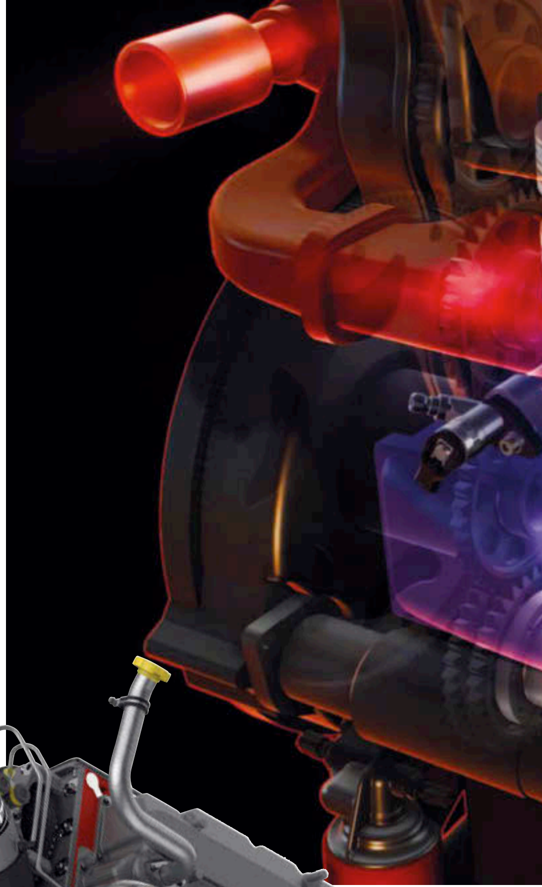
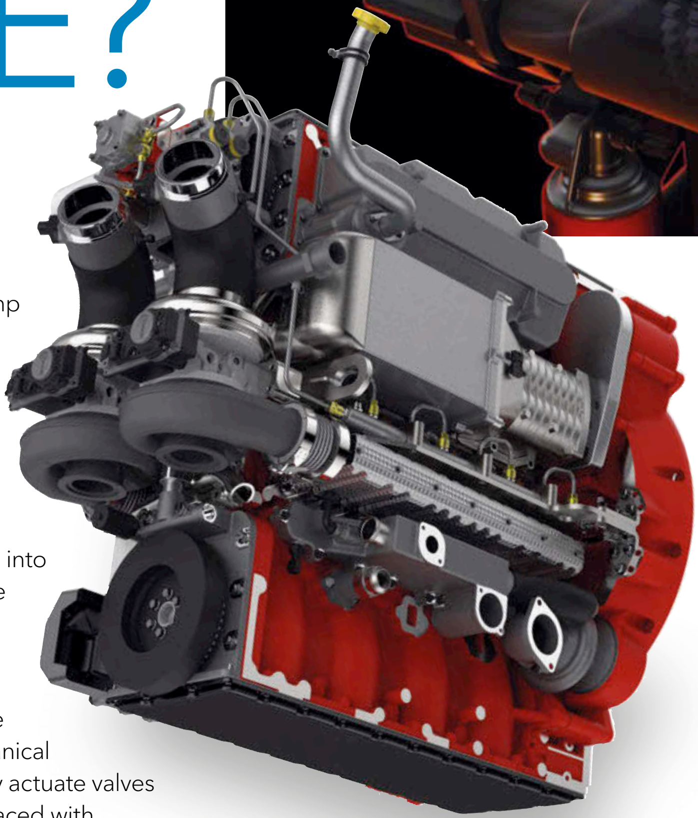


SIX POTS OR THREE?

Cylinder deactivation could be a path to the fuel savings needed to hit EU CO_2 reduction targets. Richard Simpson explores the possibilities



Europe's heavy vehicle manufacturers have been set a stiff target for reducing CO_2 output by the European Commission. Using fuel consumption figures produced by the VECTO tool and a model baseline of 2019-20, they must slash overall fleet fuel consumption by 15% by 2025 and 30% by 2030 (see also *www.is.gd/fikava*).

The sting can be taken out of that somewhat by introducing electric vehicles for applications such as urban distribution, reducing CO_2 output there by 100%, but for the mainstays of the industry – long-haul and construction – there is no alternative to the diesel engine. So, diesel technology must be improved, and it is a tough target.

