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Steve Welch reports on a project which demonstrates that, given the right technology, issues associated with engine downsizing can be mitigated

Mike Bassett

The fundamental principle of engine downsizing is beguilingly simple. Replacing a vehicle's existing engine with another of smaller capacity but equivalent performance delivers benefits in both fuel economy and emissions.

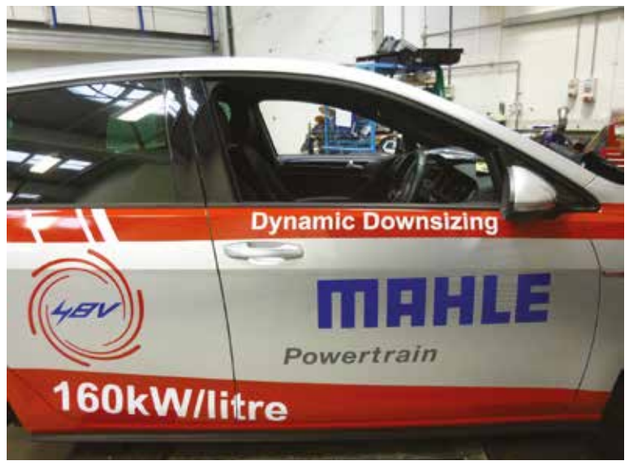
However, the reality is of course more complex. Significantly downsizing an engine can introduce driveability problems, especially at lower speeds, whilst there is also evidence that in real world use (as opposed to laboratory testing) the expected fuel economy and efficiency savings might be compromised.

MAHLE Powertrain, the engineering services division of the automotive parts manufacturer MAHLE, has run a project to demonstrate that, given the right technology, those issues associated with engine downsizing can be mitigated. The project, part-funded by the Niche Vehicle Network, considered how the addition of an electric supercharger might help a downsized engine to handle any low-speed driveability concerns.

The technology will be installed in a demonstrator vehicle on show at the CENEX LCV Event. The 'mule' vehicle is a VW Golf GTi – its 2.0 litre turbo gasoline engine is replaced with MAHLE's 1.2 litre turbocharged engine. The goal is that the downsized engine should not significantly impair the car's performance whilst improving fuel consumption and emission levels.

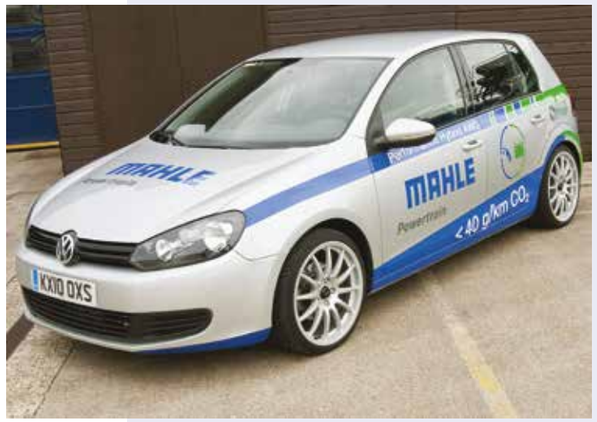
Dr Mike Bassett, head of the hybrid product group at MAHLE Powertrain, explains that the addition of Aeristech's 120,000rpm electric supercharger to a turbocharged downsized engine delivers high pressure air that at low engine speeds fills the bottom end of the torque curve, along with a high-output belt-integrated starter generator allowing the electric supercharger to run continuously when required. "Together the two technologies have allowed us to achieve high specific outputs: 160kW/litre and BMEP levels in excess of 35 bar – far higher than any gasoline engine in mass production," he says. "The demonstrator vehicle will also have an integrated starter generator and an advanced lead carbon battery pack to allow continuous powering of the charger."

He continues, explaining the thinking behind the technology in more detail: "The idea is when you are operating at a given engine speed and you need a certain amount of engine power, if you halved the engine swept volume, the relative load would be doubled. This is beneficial because gasoline engines get very inefficient as you get towards low load due to throttling losses. In order to facilitate downsizing and make it acceptable for the customer, you also need to maintain the power output of



eSupercharged demo car in final build

Through-the-Road Parallel Hybrid Demonstrator Vehicle



MAHLE Powertrain and Protean Electric have collaborated to construct and develop a plug-in hybrid electric vehicle (PHEV) demonstrator to showcase the benefits of adopting in-wheel electric motors in a C-segment passenger car. The vehicle features Protean's compact direct drive in-wheel motors with integrated inverters on the rear axle and retains the standard 1.4L gasoline engine, and manual transmission driving the front axle.

This 'through the road' parallel drive arrangement allows the vehicle to be operated in three distinct driving modes:

