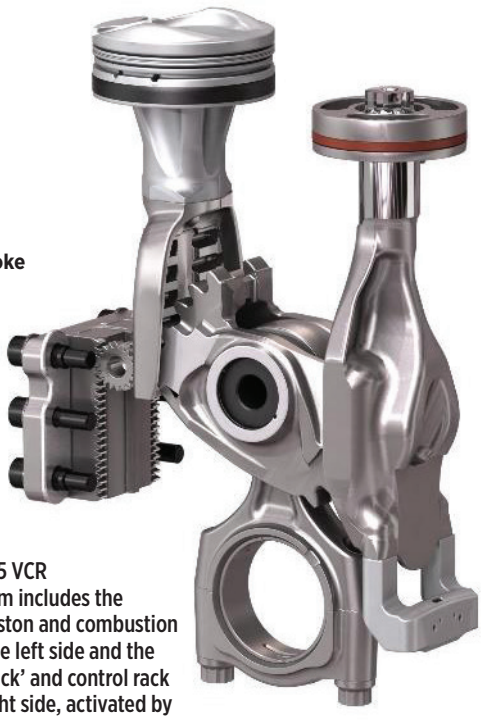
Targeting 40% BTE with advanced VCR

French engine technologists MCE-5 push their variable-compression-ratio program with new tech.

by Lindsay Brooke



The MCE-5 VCR mechanism includes the guided piston and combustion rack on the left side and the 'control jack' and control rack on the right side, activated by inertia and gas forces. The connecting rod big end is at bottom; it links to the central gear wheel in the center.

Nissan's announcement at the 2016 Paris Motor Show that it will bring a variable-compression-ratio engine to production in 2018 (see *AE* November, 2016, p. 6) energized those in the advanced-ICE development community who also have VCR technologies in the works. Varying compression ratio according to load, speed and other parameters is a significant 'lever' that has yet to be pulled, in series-production volumes, to further optimize 4-stroke efficiency.

"The automakers have picked the low-hanging 'fruit' and are now climbing higher in the technology 'tree' to pick what will enable them to achieve the 2025 CO_2 regulations," explained Henri Trintignac, Chief Executive Officer at **MCE-5 Development**. The Lyon, France-based engine-tech company has been focused on its unique VCRi system for 17 years and has documented its progress via many **SAE** technical papers and presentations over the past decade. Its first development contract, signed in 2015, is with China's Dongfeng Motor.

"The customer is interested in an engine family covering from 70 kW up to 200 kW. We do that with only three displacement variants and one bore, one stroke. Two-, three- and four-cylinder engines," he said.

MCE-5's system uses a dedicated cylinder block, cranktrain and actuators to provide continuous compression ratio control, ranging between 8:1 and [geometric ratio] 18:1 to each cylinder (see http://articles.sae.org/6043/). Trintignac, a former **Valeo** powertrain systems executive, said the turbocharged VCRi can switch from minimum to maximum compression ratios in less than 100 ms.

"We can vary the compression ratio infinitely and we can go from 15:1 to 18:1 in just one combustion cycle," he told *Automotive Engineering*. Running at part load, the effect is to minimize BSFC and maximize the "sweet spot" area on the fuel consumption map.

The company now is demonstrating the thermodynamic synergies of combining VCR with infinitely variable valve actuation. The aim is to enable enhanced Miller/Atkinson-cycle operation and thus improve part-load efficiency by reducing heat and pumping losses and optimize the compression-expansion ratio. With this combination of technologies, the inlet valves are open only during half of the compression stroke, so the effective compression ratio is in the range of 10:1.

"We can move three points of compression ratio in less than two cycles," Trintignac reported. "And yes, we spend a lot of time on controls development!" He said 3D combustion simulations [conducted with IFP-C3D, a parallel solver] correlate closely with data from single-cylinder bench work. The tests show an indicated efficiency increase of 12-13% between 10:1 and 18-20:1 compression ratios at low loads, with BMEP less than 8 bar, he said.

CEO Henri Trintignac: "We can vary the compression ratio from 15:1 to 18:1 in just one combustion cycle." (Lindsay Brooke photo)

The MCE-5 development team is targeting 50% brake thermal efficiency (BTE) by 2030, using a step-phase process. "For the first application by 2020, we are aiming for 40% BTE, 260 g/kW," he said. "Next, we can increase the BTE to 44-45% by 2025" then beyond through methodical technology steps.

Refinement of the VCR mechanism and controls continues while combustion engineers play with geometric compression ratios as high as 23:1. Work proceeds on high rates of external cooled EGR (up to 60%)—heavy charge dilution described by Trintignac as HCCI (homogeneous-charge compression-ignition)—aided by a super-high-energy ignition necessary for stable and rapid combustion. Engine-heat recovery strategies also are under review.

The new ignition system is dubbed SSP, or Stratified Spark Plug. Trintignac would say only that it was developed internally and it's not a plasma-based system. He claimed SSP can deliver 1 joule of ignition energy, compared with the 50 millijoules of a conventional ignition system.

Trintignac invites OEM engineers to Lyon to drive MCE-5's demo vehicle and find out more. "To the industry it's all about cost-to-benefit ratio—how many euros or dollars they have to spend to save each gram of CO_2," he noted. "Hybrid 48-volt systems save almost 15 grams on the WLTP cycle and we're in the same range, 10-15 grams.

"But the 48-volt hybrid costs 60 to 70 euros per gram saved. Our VCR costs 30 euros per gram." ■