Particle Reduced, Efficient Gasoline Engines

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Summary

The PaREGEn project call formulated a CO_2 reduction target of 15% compared to an E-segment serial production vehicle from the model year 2016. The partners of Work Package 3 (WP3) stated in the PaREGEn project proposal that this target will be reached by means of a combined approach using testing and simulation. It was assumed that not every technology package that is developed within the PaREGEn project (e.g. direct water injection (DWI)) can be implemented into the demonstrator vehicle within the project and, as a consequence, the demonstrator vehicle may not exhibit the full CO_2 reduction potential of the innovations from WP3. In order to show the full potential, therefore, the achievable CO_2 reduction potential of all innovations from WP3 and further reduction potential were planned to be investigated by means of longitudinal vehicle simulations.

This deliverable addresses above work plan. In a first step, from the thermodynamic engine perspective, a 1D Gas Exchange Model is calibrated against engine dynamometer testing data from [1] at three different operating points: Low End Torque, Rated Power and minimal fuel consumption ($BSFC_{min}$) (engine speed, n=2500 1/min, brake mean effective pressure, BMEP=16 bar).

The 1D Gas Exchange Model then is used to study a further increase in the compression ratio (CR) to CR=14:1 and 14.5:1, respectively, assuming the increased need for water injection and some disadvantage in terms of combustion speed due to the increased water/fuel ratio needed to avoid knock. It is found that a compression ratio increase is feasible with the potential to gain a further fuel consumption benefit of 1.05% in the $BSFC_{min}$ operating point. The gas exchange simulation also predicts that the full load relevant operating points, Low End Torque and Rated Power can be reached with both compression ratios by a slight increase of the water to fuel share with the pressure rise and calculated knock index.

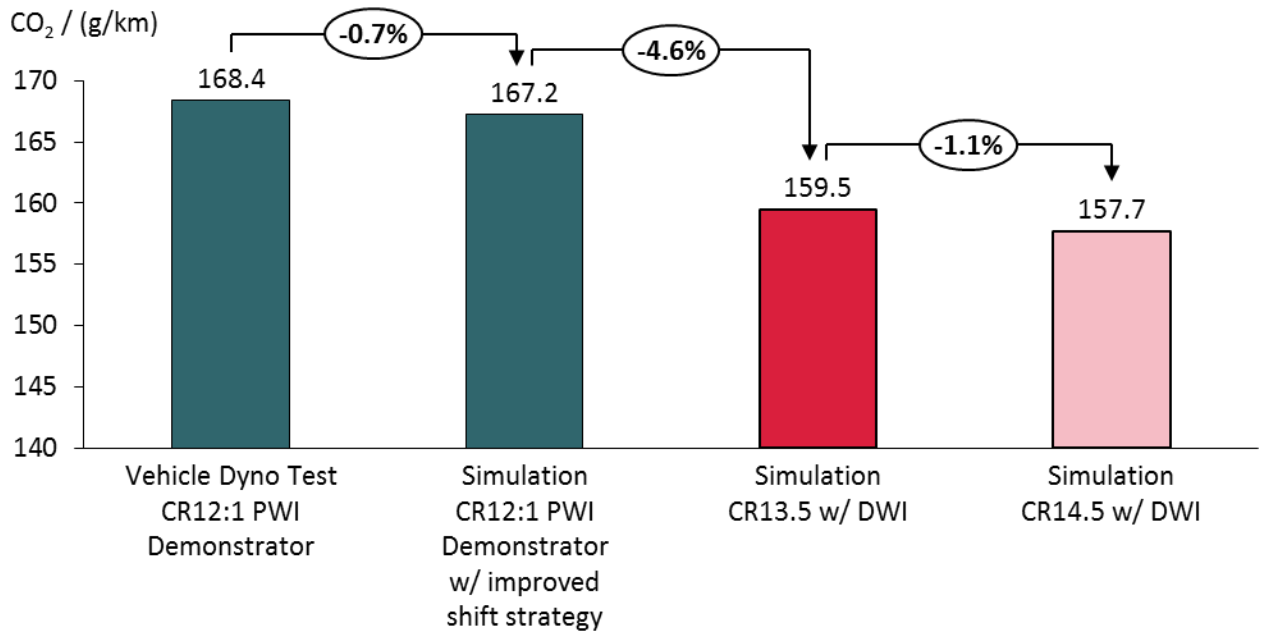
The evaluation of the different start of injection (SOI) timings, by means of in-cylinder 3D computational fluid dynamics (CFD) calculations, revealed different compression end temperatures and different levels of cylinder charge homogenization. The results indicate that there is a trade-off between good homogenisation with early injection but comparatively high compression end temperatures, on the one hand, and low compression end temperatures due to good cylinder charge cooling for late injection with lower level of homogenization, on the other. Furthermore, it is found that there is a good correlation of the injected water wall film calculated by CFD and integrated during the compression stroke to the measured blow-by on the test bench. From this analysis, it can be deduced that blow-by is increased due to injected water impingement on the cylinder liner. Therefore, to reduce blow-by impact caused by water injection, the water spray impingement on the lower section of the cylinder wall should be reduced.

