PRESSRELEASE

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Technical Information

– Optimization focus: Engine mechanics –

Less friction in the engine reduces fuel consumption

Stuttgart/Germany, September 2009—In the combustion engine, an important engineering goal is the reduction of friction due to the positive impact this has on fuel efficiency. A particularly promising approach is the optimization of the piston group and the valve train, which enables MAHLE to achieve fuel savings of more than two percent in the New European Driving Cycle (NEDC). Additional measures to minimize frictional loss in the coolant circuit and oil circuit increase the savings potential up to four percent.

The highest proportion of frictional loss (approximately 40 percent) occurs in what is known as the short block, which consists of pistons, piston pins, piston rings, connecting rods, and the crankshaft fitted with gaskets. The valve train with components such as camshafts, valves, and the lever system account for 20 percent of the friction generated in an engine. Particularly at low loads and rpms, these components generate a disproportionately high degree of friction.

Camshaft

Within the valve train itself, the camshaft is the main cause of friction. Today, plain bearings are used as the main bearings on the camshaft. During operation, a hydrodynamic lubricating film that acts to reduce friction forms between the bearing pedestal and the camshaft. However, this requires an oil pump to ensure that all operating points on the engine are supplied with sufficient quantities of oil.

An alternative is the use of a rolling bearing with a needle bearing, which requires very little space. This comparatively small modification can reduce friction in the bearings by up to 40 percent. Because the degree to which friction can be reduced depends on the number of bearing points, this concept shows the most potential in double overhead camshaft (DOHC) engines. In a modern DOHC

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gasoline engine with single-stage turbocharging and direct injection, MAHLE Advanced Engineering was able to reduce frictional loss in the valve train by an average of 300 watts. Depending on the valve train and number of cylinders, this enables a MAHLE low-friction camshaft (LFC) fitted with rolling bearings to achieve fuel savings in the NEDC of one percent in a four-cylinder engine and 1.5 percent in a six-cylinder engine.

If rolling bearings are used as the main bearings on the camshaft, this not only reduces frictional loss, but also minimizes the required pumping performance of the oil pump because rolling bearings can be lubricated with splash oil alone. In the DOHC test engine, this reduction in the required pumping performance had approximately the same effect as the reduction in friction achieved with the LFC.

Engines in vehicles with a start-stop system conserve fuel by shutting off the engine when the vehicle is stopped. However, these engines must restart after every stop, resulting in more frequent start-ups than with conventional engines. Because friction in the camshafts is relatively high due to mixed friction phenomena, particularly at low rpms, the use of LFC technology in engines with stop-start technology offers additional potential for fuel savings. Because engine friction is reduced, the starter engine can be designed smaller, has a longer service life despite more frequent start-ups, and requires less energy, thus reducing fuel consumption.

Lightweight valve

As an alternative to rolling bearings, lightweight valves can be used to reduce frictional loss in the valve train. Owing to their lighter mass, they require smaller valve spring forces, and oscillating masses in the valve train are therefore reduced significantly. Moving parts are subject to less wear, and adjacent valve train components can also be designed smaller and more cost-effectively.

MAHLE lightweight valves are made of formed, high temperature-resistant steels. Individual sheet metal components are laser-welded together and then ground like conventional valves. If necessary, these hollow valves can be filled with sodium, for better cooling on the exhaust side, for instance. In turbocharged gasoline engines, sodium-filled lightweight valves reduce temperatures in the combustion chamber. Engine "enrichment" can therefore be reduced or the engine can be operated with a higher compression ratio. Each of these measures means additional fuel savings. Another advantage of lightweight valves is that they require no design changes in the existing engine.

In a four-valve DOHC test engine using a roller actuating system between the camshaft and rocker arm in addition to lightweight valves, frictional loss was reduced by up to 60 watts per cylinder. This results in an average frictional loss reduction of 240 watts in a four-cylinder engine and 360 watts in a six-cylinder engine, suggesting a fuel savings potential of around one percent.

However, testing conducted by MAHLE revealed that the frictional loss reduction potentials of LFCs and lightweight valves only have a limited cumulative effect. This is due to the fact that the bearing friction is already reduced by the rolling bearings to such an extent that any additional reduction in the bearing load brought about by lower valve masses and spring forces have only a limited impact on overall friction levels in the valve train.

Power cell unit

The greatest sources of friction are the power cell unit (PCU) and the crankshaft fitted with gaskets. Friction in the PCU is determined primarily by the contact friction of piston skirt, the installation clearance and running clearance of the piston, and by the width, shape, and tangential load of the piston rings. This is why MAHLE has tested different piston and ring types to determine the most favorable combinations in terms of friction.

For the DOHC test engine, the best combination turned out to be MONOTHERM® steel pistons with a GRAFAL®-coated skirt, a pin with a DLC (Diamond Like Carbon) coating, and an optimized ring set. MONOTHERM® pistons have already been in use in commercial vehicle series production for quite some time. For passenger car diesel engines, as well, its production application is advantageous. Steel pistons provide a high degree of stiffness, a long service life, and extremely favorable friction coefficients, which are due to similar thermal expansion coefficients of the gray cast iron-steel pairing of cylinder bore and piston. Smaller ring widths and tangential stresses have a positive effect in the rings. In the DOHC test engine, MAHLE used nitrided steel top rings with a PVD (physical vapor deposition) running surface coating. When combined with a modified position of the connecting rods and crankshaft, the friction in the PCU dropped by up to 30 percent in some cases.

In addition to these considerations of the complete system, MAHLE conducts measurements on a live complete engine for a detailed understanding of the effect of individual modifications on the PCU. To realistically determine the effect of the modifications, individual friction-relevant parameters are evaluated in terms of speed and engine load in the complete engine operating map. All modifications show that speed and engine load influence frictional loss to varying degrees. For example, a change in the tangential stress of the rings clearly affects speed, but hardly has an effect on load. In comparison, altering the piston installation clearance has a significant impact on load. These results clearly show that modifications to optimize frictional loss in the PCU should be evaluated on a live engine whenever possible. Based on the individual parameter results gleaned from such evaluations, specific modifications can be combined to determine the optimal modification package for different engine concepts.

Fuel consumption reduced by up to four percent

MAHLE has also tested a delivery rate-optimized oil pump and a so-called split cooling system. A split cooling system is a system with separate cooling circuits for the engine block and cylinder head. Specific engine block cooling allows for greater piston clearance and oil conditioning, both of which reduce friction.

Real-world NEDC-based fuel consumption tests on a chassis dynamometer confirm the individual research results. For these tests, MAHLE installed an engine equipped with a low friction camshaft (LFC) or lightweight valves and an optimized PCU in a mid-size vehicle and compared it with its assembly-line counterpart. The engine with the modified valve train and PCU consumed approximately 2.3 percent less fuel. With the addition of an optimized oil pump and a split cooling system, fuel efficiency even jumped to four percent.

The MAHLE Group is one of the top 30 automotive suppliers and the globally leading manufacturer of components and systems for the internal combustion engine and its peripherals. Around 45,000 employees work at over 100 production plants and eight research and development centers. In 2008, MAHLE generated sales in excess of EUR 5 billion (USD 7.3 billion).

Further queries:

MAHLE GmbH
Birgit Albrecht
Corporate Communications/Public Relations
Pragstrasse 26–46
70376 Stuttgart
Germany
Phone: +49 (0) 711/501-12506
Fax: +49 (0) 711/501-13700
birgit.albrecht@mahle.com