David Needham, director of product engineering at fuel injection supplier Delphi, says: "We believe there is still a bright future for diesel in the heavy-duty truck market. Truck OEMs are looking to different technologies, each of which will bring a small incremental advantage in fuel consumption." These range from improving fuel injection systems, to recovering energy from the exhaust stream. All aim to increase combustion efficiency and/or reduce waste.

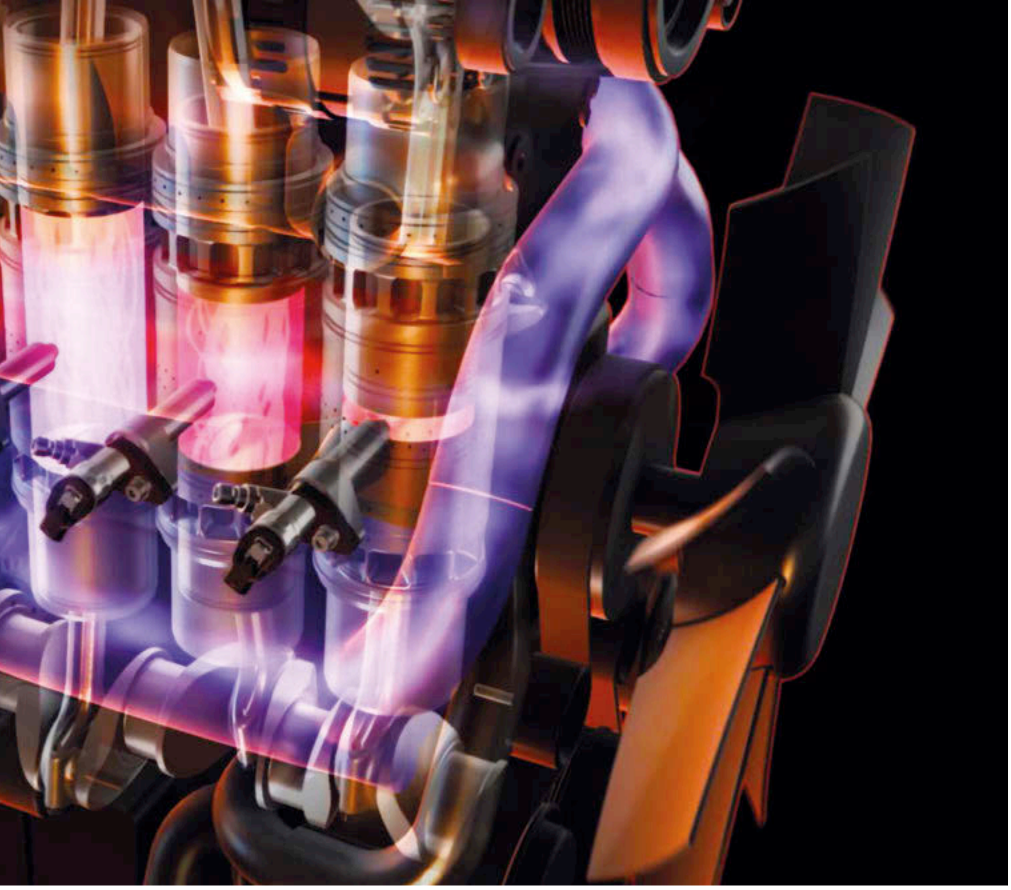
But is there a simpler way? One bold step might be to adjust the effective size of the engine to suit varying demands in a duty cycle. A tipper truck, for example, might need all of 500bhp when climbing out of a quarry laden with 20 tonnes of product, but only a fraction of that when returning empty. Could its 12-litre, six-cylinder engine be transformed into a three-cylinder, six-litre unit of 250bhp for the return journey?

Or, could parasitic losses within the engine be slashed if the mechanical camshafts that currently actuate valves and injectors were replaced with electronics? This would also give the added benefit of variable fine control over valve and injector timing, and even the rate at which valves were open and closed, which are currently dictated by cam profile. In theory, the answer is yes. Such a system would give the ability to switch cylinders in and out of use on demand.

THE NAVISTAR DEBACLE

It's not a new idea: back in 2000, when North American manufacturer Navistar was struggling to avoid the use of SCR on its truck engines, it showed a camless version of the International 530 engine. The product of five years' R&D in partnership with Sturman Engine Systems, the 530E engine was the first using camless technology to be installed in a truck: in this case an International 8100. The 530E engine used Sturman technology to operate the valves.