A GT-Drive model was built using the fuel consumption engine map for the engine prototype in the Daimler demonstrator vehicle. Based on this set-up, the GT-Drive model was calibrated against vehicle dynamometer testing results on the world harmonised light-duty testing procedure, WLTP-high cycle. The calibration results yielded good agreement within each of the WLTP testing phases of the demonstrator vehicle.

It was identified by simulation, that there is a potential to reduce the CO_2 emissions in the cycle by an improvement of the transmission shift strategy, leading to a reduction by 0.7% related to CO_2.

In a second step, the indicated (thermodynamic) fuel consumption map of the prototype engine that is used in the demonstrator vehicle was exchanged against the indicated fuel consumption map of the tested engine, as reported in D3.5 [1] with DWI and compression ratio CR=13.5:1. Longitudinal engine simulations predict a further reduction of 4.6% in CO_2 emissions, which yields a CO_2 emissions level below 160 g/km – the CO_2 emissions target for this driving cycle to show the overall 15% CO_2 emissions reduction.

As an outlook, following up on the 1D gas exchange simulations with an even further increased compression ratio of CR=14.5:1, the predicted CO_2 emissions level exhibits another, further reduction potential of 1.1%, which could come in addition to the already discussed CO_2 emissions potential (as summarised below).



Waterfall diagram for CO_2 emission results in the WLTC-H. The first bar on the lefthand side complies to result from dynamometer testing, the following two bars are results from longitudinal engine simulation using engine map data from the engine dynamometer. The last bar, on the righthand side, shows a result from longitudinal engine simulation with a further engine map scaling to higher compression ratio 14.5:1.

Appendix A – Acknowledgement

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Project partners:

#	Partner	Partner Full Name
1	RIC	RICARDO UK LIMITED
2	DAI	DAIMLER AG
3	JLR	JAGUAR LAND ROVER LIMITED
4	BOSCH	ROBERT BOSCH GMBH
5	FEV	FEV EUROPE GMBH
6	JM	JOHNSON MATTHEY PLC
7	HON	HONEYWELL, SPOL. S.R.O
8	JRC	JOINT RESEARCH CENTRE – EUROPEAN COMMISSION
9	UNR	UNIRESEARCH BV
10	IDIADA	IDIADA AUTOMOTIVE TECHNOLOGY SA
11	SIEMENS	SIEMENS INDUSTRY SOFTWARE SAS
12	LOGE	LUND COMBUSTION ENGINEERING LOGE AB
13	ETH	EIDGENOESSISCHE TECHNISCHE HOCHSCHULE ZUERICH
14	UDE	UNIVERSITAET DUISBURG-ESSEN
15	RWTH	RWTH AACHEN UNIVERSITY
16	UFI	UFI FILTERS SPA
17	UOB	UNIVERSITY OF BRIGHTON
18	Garrett	GARRETT MOTION CZECH REPUBLIC SRO

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