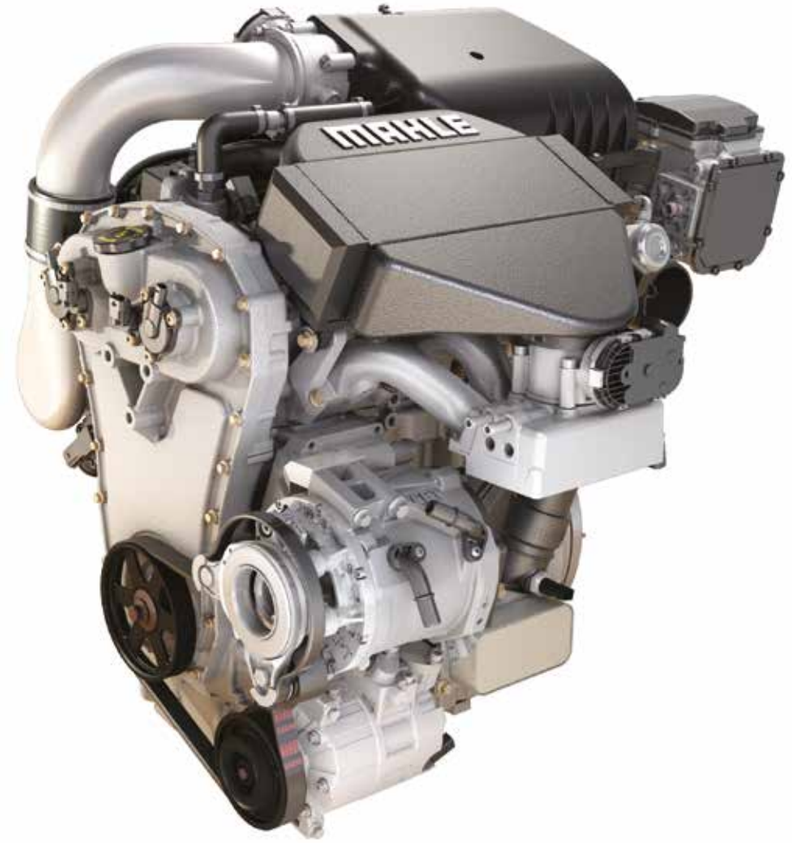
- Full electric rear wheel drive with zero tailpipe emissions
- Conventional engine front wheel drive for highway use
- Full hybrid all-wheel drive for maximum performance and traction

In addition to the fuel economy benefits of the full EV driving mode, the in-wheel motors also bring advantages in the areas of performance and handling. The immediate availability of tractive effort sharpens up the feel of the vehicle by improving the response to driver torque demand and the possibilities of advanced handling via torque vectoring are now open. Through incorporating the disc brake and associated power electronics, the in-wheel motors also provide an innovative packaging solution by fully utilising the available space within, and around, the vehicle's rear wheels.

MAHLE's Flexible ECU (MFE) has been used as the main vehicle control unit (VCU) to achieve effective control of the two independent drive systems within the vehicle. In this application, the MFE provides four key functions simultaneously – system control, system safety, traction motor torque control and interface to the donor vehicle ECU (including CAN message modification). The MFE based VCU has been developed as a modular platform for all types of vehicle control applications, targeted at prototype vehicles. MAHLE were able to quickly configure the VCU to suit this application by using a library of pre-existing control elements developed for other hybrid vehicle applications.

In terms of economy and performance data, the NEDC fuel economy was reduced from 6.4 to 1.7/100km and the CO_2 emissions from 149 to <40 g/km. The vehicle achieves an impressive 0-100 km/h time of less than 7.0 seconds (half that of the baseline vehicle) and top speed has also increased by more than 10%. In addition, the AWD capability of the dual drivetrain system enhances the dynamic behaviour of the vehicle in both high and low grip road conditions.

MAHLE Powertrain and Protean Electric have successfully converted a standard gasoline powered C-segment vehicle to a parallel hybrid architecture by applying in-wheel motors to the rear axle of the vehicle and installing a high voltage power system with appropriate adaptable control software. This convincing demonstration vehicle clearly illustrates the functional and packaging advantages of high torque in-wheel motors and the complimentary benefits of their integration into a parallel hybrid architecture. It also demonstrates the benefits offered by using a reconfigurable controller architecture. The VCU, developed by MAHLE Powertrain, is powerful enough to interact with multiple separate CAN buses simultaneously and provides an ideal platform for the development of demonstrator and niche volume vehicle fleets.



eSupercharged downsizing engine delivering 192 kW / 260 PS

the engine. To match the power output of the original engine you have to boost the engine. The degree to which you can increase the specific torque and power output of engine dictates how much you can downsize. The problem is when you downsize significantly you need to boost hard and you run into issues around engine knock and driveability."

Testing should be complete within the next few months. "This is a capability demonstrator," adds Bassett. "We are trying to attract more business for our engineering services in engine development. Ideally we would like to get more engineering programmes up and running for our regular customers who are primarily located in China, Germany, and the UK."

A further low carbon vehicle demonstrator project managed by MAHLE Powertrain involves a wheel motor powered hybrid vehicle developed in conjunction with Protean Electric, based on a 1.4 litre VW Golf (see box section left). MAHLE engineers have added wheel motors to the back of the vehicle, which alongside the conventional power train have transformed the vehicle into a plug-in hybrid. The car is capable of operating in three modes: a conventional gasoline vehicle with the wheel motors passive; a purely electric vehicle; or in a four-wheel combined mode.

"For us it was an interesting project to explore the possibilities of wheel motor technology," comments Bassett. "Wheel motors have high torque output so can use them to mimic less powerful hybrid installations. It's an interesting test bed for us to look at hybrid vehicle dynamics and the effects of hybridization over the drive cycle on fuel economy."

MAHLE Powertrain has been a regular exhibitor at CENEX LCV and hopes this year to have its largest ever presence at the Millbrook event with a range of demonstrator vehicles available to test in the Steering Pad.

"Five or six years ago it felt quite a niche event with niche demonstrator vehicles and niche companies," says Bassett. "Now there's the presence of the OEMs wanting to show their vehicles and an emphasis on mainstream business. Last year there was a real buzz about the event and it seems there is real interest from the OEMs to find out about technology and engage with the people exhibiting there."

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