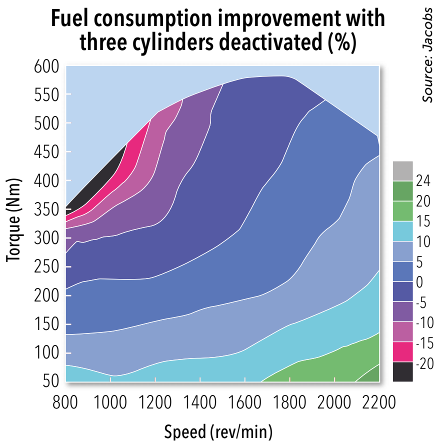
Operational advantages claimed for the engine were a torque increase of up to 40% at clutch engagement speeds, and the integration of compression braking without using a mechanical 'Jake Brake' style device. Additionally, the camless technology could control valve-seating velocity. When the rate of closing is electronically controlled with hydraulic actuation, the valves close gently, reducing wear and noise. Solid-



state electronic controls would increase reliability because they are wear-resistant, easier and faster to diagnose compared with mechanical systems, increasing the overall lifecycle value of the engines, and the electro-hydraulic air management technology provides another engineering tool to meet future emissions standards.

An International truck fitted with the camless engine took part in the famous Pikes Peak Race to the Clouds that year (Sturman's HQ is at the foot of Pikes Peak Mountain in Colorado). A 9-litre Sturman engine could, it was argued, produce comparable power and torque to a 15-litre conventional engine. Except it didn't happen: International's parent company Navistar was brought to the brink of failure by the desire to break with convention and not use SCR technology to meet EPA 10 emissions limits. The results were well-documented, and disastrous: Navistar and its customers lost millions of dollars in repair, downtime and residual values. There would be no innovative camless engines, and International switched to off-the-shelf Cummins units.

However, more recently, Cummins has itself developed a camless diesel engine with Achates Power (pictured above left), although the company remains tight-lipped about many details, perhaps because the customer is the



US Army. The opposed-piston, two-stroke unit was revealed in 2017, with the Advanced Combat Engine (ACE) being touted as a replacement for the 14.8-litre 592bhp Cummins VTA 903 T used in the BAE Systems Bradley fighting vehicle.

It features four cylinders with two opposed crankshafts linked by gears, and a total displacement of 14.3 litres. Each cylinder has two pistons which come together in the centre of the stroke. There is forced air induction through ports that are exposed at the bottom of the stroke, and diesel is injected as the piston crowns approach each other (main image shows a similar three-cylinder design from Achates Power). There are no valves, no cams and no cylinder head.

This is also not a new idea, as anyone who remembers the Commer two-stroke diesels of the 1950s will tell you. But advances in fuel injection technology mean that more can be made of the opposed engine's inherent thermal efficiency. The claimed results are startling: output is 986bhp, and compared to the VTA 903 T there is a 25% reduction in both fuel consumption and heat rejection. Footprint is essentially the same as a conventional 7-litre engine. Trials are underway, with ACE a contender to be installed in whatever replaces the ageing Bradley 'battle chariot'. Truck OEMs will no doubt be watching the engine's progress with interest: a 25% reduction in fuel consumption from the engine alone would put the 2030 VECTO target in reach.

CYLINDER DEACTIVATION

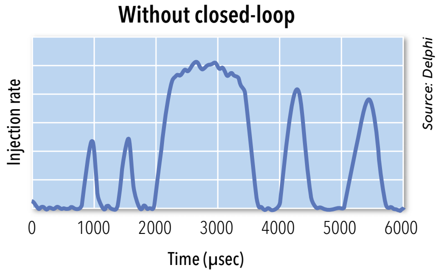
Back with more conventional designs, Jacobs of Jake brake fame is using technology developed for its engine brake to solve the first question posed here: selectively deactivating individual cylinders when an engine is running in part-load condition.

The Jacobs CDA (cylinder deactivation) system, pictured p14, has been in development for seven years, and Robb Janak, director of new technology, says its appearance on production units still remains five to 10 years away.

