Follow Up Grant ASTI14-69: Investigating the Impact of Rock Rubble on Methane-Air Explosions: High-speed Turbulent Deflagrations and transition to Detonations

Initial Grant ASTI14-02: Combustion Modeling of Explosive Gas Zones in Longwall Gobs

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Focus of the proposed follow-on work: One of the main findings of the previous work (AFSTI14) was a full-scale model which predicted and explosion of an EGZ located near the shields at the end of the longwall face which resulted in explosion velocities of 400 – 600 m/s and overpressures reaching ranging from 500 – 1500 kPa. The predictions from this preliminary work are similar to the velocities and overpressures predicted during the Upper Big Branch explosion in 2010; where investigators determined explosion pressures of 170 kPa and reflected pressure waves of 720 kPa, with flames traveling upwards of 450 m/s. While there are CFD models being developed by several researchers (including here at Mines) for predicting methane gas explosions and the resulting devastation that can occur in longwall coal mines, there is still a need for an experimental facility which can provide data which can be used to assist in the development of these models and provide crucial validation at these larger scales. The focus for this proposed work is to extend the current Mines' large-scale Gas Explosion Test Facility (GETF) to further investigate the high-speed turbulent deflagration and transition to detonation regime where explosion pressures and propagation velocities of the magnitude predicted in UBB can occur. The data obtained from this new explosion reactor will provide the necessary data to further validate the current CSM longwall coal mine combustion model and provide crucial information in the detonation regime for validation of higher-fidelity models developed by our collaborators at the University of Maryland (UMD) and the Naval Research Laboratory (NRL). Researchers at UMD and NRL have jointly developed more advanced CFD deflagration and detonation models for methane which they propose to expand to other mine gases, specifically, higher hydrocarbons (HHC), CO, H2S, H2O and other chemical species. These volatile matter gases are of particular importance when studying coal dust explosions and explosions of mine fire gases. Also expanding the scaled explosion test facilities at the Colorado School of Mines will provide necessary data for the calibration and validation of these advanced explosion models and further support the development and validation of the CSM model which will be used to develop new mitigation strategies for explosions in Longwall coal mines.

Expected research outcome: Will be the extension of an explosion vessel to provide additional insight into the complex interaction of high-speed turbulent deflagrations and detonations with a simulated gob (i.e. rock rubble). Data will be used to validate and extend CSM's high-speed deflagration combustion model and provide data in the DDT regime and further validation for collaborating researchers at UMD and NRL. Once the CSM combustion CFD models have been calibrated and validated, the models will be scaled up to full size mine workings and researchers will be able to study the impact of mine explosions and identify conditions that must be met to prevent such explosions through ventilation system design, early detection and appropriate emergency response.

Specific Aims of Proposed Research:

1. Enhance our understanding of the impact of rock rubble (i.e. the gob) on flame behavior in both the high-speed deflagration and transition of deflagration to detonation regimes. The high-speed deflagration and interaction with various rock pile geometries and materials will be a continuation of the short-term proposal (AFSTI14) and would allow further improvement of the combustion CFD model developed at Mines which has been successful in capturing the impact of rock rubble on high-speed deflagration of methane flames in cylindrical reactors ranging in scales of 1/50th to 1/8th relative to full size coal mine

workings. The proposed work is to extend the knowledge gained in the high-speed deflagration regime to the DDT regime which will allow collaboration with University of Maryland and the Naval Research Laboratory and provide valuable data that can be used as additional validation for the high fidelity combustion modeling developed at the respective institutions.

2. Provide insight into the impact of other flammable gases (HHC, CO and H2S) besides methane that can be contained in the coal strata or produced as a result of blasting or mine fires (carbon monoxide) occurring deep within the mine. Understanding how some common species (HHC, CO, H2S) found in natural gas impact the flame acceleration compared to idealized natural gas (i.e. methane) is also an important next step and would provide crucial data for combustion chemistry and for the DDT models developed at UMD and NRL. Also investigating the impact of these gases along with variation in pressure and temperature on the lower and upper explosive limits is crucial to explosion prevention strategies implemented in the mines; for example carbon monoxide (CO) has significantly wider limits ranging between 12.5 and 74% compared to the 5 to 15% explosive range for pure methane. Also it should be noted that H2S has a wide explosive range (4 to 44%) and higher hydrocarbon have lower explosive limits down to 2% which increases the risk of explosions occurring with the presence of longer carbon chain hydrocarbons.