BEYOND Euro 6

Despite the achievements of Euro 6, combustion engineering continues apace, with twin goals of improving efficiency and cutting CO_2 emissions. John Kendall looks at the future for heavy-duty diesels

Heavy-duty diesels have come a long way since the European emissions legislation began to take effect some 21 years ago. Progressive tightening of the toxic emissions requirements has given rise to several trends. Fuel injection systems, for example, have moved from mechanically-controlled, low-pressure systems with injection pressures of around 400 bar, to electronically-controlled, high-pressure units, with Euro 6 injection pressures reaching as high as 2,700 bar.

What else? Well, larger capacity, naturally aspirated diesel engines disappeared back in the 1990s and power plants have become progressively smaller, while power outputs have increased. Turbochargers have moved on from fixed-geometry turbines to variable-geometry types, mainly to help meet emissions requirements, but also improving driveability in the process. Combustion pressures have risen, too, to more than 200 bar. Then, again to meet emissions limits, after-treatment systems have become progressively more complicated – with SCR (selective catalytic reduction) and a combination of SCR and EGR (enhanced exhaust gas recirculation) now the preferred routes to compliance.

Undoubtedly, such measures have had a detrimental effect on fuel consumption so, post-Euro 6, the tide is turning in favour of reversing that and combating CO_2 emissions. Much of this is being done by reducing efficiency losses around the vehicle itself, in terms of aerodynamics and driveline friction. But how might the trusty diesel engine itself be made more efficient? With heavy diesels running at thermodynamic efficiency sub-50%, there is surely yet scope for improving engines?

Engine interventions

Waste heat recovery systems offer one avenue for retrieving some of the energy lost as heat in the diesel combustion process. Given that Euro 6 heavy diesels have reached thermodynamic efficiencies of around 46–47%, such systems could help to improve that.

But what of the engine internals? Rising temperatures and pressures have presented piston manufacturers with challenges in heavy engines in recent years. Engine manufacturers are now also asking for pistons with lower compression heights – the distance between the piston pin centre line (the small end, where the piston meets the connecting rod, which joins it to the crankshaft) and its crown.

"We're being challenged to come up with lower and lower compression height pistons," confirms Keri Westbrooke, director of engineering and technology for powertrain at Federal Mogul. "That puts in an extra dimension of challenge, because the shorter the piston, the more difficult it is to keep strong and to cool." On the other hand, the benefit is is lighter and lower reciprocating mass, which means reduced friction in the cylinder.

"A piston with a compression height potentially 20mm shorter enables engine manufacturers to do one of two things," explains Westbrooke. "They can either lengthen the connecting rod, which helps reduce friction, or they can reduce engine block height by a corresponding amount. Removing that much cast iron offers a significant weight reduction."

Piston rings, which provide gas- and oil-tight seals in the cylinders, also present a friction challenge. So, reducing that friction, without interfering with the sealing effect, is another avenue for piston and ring manufacturers to pursue. "We are looking for piston ring coatings with a much lower co-efficient of friction," states Westbrooke. "Many gasoline and light-duty diesel engines are embracing these coatings, known as DLC (diamond-like coatings) and we're starting to develop them for heavy-duty diesels, too."

The old problem for piston ring manufacturers was that high-tension rings mean good oil and gas sealing, but also high friction. "Light, lower-tension rings, using better ring coatings, would offer a direct friction reduction," confirms Westbrooke. So, if pistons can be made stronger and shorter, with better ring technology, it becomes possible to make smaller engines with the same power output as larger units, benefiting weight and fuel consumption.

Injection efficiency

Meanwhile, it's worth noting that injecting fuel at up to 2,700 bar uses some engine energy, so improving efficiency here, too, can make a difference. "One of our key drivers is to improve the efficiency of our equipment and that involves a twofold approach," explains David Draper, diesel systems engineering director at Delphi.

"First, reducing system leakages [around clearances, pumping plungers, valves, etc] and dead volumes, where we pump up to pressure unnecessarily and let it go again, will improve the system efficiency. Put all that together and, purely on improving the efficiency of generating pressure and delivering that to the engine, you could aim to improve CO_2 emissions [and vehicle efficiency] in the order of 1–2%. That may not sound a lot, but it's pretty significant when you are trying to get 49–51% overall thermal efficiency from the engine."