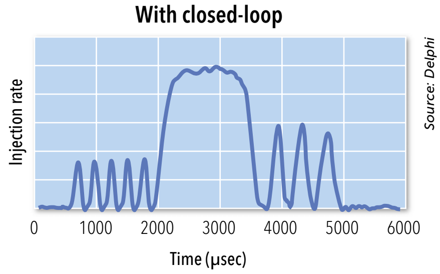
CDA works by allowing intake and exhaust valves on the selected cylinder to remain closed throughout the four-stroke cycle, while the fuel injection is also deactivated. This effectively eliminates pumping losses from the cylinder in question. Janak highlights two main advantages. One is the obvious reduction in fuel consumption (see graph above); the other is that remaining active cylinders will continue to produce hot exhaust gases and maintain exhaust aftertreatment

The Jacobs cylinder deactivation system has been in development for seven years, and its appearance on production units still remains five to 10 years away

Robb Janak



Up to five injection events per cycle
Pilot/post injections 4mg/10mg
Separation 300μsec



Up to nine injection events per cycle
Smaller pilot and post injections 2mg/5mg
Smaller separation 100μsec

temperatures in low- or no-load conditions. Conventional diesel engines struggle to keep catalysts and PM filters functioning in low-load conditions because exhaust gas temperatures fall as the engine's fuel burn declines, and current compensatory measures are in themselves fuel-wasting, as they can involve an additional post-combustion injection of fuel into the cylinder when the exhaust valve is open, or the actuation of an additional injector situated between the exhaust valves and the catalyst.

Running just half the available cylinders will produce higher exhaust temperatures as less air flows through the engine.

Current developments at Jacobs are concentrating on deactivating half the cylinders on a traditional in-line six to retain the engine's balance and minimise vibration, but other possibilities are being examined. These include idling the engine on just one cylinder, with the active cylinder being varied across the block, or deactivating all cylinders, so the engine consumes no fuel on over-run. The latter function would be used in place of today's eco-roll mode, where GPS mapping allows the truck to read the road ahead and disengages the driveline so it can freewheel down hills where it is safe to do so.

THE EXTENT OF FUEL SAVING

In normal use, the ability to effectively vary engine displacement according to power demand will save fuel. Jacobs' research indicates an average saving of 5% across a broad range of applications. In US tests, Jacobs' system was installed on a 13-litre truck engine and revealed a 3% improvement in fuel consumption, and a decrease in NOx emissions when cold with three cylinders deactivated, as the hotter exhaust from the remaining pots maintains the SCR system in its most efficient range of 250–400°C.

Eaton is claiming fuel consumption reductions of 3-8% from a similar system, and is also working on variable valve timing to delay intake valve closing and advance exhaust valve opening to further save fuel and reduce NOx. It also offers a twin-vortex ERG pump which reduces parasitic losses and enables replacement of a variable-geometry turbo and associated EGR valve with a fixed-geometry turbo.

At Delphi, Needham is confident that its DF21 modular fuel injection system, incorporating the F3 injector with a 1mm needle and closed-loop control, will play a significant role in meeting VECTO 2025. He cites five areas of improvement: increased mechanical and hydraulic efficiency with reduced leakage and parasitic loss; better combustion from injector pressures of up to 3,000bar reducing the required EGR rate; the opportunity to vary injection rates to suit individual engine designs; multiple injection events, allowing designers to 'go hunting' for the most economical injection strategy for the desired NOx level (see graphs above); and the ability to match the spray pattern to the engine manufacturer's chosen combustion-chamber shape, avoiding diesel hitting the cylinder walls. Needham says a like-for-like fuel saving on the order of 1.5-2% from the F3 injector is achievable. Delphi's F3 injector is likely to appear on a DAF or Volvo Group engine at the IAA Show next autumn.

There's more to come from Delphi's F4 injector, which is in development. This allows varying 'shapes' for different injection events in the same combustion cycle. For example, the pilot injection, primarily to reduce noise, is most effective if the injection rate rises progressively: that's called a 'tapered' event. For the main power injection, a short, sharp 'square' event is better. The F4 can also shift to a tapered main injection profile during cold start, reducing engine-out NOx during warm-up when the SCR is less effective. This becomes more important with hybrid drivelines, where several cold engine starts may take place in a single work cycle. TE