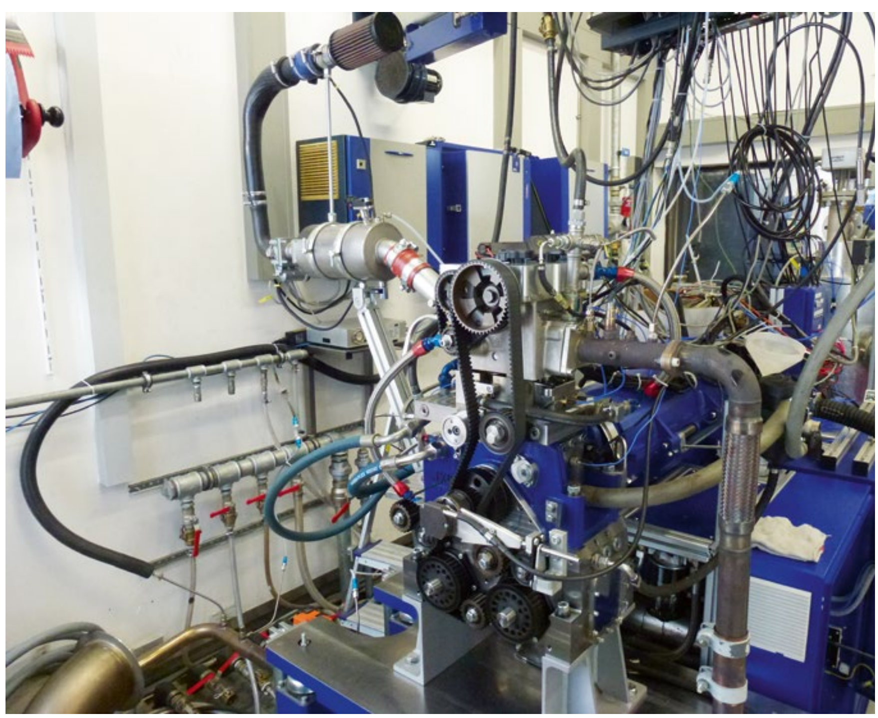

FIGURE 3 Frisc engine and test bed (© AVL)

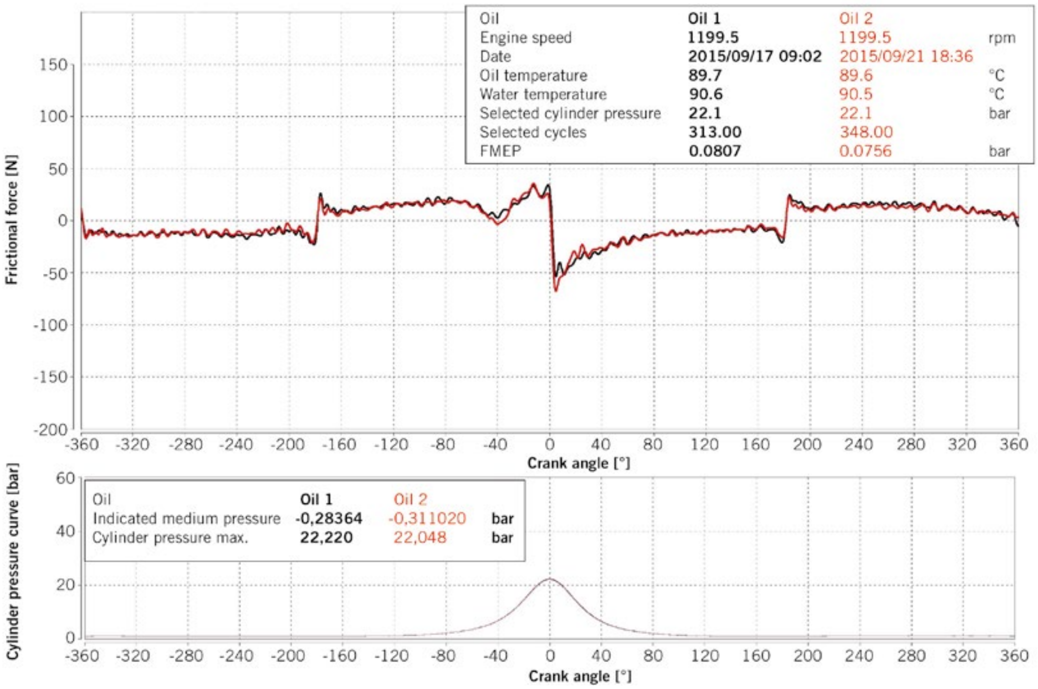

FIGURE 4 Friction results, 1200 rpm, motored (© AVL)

table on top right corner shows the friction mean effective pressure (FMEP) which is an integral value to justify the different lubes. The behavior of the oils shows also differences: Oil 2 shows higher friction losses in the combustion/compression turn around point but shows less friction at all other points.

