Follow Up Grant ASTI14-82: Validation of the Gas and Dust Explosion Model

Initial Grant ASTI14-05: Development of a Gas and Dust Explosion Model

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Focus of the proposed follow-on work: However, in spite of a general success of our previous project, ASTI14-05, the outcomes of this research were "academic" to some extent such that a set of parameters from real coalmines remained unknown. In particular, smooth walls of a tunnel were considered while they may appear rough and/or obstructed in the practical reality. Consequently, there is a need to quantify these unknown parameters and new features, such as in-built obstacles, and then provide a more robust validation of our model to justify its applicability to capture combustion in coalmines. Proposing a way to provide such a successful validation constitutes the content of the proposed research.

Expected Outcome: As stated above, research outcomes of the previous project, ASTI14-05, appeared academic, to some extent, with a number of parameters and characteristics from real coalmines unknown. In this respect, there is a critical need to reduce the gap between the academic study and practical applications by validating the D-GEM, especially, the analytical model. While some validation has been done in our initial exploratory grant, ASTI14-05, a more robust validation of the model is required and desired before proceeding further with its development or assessment of specific applications. It is noted that the experts may feel uncertainty regarding abilities of this type of an analytical approach to accurately capture the changing dynamics and combustion properties associated with the explosion front environment in an actual explosion event in a coalmine.

Specific Aims of Proposed Research:

- First and foremost, we propose to perform "in-situ" experiments to validate our model. The experiments will be performed by our subcontractor Dr. Ranwgala of the Department of Fire Protection Engineering of the Worcester Polytechnic Institute (WPI). More details of the WPI experiments will be presented in the next section. Upon successful completion of this experimental work, we will know more constants and other parameters involved in our model, and thereby will be able to validate the model by available data in the literature.
- Second, it is highly important to compare our model to the available research outcomes of other researches working in the field of coalmining fire safety. In this respect we will pay a special attention to the comprehensive numerical simulations conducted at the University of Maryland (UMD), College Park, under the Alpha Foundation grant AFC215-20. To be specific, we will have compared the analytical model ASTI14-05 and the numerical simulations AFC215-20 for various configurations employed in the latter. Similarities and differences of the flame propagation and behavior will be identified, with various flame characteristics such as the flame shape, velocity and acceleration rate to be compared for various thermal-chemical parameters of the flame as well as for various configurations.
- Here, a special attention will be paid to extend the theoretical approach from one based on finger flame acceleration to that based on obstacles. While obstacles appeared beyond our consideration in the previous project has certified the importance to account for the presence of obstacles in a coalmine fire scenario. This is because coalmines usually involve long tunnels with possible crosscuts, and with rubble or equipment on the floor, constituting blockages/obstacles. Consequently, the role of obstacles will be accounted in the proposed research. In fact, the implementation of obstacles into our exiting model is not hard because both finger-flame acceleration and obstacles-driven acceleration have many features in

common. In particular, both acceleration mechanisms are prompt, self-similar and Reynolds independent. However, acceleration due to obstacles can be much faster and unlimited in time: it does not terminate when the flame skirt contacts a tunnel wall.

- Consequently, the mechanisms of flame acceleration in tunnels due to (i) finger-like flame shape, (ii) wall friction, and (iii) obstacles faced on the flame track will be combined into a unified analytical approach, which will subsequently be incorporated into our formulation developed in the original project ASTI14-05. This will bring onboard a set of new parameters to consider such as the blockage ratio, the length and width of the obstacles, the spacing between the neighboring obstacles etc. The impact of these quantities on flame propagation will be identified and tabulated within a detailed parametric study. Similar to ASTI14-05, we will start the analysis with laminar homogenously-gaseous combustion and then extend it to the dusty-gaseous environments. As a result, we will extend the analytical and computational approach of ASTI14-05, GEM/D-FEM, to describe flame acceleration in obstructed tunnels; and we will validate the formulation by the computational results of the project AFC215-20.
- Finally, we will perform an extensive literature overview in order to secure the relevant data available in the literature, and we will validate our model by such a data, when possible. In particular, shock tube experimental testing is oftentimes employed to simulate various explosion behaviors related to coalmines, including conditions that are described by the D-GEM such as flame acceleration and the flame evolution from a deflagration to a detonation.