MORE FOR

OEMs are looking to improve diesel emission performance by modifying the aftertreatment and engine control system, writes Will Dalrymple

Although the detail of the forthcoming Euro VII emissions requirements are not expected to be published until later in the year, the headline figure poses huge challenges on its own: CO_2 reductions of 15% by 2025, and 30% by 2030, as measured from a 2019 baseline. (Although it is widely expected that limits on other gases emitted will be further tightened).

Truck and engine OEMs and suppliers are gearing up to rise to this challenge, and that of other regulations around the world, including US EPA (the national standard) and CARB (from the US state that has generally been the strictest, California), as well as possibly China.

Simplistically speaking, government standards apply to two types of pollutants: CO_2, which is not particularly harmful to humans directly, but harms the earth as a greenhouse gas. In a truck is produced in proportion to the amount of fuel consumed. And then there are a number of other gases that directly harmful to human health produced during combustion, including oxides of nitrogen (NOx). Since promulgation of Euro VI, they have been controlled in vehicle systems by exhaust gas recirculation within the engine, and selective catalytic reduction (SCR) aftertreatment systems that convert the harmful gas into harmless nitrogen gas with the help of ammonia gas generated from liquid AdBlue.

During normal operations, such systems have proven their effectiveness at reducing NOx. According to Matt Henry, technical lead at Cummins Emission Solutions, the chemical catalysts used in SCR systems are most efficient at temperatures of between 200-450°C. But below 190°C, very little NOx is converted. And that is a problem for every commercial vehicle that ever starts from cold, or is ever stuck in slow-moving traffic.

Gabriel Roberts, director of product development at Jacobs Vehicle Technologies, distinguishes between two different operational situations. Current thermal management strategies for what he calls the 'get it warm' phase include extra and late injection during cold starts and engine throttling. These have the disadvantage of running inefficiently until the engine is warm.

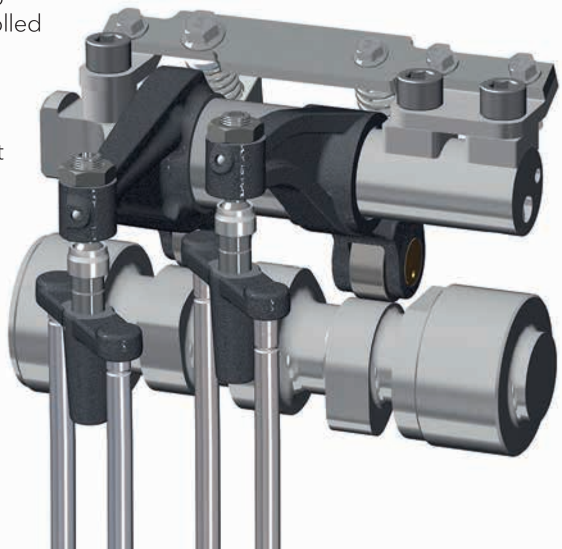
A new Cummins Emissions Solutions system has found a way to partially avoid having to do that. Exhaust temperature starts to cool as soon as it leaves the turbocharger, and in Euro VI engines, the SCR is mounted last in the emissions train, and so is the coldest part.

