Diesel efficiency improvement with Particulates and emission Reduction

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Project partners:
1 - AVL - AVL List GmbH - AT
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
10 – IVECO – IVECO S.p.A. - IT
11 - RCD - Ricardo Plc – UK
12 – ECN – ECOLE CENTRALE DE NANTES – FR
13 – SIE - SIEMENS INDUSTRY SOFTWARE SAS – FR
14 - VIF – Kompetenzzentrum – Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH - AT
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Publishable Executive summary

The objective of the task 2.5 is to complete research and development in the domain of the soot emissions modeling and prediction in a system simulation context. The partners’ activities have focused on the research and prototyping of new modeling approaches but have also paid attention on the actual application of the developed models on real use cases through the definition and implementation of methodologies to support the model set-up, parameter identification and analysis. Since the final goal is to achieve emissions evaluation at the vehicle level - on realistic driving conditions - a special attention has been put on the capabilities to include the developed engine/soot models in full powertrain and vehicle models.

Ecole Centrale de Nantes, IFP Energies nouvelles and Siemens collaborated on the research and evaluation of new and improved modeling capabilities, addressing several level of models, from pure map-based to detailed phenomenological approaches, to match the variety of the engineering requirements.

IFP Energies nouvelles has investigated a new phenomenological soot formation model. The prototyped soot model has been integrated into the DFM (Dual Flame Model) combustion model: a physical 0D combustion model for Diesel applications, developed and continuously improved at IFPEN. The DFM formalism permits to represent with good accuracy the in-cylinder combustion process scenario, by accounting for the first order relevant physics impacting fuel oxidation. Such an approach presents several advantages: first, it allows to account for the impact of engine actuators on combustion (e.g. injection systems performing complex injection strategies, low pressure and high pressure EGR loops,...) and then to describe the pollutant emissions formation processes, like CO and NOx, whose chemical kinetics depends strongly on the in-cylinder thermochemical conditions. To get access to the thermochemical mixture properties holding the soot kinetics, a spray-model was integrated into the DFM model to enrich the combustion scenario description given by the model.

Figure: Contribution of the partners in the modeling activities of WP2
This spray model showed its potential for simulations of Diesel sprays. The soot kinetics approach, integrated into the proposed spray model to describe soot production/destruction source terms, was inspired by the one proposed by Bayer and Foster, but modified to account for soot efficiency production and to make it suitable to describe combustion processes associated to multiple injection patterns. The resulting model has been prototyped by IFPEN, validated on a first application case and integrated in the Simcenter Amesim software with the support of Siemens.

Ecole Centrale de Nantes investigated three modeling levels, from map-based, to Mean Value and crank-angle based approach.

The map-based model relies on a simple formulation where the main engine variables are tabulated from test data, providing outputs as a function of the engine speed and load (BMEP). The emissions including soot mass can be easily implemented in such a model provided the appropriate measurements are available. The short simulation times offered by the map-based approach ease its implementation on full vehicle models. The simple approach however does not reflect the complexity of the engine controls, leading to possible discrepancies when applied for real life scenario.

The second level corresponds to the Mean Value Engine Model which makes use of a 0D physical model for the air path system and a combination of physical equations (mass and energy balance) and look-up tables for the modeling of the in-cylinder process. The implementation of engine-out emissions and soot models on such an approach relies on correlations and/or maps, offering more flexibility than the pure map-based approach for the handling of the engine controls including EGR rate, air/fuel ratio. This would lead to a better prediction of the engine-out emissions in real life scenario and driving cycles with short simulation times.
The last modeling approach investigated by ECN is based on the combination of a phenomenological combustion heat release model (based on the Barba formulation [48]) and an empirical soot formation model.

The purpose of this modeling approach is to find a good tradeoff between prediction accuracy and calculation times, offering fast evaluation of the soot levels in the context of engine control developments.

Complementary to the activities done at engine model level, real driving emission prediction capabilities also imply realistic engine model boundary conditions. To do so Siemens has focused his research and development efforts toward a system approach integrating task’s partners’ results, offering the full capacity to assess the emissions at the vehicle level over driving cycles. Several improvements have been prototyped so as to deliver a full flexibility for the handling of complex mission profiles including Real Driving Emissions.
Taking the benefits of using the same system simulation platform (Simcenter Amesim) for their research and prototyping activities in dieper, ECN, IFPEN and Siemens have been able to rapidly implement and test new models and features combining their results. Following a component-based approach, new models can be easily assembled and combined beyond their initial layout, offering a flexible modeling environment able to address new powertrain configurations and for multiple vehicle attribute analyses.

**Dissemination of the project results:**
Presentation: Siemens presentation of new models implemented in Simcenter Amesim 16: See in Appendix A.