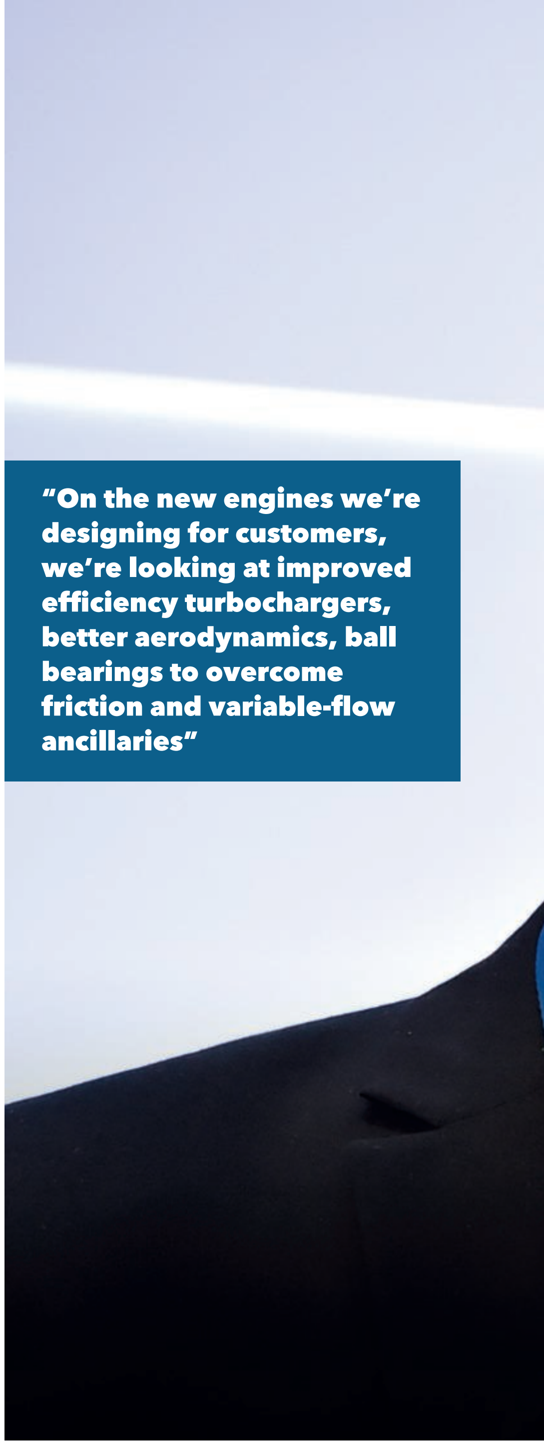
Refreshed **engineering**



"On the new engines we're designing for customers, we're looking at improved efficiency turbochargers, better aerodynamics, ball bearings to overcome friction and variable-flow ancillaries"

'Euro 7' is likely to focus on CO_2, but also further driving down NOx and particulates. Brian Tinham listened to Ricardo luminaire Andy Noble on how to make powertrains cleaner and more efficient

Ricardo's most recent review of heavy-duty diesel engine technology, conducted on behalf of the Energy Technologies Institute, concluded that powertrain developments are likely to be evolutionary, rather than revolutionary over the next decade. Why? Because they are driven primarily by the increasingly challenging requirements of global vehicle emissions regulations. So said Andy Noble, Ricardo's head of heavy-duty vehicles, opening his address on 'Euro 7' at the IRTE Conference.

Noble conceded that more radical engines, such as hybrids, plug-ins, fuel cells, etc, may be adopted, particularly on lighter commercials and buses. Additionally, electrification of auxiliaries and increasingly intelligent transmissions will make a difference. But for long-haul, heavy transport and distribution vehicles, it's mostly going to be about further developing diesel engines and their after-treatment systems.

So what's the background? Noble explained that Euro 6 has its counterparts around the world – particularly in the US and Japan. "Developing geographies are starting to catch up, and by 2020 we expect to see virtually all major markets up to Euro 6 or equivalent. But by then, emissions limits will be even tighter in the US and Europe, because air quality – particularly in cities – is still a problem. Additionally, greenhouse gases will be monitored – starting in 2018 in Europe – because cars, trucks and buses are being seen as responsible."

It's happening already. Noble pointed to the currently voluntary emission limits in California, with NOx targeted at just 7% of Euro 6. "Those limits will become mandatory. They're being phased in from 2023. So the US is serious about NOx." And Europe, he said, is likely to move in a similar direction.

So, what is a notional Euro 7 – none has yet been defined – likely to demand? "Given the air quality danger in London and other cities, we believe that NOx, and especially NO_2, will be forced down. NOx limits are likely to be halved and NO_2 will be about a quarter of that. And, because the anti-diesel brigade wants to reduce the size of soot particles we count, we're expecting that to move down from the current 23 nanometres to everything over 10 nanometres."