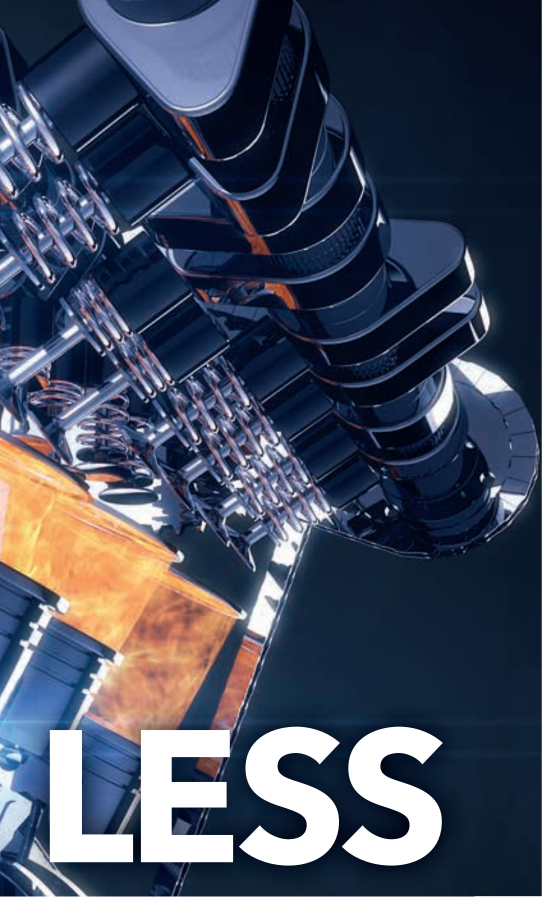
While Euro VI systems involve a single AdBlue dosing point, Cummins has devised a double-dosing system (pictured, p12). That allows OEMs to move a portion of the AdBlue injection to a point closer to the heat source, which might be 50°C warmer than at the end of the chain, so some NOx conversion can happen more readily in light load and cold-start conditions.

Scania, which will launch the system to the market later this year on its new V8 engine, claims it will reduce NOx production by 50% of today's regulations (although it did not specify which ones).

Henry qualifies the amount of savings by saying that results on every installation will differ, and injector positioning depends on an individual engine or vehicle's space constraints. But in any case, offering double dosing increases OEMs' design flexibility in meeting the regulatory requirements.

He also points out that engineers cannot simply move all of the AdBlue injection in front of other elements in the emissions aftertreatment system, which also includes the diesel oxidation catalyst and diesel particulate filter. A passive regeneration cycle reacts to the





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flow of NOx; NO_2 flowing over a DPF reacts with carbon (soot) and turns it into CO_2, and keeps the soot from building up. Putting a 100% SCR in front of a DPF will decrease NO_2 flow to almost zero; that will load the DPF heavily. That can only be overcome by having a hydrocarbon doser downstream of the SCR and upstream of the DPF to perform active DPF regen. He adds: "This technology is balanced; by moving a portion of the reaction upstream, you are able to improve the flexibility of temperatures available to convert NOx. But just a portion; over the drive cycle you need to make sure there's enough NO_2 flow to accomplish passive regeneration."

The new Cummins system also offers the possibility of dynamically varying the ratio of AdBlue injection between the two locations, so for example more of the reaction could be moved to the downstream location when the engine is highly loaded at the top of the torque curve and at the highest temperature.

KEEP IT WARM

The other emissions problem – which Roberts calls 'keep it warm' – is no less important. Imagine a warmed-up engine is operating in efficient mode, say on a motorway, which then runs into a traffic jam. Without the revs pumping diesel through the engine, it cools down, and so does the SCR catalyst, until that system no longer converts the NOx that the engine continues to produce.

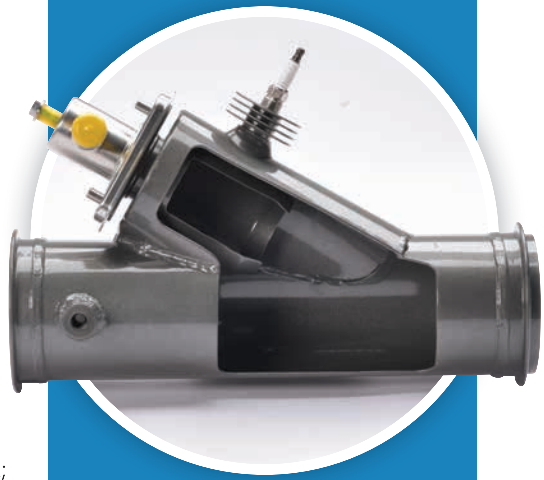
A technological solution not yet on the market is also promised to help with that: Jacobs' cylinder deactivation (CDA; pictured left and p12). It keeps the inlet and exhaust valves of certain engine cylinders (two to four in a six-cylinder engine) closed in low-load scenarios.

