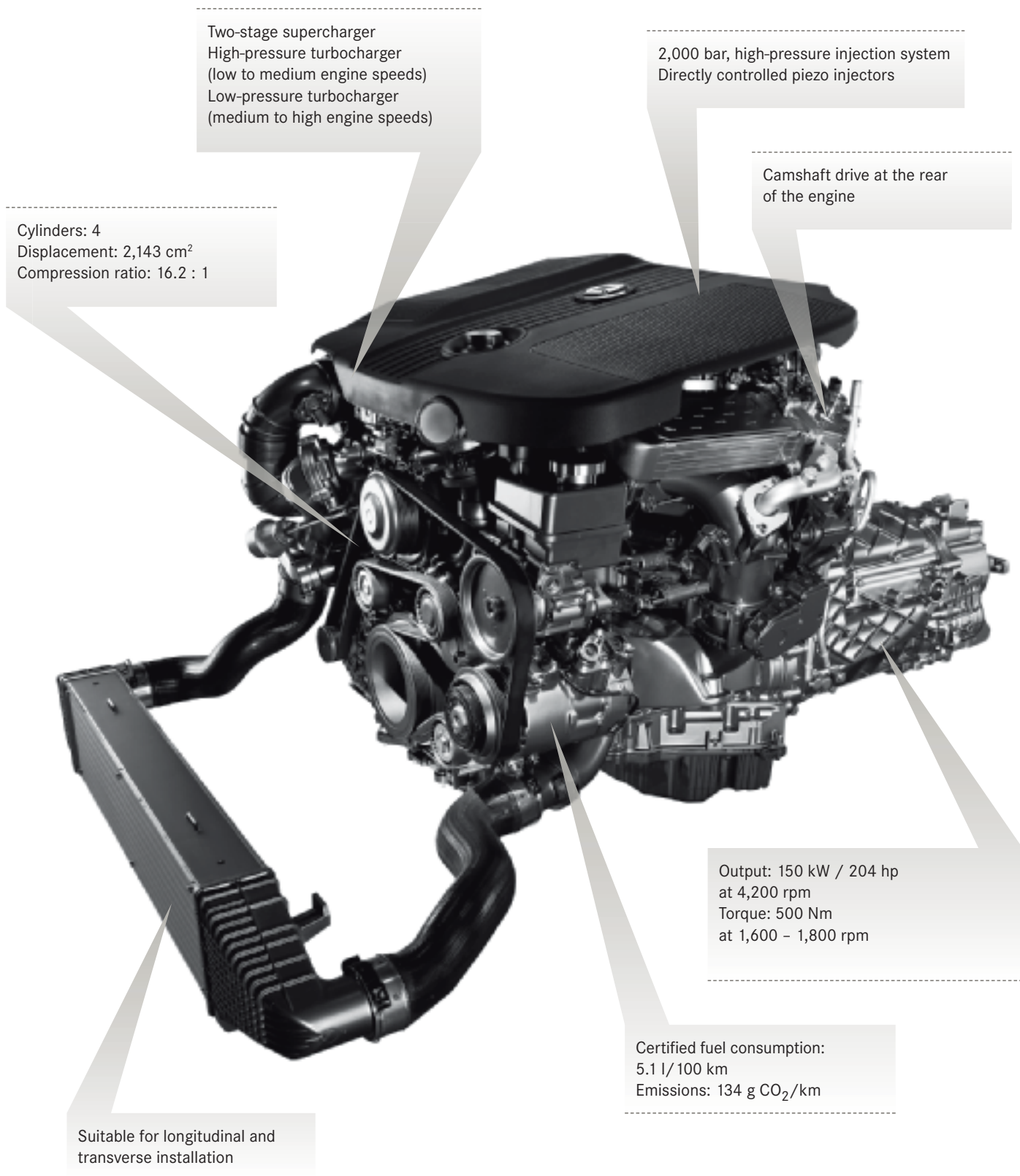


ENGINE RESEARCH

# OM651

|-- **Text** Eberhard Buhl |-- **Photos** Kurt Henseler

The project originated with the idea of creating a diesel drive system suitable for a universal range of applications: the OM651 world engine. After approximately 100,000 hours on the test rig, the new four-cylinder diesel engine is now in series production.