DRICON: REPRODUCIBLE MEASUREMENTS ON THE CHASSIS DYNAMOMETER

A prerequisite for emission- and fuel consumption investigation on the chassis dynamometer is the reproducibility of measurements. Emission tests are mostly driven by human drivers who are following the vehicle speed demand trace on a driver's aid monitor. To measure smallest differences in fuel consumption the driven vehicle speed must be the same in all measurements. This also applies to the moment of switching the selector lever from neutral mode to drive mode.

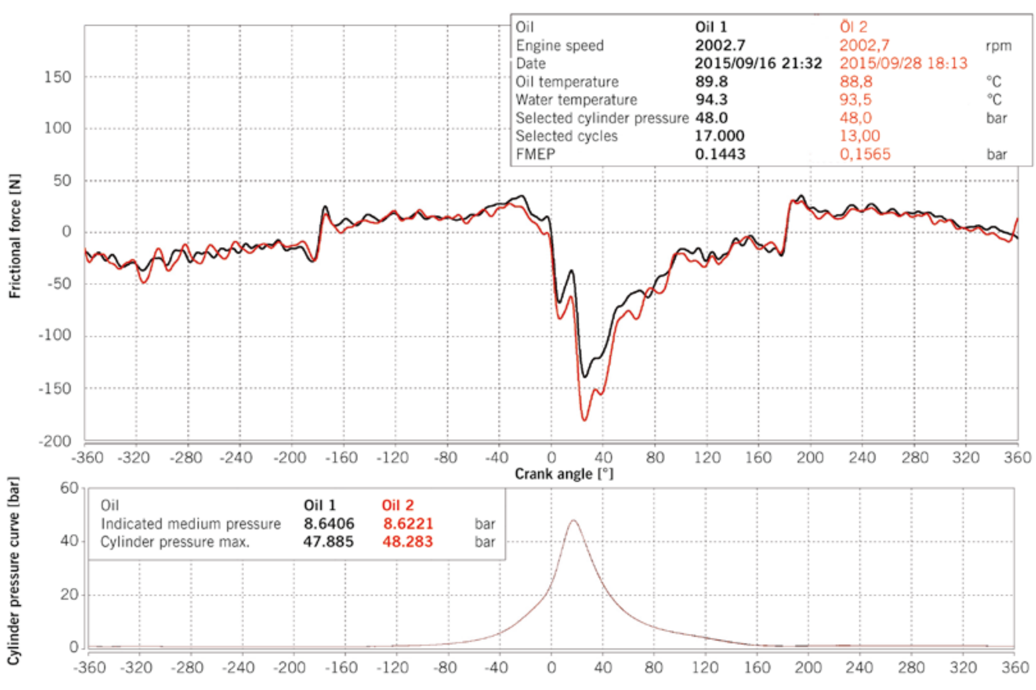

FIGURE 5 Friction results, 2000 rpm, fired (© AVL)

FIGURE 6 Dricon (© AVL)

Human drivers are limited in driving reproducible tests. Even at similar driven vehicle speed traces the style of driving has essential influence on the engine torque build up, on gear shifts and therefore on the fuel consumption. To eliminate the human driver's influence the vehicle automation system Dricon, **FIGURE 6**, can be used. Dricon can perform driving cycles with vehicles with automatic transmission via electrical simulation of the accelerator pedal signals and the usage of a brake actuator, **FIGURE 7**. With this innovative method different ECU datasets, fuels and other fuel consumption influencing parameters can be investigated without the influence of human driving.

The procedure of an automated fuel consumption or emission investigation test can be separated in into conditioning, emission measurement and post processing.

At both cold start and warm start tests the vehicle has to be in the same initial condition, just the investigated variations (e.g. different fuel, parameterization of fuel consumption- or emission relevant maps of the engine control unit or activated or deactivated power consumers) may be varied. The condition of the exhaust after-treatment has to be the same for each test. Therefore a conditioning cycle is performed where the regeneration of the particle filter, storage catalyst or similar systems is done manually. Afterwards the vehicle has to stay in a conditioning room for a specified time to guarantee the same initial temperatures for each test. During the conditioning the vehicle battery has to be charged to ensure a constant power consumption of the dynamo during the emission test. Additionally the tire pressure has to be at a constant level.

Before the start of the emission measurement it has to be ensured that all mechanical and electrical power consumers such as air condition, light or radio are in the desired state.

