Diesel efficiency improvement with Particulates and emission Reduction

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Project partners:

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2 - REN - Renault SAS - FR
3 – IFP – Energies nouvelles – IFPEN – FR
4 - CMT - Universitat Politecnica de Valencia – ES
5 - JM - Johnson Matthey Plc - UK
6 – CONTI – Continental Automotive France SAS – FR
7 – BOSCH – Robert Bosch GmbH - DE
8 - CNR - Consiglio Nazionale delle Ricerche – IT
9 – FMF - FPT Motorenforschung AG – CH
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Executive publishable summary

The fight against the global warming and the reduction of the air pollution are meaningful environmental concerns in our industrial societies and involve pursuing the continual effort of reduction of the fuel consumption and of limitation of pollutants emissions due to internal combustion engines. Among the new and promising technologies suited for achieving these goals, the Variable Compression Ratio (VCR) offers the opportunity to adapt the compression ratio to the load and engine speed and to possibly reduce the fuel consumption. In this frame, this deliverable is dedicated to the design of Diesel combustion systems adapted to VCR engines. The design process is achieved out thanks to Computational Fluid Dynamics (CFD) simulations performed with CONVERGE CFD code (https://convergecfd.com/)

The design of a Diesel combustion system consists in defining a coherent combination of a bowl shape, of an injector nozzle and of an in-cylinder aerodynamic (swirl magnitude). Two different Diesel applications, passenger car (PC) and LCV (Light Commercial Vehicle), are here examined. Both engines differ among others by the displacements: 500 cm^3 for the PC engine versus 750cm^3 for the LCV engine and by compression ratio respectively 16:1 vs. 18:1. Regarding the VCR application for both engines, three discrete compression ratios (CR) depending on the engine load are implemented based on the recommendations from deliverable D2.1, refer to the table below.

	PC	LCV
Mid-load	16:1	18:1
Low-load	20:1	22:1
Large-load	14:1	16:1

Table: Compression ratio per load for both PC and LCV applications

Large CR are employed for small loads in order to benefit from the large thermodynamic efficiency, small CR are used for large loads due to the maximal in-cylinder pressure constraint, and the reference CR is used for the medium loads. From a design point of view, the bowl volume is defined on the basis of the largest compression ratio, and the decrease of CR is fulfilled by increasing the piston to head clearance (*i.e. squish distance)*. Therefore, the challenges consist in defining a combustion system which can operate different squish distances and thus different locations of interaction between the fuel spray and the piston wall on one hand, and in achieving an efficient combustion despite the significant reduction of the bowl volume on the other hand.

The same computational methodology for the design process has been followed for both PV and LCV applications. The first step is dedicated to the calibration of the CFD tool. Indeed, some parameters from the spray and combustion sub-models need to be adjusted by a confrontation between the numerical results and the experimental data. This calibration is carried out on the basis of the reference engine and several operating points are investigated in order to enforce the robustness of the calibration. The second phase is dedicated to the design of the combustion system. Two different design approaches described below are deployed:

- Manual optimization: This approach consists in a manual drawing of the bowl profile and in an examination of the results for each new design in order to orient the design. Mono-parametric variations are here preferred as they allow a better understanding of the individuals effects.
- Automatic optimization: In this approach, a Design Of Experiment (DOE) of the geometrical parameters of a parameterized CAD is performed. This approach requires much more computations but allows in assessing a wider geometrical space as well as in appreciating the cross variations.

Regarding the design of the VCR combustion system for the PC application, a piston bowl with two mixing zones has been designed. This kind of bowl shape has indeed been shown to be less sensitive to a variation of the location of interaction between the fuel spray and the piston wall. For the PC application, the recent progresses in the development of Diesel combustion system have been considered and a decrease of the swirl number at BDC down to 1.0 is retained as well as an increase of the maximal injection pressure from 2000 up to 2500 bar. A matrix of five nozzles with variations of permeability and of holes number is examined. Both manual and automatic approaches

described above have been employed in order to first rough out the design and then to optimize finely the geometry. A total amount of about 500 simulations have been performed and have allowed in selecting three bowl profiles with their best suited nozzles. On the basis of these three selected combustion systems, promising results compared to the reference engine are excepted for large load operating points and the hard spot is related to the soot emissions for the intermediate load point.

Regarding the design of the VCR combustion system for the VLC application, the same kind of bowl shape with two mixing zones has been examined. No evolution of the injection system has been considered and the swirl amount at BDC is the same as the reference. Manual optimization based on mono-parametric variations has been performed and among all the tested geometries, one is revealed as promising because it allows in reaching the targeted power at full load while bringing fuel consumption benefits at smaller loads.

Next step of Work Package 2 will be dedicated to the experimental assessment of the proposed geometries and to check the CFD predictions in terms of fuel consumption benefit and pollutants reduction.