Case Study Template

Please complete 3 short case studies (max. 2 pages each). These case studies can be updates of the ones submitted as part of the review in February 2015 or new case studies that have been developed in the current reporting period.

1. Title of Case Study: Large Eddy Simulation of a spark-ignited methane-air jet flame

2. Grant Reference Number: EP/K025791/1

3. One sentence summary: Because of the practical importance of flame edge evolution in automobile and gas turbine engines, the evolution of flame edge in a spark-ignited methane-air jet flame is investigated using LES with a partially premixed combustion model and both the final lift-off height and transient evolution are captured accurately.

4. One paragraph summary:

The unsteady evolution of lifted methane-air jet flames following a spark ignition is computed using Large Eddy Simulation (LES). A presumed joint Probability Density Function (PDF) approach is used for the sub-grid combustion modelling which accounts for both premixed and non-premixed combustion modes. Two flames, one with high and another with low jet velocities are investigated and the computed transient evolution of flame leading point and the final lift-off height agree quite well with the measurements. The joint PDF of the axial and radial stabilisation locations shows a correlation between the fluctuation amplitudes in these two directions and the jet velocity. The flame leading point evolution in the three-dimensional physical space is visualised using its trajectory, starting from the ignition location to the final lift-off height. A spiral-shaped path is observed for both velocity cases showing different flame propagation behaviours at different heights from the jet exit.

5. Key outputs in bullet points:

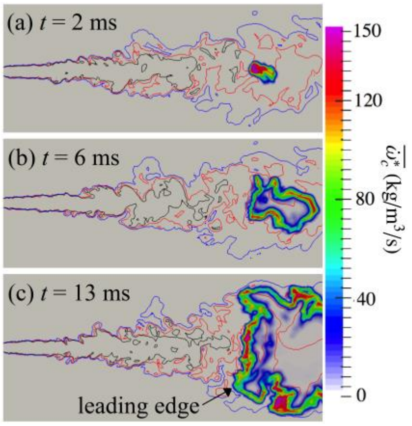
- A new partially premixed combustion model with low computational cost, for LES paradigm, is developed and validated
- Deeper physical understanding of the spark ignition process in jet flames is gathered

6. Main body text

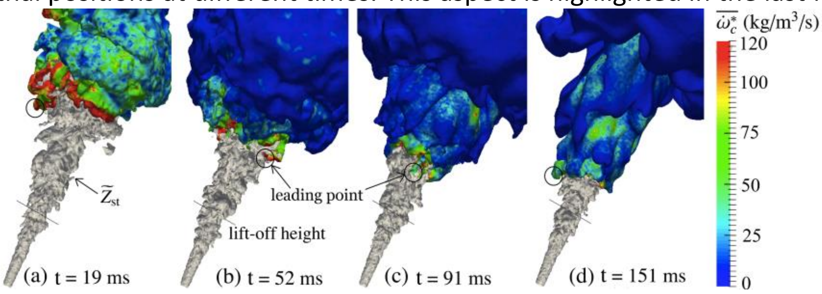
Spark ignition process involving a transient growth of an initial flame kernel to a fully burning flame is crucial for many practical devices. Understanding the underlying physics of this transient process is of prime importance to develop practical control strategies especially for high-altitude operating aero gas turbines and rocket engines. Large Eddy Simulation (LES) is well suited for this and becoming attractive because of rapid advances in computing hardware and algorithms, and sub-grid scale (SGS) model development. The objective of this study is to investigate the dynamical evolution of lifted flame and its interaction with the turbulent flow using LES with a presumed sub-grid PDF approach for partially premixed combustion.

As the combustion is partially premixed in the stabilisation region of lifted flames, the sub-grid combustion model must include both premixed and non-premixed combustion modes. Such a model tested for RANS approaches in previous studies, showing good capabilities, is extended for LES.

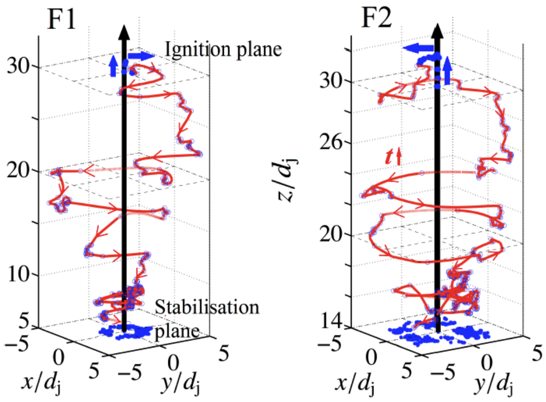
The figure below shows the formation of the flame leading edge from an initial spark. During the initial stages, the combustion is contained within flammable mixtures, which suggests that this model can capture the edge flame evolution well.



The figure below presents a typical 3D evolution of the flame leading edge for four instants using iso-surface of temperature with T =1200 K coloured by reaction rate. The gray surface is the stoichiometric mixture surface. As highlighted by the black circles, the leading point appears at different azimuthal positions at different times. This aspect is highlighted in the last figure showing



the 3D trajectory of the leading point from its initial location to the final lift-off height for two flames, F1 and F2, with different jet exit velocities. The leading point trajectory seems to follow a spiral-shape for both F1 and F2 flames.



7. Names of key academics and any collaborators: Cambridge University - Professor E. Mastorakos conducted the experiments with one of his PhD student.

8. Sources of significant sponsorship (if applicable): Cambridge Common-Wealth Trust, China Scholarship Council.

9. Who should we contact for more information?

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