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: Puffing and microexplosion dynamics and effects on mixing and combustion of emulsion fuel droplets

2. Grant Reference Number: EP/J018023/1, EP/K025171/1, EP/K025163/1

3. One sentence summary: High-fidelity simulation has been used for the first time to investigate puffing and microexplosion dynamics of an emulsion fuel droplet and a droplet group and its effects on fuel-vapour/air mixing and combustion.

4. One paragraph summary: Blending biofuel into conventional fossil fuel is an important step towards a low-carbon economy. If the boiling points of different fuel species in an emulsion droplet are considerably different, puffing or microexplosion may occur due to superheating of the embedded sub-droplets. In this study high-fidelity simulation has been used for the first time to investigate puffing and microexplosion dynamics and its effects on fuel-vapour/air mixing and combustion. The research findings will be used to guide the development of accurate droplet breakup models to be incorporated into high-fidelity simulation of spray combustion of complex fuels.

5. Key outputs in bullet points:

(1) J. Shinjo, J. Xia, L.C. Ganippa, A. Megaritis, "Physics of puffing and microexplosion of emulsion fuel droplets", PHYSICS OF FLUIDS 26 (2014) Article Number: 103302.

(2) J. Shinjo, J. Xia, A. Megaritis, L.C. Ganippa, R.F. Cracknell, "Modeling temperature distribution inside an emulsion fuel droplet under convective heating: a key to predicting microexplosion and puffing", ATOMIZATION AND SPRAYS (2016) http://dx.doi.org/10.1615/AtomizSpr.2015013302.

6. Main body text

Recently, blending biofuel into conventional fossil fuel has been of great interest to promote the use of sustainable, renewable fuels. Due to the difference of physical properties such as the boiling point between different fuel species, new phenomena such as microexplosion appears when the blended fuels are used in combustion engines.

In fuel emulsion, minor fuel species can exist as sub-droplets in the parent oil droplet. If the boiling point of the sub-droplet species is considerably lower than that of the parent droplet, superheating of the minor fuel species will occur, leading to nucleation. Boiled vapour bubbles will be generated and grow. The rapid growth of a vapour bubble can lead to violent breakup of the parent fuel droplet. If the extent of the breakup is limited, puffing is usually used to describe the intermittent ejection of boiled vapour from inside the parent fuel droplet.

It is clear that puffing and microexplosion can be important for fuel spray atomisation as another important mechanism of secondary breakup and atomisation. Due to the complex physics involved in the process, however, the scientific understanding of puffing and microexplosion was still limited.

The EPSRC project EP/J018023/1 has enabled this interesting and important research, with the support of computing resources on ARCHER from EP/K025163/1. High-fidelity simulation has been used for the first time to investigate puffing and microexplosion dynamics from first principles. In the simulation, we have been able to directly simulate the dynamics of all liquid/gas and liquid/liquid interfaces, taking into account mass, momentum and heat transfer across an interface. Shown in Fig. 1 is the puffing and after-puffing dynamics of an ethanol-in-decane emulsion droplet [1]. In Fig. 2, interactions between puffing and the droplet wake flame occur [2].

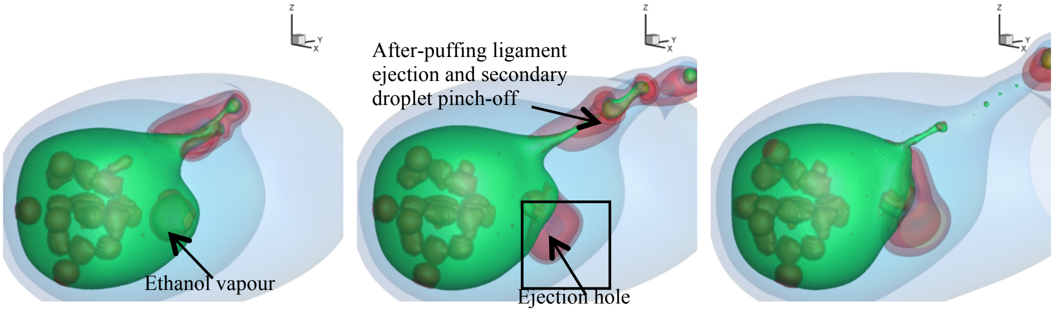

Fig. 1: Puffing and after-puffing of an ethanol-in-decane emulsion droplet [1].

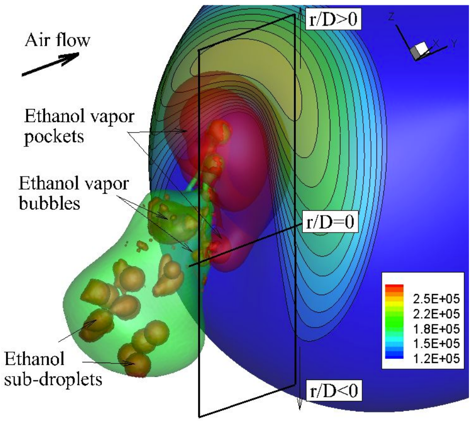

Fig. 2: Interactions between puffing and the droplet wake flame [2].

The research findings filled an important knowledge gap in fuel spray atomisation and combustion processes: puffing and microexplosion dynamics and its effects on fuel/air mixing and combustion. More accurate droplet breakup models can be developed based on the present study and used to predict spray processes of complex fuels, which will be extensively used in combustion engines to achieve a low-carbon economy and sustainable development.

[1] J. Shinjo, J. Xia, L.C. Ganippa, A. Megaritis: Puffing-enhanced fuel/air mixing of an evaporating n-decane/ethanol emulsion droplet and a droplet group under convective heating, Journal of Fluid Mechanics, minor revision submitted.

[2] J. Shinjo, J. Xia: Combustion characteristics of a single decane/ethanol emulsion droplet and a droplet group under puffing conditions, submitted to the 36th Int. Symposium on Combustion.

7. Names of key academics and any collaborators:

Dr Jun Xia: Senior Lecturer at Brunel University London
Dr Junji Shinjo: Research Fellow at Brunel University London

8. Sources of significant sponsorship (if applicable): N/A

9. Who should we contact for more information?

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