HOT STUFF

Last month, Federal Mogul unveiled its technology strategy for heavy-duty engine pistons and associated components for an age of waste heat recovery. John Kendall reports from Munich

In the wake of Euro 6, it is clear that EU legislators' attention will primarily be focused on reducing CO_2 emissions. That chimes well with vehicle manufacturers, which have been engaged in engine downsizing for the past 25 years. Indeed, few modern engines are now larger than 13 litres.

Such moves have helped reduce CO_2 and fuel consumption, but have also resulted in engines typically working harder. That means cooling requirements are greater than ever before.

The industry needs to step up to the plate here. Why? Because beyond vehicle aerodynamics and low rolling resistance tyres – both expected to play their parts in CO_2 reductions – the real deal will be further improving driveline efficiency. That and recovering waste heat energy for feed back into the driveline.

So there are implications for both engine and component designers such as Federal-Mogul, which majors on everything from pistons to rings, valves, valve seats, cylinder liners, bearings and seals. And that is why the company's recent unveiled technology strategy for waste heat recovery is so interesting.

Federal-Mogul's Envirokool heavy-duty diesel steel piston will get its debut at the IAA Hanover commercial vehicle show in September. What's new is a sealed-for-life cooling chamber inside the piston crown filled with cooling oil and an inert gas, designed to prevent the coolant from oxidising. After the chamber has been charged with the oil and gas mix, it is sealed permanently with a welded plug.

ELEVATED TEMPERATURES

The cooling chamber enables the piston crown to withstand combustion temperatures more than 100°C greater than today's maximum. As a result, carbon deposits that would normally form on the cooling gallery can be burnt off, ensuring that the latter continues to dissipate heat for the life of the piston.

The principal cooling method for the cooling gallery is an oil cooling jet, directed at the underside of the piston. However, Federal-Mogul claims that, because the gallery becomes so effective, the oil jet flow can be halved. That also reduces parasitic losses, while de-coupling the engine oil from cooling.

"This technology is mainly applicable to engines with waste heat recovery," explains Norbert Schneider, director of global application engineering at Federal-Mogul. Why? He makes the point that simply making a piston hotter doesn't itself save fuel. "Right now, the piston is cooled with lubrication oil. All that energy is then dissipated by the radiator, so is totally wasted.

"The idea here is to increase the temperature of the exhaust gas by cooling the piston less. But then the piston gets hotter, which is why we need this technology. However, with much hotter exhaust gases, [engine designers] can recover a significant proportion of this [much greater] waste heat."

Received wisdom suggests that up to 5% of energy can be recovered from waste heat systems and fed back to the drivetrain. The favoured method is a heat pump, converting heat into mechanical energy. "Future legislation will demand a significant reduction in fuel consumption for truck engines and right now this [approach] is seen as having serious potential," says Schneider.

However, raising exhaust gas temperature will present other challenges

“The very high level of alloying elements present makes these materials quite special”
Guido Bayard

for engine designers as it will also lead to increased formation of NOx emissions, currently controlled by EGR (exhaust gas recirculation) and/or SCR aftertreatment systems.

“It will be several years before we can expect Envirokool to go into production,” agrees Scheider. “This is a relatively early stage. We have been carrying out testing for two years with more than a thousand hours of successful results so we are now in a pre-development stage with a small number of engine companies. We would expect mass production from 2021.”

SMARTER ALLOYS

But engine downsizing has also been the trigger for new inlet and exhaust valve materials. With 10- and 11-litre engines now capable of around 500bhp, valves that can withstand higher temperatures and combustion pressures of 220bar and above have become necessary. Greater levels of EGR have also exposed valves to wet corrosion risk.

Additionally, engine braking systems such as Jacobs’ Jake Brake add mechanical loading to valves. And yet the pressure to reduce the cost of components continues to grow. These factors have triggered research into new materials for valves, seats and guides.

Focusing first on cost, high nickel content is a key issue, as Gian Maria Olivetti, chief technology officer at Federal-Mogul Powertrain, explains. “For demanding applications the conventional answer is a premium material such as our ECMS-Ni80A. But with a nickel content greater than 70% this is not always an economic solution. So we have established new ways to make more effective use of alloying elements such as nickel – by validating materials with equivalent hot strength to ECMS-Ni80A, but lower alloy content.”

By researching combinations of materials, such as nickel (Ni), chromium (Cr) and manganese (Mn), suitable new metals can be formulated, he explains. For its part, Federal-Mogul has developed an upgraded alloy, which the company calls ECMS-2512NbN, using standard CrMn heat-treated steel.

This material has been designed for use in both inlet and exhaust valves that see higher temperatures. Standard steels contain around 3% nickel, but by increasing this content to around 12% and fine-tuning the combination of other alloys, it is possible to improve both hot strength and corrosion resistance, says Olivetti.

Meanwhile, where higher temperature performance is a requirement, Federal-Mogul claims that its ECMS-Ni36 alloy can offer better resistance to hot oxidation than its industry standard equivalent ECMS-3015D – a heat-treated steel with 15% Cr and 31% Ni. Despite comprising only 36% nickel, this alloy offers similar tensile strength to the superalloy ECMS-Ni80A, which consists of more than 70% nickel.

“The very high level of alloying elements makes these materials quite special,” comments Guido Bayard, director of global valve train technology for Federal-Mogul Powertrain. “In order to predict reliability and conformity to engine applications, a wide range of rig and laboratory tests on wear, corrosion and durability have been conducted, with a series of engine application trials on dynamometers also completed.”

In fact, Federal-Mogul has already started series production of valves made from ECMS-2512NbN and ECMS-3015D. Trials are underway with unnamed customers using ECMS-Ni36 ahead of other production launches. Both ECMS-2512NbN and ECMS-Ni36 are suitable for valves in 10–16-litre engines, including for on and off-highway.

That said, similar challenges for valve seat inserts and valve guides have also triggered developments with new powder metal materials. Federal-Mogul claims these, too, can contribute to reduced CO_2 emissions by enabling gas flow across the valve seat chamfers to be more efficient. TE