Project Title: The Impact of Contractor Utilization on Health and Safety.

Organization: Boston University School of Public Health

Partnerships: None.

Investigator(s): Leslie I. Boden

Focus Area: Safety

SYNOPSIS

Problem Statement and Justification: How a firm chooses to allocate employment has important consequences for the health and safety of workers. In many other high risk industries such as construction and the petrochemical industry, contracting arrangements have been linked to higher fatality and injury rates. Within the mining industry, it has also been used to avoid collective bargaining arrangements and pension liabilities. The question is whether such arrangements also have an effect on worker health and safety in a manner similar to what is evident in other industries. Contractor utilization, as measured by MSHA, in underground coal mining has experienced sustained growth over the past 25 years. But determining contract operations have not been done on a systematic level and it is unclear what its true prevalence is and resultantly the effect on workers in the underground coal mining industry.

Impact of the Research: Understanding the relationship between contract work and workplace injury and illness is an important aspect to consider in any strategy used to improve worker outcomes. The primary barrier to understanding this relationship is a lack of data on these contracting arrangements. This project will collect data the necessary data to determine the contractual arrangements for operating a mine. It will also provide statistical analysis of the data in order to formally determine the relationship between organizational arrangements and worker health and safety. If differences in health and safety risks exist across organizational choices, it will provide insight into why. This may help to focus resources devoted to improving miner health and safety.

Objective(s) and Research Approach: The three following objectives are the focus of this project:

1) Identify contract operations and determine contractor historical status beyond current information using environmental reclamation information.
2) Identify changing patterns in contractor utilization over time and assess the risk it poses to workers.
3) Test the hypothesis that that underground coal mines operated by independent contractors is more hazardous than similar non-contract mines.

To address these objectives, the following research approach will be taken:

1) Traditional data sources on the mining industry will be gathered and compiled from the EIA and MSHA.
2) We will gather data from the Office of Surface Mines (OSM) on mines in Kentucky to determine who holds the reclamation bond for current and historical operations in the state. Discrepancies between bondholders and operators listed in the OSM database and the MSHA data will provide information on which mines are likely contract operations. Mines identified by this process will be confirmed with experts in Kentucky’s state agencies
3) Finally a statistical analysis of a number of outcomes, such as injury rates and citation occurrences, will be done to determine the relationship between contract operations and miner health and safety risks.

Project Title: Combustion Modeling of Explosive Gas Zones in Longwall Gobs

Organization: Colorado School of Mines

Partnerships: None

Investigators: Gregory Bogin Jr., Jurgen Brune, John Grubb

Focus Area: Safety

SYNOPSIS

Problem Statement and Justification: Several mine fires and explosions, including the disaster at the Upper Big Branch mine in 2010 that caused 29 fatalities, have demonstrated that explosive gases can accumulate and explode within gobs of underground longwall coal mines and expand into the active face areas of the mine. Based on studies from numerous past mine explosions and fires, explosive gas zones (EGZs) exists in most, if not all longwall gobs. Several studies have been conducted looking at reducing the size of EGZs within the gob using various ventilation schemes.

Impact of the Research: The ultimate goal of this proposed research is the development of a CFD model of the longwall gob that can simulate EGZs based on various ventilation schemes and includes a combustion model to simulate explosions within the gob to determine the explosion hazard to miners working in the face or bleeder areas surrounding the gobs. Understanding the impact of an explosion in the longwall gob can guide new designs for mitigation strategies or containment of an explosion or improve the mine's emergency response and evacuation protocols to increase miners' safety. Currently there are models, which can predict location and volume of EGZs in a longwall gob, but are not capable of predicting the impact of explosion on miners if it occurs in the gob or nearby areas.

