1. Project Title: UK Consortium on Turbulent Reacting Flows (UKCTRF)

2. Title of Case Study: Fully Coupled Fluid-Solid Simulation of Upward Flame Spread and Fire Growth

3. Summary of Case Study:

Flame spread is an important topic for addressing fire safety concerns and it is often classified as either counter-current (opposed) or concurrent. For counter-current flame spread, the direction of flame spread is opposite to that of oxygen diffusion resulting in a steady flame spread rate that has been well addressed. Concurrent flame spread for vertically oriented surfaces (upward) in buoyancy driven flames are, however, much less understood. But in the meantime, it is a critical aspect of accidental fires because of its inherent high speed and of the further damage to surroundings. While there have been many studies of upward flame spread along vertical surfaces and of horizontal flame spread along horizontal surfaces, few investigations have systematically addressed the dependence of the spread rate on the orientation angle of the surface. This Case Study involves the use of Archer to facilitate the numerical simulations by an Incoming International Fellow (IIF) funded by the European Commission's Marie Curie Programme. The main objectives include:

1 Development of a fully coupled fluid–solid approach to simulate co-flow flame spread over the polymethyl methacrylate (PMMA) and cardboards at different angles of inclination.
2 To examine and select appropriate solid pyrolysis models for PMMA and corrugated board, including using latest experimental data to enhance existing models.
3 Validation over a range of flame spread scenarios including generic configurations at different scales using primarily PMMA but some latest data using corrugated board typical of warehouse applications.
4 The validated model will then be used to predict upward flame spread in parallel panels representative of large scale fires.

FireFOAM, the large eddy simulation (LES) based fire simulation solver within the open source computational fluid dynamics (CFD) Toolbox OpenFOAM®, is used as the basic framework for the numerical study.

4. Key outputs:

A fully coupled fluid-solid approach for flame spread simulations has been developed using FireFOAM, a large eddy simulation based fire modelling solver within the OpenFOAM® toolbox. The Arrhenius type pyrolysis model developed by FM Global is used along with their measurements of the PMMA physical properties as input data. The key advantage of this model is that it does not require the pyrolysis temperature as input data unlike some other previously used models, which resulted in the predictions being dependent on the chosen pyrolysis temperature of PMMA, which varies from about 543 K to 658 K as reported in the literature. The experimental set up of Saito et al. (Proc. 1st Int. Symp. on Fire Safety Science, 75-86, 1986) was chosen for model validation as this is only set of tests which measured the transient wall temperature distributions. Unlike previous simulations which used assumed heat flux to trigger flame spread, the combustion process on the precursor gas burner was simulated to provide realistic heat source for pyrolysis. The predicted wall temperature profiles, pyrolysis height, heat release rate have been compared with the measurements. To the best of our knowledge, none of the previous numerical simulations of flame spread on PMMA, including predictions for this set of tests, presented results for wall temperature predictions. The comparison will hence serve as a good measure about the reliability of the present approach.

The project extended the long term collaboration between the PI and FM Global into a new domain. The PDRA gained new knowledge and training. The new development in FireFOAM will eventually be openly released on the internet to the international research community for free downloading once gone through careful validation and separate check by FM Global.

5. Names of key academics and any collaborators:

Jennifer Wen

6. Sources of significant sponsorship (if applicable):

European Commission €315K Oct. 2013 to Oct. 2015
FM Global, an international insurance company, US$60K for 2014 and 2015.

7. Who should we contact for more information?

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