Particle Reduced, Efficient Gasoline Engines

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Written By	Bastian Lehrheuer (RWTH) Christopher Kupiek (FEV)	2018-05-09 2018-05-09
Checked by	Jens Ewald (FEV)	2018-06-26
Approved by	Andreas Manz (BOSCH) Niall Turner (JLR) Simon Edwards (RIC) - Coordinator	2018-06-08 2018-06-21 2018-06-27
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Publishable Summary

In the scope of the PaREGEn project, a new stoichiometric downsized gasoline direct injection engine is developed, which aims to increase fuel efficiency while fulfilling Euro 6 real driving emission (RDE) restrictions. The basis for the engine development is the M270/M274-powertrain of the Daimler engine family. A reduction in CO_2 emission of 15 % from this basis is targeted.

The key technologies to achieve this ambitious goal are the application of the Miller Cycle, water injection and increased compression ratio. These technologies have to be considered in the layout of the combustion system. In particular, the layout of the water injector and a combustion chamber design modification with increased compression ratio have to be designed and assessed.

The water injector was assessed in transient 3D-CFD simulations. Two different injector layouts were compared for three operating points. It is important that the injection simulation reliably models the injection behaviour. A calibration of the injection model is needed in order to predict spray behaviour, in terms of penetration length and spray shape, correctly. In advance of the transient in-cylinder injection simulation, the injection model was calibrated with the help of shadowgraphy images from optical water injection measurements in a constant pressure vessel.

The shadowgraphy images were compared to the simulation results and showed a good agreement. This indicates that the injection simulation reliably predicts the spray behaviour under engine relevant conditions. Hence, the transient in-cylinder simulations are also expected to lead to reasonable results for the water injection and help to assess the water injection’s effect on the engine performance.

Both of the two water injector layouts targeted, with their wide shape, keep their shape stable under all the relevant pressure and temperature conditions. Spray collapsing cannot be observed. Spray collapsing would lead to a very stratified water mixture and to a very large penetration length with an increased risk of wall impingement. Therefore, spray collapsing should be avoided, as is achieved with the two proposed injectors. On the other hand, the injector funnel in the combustion chamber is not hit indicating that the targets are also not too wide.

In the vertical, the two proposed injectors show a different direction. The target of the injector W2 is directed more towards the piston. This direction in general helps to improve the homogeneity of the water distribution and also shows a lower risk of water wall film formation. The improved water homogeneity leads to a more homogeneous cooling effect of the water evaporation inside the combustion chamber, which is advantageous in terms of the avoidance of abnormal combustion like pre-ignition and knock. The reduced amount of water wall film increases the amount of water, which evaporates and cools the in-cylinder trapped mass. Hence, the better behaviour of injector W2, in terms of wall film, also improves the positive effect on the avoidance of abnormal combustion. Summarized, it can be said that injector W2 meets the requirements in terms of spray behaviour, so as to be used in the direct water injection system of the PaREGEn engine.

The compression ratio increase is realized by a piston modification. A new piston design, which increases the compression ratio from 12.8 to 13.5:1 was presented and assessed in transient in-cylinder CFD simulation, to investigate the influence of the increase on charge motion and combustion behaviour.

The piston modification was sufficient to increase the compression ratio to 13.5:1 without changing other parts of the combustion system. Squish height and valve pockets were taken over from the base piston. Against expectation, the modified piston showed a positive effect on the charge motion at the full load operating points. The stronger charge motion also led to an increased turbulent kinetic energy near the spark, which enhances the combustion speed. This finally leads to a more stable combustion with a more knock

resistant behaviour. The centre of combustion can be set earlier, which increases the thermal efficiency. In the investigated part load operating point, the charge motion for the modified piston is basically at the same level as for the base piston. Here as well, the charge motion is not significantly weakened by the higher compression ratio piston with its elevated shoulders. For the part load operating point, the strong charge motion ensures the compatibility of high residual amounts with its positive effect on engine efficiency.

Appendix A – Acknowledgement

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Project partners:

#	Partner	Partner Full Name
1	RIC	RICARDO UK LIMITED
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