Objective(s) and Research Approach: The specific objectives and approaches for this proposed research is: 1) Investigate the explosive gas zones (EGZs) in gob-like conditions using an explosion testing apparatus. A gob explosion simulation apparatus (GESA) will be constructed to study flame propagation through rock rubble with various gob parameters (e.g. permeability, moisture content, barrier length, material prope11ies, and various methane-air concentrations). This will provide insight into the impact of the conditions found in the gob on explosions and flame propagation providing more accurate parameters to use in developing the combustion model. 2) Development and validation of a CFD combustion model using experimental data obtained from the proposed design of an experimental apparatus to study the impact of explosions within a longwall gob. A CFD combustion model of the test apparatus will be developed and validated with the results of the physical explosion tests. This validation is critical to gain the explosion propagation, pressure and flame spread parameters that are needed to examine EGZ explosions in longwall gobs. 3) Finally, incorporating the CFD combustion model into the full CFD ventilation model to investigate the safety hazard of EGZs based on methane/air concentrations, volume, location, gob conditions (e.g. porosity, permeability, moisture, etc.), and effective source of ignition. Researchers will use the results from an existing CFD numerical model of a longwall gob developed at CSM as the initial conditions for the combustion model and examine how flames, pressures, gases and other hazardous effects will propagate through the gob and into the active mine workings as a result of an EGZ explosion. Determining the specific hazards that miners may face as a consequence of such explosions and safe conditions (distance from face, volume and gas composition) that must be maintained to control the safety hazard from EGZ explosions. Each of the three objectives are interconnected and will rely on an iterative approach to finalize a model which will be capable of assessing the potential explosion hazard to miners due to the EGZs in the longwall gob.

Project title: The Precise Determination of Rockbolt Performance Underground

Organization: Southem Illinois University Carbondale

Partnerships: Yieldpoint Inc, Kingston, Ontario, Canada

Investigator: A.J.S. (Sam) Spearing

Focus area: Safety

SYNOPSIS

Problem Statement and Justification: All previous *in situ* rock-bolt monitoring (mainly load versus displacement) solutions to date have been implemented via two methods. The first method incorporated opposing pairs of short base-length resistive strain gauges on opposing sides of a roof bolt. A more recent method incorporated long base-length displacement strain gauges spaced at regular intervals on opposing sides of a roof bolt in a similar fashion. Both of these methods have involved only two slots, along the rock bolt length, containing the strain gauges. It has been found that these designs have significant shortcomings as neither captures the entire strain profile along the bolt and both have inherent errors because only two slots are used. This project makes use of a novel monitoring technology that uses optical fibers in both two, and three slots in rock bolts, and represents the most innovative rock bolt monitoring technology to date. Preliminary tests have indicated that this is truly a ground- breaking technology.

Impact of the Research: The overlying focus of this project is to improve rock-related safety and potentially optimize the design of primary roof bolts in coal mines by measuring and understanding the loads in resin grouted rock bolts over time. This could potentially result in improved safety combined with increased productivity and possibly even reduced costs.

Objectives and Research Approach:

Objective 1 – Laboratory studies and instrumentation validation. This involves comparing the bolts with two slots using short gauges, long gauges and optical fibers under different loading conditions and at different orientations in the laboratory. Bolts with three slots and optical fibers will also be used. It has been found that the two-slot short gauge and long gauge designs have significant shortcomings as neither captures the entire strain profile along the bolt. By using only two slots, the load profile can easily misrepresent any reactive loads in the bolt depending on where the load is applied relative to the two slots. Considering that to obtain a strain tensor, three gauge rosettes are needed, and for the same reasons, three orientations of strain gauges along a bolt should also be needed (i.e. 3 slots).

Objective 2 – Installation of instrumented bolts in the field. The monitoring technology that offers the most thorough and reliable load monitoring along the bolt will be installed under various conditions underground. Coal mines have already offered underground sites.

Objective 3 – *In-situ* monitoring and reporting.

Project Title: Early-Warning Safety Hazard Predictor for Preventive Ventilation Management

Organization: University of Nevada, Reno, Department of Mining and Metallurgical Engineering

Partnerships: Barrick Goldstrike Mines, Inc., Turquois Ridge Joint Venture, Ohio Automation, Inc.

