PRESS FILE

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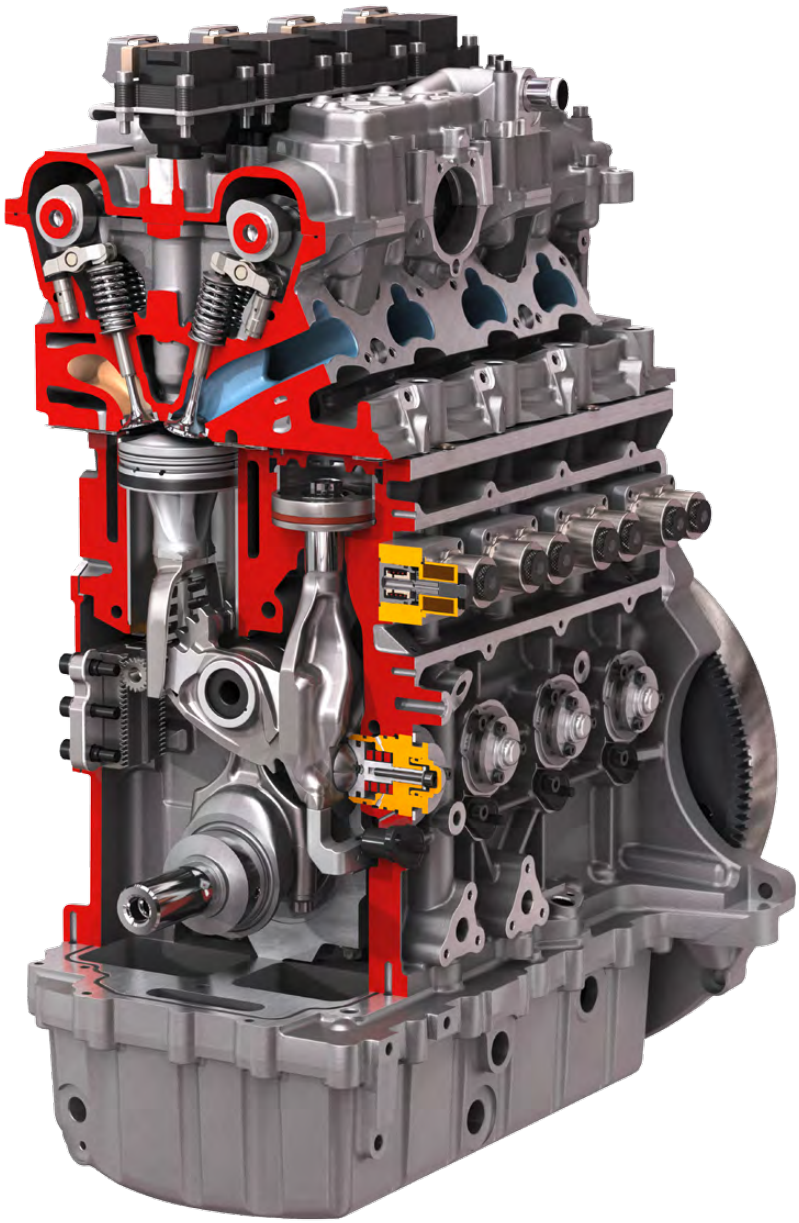
2018

MCE5
BEYOND STANDARDS

VCRi by MCE-5



"a key technology for automobile powertrains up to 2030 and beyond."

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BEYOND STANDARDS

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ENERGY EFFICIENCY AND DRIVING PLEASURE:
THE TORQUE AND FUEL CONSUMPTION LEVELS OF DIESEL ENGINES,WITH

The improved efficiency of gasoline engines is the key to meeting future environmental standards

Countries around the world have introduced strict regulations to limit vehicles pollutant and greenhouse emissions. The automotive industry is required to make a significant effort, for example, in Europe, average CO_2 emissions being reduced from 146g/km to 95g/km between 2010 and the end of 2020, equivalent to a 50% increase in engine efficiency. The new Real Driving Emissions (RDE) tests, which will reduce the difference between the test emissions and consumption and those in real use, and public dissatisfaction with diesel engines will tighten standards which are already very strict. In 2025, more than 75% of vehicles will be powered solely by gasoline engines. A major improvement in their efficiency is mandatory to meet future environmental standards.

