View from the TOP

Emissions and CO_2 legislation continue to drive the development of commercial vehicle engines, reports Ricardo chief engineer Andrew Banks

For air quality, the Euro VI emissions regime is quite demanding: NOx is 460mg/kWh and tail-pipe particulate matter emissions are 10mg/kWh; both are measured in the transient, WHTC cycle. Three years before Euro VI, the USA's diesel emissions regulations established by its Environmental Protection Administration were even more restrictive on air quality: 268mg/kWh for NOx and comparable levels to Euro VI for PM (13mg/kWh).

Future policies will curb the use of higher-polluting vehicles, especially diesel. Ricardo believes that post-Euro VI, statutory NOx emissions levels will be approximately cut in half, perhaps to 230mg/kWh in the WHTC cycle. In addition, there may be a new limit on the particularly harmful component of NOx, NO_2, perhaps to 110mg/kWh in the WHTC, or to a maximum of 50% of total NOx.

Elsewhere, the developing world is catching up: India and China also have plans to introduce Euro VI-equivalent emissions restrictions, coming in 2020 in India, and starting next year in Beijing, to roll out nationwide from perhaps 2022. Industry has perhaps not received sufficient credit for achieving these levels of reductions. And the US state of California, which enforces its own emissions rules, may impose very low NOx levels soon, too. Levels of 134mg/kWh are currently only voluntary, but Californian authorities hope to make such ultra-low NOx standards mandatory in the early 2020s.

Reducing NOx levels can impact fuel consumption negatively. Ricardo estimates that systems required to reduce the EPA 2010 legislation levels by up to 75% might cause a 2% composite fuel penalty. Technology using NOx adsorbing catalysts can boost the reduction to almost 90%, but at the cost of a 3% penalty.

During a time of some geopolitical uncertainty, the diesel engine world is also unsettled, with the VW emissions scandal, and this summer's announcements by Britain, France and China suggesting that they may ban diesel and petrol engines: the first two by 2040, the latter's timescale is uncertain. Even diesel engine manufacturer Cummins announced plans to launch an electric truck recently, a demonstrator of which uses a 140kWh battery pack instead of 12-litre engine for a 100-mile range. A range extender model incorporates Cummins' B4.5 or B6.7 engines, offering 50% fuel savings compared to today's diesel hybrids.

So, it might be useful to consider then the strengths, weaknesses, opportunities and threats of the diesel engine for the next 15 years or so, to 2030. Its strengths include: low fuel consumption under typical road operating conditions; a low-cost, robust and durable design good for a million miles; the engine matches well to the SCR for efficient NOx reduction; and there is a well-defined existing fuel infrastructure.

Weaknesses of the technology include: the high cost and complexity of emissions aftertreatment systems; future potential reliability problems with VVA (variable valve actuation), complex EGR (exhaust gas recirculation), ORC (organic Rankine cycle) and eTurbo; and NOx treatment process limitations below about 200°C.

Threats include the risk that California's proposals for very low NOx emission standards will spread elsewhere; and that the concerns about diesel health effects will continue to grow. Another threat is the potential competition from gas engines from manufacturers including Cummins and Volvo, which has just launched a new direct injection diesel and gas technology.

Opportunities include: increasing engine efficiency through waste heat recovery, to around 50% BTE (brake thermal efficiency); very high NOx conversion efficiency by thermal management; the possibility of developing a close-coupled SCR (selective catalytic reduction) on the diesel particulate filter; and further improvement in engine efficiency and noise by multiple high-pressure injection and higher maximum cylinder pressure in the base engine design.

RESEARCH PROJECTS

Looking to the future, Ricardo was involved in the collaborative research project CO_2RE, which examined ways to reduce CO_2 in truck operations, that finished in 2016. This is topical, as the EU will introduce CO_2 targets for heavy-duty vehicles starting in 2020. CO_2RE developed a simulation of the potential savings of moving to a hybrid diesel/electric engine for different duty cycles, a long-haul cycle on a 7.7-litre Euro V Mercedes-Benz Actros artic, and continuous motorway driving in a Euro V Volvo FH tractor and trailer.

Results were mixed. Large benefits were found in the first case: a hybrid drivetrain featuring 5.5kWh, 150kW ISG battery, with modifications for Euro VI compliance (including SCR and friction reduction), produced a reduction of about 15% in predicted vehicle total cycle fuel consumption compared to the original Euro V engine. Two other modifications improved that reduction slightly more: the EATS (exhaust aftertreatment system) that reduced back pressure by 50%, and the 'Nowaste' waste heat recovery system that powers engine auxiliaries.

Benefits were more muted in the constant-

FACT
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speed truck. After conversion to a Euro VI level-compliant model with SCR and friction reduction, the now-454bhp engine fitted with 1.8kWh, 150kW ISG battery produced vehicle total cycle fuel consumption savings of about 10% compared to the original Euro V engine. That figure includes savings from VVA and two-stage boost system, and also includes the 'Nowaste' waste heat recovery system.

Now, Ricardo is working on a €20 million collaborative research project in the Europe-funded Horizon 2020 programme on heavy-duty gas engines for long-distance goods transportation: HDGAS. The Ricardo approach is single-fuel LNG on an IVECO 13-litre engine with direct injection, producing a lean burn with EGR emissions technology, featuring high-energy ignition.

For medium- and heavy-duty trucks, a number of features and enabling technologies seem likely to appear in powertrain developments to 2025. As far as engine performance goes, higher specific outputs are likely, at levels greater than 32kW/litre, and higher peak cylinder pressures, too (270 bar).

Also in the engine, the trend toward engine downsizing (medium trucks) and downspeeding (heavy trucks) involves these technologies: waste heat recovery, CNG/LNG combustion, the use of e-ancillaries, VVA or eBoost, and cylinder deactivation. Aftertreatment continues to develop, particularly on the back of SCR+DPF systems. Enablers include cold-start NOx catalysts and ultra-high efficiency SCRs. Transmission technologies coming are GPS-linked gear shifting and route learning, plus light weighting, thanks to technologies such as e-transmissions, torque fill-in and KERS (kinetic energy recovery systems). Some take-up of battery, hybrid and 48V mild-hybrid electric vehicles is expected, thanks to improvements in stop/start and battery technologies. Controls are likely to change as well, with new methods, including model predictive control, model-based design toolsets, new sensors for smart diagnostics (OBD) and for example e-Horizon in-the-cloud prediction of road conditions.

By 2030, Ricardo expects mass electrification of passenger cars, though their penetration rates depend on segment. Long-haul and heavy-duty applications may not be so well-suited to batteries; they will require low-carbon liquid fuels. Trucks with less arduous duty cycles may fall in between these extremes.

An alternative to on-board energy storage for zero-emissions operation is a railway-style catenary or pantograph system as demonstrated by Scania. But it would require a dual catenary to complete the circuit, as there is no current return path via the track, as on railways. Infrastructure cost might be several million dollars per km, and an open question would be which organisations would pay for that.

Renewable hydrogen fuel cell trucks or renewable waste/electricity to liquid fuels such as methane and syngas are also options. ■