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PRESSRELEASE

Technical Information

– Optimization focus: Thermodynamics –

Fewer nitrogen oxides through higher EGR rates

Stuttgart/Germany, September 2009—Future emissions limits for gasoline and diesel engines in both passenger cars (EURO 6) and commercial vehicles (US 2010 and EURO VI) are set to undergo drastic tightening, particularly in terms of NO_x emissions. A major challenge for engine development engineers, therefore, is to further reduce NO_x emissions without increasing fuel consumption at the same time. The first approach is to develop internal engine modifications with the objective of achieving better combustion results. Exhaust gas recirculation (EGR) plays a key role in such an approach. MAHLE has developed a control flap system that enables a significant increase of up to 50 percent in EGR rates without negatively impacting fuel efficiency. Alongside achieving lower emissions, an EGR system also reduces the need for extensive exhaust gas aftertreatment, through selective catalytic reduction (SCR), for example. This mechatronic control flap system has already been successfully tested in a number of commercial vehicle and passenger car engines and is now in the series development stage.

High EGR rates are an effective means for reducing nitrogen oxide emissions in combustion engines because the portion of gas remaining in the combustion chamber lowers the peak combustion temperature—resulting in decreased NO_x formation. In modern combustion engines, however, with the turbocharger configuration being designed to achieve high fuel efficiency, the pressure gradient across the exhaust and inlet manifolds is often insufficient to achieve the required EGR rates on a continuous basis. In fact, there is even a risk of just the opposite effect: Today, to achieve an appropriate pressure gradient between the exhaust back pressure and the charge air pressure, throttle plates are used in some cases, either as exhaust back pressure valves or as diesel throttle flaps on the intake side. However, in situations involving negative scavenging pressure, these types of flaps are subjected to high

temperatures and excessive contamination in the exhaust system. This causes the exhaust back pressure to increase, resulting in decreased thermodynamic performance of the engine. When used on the intake side, they cause throttle losses.

Even the use of exhaust gas turbochargers with variable turbine geometry (VTG turbochargers) is only of limited help in such cases, because a turbine guide vane in the closed position has the same throttling effect as an exhaust back pressure valve. Thus, all these methods drive fuel consumption up.

Fast-switching charge air valve for ultra-high EGR rates

In an effort to improve the mass flow of both charge air and exhaust gas, MAHLE has developed a control flap system known as the fast-switching charge air valve. This mechatronic component makes it possible in commercial vehicle diesel engines, for example, to increase the EGR rate while at the same time reducing the charge cycle work ("dethrottling"). The valve with a rapidly revolving flap, which is actuated by a brushless DC motor, is installed in place of the conventional diesel control flap in the charge air line upstream of the EGR feed point. During a combustion cycle, the continuously revolving valve briefly closes off the cross section of the charge air line, thus temporarily reducing the charge air pressure level at the EGR feed point located downstream. This creates a more favorable pressure gradient for exhaust gas to flow into the charge air line.

During a test implementation of the fast-switching charge air valve in a commercial vehicle engine, extremely high exhaust gas return rates of up to 50 percent were achieved across broad engine map areas, and significant benefits in NO_x emissions and specific fuel consumption were measured. This internal engine modification thus offers the potential to greatly reduce the cost and complexity of exhaust gas aftertreatment systems.

The fast-switching charge air valve achieves the greatest pressure reduction when its closing coincides with the maximum piston speed of the aspirating cylinder. Synchronizing valve closing with the exhaust pressure surge at the EGR feed point further increases the EGR rate. The revolving motion of the flap is optimally adapted to engine operation by the servomotor, but is independent of the engine itself. This gives the fast-switching charge air valve the flexibility to close off or open the channel cross section as needed. The brushless DC motor gives the valve an extremely dynamic control mechanism, which precisely adjusts the required phase modulation from one cycle to the next. This enables the system to cope with sudden transient load increases—something that cannot be achieved in throttle flap-regulated systems, for example. Moreover, because it opens the entire charge air line cross section again immediately after closing it off, the fast-switching charge air valve principle of operation stands in stark contrast to the constant throttle principle. Because the "throttling" action is only temporary in this case, it does not have a negative impact on fuel economy resulting from increased charge cycle work. And with the controlled pivoted flap system being located on the fresh air side, it is not exposed to the high exhaust gas temperatures or to the pollutants present in the exhaust gas.

With the highly dynamic system design and responsive electronic activation of the fast-switching charge air valve, it is possible to achieve virtually delay-free, on-demand control of EGR rates in the entire engine operating map—including the cold start phases, something that will become increasingly important in light of future test cycles.

Ultra-high EGR rates—worth the investment

In terms of combustion, ultra-high EGR rates have side effects as well, such as a longer ignition delay, local oxygen deficiency, and slower energy conversion overall. Further modifications can help offset these side effects; these include a higher charge air pressure, specific shaping of the injection characteristic, combustion chamber design, and/or additional charge motion modifications. Initially, these solutions may result in higher system costs, but because they

reduce NO_x formation, high EGR rates eliminate the need, for instance, of a selective catalytic reduction (SCR) system for EURO V. When an engine concept is designed specifically to meet emissions limits through internal engine modifications, a comparison of overall costs shows that the expenditure for high or ultra-high EGR concepts (40 percent EGR rates and higher) is far less than that of an SCR exhaust gas aftertreatment system for nitrogen oxide. The fast-switching charge air valve offers considerable potential for internal engine compliance with EURO 6 emissions limits as well.

Optimized valves in the EGR line

MAHLE has also developed innovative valve solutions for use in the EGR line. For example, the MAHLE knee-lever flat seat valve, with its extremely high opening forces, is suitable even for large EGR line cross sections and therefore for the large gas throughputs involved in high EGR concepts. The knee lever mechanism enables precise control of the exhaust gas stream, while at the same time, high actuating forces prevent the valve from seizing due to soot deposits. Depending on requirements, the knee-lever flat seat valve can be fitted with integrated control electronics including positioning sensor technology for determining the valve position; this enables extremely precise measurement of the exhaust gas stream flowing into the EGR line. Passenger car diesel engines using this valve generate up to eight percent fewer raw NO_x emissions compared to engines with conventional EGR valves.

Based on this valve, MAHLE has developed an innovative EGR valve for gasoline engines for high-load applications that significantly reduces the exhaust gas temperature and thus the need for air-fuel mixture enrichment in the efficient downsizing engines, with their higher specific load. As a result, fuel consumption is reduced in these map areas by up to nine percent.

MAHLE even offers a fast-switching valve for exhaust gas recirculation lines: The fast-switching exhaust gas valve, fitted in the exhaust gas line of diesel engines downstream of the charge air cooler, achieves ultra-high exhaust gas return rates through amplification and extremely precise control of exhaust pulses. This electromagnetically actuated revolving exhaust gas valve opens and closes the line cross section, making use of pressure waves generated when exhaust gas is expelled from individual cylinders to recirculate the exhaust gas. With its responsive system dynamics, the fast-switching exhaust gas valve enables controlled adjustment of the EGR even under transient engine operating conditions.

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