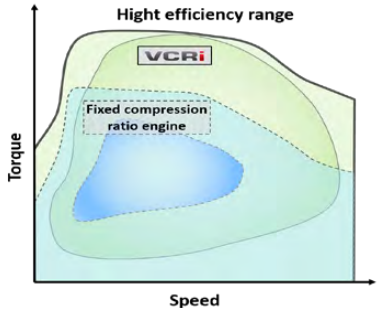
Variable compression ratio is a disruptive technology which will make it possible to meet these targets

Gasoline engines have been improved continuously over the last 120 years. The maximum efficiency of the best engines currently available is 35%, with an official record of 40% for the engines fitted to hybrid vehicles from some manufacturers. This efficiency is achieved over a very limited range of operating conditions and reduces very rapidly as soon as the conditions are changed. Expected incremental improvement will not be possible without a technological leap. In the history of engine development, each significant improvement in efficiency has resulted from controlling an influential parameter using a new technology: air-fuel ratio (fuel injection), ignition timing (electronic ignition), combustion cycle (variable valve actuation) and flame speed and stability (direct injection, exhaust gas recirculation (EGR)). The only major influential parameter that remains uncontrolled is the compression ratio.

The VCRi variable compression ratio system is the result of 15 years development by MCE-5

The first patents describing a variable compression ratio system date from the 1920s. Over the past twenty years, many manufacturers have developed a number of different devices. One of the leading carmakers announced that vehicles with variable compression ratio engines of “multilink” type will be available for the first time in 2018. MCE-5 began its research in 2000 which led to the development of the VCRi system based on a gear transmission system which is scheduled to be put on the market before 2020.

Compared with existing technology, VCRi technology can reduce CO_2 emissions by up to 30% and increase vehicle dynamics at an acceptable price



MCE-5 has shown that the maximum efficiency of a VCRi engine exceeds 40% and above all that efficiency is higher than 35% over most of its operating range.
This performance is achieved by the optimum exploitation of the Miller-Atkinson cycle. At low loads, a compression ratio of up to 18:1 is combined with variable valve actuation to give an effective expansion ratio up to twice the effective compression ratio while ensuring that the effective compression ratio remains high. At high loads, the compression ratio is reduced to 8:1, so that the air-fuel ratio is stoichiometric over the whole engine operating range, including maximum power, guaranteeing low fuel consumption and low emissions in real driving conditions and in the RDE tests. MCE-5 estimates that VCRi technology can reduce CO_2 emissions by up to 30% compared with a 2015 fixed compression ratio engine.
VCRi has a wider range of compression ratios and a faster compression ratio adjustment than multilink systems. Furthermore, the adjustment is independent for each cylinder, which is essential for very high compression ratios. Finally, the VCRi engine design results in lower friction. The potential reduction in CO_2 emissions from the VCRi is, therefore, greater than for multilink VCR engines. The total additional cost of the VCRi engine over fixed compression ratio engines is estimated to be less than €30 for each gram of CO_2 gained per kilometre, less than half of that of 48V mild hybrids.

The development potential of the VCRi engine will make it possible to comply with the stricter standards to be introduced in 2025-2030

Most of the benefits of using 48V mild hybrid technology can be combined with the advantages of VCRi technology. MCE-5 aims to increase the maximum efficiency of a VCRi engine to 44% with stoichiometric air-to-fuel ratios. In the longer term, it should be possible to achieve close to 50% maximum efficiency by incorporating homogeneous charge compression ignition technology. VCRi technology still has, therefore, considerable potential to meet the standards that will come into force from 2025 onwards. In the shorter term, the gasoline VCRi engine is an alternative to the diesel engine. It is less expensive with equivalent CO_2 emissions and lower NO_x and particle emissions, while providing a better driving experience with greater flexibility and a noise and vibration signature similar to that of a fixed compression ratio gasoline engine.

The VCRi engine is being developed in collaboration with an automotive manufacturer with intent to enter production before 2020

The manufacturing maturity of VCRi technology now enables the development of production applications. In 2015 MCE-5 began development with the automotive manufacturer Dongfeng, aiming to put the engine into production before 2020. VCRi technology is a credible solution for meeting stricter standards which will be introduced at this time.

