Potential of a Variable Compression Ratio gasoline SI Engine with very high Expansion Ratio and Variable Valve Actuation

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ABSTRACT

Variable Compression Ratio (VCR) engine is seen as one of the next improvements of Spark Ignition (SI) engines. Regarding at the robustness of fuel consumption improvement of a technology though different Driving Cycles (NEDC, WLTC, Artemis, FTP, Real Driving Cycle…), the association of Variable Compression Ratio (VCR) engine with simple mechanical Variable Valve Actuation (VVA) is a promising solution for a “right sized” engine compared to highly downsized engines.

OD/1D GTPOWER™ simulations show a clear potential when coupling VCR engine with simple VVA (VVT + continuous mechanical VVL) in order to optimize both Compression and Expansion Ratio through the engine map. The consumption benefit on driving cycle of the VCR-VVA association is superior to the sum of the benefits of VCR and VVA alone. These simulations also demonstrate the thermodynamic benefit of increasing the geometric Compression Ratio (>18:1) on a larger range of the engine map thanks to a lower effective Compression Ratio with VVA (Atkinson / Miller Cycle effect) compared to VVT strategies.
3D combustion simulations with IFP-C3D™ have been used to design a high geometric Compression Ratio combustion chamber aimed at Early or Late Intake Valve Closing (EIVC - LIVC) strategies. The bowl design and especially the squish area are of high importance for wall thermal heat transfer and combustion efficiency. 3D combustion simulations show an indicated efficiency increase from 8 to 13% between Compression Ratio 18:1 and 10:1, in the range of 1500 to 2000rpm - 3 to 8bar IMEP. Single cylinder engine tests are in preparation to validate the simulations.

MCE-5 VCR-i engine is well suited for these strategies thanks to its large range of Geometric Compression Ratio (possibly from 8 or 9:1 to more than 20:1) and its specific individual cylinder actuation, as it controls high geometric Compression Ratios accurately. A BSFC value of 220g/kWh can be obtained with MCE-5 VCRi engine, VVA, single turbocharger and high geometric Compression Ratio, in the range 6- 10 bar BMEP / 1500-3000rpm.

The fuel consumption on various driving cycles is calculated on middle class vehicle (segment C - 1200kg kerb weight) with 3 cylinders engine of 80-90 kW equipped with VVA, single turbocharger and Start & Stop. It shows a fuel consumption reduction of 6% on WLTC v4 driving cycle between MCE-5 VCRi and 10:1 fixed Compression Ratio engines. Larger fuel consumption reductions up to 10% are expected for engines of larger sizes engine and higher brake powers.

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BIBLIOGRAPHY

D. Akihisa , D. Sawada - Toyota Motor Corporation. (2010). Research on Improving Thermal Efficiency through Variable Super-High Expansion Ratio Cycle. *SAE International 2010-01-0174.*

Heywood, J. B. (1988). *Internal Combustion Engine Fundamentals.*

M. Yamakawa, T. Youso, T. Fujikawa - Mazda Motor Corporation. (2011). Combustion Technology Development for a High Compression Ratio Engine. *SAE International 2011-01-1871.*