Burning ambition

As Euro 6 engined trucks take to the road, Brian Tinham assesses the challenges most likely to come next – and the engineering developments most likely to deliver solutions

Gian Maria Olivetti: "Think where we would be now, if we had been able to focus exclusively on fuel saving, rather than sacrificing that to achieve emissions reduction"

Yes, we're witnessing very significant developments in heavy-duty engines on the run-up to implementation of the Euro 6 emissions legislation (64/2012, 582/2011 and 595/2009). But, no, that doesn't mean the diesel technology race is over. We can surely expect improvements in everything from injector systems (operating pressure, nozzle design, electronic control) to pistons and cylinders (materials, profiles, friction reduction), turbo arrangements and waste heat recovery systems.

What's more, this time, the goal throughout will almost certainly be on improving fuel economy, not further reducing NOx and particulates, as has been the primary objective to date. That's not just because transport operators want engine designers to focus on cutting consumption and reducing their single biggest operating cost. It's also because it's highly likely that the European – and the US and Japanese – authorities will want to shift the emphasis squarely onto CO_2 mitigation, in order to help save the planet.

That's certainly the view of industry pundits. Gian Maria Olivetti, chief technology officer of Federal-Mogul Powertrain – formerly chief engineer at FPT (Fiat Powertrain Technology) – is one saying he cannot imagine a mandate for further dramatic emissions reductions. "With Euro 6, they're already extremely low." And world-class engine development specialist Ricardo's chief engineer Chris Such agrees, adding: "Anyway, with Euro 6, emissions control is very close to the measurable limit, using current sensing technology."

So let's look at some detail. Olivetti makes the point that, in fact, trucks have seen a total of some 20% fuel economy improvement over the last two decades – and that's in spite of the EC's emissions diktats. "Think where we would be now, if we had focused exclusively on fuel saving, rather than sharing the benefit with emissions reduction… There are still many improvements we can see for diesel engines, without compromising engine-out emissions. And combustion technology will be at the centre, delivering 5–8% over the next five years."

For him, one of the most significant developments will be an increase in injection pressure – from the current 2,000–2,300 bar to around 3,000 bar, supported by improved common rail systems. "That will bring many advantages," insists Olivetti. "Smaller injector nozzles, for example, will mean even better atomisation of the fuel, which is so important for combustion. It will enable better mixing, but also a significant reduction in combustion duration, which just hasn't been possible before."

Combustion challenges

He acknowledges that this is not going to be trivial. Part of the challenge will be improving some of the components around the combustion chamber, including pistons and liners, to handle the increased thermal load and cylinder pressures – likely to rise by an order of magnitude to 250–300 bar peak. Another will be enhancing the sophistication of turbo charging to further increase air pressure in the cylinder inlet manifold to 4 bar nominal – in this case to improve the energy release profile. And yet another will be reducing friction, notably associated with the pistons and rings, which Olivetti explains currently account for about 4% of engine losses.

"Federal Mogul is currently developing pistons, piston rings and cylinder liners to cut friction losses," says Olivetti. He points, for example, to a new generation of steel and high-strength alloy pistons

that will not only withstand the much higher cylinder pressures, but also allow designers to reduce the compression height (from the pin bore to the top of the piston).

The result: longer con rods and hence reduced lateral forces and friction on the piston, without changing the geometry of the engine package.

"In addition, we're looking at significantly downsizing the surface area of the piston skirt, again to reduce friction. Then, we're also developing a new skirt coating, with anti-friction additives and carbon fibre reinforcement, which gives outstanding wear performance, while minimising friction."

Materials and coatings

And he adds that Federal Mogul is also working on a new material and coating for piston rings – especially the compression ring – that will enable a thinner section. Radial forces between the ring and the liner will be reduced and, yet again, friction will fall. "We have several programmes underway with most of the global OEMs and, together, these developments alone should deliver a 2% fuel economy improvement over, say, the next five years."

Fascinating stuff, but Ricardo's Such believes we can expect even more. Indeed, he describes combustion as "entering a new era" as "the boundary conditions for engineering change". For him, key drivers are engine down-sizing and down-speeding, while chief enablers – beyond rising injection pressures and multiple injections etc – include variable valve actuation, high-efficiency SCR (selective catalytic reduction), turbo compounding and a re-emergence of the Rankine cycle.