At a warm start test a defined warm up program is performed to always ensure the same starting conditions for the measurement program. After that the automated driver is started synchronous with the emission measurement. The engine start and the selector lever positioning also have to be done at a specified time. When the emission measurement is finished a coast down test is performed. In this test, the chassis dynamometer is in motoring mode and sets the vehicle, which is in transmission mode neutral, to a defined vehicle speed. Afterwards the vehicle coasts down in street simulation mode. All, after the

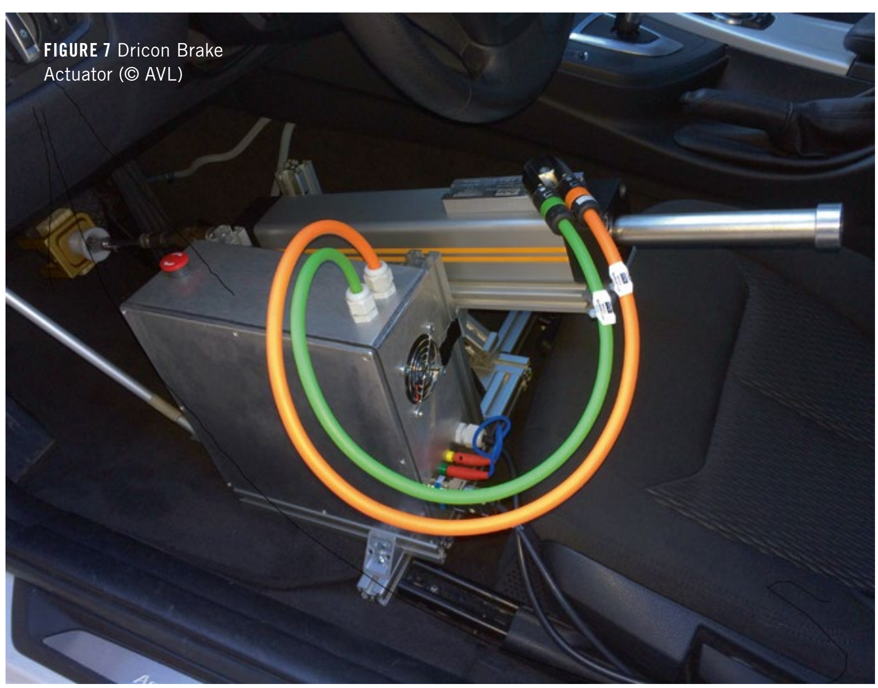

FIGURE 7 Dricon Brake Actuator (© AVL)

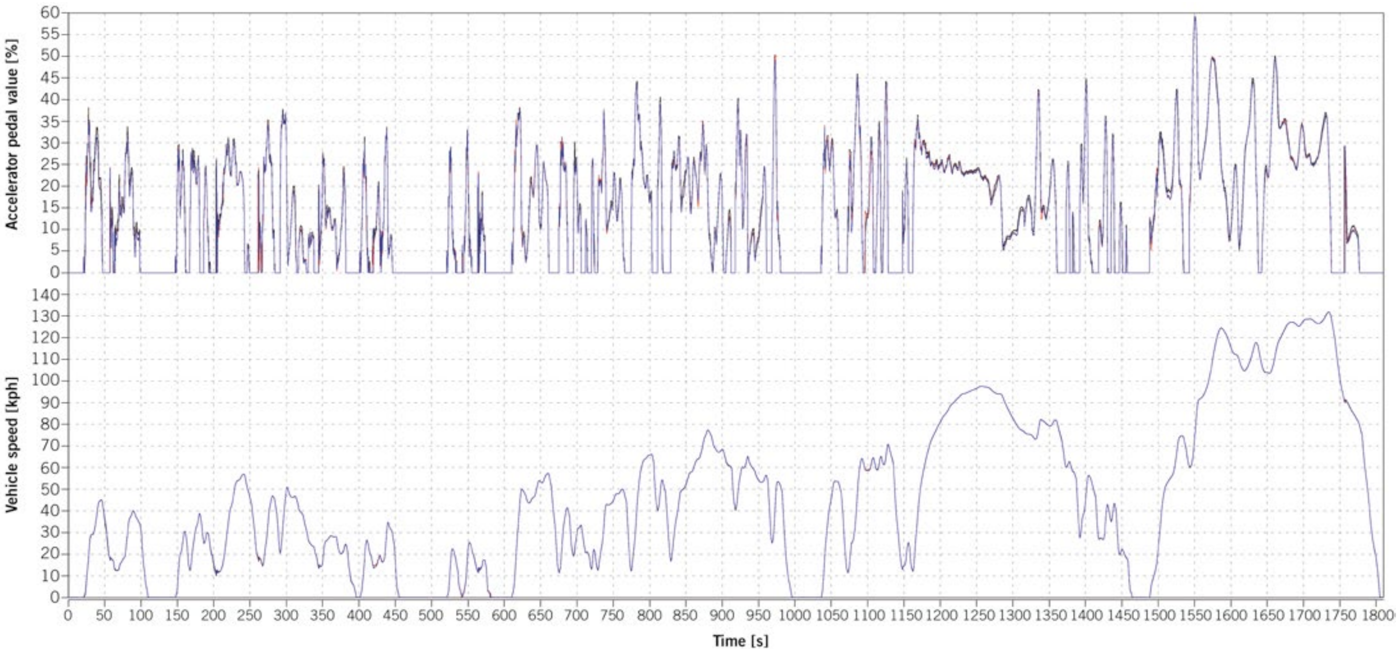

FIGURE 8 Three WLTC C3 cycles (© AVL)