Roberts explains how it works: "When we deactivate the valve, the cylinders act like an air spring. The piston operates normally, however pumping losses are reduced and most of the energy used to compress the air is returned to the crankshaft." Meanwhile, the cylinders that are working normally run in a higher efficiency range; 20-25% fuelling instead of 5-10%, he says. "When we take the total system combined, those three cylinders have greater temperature and reduced mass flow in the engine, so they increase overall enthalpy, which is a function of mass flow and temperature. Increased temperature and lower flow, so greater enthalpy through the catalyst, leads to increased temperature at the catalyst."

Roberts observes: "CDA is good for 'get it warm', but more ideal for 'keep it warm'. Cummins and Jacobs' solutions work well together, because they are solving different problems."

Jacobs originally developed CDA for its high power density engine brake, which has been launched on the 11- and 13-litre Sinotruk Yellow River tractor units of China National Heavy Duty Truck Co.

A key part of CDA is the collapsing bridge. In normal operation, this controls valve opening though a mechanical linkage between camshaft, rocker arms, valve bridge and exhaust valve. But when an internal oil circuit is pressurised by a solenoid, it depresses an internal pin that makes the valve bridge collapse (slide) so camshaft movements do not transmit from the rocker arms to the valves, and the valves remain closed.



OTHER WAYS TO SKIN A CAT

Another way to improve the conversion of NOx in chilly aftertreatment systems is to heat up the catalyst, rather than, or in addition to, the SCR system. At least three suppliers have developed systems to do just that: Faurecia, Emitec and Eberspacher. Faurecia's system for passenger cars and LCV claims to reach temperatures of 400°C in less than 10sec for gasoline engines. It also offers a heated AdBlue doser for commercial vehicles that it says can be retrofitted to normal SCR systems. Claimed benefits include reducing deposits, more efficient conversion and lower energy consumption.

In addition, Eaton and Tenneco have announced a cooperation to develop an exhaust aftertreatment heater, in which Tenneco's Cold Start Thermal Unit (pictured above) is combined with Eaton's electrically-powered TVS Roots blower to heat up the catalyst independent of engine temperature.

A number of versions of CDA and control systems are currently in development with engine OEMs. Limited data has been released for two systems. The first, being developed with US engine manufacturer Navistar as part of the US EPA Supertruck II programme, divides the cylinders into two groups or banks: three that are on, and three that are off. The other system being developed by Cummins and Tula Technologies with Jacobs is called 'dynamic skip fire'; it randomises the amount of cylinders being deactivated based on the load, temperature requirements and operating profile.

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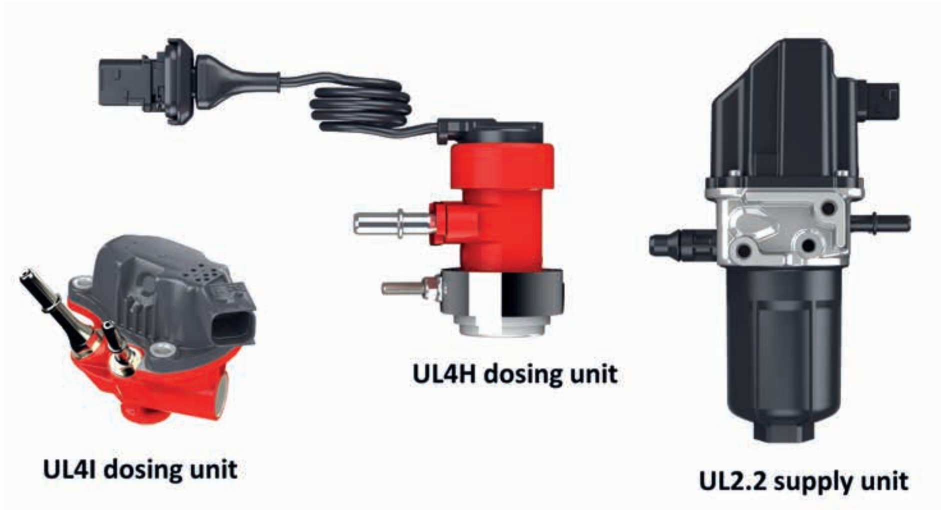
Matthew Henry

Although the technology is still in the R&D and production trial phase, early results are promising. For example, the Navistar system was recently tested on two test cycles: a US FTP hot cycle, and a low-load cycle (LLC7) expected to be used in California. Over the former, the test found 45% reduction of NOx emissions, and on the latter 1.5% reduction of CO_2, and 66% less NOx and 3.7% reduced CO_2 at low loads. Roberts speculates that the Euro VII requirements will include some portion of the low load cycle, so that US test would have relevance for users across the pond.