Looking first at variable valve actuation, Such points, for example, to Daimler's exhaust cam phaser, as used on the new Mercedes-Benz OM936 mid-duty engine, which has two overhead camshafts, one for air intake, the other for exhaust. This makes it possible to control the exhaust temperature and so, in turn, optimise thermal management for the after-treatment systems.

As for SCR developments – notably with Iveco, through FPT, achieving 96% efficiency on its Euro 6 engines – Such says these could change everything. "They mean you don't need such low engine-out NOx, which, in turn, allows you to reduce EGR [exhaust gas recirculation]. Iveco has gone public with no EGR, but others, such as Volvo, are using un-cooled EGR and so saving money and weight."

What about turbo compounding? "This is now about waste heat recovery," comments Such. "Volvo, for example, previously used turbo compounding on its D12, but then dropped it when they increased the swept volume with the D13. However, they're bringing it back to enable energy recovery, and hence reduce fuel and CO_2."

It's the classic arrangement, says Andrew Nicol, technical specialist in Ricardo's performance and

Downsizing dilemma?

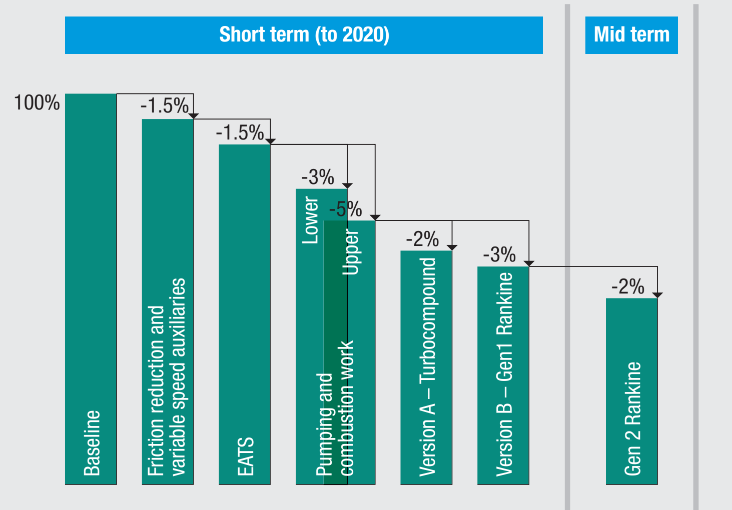
If you're worrying that down-sizing will mean lacklustre acceleration from rest, then don't. Andrew Nicol, technical specialist in Ricardo's performance and calibration group, suggests that the solution is well within our grasp – in the form of two-stage sequential boosting that delivers high torque at low speed.

"The conventional approach is one small turbo, which speeds up fast at low torque, and one larger unit, upsized a little, which isn't big on power, but does generate more torque at low speed. Another way is to design in a VGT [variable geometry turbocharger]. And one step up from that is turbo compounding, which squeezes even more torque out at low speed."

What about over-stressed small engines that might fail early? Nicol says that won't happen: "Most of the recent mid-range 7–8 litre units are more like small heavy-duty than large medium- or light-duty engines. Iveco's Cursor 8 and Mercedes' OM930 series, for example, are both used in heavy truck applications. We're going to see a lot more medium-duty engines, going forward."


Andrew Nicol, of Ricardo

CO_2 reduction scenario for heavy duty diesel engine referred to ESC



Source: Ricardo Analysis

Diagnostics upgrade

For technicians concerned about the likely complexities of repair and maintenance in the face of undeniably more sophisticated injection and combustion systems on Euro 6 engines, Delphi Diesel has a message: don't worry.