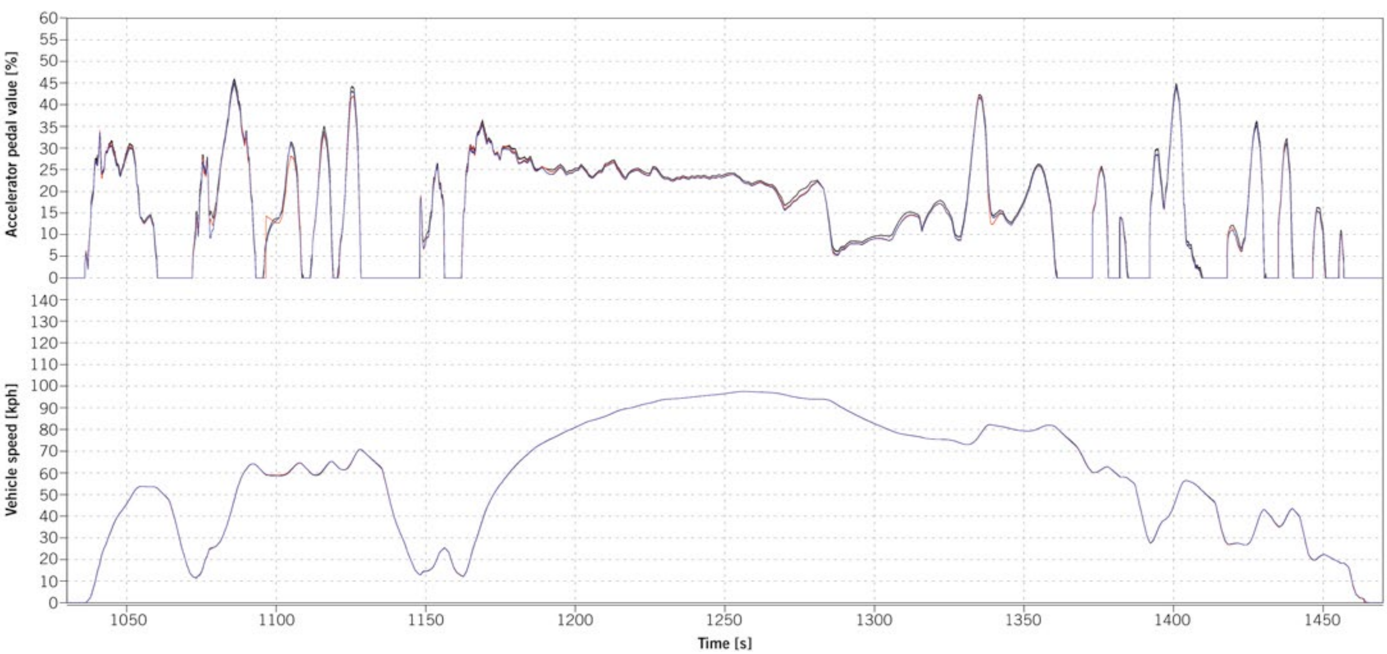

FIGURE 9 Three WLTC cycles – detailed (© AVL)

emission tests, performed coast downs must show velocity-time- traces with low deviations. Deviations represent different frictions conditions inside the powertrain or a different rolling resistance of the tires.

A basic requirement for the analysis is the same vehicle speed trace for the measurements that are to be compared. During the investigation of the traces it is already possible to determine differences in accelerator pedal values and therefore in fuel consumption. **FIGURE 8** shows three WLTC class 3 emission cycles (cold start) which were performed with the described method. Test 1 (black trace) was performed with activated air condition, at test 2 and 3 the air condition was deactivated. As a result of the high reproducibility of all measurements the driven distance is exactly the same.

Despite the almost congruent vehicle speed traces, **FIGURE 9**, shows a difference in the accelerator pedal actuation and therefore a different engine torque request of the engine because of the activated air condition.

REFERENCE

[1] Fuel additives: Use and benefits. ATC Document 113, (2013), Technical committee of petroleum additive manufacturers in Europe