Turning up the heat on gas drivelines

A recent research programme explored the future development of a heavy-duty engine type that illustrates the benefits of using natural gas instead of diesel fuel. Steve Banner reports

Lean-burn gas engines could have a major role to play when it comes to cutting CO_2 emissions from long-haul trucks. So says Andy Noble (pictured), head of commercial vehicle, off-highway, defence and industrial market sector at Ricardo Global Automotive.

He points to a major collaborative project, which wound up earlier this year and which demonstrates that such engines can offer a more-than-10% CO_2 reduction when compared with their counterparts of five years ago. They can comply with Euro VI+, he adds, while offering a potential range of up to 800km.

The project he refers to was funded by the European Union to the tune of €20m. The motor industry itself contributed €7m to an initiative that involved truck manufacturers, Tier 1 component suppliers, research and development consultancies and universities, and took three years to complete.

A key role in this project – and an aspect of it that Ricardo was closely involved with – was played by a 2013-vintage Fiat Powertrain Technologies (FPT) Cursor 13 six-cylinder in-line 12.88-litre natural gas engine with 454bhp on tap. It has a 135mm bore and a 150mm stroke and acted as a baseline. The Cursor engine is, of course, installed in IVECO trucks. IVECO is heavily promoting the use of gas trucks on trunking work, with increasing success in both mainland Europe and the UK.

The baseline engine's combustion system was altered with tumble-generating intake ports, a pent roof combustion chamber and double overhead cams. A direct-injection fuel system was fitted, as were variable valve actuation and corona ignition.

Corona ignition creates a significantly larger high-intensity plasma ignition source, spread throughout the combustion chamber, when compared with conventional spark ignition. The latter solely creates a small arc in the gap between the electrodes of a spark plug, as opposed to corona ignition's high-energy, high-frequency electrical field which creates multiple streams of ions.

The result is more thorough combustion, which means that combustion strategies such as lean burn can be used along with highly diluted mixtures and very high levels of exhaust gas recirculation.

FACT
Methane slip was the principal difficulty with the lean-burn engine project. Getting the aftertreatment right was a challenge

Three prototype engines were built. One was installed in an IVECO demonstrator, while two were sent to test benches; one at FPT, which was a stoichiometric version, and one at Ricardo, which was the lean-burn variant.

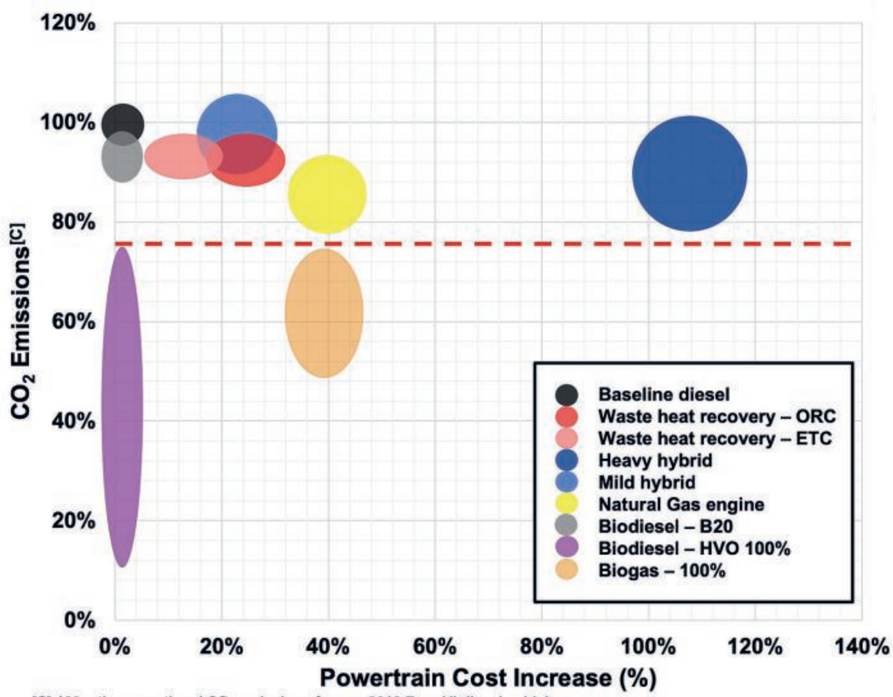
The lean-burn engine performed especially well, Noble says. With over 500 testing hours accumulated, CO_2 was reduced compared with the 2013 engine by 16%, and the engine was up to 5% better on CO_2, compared with the stoichiometric version with the same engine hardware.

