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: Direct Numerical Simulation of Turbulent Premixed Reactive Flows

2. Grant Reference Number: EP/K025163/1

3. One sentence summary:
Parametric Studies Reveal the Bending Effect in High-intensity Turbulent Premixed Flames

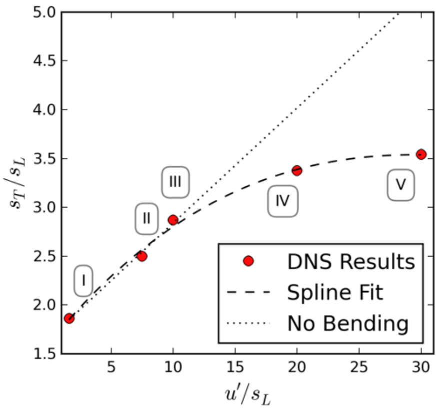
4. One paragraph summary:
In turbulent premixed flames, much experimental evidence points to a strong influence of pre-mixture turbulence intensity on the turbulent burning velocity. The linear enhancement of turbulent burning velocity in low-intensity turbulence is predicted accurately by current models. In contrast, the deviation from linearity in high-intensity turbulence, known as the "bending effect," remains to be explained. The present work has employed Direct Numerical Simulation (DNS) to investigate the bending effect. From the ensuing analysis, it is evident that flame surface area reflects distinctly the variation of turbulent burning velocity with turbulence intensity. Local flame quenching does not appear to be the primary mechanism behind the bending effect.

5. Key outputs in bullet points:
(e.g. new knowledge, new collaborations, technology, trained people etc)

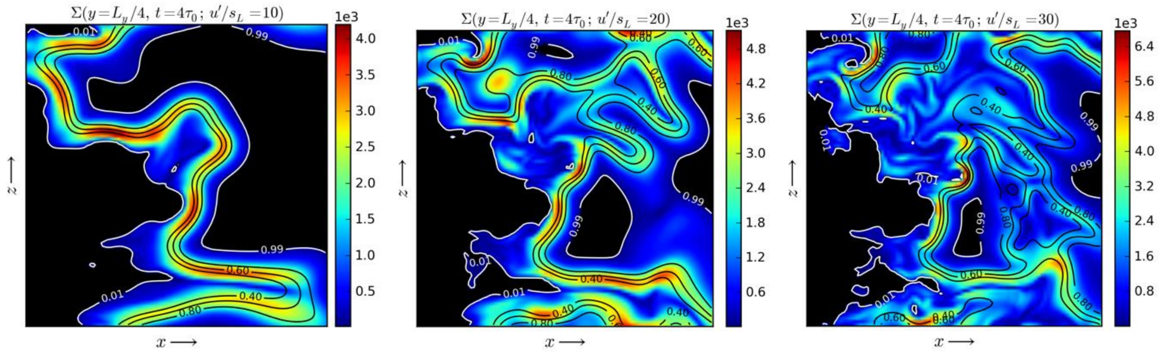
Knowledge: A first explanation of the bending effect has been provided based on DNS.
Skill: The project has trained the student in advanced computing with Fortran.
Dissemination: The following articles have been submitted, presented and published:

1. G. V. Nivarti, R. S. Cant, Aerodynamic quenching and burning velocity of Turbulent Premixed Methane-Air Flames, in: Proceedings of ASME Turbo Expo 2015: Turbine Technical onference and Exhibition, 2015
2. G. V. Nivarti, R. S. Cant, Premixed flame propagation in high-intensity turbulence: investigating the role of detailed chemistry, in: 25th International Colloquium on the Dynamics of Explosions and Reactive Systems, 2015
3. G. V. Nivarti, R. S. Cant, Direct Numerical Simulation of the bending effect in turbulent premixed flames, Proceedings of the Combustion Institute (submitted), 2016

6. Main body text
(1-2 pages maximum, including figures/pictures, tables, quotes, infographics)
The turbulent flame speed is a basic measure of the burning rate of a fuel-air mixture. The variation of turbulent flame speed with increasing turbulence intensity is an unresolved persistent problem in combustion theory. Experimentally, it has been observed that, with all other parameters held constant, the variation turbulent flame speed with increasing turbulence intensity is nonlinear [1]. An explanation to this effect, known as the bending effect, will help develop better models for turbulent combustion in applied and theoretical avenues of research.



In the current work, a compressible 3D formulation of the Navier-Stokes equations is solved along with thermo-chemical transport using the CFD code SENGA2 in a cubic domain containing a statistically-planar stoichiometric methane-air flame propagating along the axis. Across 6 parametric simulations, the classical bending effect has been capture (right image) for the first time using Direct Numerical Simulation (DNS). Further, the Flame Surface Density (FSD) approach [2] was used to explain the bending effect observed. A qualitative glance of FSD images (below) shows that laminar flamelet structure is retained largely within the flame brush. Further quantitative analysis has also shown that a competing effect between strain rate and curvature leads to the bending effect. The novel explanation might lead to improving combustion models in the near future; further work and analysis to pinpoint the effect is ongoing.



[1] D. Bradley, How fast can we burn?, Symposium (International) on Combustion 24, 1992.

[2] S. B. Pope, The evolution of surfaces in turbulence, International Journal of Engineering Science, 1988.

7. Names of key academics and any collaborators:

(Include organisation details)

Mr. G. V. Nivarti (University of Cambridge), Prof. R.S. Cant (University of Cambridge)

8. Sources of significant sponsorship (if applicable):

(Amount, sponsoring organisation, date)

PhD Student Scholarship, Cambridge International and Commonwealth Trust [2013 – 2016]

9. Who should we contact for more information?

(Include e-mail and tel. number)

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