The new generation of engines didn't appear overnight. The Daimler engineers spent many years conceiving and designing the new series of advanced diesel engines and preparing it for series production. And, as always, the specialists from Advanced Engineering and Series Development worked hand in hand. The concept phase for the OM651 began at Advanced Engineering back in 2003. According to Franz-Paul Gulde and Johannes Leweux, the initial goal was solely to develop the technology for the planned engine's components or to modify tried and tested systems. Gulde is Head of the Car Diesel Engine department at Advanced Engineering; his colleague Leweux is responsible for OM651 Product Development. The team of engineers didn't have to start from scratch for all the components; in some cases they were able to use technologies that had proven their worth in other projects. After all, Daimler currently makes a very broad range of diesel engines, from the world's smallest diesel – the three-cylinder engine of the smart – to the Actros truck's V8 engine, with its 16 liters of displacement and 2,800 newton-meters of torque.

Some of the issues that had to be resolved were whether the engine concept could remain unchanged for the specified goal; whether the pistons, injection system, and exhaust gas recirculation could remain unmodified; and where completely new solutions would be required. The advanced engineering specialists headed by Gulde analyze, test, and develop components to a point where they are technologically advanced enough to represent a "set of practicable technological solutions" that can be handed over to the colleagues at Series Development. In the case of the OM651, however, little could remain the same as it originally was, says Leweux: "We planned to conduct an especially intense concept phase for this new engine generation – one that would require far more work than usual. In the second development phase that followed we spent another three years making the engine as a whole ready for series production in time for its market launch in 2008."

**Ambitious project** The requirements were tough, and the goals were very ambitious. According to Leweux, "our key requirements included reducing our previous diversity of engines and creating a single base engine for as many passenger and commercial vehicle applications as possible, from the C-Class to the Sprinter." Another goal was to ensure

that the various types of mounting would require as few specific changes to the connections and drives as possible – requirements that also applied to components such as the supercharger unit and exhaust gas recirculation system. During one of the early development phases it became clear that emissions regulations would be made much more stringent not only in Europe, but to an even greater degree in the U.S. Fuel consumption would also have to be greatly reduced, of course, even though the current trend is toward much higher outputs per liter of displacement. "It was clear to all of us that a competitive four-cylinder diesel engine in 2008 would have to generate around 150 kilowatts," adds Gulde. But how could all these different needs be reconciled, and where would it be best to start?

**One for all** "At the beginning of the process you always have to determine which basic attributes the new engine should have," says Leweux. "A very compact base engine with only four cylinders should be suitable for all key types of vans and passenger vehicles, in both longitudinal and transverse mounting. And its installation should require only a simple rearrangement of the drive components."

To make this possible, new and rather unusual ideas had to be developed – for example, when it came to positioning the camshaft drive. Because the hoods of today's vehicles are generally low in front, the engineers decided in favor of a shortened chain drive, which they simply moved to the rear of the engine block. Another change involved the high-pressure injection pump, which is normally adjacent to the camshaft. "But we were unable to come up with a design that would have worked with both longitudinal and transverse mounting, so we placed the pump on the side of the crankcase," says Leweux. "We use a space-saving gear system to drive the injection pump, the oil pump, and the balance shaft."

Unlike the trend toward more compact dimensions, the need to reduce emissions left almost no leeway, because regulations in Europe and in the U.S. are becoming more and more demanding. "This is why emissions characteristics are really the key issue for every diesel developer," explains Gulde. "And even though downstream technology such as SCR can subsequently improve emissions considerably, our objective with the OM651 was to achieve our target purely by means of in-engine measures."

## FOCUS

### BASE ENGINE

**1** compact engine for many different applications. The OM651 replaces several previous engines and is installed in a variety of vehicle models, ranging from the C-Class to the Sprinter. The base engine is thus designed to keep the number of specific components required for the different variants to a minimum.