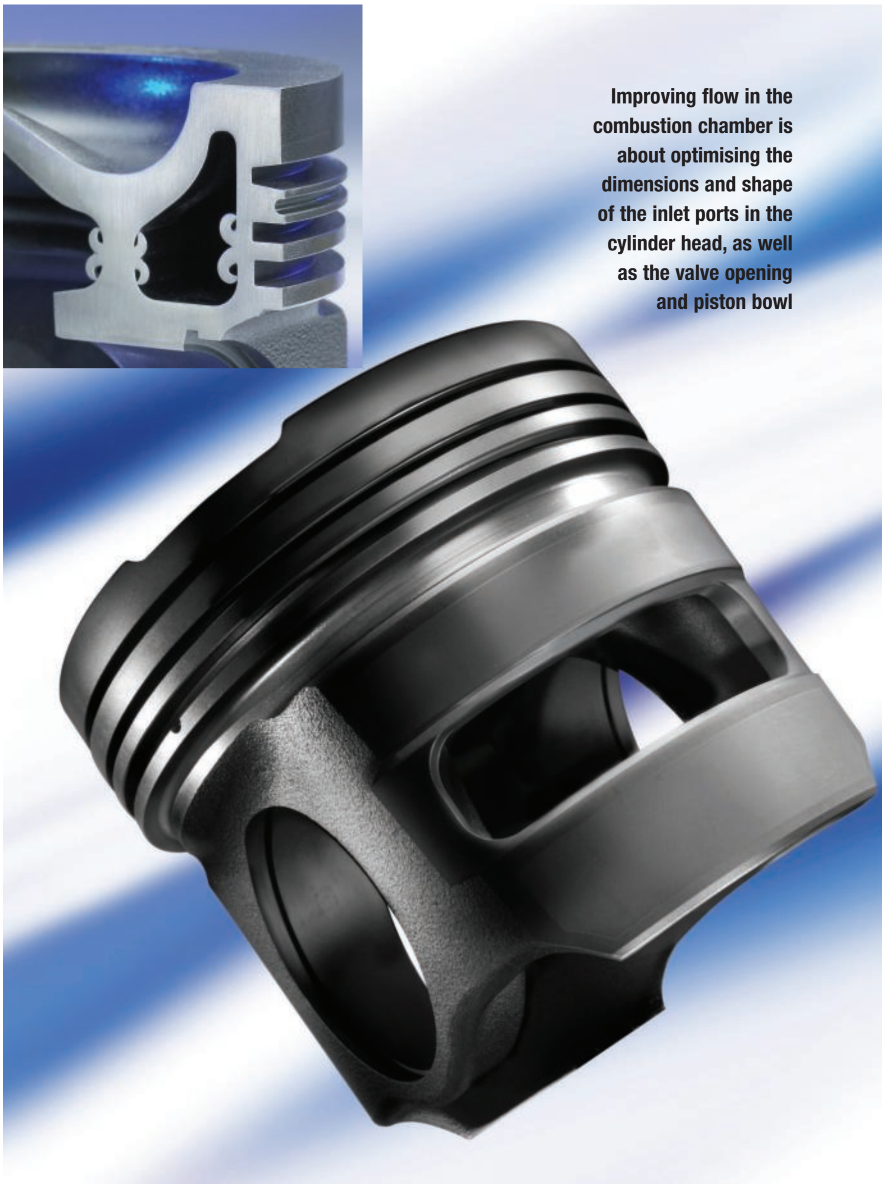
And he continues: "A second way is providing equipment that delivers the right fuel injection characteristics – be they pressure, or multiple injections, or rate shaping, or type of injections. Over the next five years, we don't expect to see massive changes: we expect incremental changes but the diesel cycle is fundamental."

Ron Borsboom, director product development at DAF Trucks, agrees that the profile of fuel, as injected, is key to improving efficiency. "How close can we get to near-perfect combustion in a very short period of time? The reason for relatively high injection pressures is to make sure that fuel is injected in as short a time as possible consistent with the air supply being capable of burning it."

For him, it still makes sense to inject fuel even faster. "If the supply of fuel is achieved in the best possible way, then the focus will be on how we get air to the fuel molecules as quickly as possible," explains Borsboom. "A lot of that is about improving flow in the combustion chamber, which is generated in several ways. One concerns the dimensions and shape of the inlet ports in the cylinder head. Another is how the valve opening is designed. And another important item is the shape of the piston bowl."

And there's another aspect: "At the moment, your valve timing is always a compromise, because you've got one camshaft," comments Martin Flach, product director at Iveco UK. "That runs throughout the mapping, when you open and close valves. At different points in the map, you might want different valve opening and closing to maximise efficiency.

"But the challenge with electrical valve opening and closing is that the currents are high. So you don't want a 24V system. You need to be upping the voltage, otherwise the cables are unmanageable, trying to reach the solenoid to open the valve. That sort of technology could offer some opportunities, but it all comes down to cost-benefit."



Improving flow in the combustion chamber is about optimising the dimensions and shape of the inlet ports in the cylinder head, as well as the valve opening and piston bowl