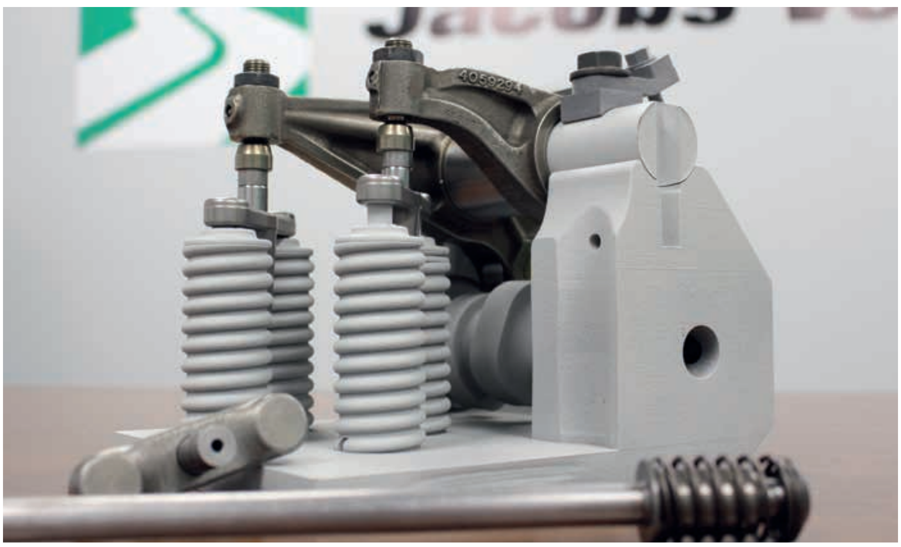


OTHER TECH

These aren't the only relevant valve control strategies that could help OEMs. Two in particular, which are compatible with CDA, are early exhaust valve opening (EEVO) and late intake valve closing (LIVC). The first, which benefits 'get it warm', takes some of the combusted energy from the power cycle and throws it into the tailpipe to heat the aftertreatment system. That system provides heat, but at the expense of fuel.

On the other hand, LIVC would extend the engine's ability to vary compression ratios; that helps with 'keep it warm'. Roberts offers a scenario of an HGV accelerating to join a motorway. "When you are getting on the highway, it's a high-power mode; you are closing the exhaust and intake valves normally to achieve a high compression ratio. But then when you are on the highway, you're driving at 80kph, you're only at 50-60% throttle, and the engine valve timing and effective compression ratio can be modified to achieve higher efficiency because it is in a lower power operating range.

"As the truck moves to cruising, it drops to 17:1 or 16:1 for better fuel economy and better efficiency of the engine. So LIVC closes the intake early or late – specifically late is better – and that modifies the effective compression ratio. You take a 20:1 engine and then switch into LIVC mode and modify to a lower compression ratio, and you gain a little efficiency. When you do that, you also produce a bit more temperature, which keeps the aftertreatment happy. LIVC has a wider operating range than CDA and can be used at higher loads and RPM than CDA. That's interesting particularly in Europe, where CO_2/fuel economy is an important driver."



Given how global emissions regulations are playing out, Roberts predicts that advanced valvetrain technologies will be needed by OEMs in the 2027-2030 time frame. That date includes the launch of its own CDA.

He concludes: "Cummins offers 2-3% fuel improvement for dual dosing. But that's not nearly enough to meet the requirements on its own. It is likely that a combination system of internal engine solutions (CDA, LIVC, EEVO), and external engine solutions (dual dosing, close coupled SCR, electrically-heated catalyst) is needed to meet upcoming EPA, CARB, and EU emissions requirements." TE

FURTHER INFORMATION

Jacobs CDA explained – www.is.gd/nemogi
Collapsing bridge video – www.is.gd/ucuqus