"Our goal was to create a compact base engine with a very high level of commonization"

Johannes Leweux,  
OM651 Product Development



**JOHANNES LEWEUX**  
OM651 PRODUCT DEVELOPMENT



**FRANZ-PAUL GULDE**  
ADVANCED ENGINEERING  
CAR DIESEL ENGINE

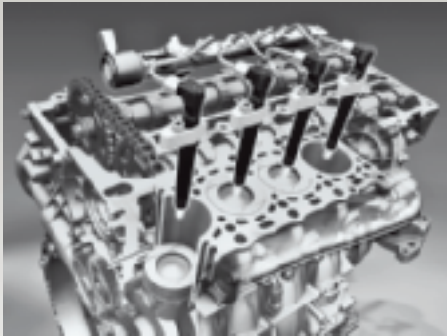
## FOCUS

## FUEL INJECTION

# 2,000

bar

injection pressure and the first directly controlled piezo injectors in a series-produced engine demonstrate that the level of innovation in the OM651 is far above average. As a result, the injection system now reacts much faster than was previously the case.



“We already have lots of new ideas for further improving efficiency”

Franz-Paul Gulde,  
Advanced Engineering Car Diesel Engine

“The lower the mass concentration of oxygen in the combustion chamber, the less NO<sub>x</sub> is generated,” explains Gulde. “We rely on this principle in our solution, which combines exhaust gas recirculation with supercharging.” The recirculated exhaust gases decrease the oxygen in the combustion chamber, thereby reducing the NO<sub>x</sub> generated during combustion.

At the same time, the exhaust turbochargers boost the proportion of air in the chamber, while improving thermodynamic efficiency and fuel economy. This enables the new four-cylinder diesel to meet the EU5 emissions standard without a need for additional measures, such as selective catalytic reduction (SCR). “We achieved a lot in the OM651 by cleverly coordinating the various systems,” says Gulde.

**Twin supercharger** In another new approach, the engineers used two-stage turbocharging. “Previously we used this process only in commercial vehicle engines,” says Leweux. “This is the first time it has been transferred to a compact car engine.” The new approach was used because conventional supercharging concepts quickly reach their limits in downsized diesel engines with high specific outputs. They cannot provide sufficient pressure when the vehicle begins to move or is running at high engine speeds. “The two-stage concept, however, has a small, quick-starting high-pressure turbocharger that works in conjunction with a larger low-pressure turbocharger to provide a substantial torque of 500 newton-meters at engine speeds as low as 1,600 rpm,” says Leweux. “The low-pressure turbocharger works on its own once the engine reaches medium speeds. All in all, this greatly improves handling and fuel consumption across the entire range of engine speeds, while also reducing emissions.”

There are also innovations in the injection system. The engine developers initially considered several different technologies. After extensively studying, comparing, and evaluating their functionality, the developers “ultimately chose directly controlled piezo injectors,” says Leweux. “We were especially impressed by the steeper injection rate this system attains, and by the so-called profile.” The response times are much slower in conventional systems using magnetic coils.

Fuel consumption has also improved, as the system is used with impressive energy-sav-

ing solutions, such as the volume-regulated oil pump and the vacuum-switchable water pump. The new engine now powers the Mercedes-Benz C250 CDI BlueEFFICIENCY, which consumes only 5.1 liters/100 kilometers and emits 134 grams of CO<sub>2</sub>/kilometer. The engine will also soon be used in the Mercedes-Benz E-Class, S-Class, GLK and Sprinter.

**Ideas for the future** Despite this achievement, Gulde’s team is working closely with the series developers to come up with concepts for diesel engines that “might be launched on the market in five or six years.” It’s possible that this will lead to sweeping changes as well. “Among the issues being discussed is how far engines can still be sensibly downsized,” says Gulde. “It would be conceivable, for example, to regard the OM651 as a basis for compact diesel engines for use in hybrids.”

The focus, however, is on achieving more advances in terms of emissions and fuel efficiency. To this end, the engineers are working on new technologies such as electronically controlled multi-path exhaust gas recirculation systems, and further exploiting the potential of piezo injection systems. “Piezo injectors can do more than just open and close nozzles,” says Gulde. “By moving the jet needle to precisely defined positions, they can bring further benefits.”

And although the engine designers have accomplished so much to date with the OM651, more advances will have to be made quickly in order to meet increasing demands. ::

## WEB TIP



In addition to this article, HTR online offers more OM651 technical details and an interview

focusing on the development potential of the gasoline engine.

- |-- Data sheet: Special technical features of the OM651
- |-- Workshop talk from HTR 01/08: “Engine Research and Development” with Erhard Rau and Peter Lückert

[www.daimler.com/innovation](http://www.daimler.com/innovation)