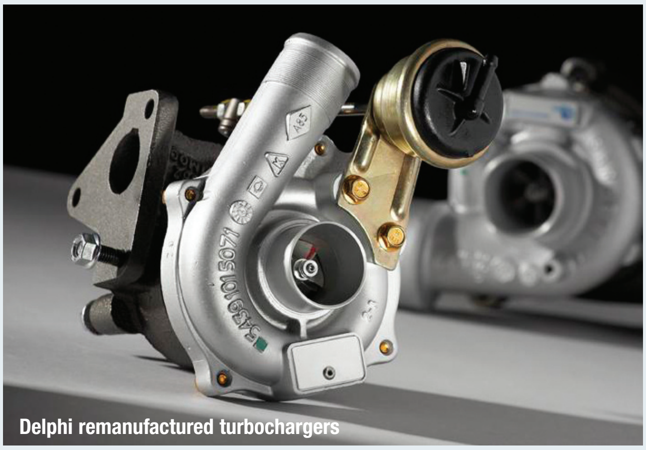
Philippe Desnos, vice president of global marketing at Delphi Diesel Systems Aftermarket, understands only too well the impact that the step-change in emissions management technology will have on service organisations everywhere. For workshop managers, technicians and the operators, he says: "We already have in place the systems and training to handle repairs promptly throughout the Delphi network."

And those systems will very soon cover not only the company's injection systems, but also other devices, including turbochargers and after-treatment, that are linked so closely to vehicle performance.

"It is critical that our diagnostics [for Euro 6 engines] can quickly identify whether problems are due to the common rail system or the turbo, SCR [selective catalytic reduction], EGR [exhaust gas recirculation], DPF [diesel particulate filter] etc. So this year we launched our fifth Delphi Service Centre module, focusing on emissions, and early next year we will introduce another tool covering all these components, to help simplify and speed up diagnostics."

That will be an addition to the company's existing tools, which currently cover diagnostics for engine management, air conditioning, braking and suspension systems. "There will be two levels of software – one for workshops – dealers and the independents – and the other for Delphi's repair network."

But it doesn't stop there: importantly, Desnos says that Delphi is investing heavily in support, by setting up a hotline for technicians needing answers fast. All of this, he says, is aimed at getting to the cause of any problems as quickly as possible, so that the right parts are either sorted on site or swapped out for return to the repair network.



Delphi remanufactured turbochargers

calibration group: "You build in a low-pressure downstream turbine to optimise the expansion ratio, which provides energy on a shaft that can be transmitted to the drivetrain or a generator. The only issues are: the turbine spins at a different rate to that of the engine, so it has to be managed; and, to extract meaningful energy, engines have to be worked quite hard."

Rankine revival

For Such, though, this is where the Rankine cycle comes in – providing an even better way to take advantage of energy normally lost down the tail pipe and/or the EGR cooler, where one is fitted. Indeed, he believes Rankine has the potential to dwarf fuel savings from either combustion or friction reduction improvements. "The Rankine cycle could offer as much as a 5% improvement," he asserts.

Putting meat on those bones, Nicol explains that Rankine starts with waste exhaust energy heating a fluid (typically, ethanol and water). This transitions to the gas phase in a boiler and drives an expander, which either contributes power back to the engine crankshaft or produces electricity – for example, to drive the auxiliaries. Then there's a condenser, which converts the gas back to a liquid, and a pump to drive the fluid back to the boiler.

Clearly, just as with turbo compounding, the Rankine cycle works best when engines are driven hard. But, given the current trend to downsize and down-speed engines – again to cut fuel consumption – the timing couldn't be better. As Such puts it: "Downsized engines have inherently lower friction, reduced swept volumes and higher exhaust temperatures – which also help to optimise the operation of high-efficiency SCR and DPF [diesel particulate filters] equipment. That's one of the reasons why there's so much development on the Rankine cycle: virtually every manufacturer now has a demonstrator. Cummins, for example, has it on about five trucks currently in testing."

However, we're talking at least five years until this technology is available. "We've been running engines with a Rankine cycle and they're very complicated," comments Such. "One of the problems is that we're working with prototype equipment, so it's not 100% reliable – especially the expander, which could be a turbine or a reciprocating piston machine, like an air compressor. The other point is the weight penalty, which is between 150 and 200kg. That's not a good thing for CO_2, although downsizing does also mitigate that problem."

What about cost? Such says current estimates suggest that payback should easily be achieved during the life of a truck, as a result of the fuel reduction. "It could even be less than a couple of years, depending on fuel prices and the distance covered," he says.