VCRi is a non-exclusive technology that can be used on a large scale and significantly reduce pollutant emissions from cars

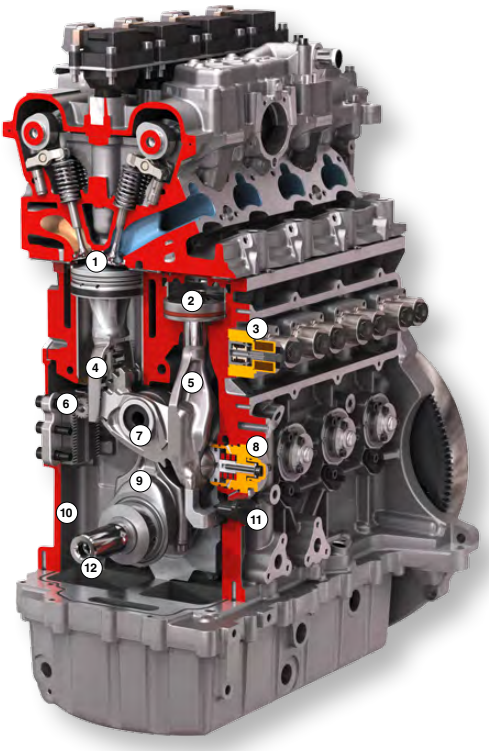
A technology that reduces car emissions can only be effective if it is used on a large scale. MCE-5's VCRi technology can be used by any manufacturer, which opens up the possibility of using it for a large proportion of the cars that will be produced from the next decade onwards.

"Progress is worth nothing unless it is available to all."

VCRi TECHNOLOGY

The compression ratio is the ratio between the volumes of the combustion chamber at bottom dead center and top dead center positions of the piston (1). VCRi technology adjusts the compression ratio by changing the position of the control jack (2) and rack (5), which rotates the wheel (7) around the gudgeon pin fitted in the connecting rod (9), changing the position of the combustion rack (4). The adjustment is driven by the inertial forces (to increase the compression ratio) or combustion gas pressure (to decrease the compression ratio) applied to the piston. The control jack can only move when the VCR actuator (3) connects the upper and lower control jack oil chambers together. This is controlled by the engine management system to set the optimum compression ratio depending on the engine operating conditions. The synchronized roller (6) prevents lateral forces on the piston, while the hydraulic pusher (8) controls the system clearances to ensure silent operation at all times.

VCRi is distinguished from competing systems by its ability to provide a continuous, rapid, precise compression ratio adjustment over a wide range and with a very high maximum ratio (>18:1), to adjust each cylinder independently and to operate using the internal forces in the engine. These unique features make it possible to implement the highly efficient innovative thermodynamic cycles required for meeting the targets to be set in future regulations.



1. Guided piston
2. Control jack
3. VCR actuator
4. Combustion rack
5. Control rack
6. Synchronized roller
7. Gear wheel
8. Hydraulic pusher
9. Connecting rod
10. Crankcase
11. Position transducer
12. Crankshaft

MCE-5 DEVELOPMENT, **OPEN INNOVATION FROM RESEARCH TO INDUSTRY**

MCE-5 DEVELOPMENT is an independent technology incubator whose mission is to transfer innovative power train technology, aimed mainly at reducing pollutants and CO_2 emissions, to corners of the automotive ecosystem.

MCE5
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FACT SHEET

Date of creation

January 2000

Head Office

Villeurbanne – France

Chairman of the board of directors

Chief Executive Officer

Jean-François Roche

Key figures

700 shareholders as at December 31, 2017
Staff: 50 employees
80% with engineering degrees and doctorates
R&D investment: > €100M
Industrial network and partners: more than 60 companies including tier 1 automobile equipment manufacturers

Business model

Exploitation of intellectual property rights and know-how

Field of activity

Automobile powertrains: internal combustion engines, hybrid engine technology, energy recovery, storage and restitution

Portfolio technologies

Variable compression ratio VCRi
High energy ignition SSP

Awards

Winner of the R&D prize for Innovation of Franco Chinese teams - 2015 Climate Solutions, by the France-China Committee

Winner of 2015 SME Initiative by the Commissariat Général à l'Investissement (General Commission for Investments)

CLEPA 2017 Innovation Award in the category "Environment" by the European Association of Automotive Suppliers

The VCRi has been developed in a series of engineering programmes that have attracted funding from a wide range of public French and European institutions.