TIGHTER EMISSIONS LIMITS

If such legislation is brought in, the latter poses two challenges. First, how to measure particles that are so small and unstable – suitable instrumentation is not yet available. And second, the obvious requirement for finer DPFs (diesel particulate filters), which has its own implications for increasing engine back-pressure. "That may not be good news for fuel economy and hence also for CO_2 emissions," explained Noble.

But, as already mentioned, greenhouse gases are coming under the spotlight, too. So Euro 7 is bound to bear down on CO_2 emissions. Pointing again to the US, Noble observed that regulations there have already been formalised through to 2027, looking for a 24% improvement in fuel economy (and commensurate CO_2 reduction) by means of technologies including aerodynamics, lightweighting – but, again, also engine developments.

"Here in Europe we have the whole vehicle CO_2 emissions simulation tool VECTO, which takes engine dynamometer data and predicts trucks' CO_2 performance. VECTO is intended to level the truck manufacturers' playing field, and so incentivise CO_2 improvement for the engine and the vehicle. In 2018 the OEMs will need to declare their CO_2 numbers. Beyond that we expect mandatory limits under Euro 7 within two years."

So, taking it from the top, what can engine manufacturers do about achieving ultra-low NOx (10% or less than Euro 6)? "They'll need to focus on

FACT
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the SCR [selective catalytic reduction] system and improve its efficiency," Noble told delegates. "On the thermal side, it's about getting that catalyst into the optimal operating window for high efficiency as quickly as possible. And before that, we're looking at potentially an additional NOx storage catalyst."

But the other angle concerns AdBlue dosing: "The chemical plant will get more complicated and sophisticated. It will be harder to control and package but there are ways… The most promising, but also the riskiest, involves injecting AdBlue upstream of the turbocharger followed by a very close-coupled SCR catalyst that gets working quickly. The question is what that urea will do to the turbine in terms of fouling and durability."

Turning then to CO_2, Noble pointed out that currently best-in-class HDD [heavy-duty diesel] engines are in the low to mid 40s per cent thermodynamic efficiency, with Daimler declaring 46% on its latest Mercedes-Benz engine. "We can see improvements through engine down-speeding and downsizing, but also using measures such as critical engine component friction reduction and variable ancillaries that only pump air, coolant and oil as required. Certain modest improvements can also be made with the exhaust after-treatment system."

All are aimed at improving combustion efficiency and reducing losses, but other avenues to pursue include turbo compounding – with two-stage turbos, e-turbos, etc – and waste heat recovery systems, especially those using Rankine cycle, he said. "On the new engines we're designing for customers, we're looking at improved efficiency turbochargers, better aerodynamics, ball bearings to overcome friction and variable-flow ancillaries. Then, in terms of mechanical design, we're looking at an offset crankshaft … to reduce thrust friction. It's been done in cars, so we're going to do it for HDD engines. And we're using low-friction coatings and re-profiling of the reciprocating group."

Looking at the issues, Noble pointed out that, while increasing the compression ratio improves thermodynamic efficiency, it also results in higher peak cylinder pressure. That means designers have to make the engine bigger and stronger. And that, in turn, compromises weight and friction. Faster combustion is also good, because it's more efficient and cleaner, but you've got to minimise heat transfer losses. "So it's about trade-offs."

CORE CONFIRMS PROGRESS

Ricardo's work with single-cylinder engines at up to 300bar peak cylinder pressure (conventionally 200–220bar) and 3,0000bar fuel injection rail pressure (compared to today's 2,400bar) has been instrumental in finding answers. And Noble added that the now completed CORE (CO_2 reduction for long-distance transport) project has confirmed a 15% potential CO_2 improvement through a combination of the above measures.

"The main hitters in the CORE project came from the engine improvements I've outlined, as well as a mild hybrid 150kW starter generator. Incremental improvements were also seen from increasing the efficiency of the after-treatment and adding waste heat recovery systems."

So what might a truck engine look like in 2025? Noble was unequivocal. "By 2025 we expect to break the longstanding 50% limit on thermal efficiency. We could even take that up to 60% if more revolutionary engine designs, such as split cycles, are adopted. Six cylinder engines with compression and expansion performed in different cylinders could power future commercial vehicles."

Either way, Noble expects downsized engines delivering torque at lower speed – probably running with more ratios, to accommodate narrower power bands, and using smart shifting software based on GPS. "They may also be using alternative fuels but they will definitely run at higher peak cylinder pressures. The result will be 32–36kW of power per litre swept volume, with ultra-low NOx and real-world emissions all under control." ■