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Vapour Cloud Explosion Modeling using the Porosity Distributed Resistance (PDR) approach

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1. INTRODUCTION and OBJECTIVE

The interaction between chemistry and turbulence implies that the modeling of turbulent combustion is computationally challenging, especially for scenarios that entail complex geometries and large spatial scales. Vapour cloud explosion modeling in confined and congested domains has challenged researchers for half a century. Various models and tools have been employed to predict overpressures generated from gas explosions. The models are briefly classified as empirical, phenomenological, and computational fluid dynamics (CFD). The use of empirical and phenomenological models is limited to systems of limited size and complexity. Hence, CFD modeling has become an essential part of gas explosion studies [2]. In the present study, the premix and compressible combustion solver PDRFoam is evaluated for fuels such as methane, propane, and hydrogen.

Hydrogen combustion, which has no greenhouse effects (green hydrogen), has been considered a promising replacement for fossil fuels. With a wide flammability range and low ignition energy of hydrogen, safety is one of the most critical issues to be addressed while replacing fossil fuels with hydrogen [3]. Challenges with computations for safety studies are large scale domains and the mathematical modeling of complex physical phenomena. The Porosity Distributed Resistance (PDR) approach can be one of the practical solutions to overcome these challenges [1]. PDR is a cartesian-based method. PDRFoam was developed as an application in OpenFOAM. The equations for mass, momentum, enthalpy, and regress variables are modified based on the PDR approach and solved. PDR approach models the effect of smaller scale geometries such as pipes, vessels, racks, etc., and resolves the large scale obstacles [1]. Figure 1 describes the obstacle configuration for the Hydrogen Safety for Energy Applications (HySEA) P1B3 case, where P1 is the pipe rack, and B3 is the bottle basket.

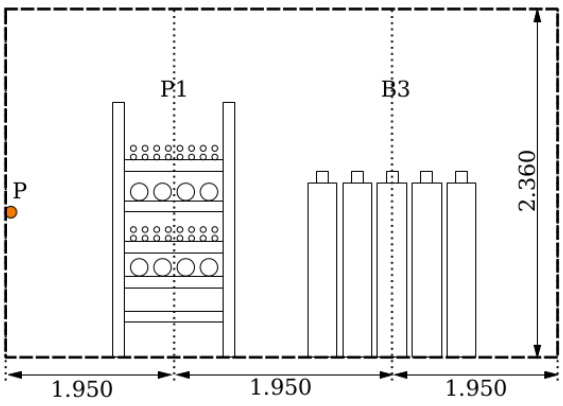

Figure 1: Schematic representation of HySEA P1B3 hydrogen case, where P represents ignition point.

2. RESULTS

The numerical evaluation is done against small as well as large-scale experiments. J Puttock et al. [1] have validated PDRFoam against ERGOS, MERGE, and Buxton unconfined or S-series experiments. The deviation between the predicted overpressure and experimental overpressure was found in an acceptable range [1]. In all the validation cases, methane or propane has been used as fuel. In the present study, validation for hydrogen is also included using the HySEA experiments [2].

PDRFoam solves the transport equation for the flame wrinkling around obstacles such as pipes. Including flame wrinkling, effects make the turbulent regime predictions better than those obtained using other solvers. Flame wrinkling also plays a vital role in overpressure prediction. Figure 2a shows the flame interaction with obstacles in HySEA hydrogen cases. It is clear from the figure that as flame propagates, it pushes unburnt gas, eventually resulting in overpressure generation and flame acceleration. Figure 2b shows predictions against different experiments. The predicted overpressure values in most of the cases are more than the experimental overpressure values.

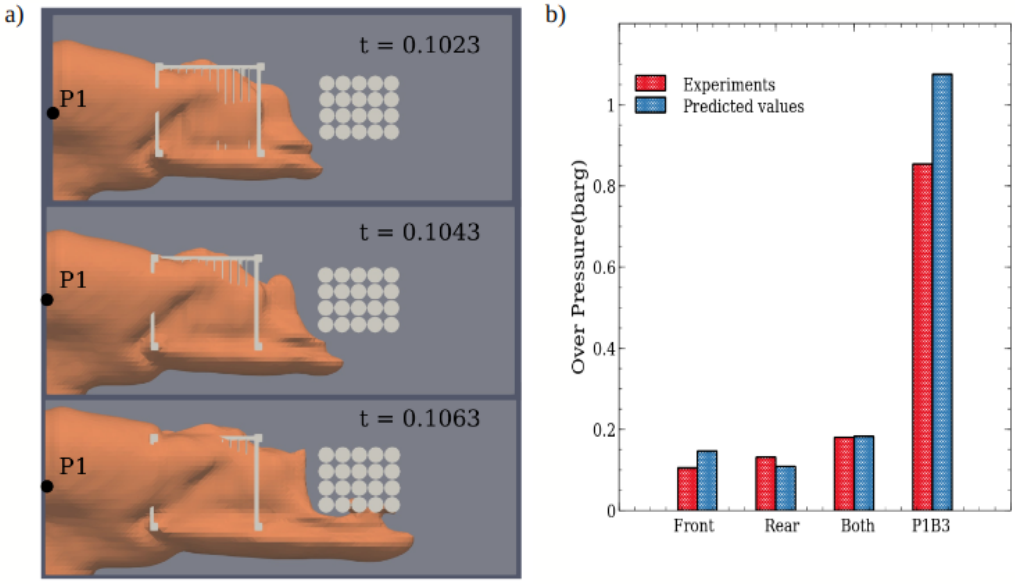

Figure 2: a) Hydrogen flame interaction with obstacles in the HySEA P1B3 case, where P1 represents ignition point; b) Overpressure prediction compared with experiments.

3. REFERENCES

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