Case Study Template

Please complete 3 short case studies (max. 2 pages each). These case studies can be updates of the ones that have already been submitted (if so please note this in the case study title) or new case studies that have been developed in the current reporting period.

1. Title of Case Study: Unified modelling framework of sub- and super- critical injection dynamics
2. Grant Reference Number: EP/P012744/1
3. One sentence summary: This project aims to offer a generalised numerical approach that can be used in order to unveil the complicated dynamics of the transition of subcritical to super- critical injection phenomena
4. One paragraph summary: Despite many previous (mostly experimental) efforts to characterise super-critical injection conditions, they still remain a challenging fluid dynamics problem due to the multi-scale, multi-phase character of the complex physical phenomena that governs it. This project aims to offer a systematic approach towards a better understanding and prediction of the transition of subcritical to super-critical injection phenomena, combining novel state of the art simulations with experiments already performed by the University of Brighton and Sandia National Laboratories for diesel engine conditions. The model will include real gas effects and target both primary and secondary atomization regions at the limit of transition between subcritical to super- critical conditions. Such an approach is currently lacking from commercial and open source simulation tools. The new framework will be developed within Large Eddy Simulations (LES) and will be based on the extension of ideas also used in probabilistic modelling of flame interfaces (surface density approaches). The major strength of the approach is that it does not include any a priori region-dependent assumptions for the liquid-gas volume fraction in the computational cells, and bypasses the spherical vision of the liquid structures that compose the spray. Thus, it can be applicable both to the near-nozzle and the dilute spray areas, and represent both sharp (as in the case of sub- critical injection) and diffused (more representative of super-critical conditions) interface.
5. Key outputs in bullet points: This project will take an innovative modelling approach to unveil the mechanism of the transition of sub to super-critical injection, pushing forward towards novel, energy efficient future engines aiming at: 1. Derive a generalised LES framework based on probabilistic surface density to model liquid evolution from near nozzle to full atomization area in a unified manner 2. Unlock the physics of a very complex fluid dynamics problem at a fundamental research level 3. Address the current needs of the automotive industry. The code to be developed aims to model realistic pressure and temperature scenarios unsatisfactorily modelled by existing methodologies. A leading companies in the field, Ricardo UK Ltd, is an active partner in this project since the new framework can be used to improve the design and manufacturing tools

4. Apart from the automotive sector, this proposal has the potential for a wider impact in various other fields that supercritical sprays are involved, since is expected that some of the results will be directly applicable to the modelling of other spray phenomena (e.g. aerosol sprays in medicine or agriculture).

5. Contribute to the training of the next generation of CFD engineers

6. Main body text

The methodology is organized according to four work packages (WP) to address the objectives of the research

WP1 Initial Project Set-Up
WP2 Implementation of Real-Gas Effects in the CFD solver
WP 3: Develop and implement in the CFD solver the surface density model for sub and super- critical conditions
WP4 Validate the model against experiments and elucidate by calculation the mechanism of sub- to super- critical transition

Results from Initial Phase:

In the Initial phase of the project we extended to LES and evaluated the Eulerian Lagrangian solver of OpenFoam for the prediction of a high pressure n-dodecane spray (Sandia Spray A). Following some preliminary results are included:

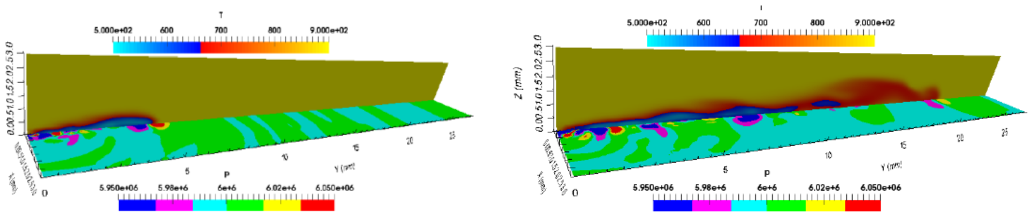

Figure 1: Characteristics of the transition from subcritical to supercritical regime in high speed spray flows at different time instants (a) t = 0:004ms (b) t = 0:02ms.

[1] Vogiatzaki et al, Proceedings 28th European Conference on Liquid Atomization and Spray Systems (ILASS) 2017. [2] Li et al, THIESEL 2018, Poster [3] Li et al ICLASS 2018

7. Names of key academics and any collaborators:

PI: Dr Konstantina Vogiatzaki, Post Doc Dr Cuicui Li
Internal Collaborators (UoB): Prof C. Crua, Prof S. Shazin
External Collaborators (MIT): Prof A. Ghoniem

8. Sources of significant sponsorship (if applicable):

(Amount, sponsoring organisation, date)

9. Who should we contact for more information?

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10. Please indicate if you would like this case study to be included on the Consortium's ARCHER web-page. Yes

To keep in mind:

- The sentence and paragraph summaries should be able to stand alone – they are the sort of things that can be put on a slide or in a `highlight
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