The engine's target performance – 2,200Nm at 1,000rpm and 370kW at 1,900rpm – was reached with fuel consumption well below the 200g/kWh target, with brake thermal efficiency above 40%.

FACT

Heavy-duty diesels are likely to emit 10-15% less CO_2 by 2030 than in 2018. That sounds laudable, but it is only 50% of the European Union's target

Typical 2030 capital cost versus operational CO2 emissions for a 40t long-haul truck – Ricardo analysis



[C] 100 = the operational CO_2 emissions from a 2018 Euro VI diesel vehicle

A difficulty with compressed natural gas (CNG) and liquefied natural gas (LNG) engines is that they emit methane, which has a global warming potential per kg approximately 30 times that of CO_2. So there was a need to develop a stable methane oxidation catalyst with improved sulphur resistance and durability, says Noble.

"Methane slip is the principal difficulty," he says. "It gets into all the crevices in the engine and does not burn properly. So getting the aftertreatment right was a challenge. However, we didn't need a particulate filter because the combustion was really clean."

The problem with methane oxidation catalysts, he says, is that light-off occurs at approximately 400°C, with high efficiency only being achieved above 500°C. What is more, they are known to deactivate, and become poisoned by sulphur. One of the features of the chosen aftertreatment system, therefore, is a three-way catalyst positioned before the methane oxidation catalyst to help protect it from sulphur's effects.

So could lean-burn gas be a sensible direction to head in? The lack of maturity of some of the technologies used – especially the injectors and the corona injection system – hampered progress, says Noble, but he believes it can be overcome. "Further development can be expected to realise greater benefits," he observes.

What about some of the alternatives to gas: battery power, for example? "To achieve a range of 800km, a 40-tonne truck would need a 10-tonne lithium-ion battery that would cost £270,000," he points out. And such batteries have only modest levels of energy density, he adds.

"If it's energy density you are looking for, then you can't beat conventional fuels, such as gasoline, kerosene and diesel," Noble observes. They offer an energy density of 12kWh/kg, he says. LNG (less than 8kWh/kg) and CNG (under 4kWh/kg at 250bar) are some way behind them, but they are way ahead of lithium-ion batteries (right at the bottom and almost off the scale) and hydrogen (2kWh/kg at 700bar). Use compressed hydrogen, and the 40-tonne truck referred to earlier would need a 1,500-litre tank weighing 1.5 tonnes, he says.

Diesel engines can be developed further, and Noble sketches out some of the features an 11- to 13-litre 350-400kW diesel for a 40-tonner might have in 2030. It is likely to be married to either an automated manual or a dual-clutch transmission, he suggests – which indicates that there will be no significant role to play for the fully-automatic heavy truck transmissions promoted by Allison.

Complying with Euro VII would involve it having a peak cylinder pressure of 280bar, he predicts. Fuel injection pressure will be at 2,800bar with injection-rate shaping, and the engine will feature variable valve actuation with lost motion, a variable-displacement oil pump, an advanced water pump and a CGI (compacted graphite iron) cylinder block and head with steel pistons. Aftertreatment will include selective catalytic reduction with a soot filter.

Down-speeding will deliver a 3% CO_2 cut, he says, while better combustion will deliver a similar improvement. Other sources of CO_2 reduction will include variable valve actuation, greater aftertreatment efficiency and friction reduction and variable speed ancillaries, all of which should provide a 1.5% cut apiece.

As a result, heavy-duty diesels will emit 10% to 15% less CO_2 by 2030 than they did in 2018. While on the face of it that sounds laudable, unfortunately it is only 50% of the European Union's target, says Noble, and using a diesel hybrid solution will not be sufficient to bridge the gap. "Going hybrid adds to the cost, too," he says.

Biofuels could help diesel's case, he agrees, but the take-up of biofuels may be limited by feedstock availability, he contends; and gas engines can achieve low CO_2 levels without having to resort to them.

His conclusion? It has to be gas. "Gaseous fuels, including natural gas and biogas, are key pathways towards achieving CO_2 and greenhouse gas reduction for heavy-duty, long-haul transportation," he states – a conclusion fleet engineers responsible for inter-urban fleets may care to ponder.

Much, of course, depends on the quality and availability of the fuel, aftersales support by the truck manufacturers concerned and the taxation regime the government chooses to impose. ■