PhD fellowship – PPRIME (Poitiers)

Development of Data Assimilation tools for augmented estimation of internal combustion engine flows

Laboratory: Institut Pprime, Poitiers, France

Keywords: Data Assimilation (DA), Ensemble Kalman Filter (EnKF), Large Eddy Simulation (LES), hydrogen

Topic: In the context of the automotive industry, recent studies provided by the International Energy agency (AIE) [1] and La Plateforme Automobile (PFA) [2] agree that 77% of sold vehicles will be equipped with a spark-ignition engine (SIE) while only 12% will be all-electric vehicles by 2035. In OECD countries, the electrification of vehicles and the improvement of the efficiency of internal combustion engines (ICE) are the main levers to reduce greenhouse gas emissions. To meet such expectations, the SIE is seen as the most interesting ICE technology, due to its cost effectiveness and the relative simplicity and efficiency of its exhaust gas after-treatment systems. However technological challenges have to be tackled due to the use of zero-carbon fuels, such as hydrogen, and to the diversification of hybrid applications (e.g. cold start, extreme operating conditions, restart in hybrid vehicles, coupling electrical and thermal engines). Designing and calibrating SIE to achieve optimal performance (high efficiency and low pollutant emissions) under real driving conditions requires better mastery of flow aerodynamics, mixing and combustion down to the individual engine cycle. Therefore, Large-Eddy Simulation (LES) studies are required for the accurate prediction of undesired events (e.g. knock) or to assess engine combustion stability for a wider range of operating conditions to meet real driving emissions (RDE) expectations [3]. One problematic aspect of such numerical tools is that it is difficult to prescribe boundary conditions able to replicate the fine perturbations observed in real systems. These perturbations, which are uncertain in an epistemic sense, may drive the evolution and the emergence of rare events which can in turn affect the global performance of the engine.
The overall objectives of the ANR-PRC-2020 project ALEKCIA, in which this PhD fellowship is integrated, are to develop innovative game-changing tools providing augmented prediction and analysis of complex turbulent flows with a focus on real engine operations to: 1/ better capture time-resolved events, 2/ increase understanding and control of the origins of undesired behaviors in turbulent reactive flows.

Objectives: The present PhD fellowship aims for i) improving the reliability of the LES by enriching its predictions with information from highspeed PIV or other measurements (such as local pressure evolution in time) and ii) optimize the calibration of the LES models and boundary conditions through a data-driven approach. To do so, tools from Data Assimilation (DA) [4] will be employed to derive the physical evolution of an augmented state, which will be obtained coupling several heterogeneous and uncertain sources of information. These sources include numerical results from LES as well as experimental data. The research work will be performed using a reduced-order strategy based on the ensemble Kalman Filter (MEnKF) developed by the team [5,6]. This tool, which is currently developed using an in-house code, will be integrated in the opensource platform OpenFOAM [7]. The MEnKF will be initially integrated within the numerical algorithms of the code in an intrusive way. Further development aims for the preparation of a non-intrusive Python interface which will be used to apply the MEnKF method to a larger class of CFD solvers. These solvers will be used as a black box providing the physical fields used in the assimilation process. Initial applications will deal with academic configurations such as the turbulent pipe flow. The final target of this PhD fellowship is the assimilation and optimization of the flow inside a combustion chamber, combining LES and experimental data obtained in a research engine at PRISME, Orleans (France).

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PhD supervisors: Dr. M. Meldi (Pprime), Dr. K. Truffin (IFPEN)

Profile: candidates for this PhD position will have skills in the numerical simulation of turbulent flows and / or Data Assimilation using sequential approaches. A Master's degree in these areas of expertise is required.

Additional information: the start date for the PhD fellowship is set to the 1st of October 2021 for a duration of three years. Applications (CV + motivation letter) should be sent via email to the PhD supervisors before the 1st of July 2021.

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References:

[1] "World Energy Outlook 2019", IEA, https://www.iea.org/reports/world-energy-outlook-2019 (2019).
[2] https://pfa-auto.fr/wp-content/uploads/2018/06/2018-Novembre-Note_technique_PFA.pdf (2018).
[3] K. Truffin, C. Angelberger, S. Richard, C. Pera, Using large-eddy simulation and multivariate analysis to understand the sources of combustion cyclic variability in a spark-ignition engine, *Combustion and Flame* 162 4371–4390 (2015).
[4] M. Asch, M. Bocquet and M. Nodet, Data Assimilation: methods, algorithms, and applications. *SIAM* (2016).
[5] M. Meldi, A. Poux, A reduced order model based on Kalman filtering for sequential data assimilation of turbulent flows, *Journal of Computational Physics* 347 207–234 (2017).
[6] G. Moldovan, G. Lehnasch, L. Cordier & M. Meldi, An intrusive multigrid / ensemble strategy for sequential Data Assimilation. Submitted to *Journal of Computational Physics* (2020).
[7]www.openfoam.com