Investigator(s): George Danko, Davood Bahrami

Focus Area: Safety

Problem Statement and Justification: Recognition of safety hazard is difficult because of the complex nature of information from atmospheric and other conditions underground. Large amount of monitored data may be available from measurement by sensors such as air velocity, pressure, hazardous gas contaminants, temperature, and roof stability. However, it is difficult to recognize problem-causing trends from the measurement data with time-dependent variations. In addition, the combined effects of various signal trends must be interpreted simultaneously with their cross-effects. Safety hazard recognition and prediction algorithms are needed to foresee the possible outcomes of intertwined signatures of various problems by continuous observation. For example, a steady, continuous CH_4 concentration measurement together with a sharp drop in barometric pressure from the monitoring sensors may indicate a potential hazard in future time due to pressure-induced methane increase from the coal seam or the gob. A computer algorithm extrapolating the possible outcomes from real-time monitored data can predict this future increase. A forward-in-time and forward-in-space prediction then may trigger a safety-warning message to mine management to prevent the accident from happening.

Impact of the Research: Our research objective is to develop Early Warning Predictor (EWP) software that forward- predicts ventilating air conditions at an early time before the hazard actually fully develops in real time. The EWP will provide informed prediction forward with space and time based on a calibrated Ventilation and Air contaminant Model (VAM) as well as sensor inputs from the monitoring system. The innovative EWP will be able to determine and flag a warning alarm for the management to act for resolving a hazardous condition before the actual safety hazard will have developed. The early-warning signal will provide time for safety management that may include directing the miners to the nearest emergency rescue chambers.

Objectives and Research Approach: The EWP system are to run five real-time processes simultaneously for: (1) interpreting the mine monitoring signals in comparison with the VAM transport model; (2) validating both the model and the sensor readings in their relationship to each other; (3) identifying plausible source changes as reasons for differences other than model error or sensor malfunction as unexpected changes in the model boundary conditions; (4) evaluating the hazard conditions at critical locations; and (5) extrapolating the trend with time and flag crossing points with maximum threshold values for issuing an EWP alarm. The EWP system will be tested for a suit of disturbances in the computer laboratory at UNR to provide controlled test conditions. The VAM model (either VnetPC, Ventsim, MineVent, or MULTIFLUX) of the partner mines will be imported for the studies to create the internal simulation model for the perturbations in the EWP. The mine monitoring system layout and the measurement accuracy as well as uncertainty range will be acquired from the partner mines for the development and test runs of the EWP. The EWP system will be tested for correct forecasts of hazardous scenarios during their development but before the thresholds for accidents have been crossed due to such as: partial collapse of a hazardous roof section; methane inburst from the strata; booster fans malfunctions; fan starts or stops to cause barometric pressure variation that may trigger pressure unbalances and methane inflow from sealed areas, seams, or gob. We may add further scenarios upon request from our mining partners as a follow-up study.

Project Title: Development of a Gas and Dust Explosion Model

Organization: West Virginia University Research Corporation

Partnership: Worcester Polytechnic Institute

Investigator(s): V'yacheslav Akkerman, Ali Rangwala

Focus Area: Safety

SYNOPSIS

Problem Statement and Justification: Modern coal-mining machinery has significantly increased the portion of small-size coal dust collected in intake/return airways and the particle size provides a substantial impact in accidental gas and dust explosions representing a hazard to both personnel and equipment in coal mining industry. The modern knowledgebase about dust explosions does not provide an acceptable level of risk and therefore should be addressed, from a fundamental viewpoint. Consequently, a computational model capable of quantifying the probability and associated hazards of spontaneous ignition, deflagration as well as the likelihood of a deflagration-to-detonation transition (DDT) event is highly needed. The present project is a conceptual initiative step towards such a model.

Impact of Research: The primary goal of this project is the developing of a computational platform for modeling gas and dust explosions in applications of a serious hazard to life and property such as coal mines. The study is unique since the physical understanding of the controlling mechanisms associated with particle-air flames have not been explored in depth. The platform will be based on a robust CFD code solving fully compressible hydrodynamics and combustion equations in a turbulent environment. It is noted that the majority of CFD models for turbulent combustion and explosion utilize empirical correlations between the laminar and turbulent burning velocities, and the parameters describing the turbulent flow. Consequently, these models are linked to particular configurations and therefore require an experimental quantification of the phenomenological coefficients in each particular case. In contrast, the present research incorporate a turbulent flame speed model that is analytically developed from the first principles and should therefore work everywhere within its validity domain.

Objectives and Research Approach: We shall develop a computational platform to analyze combustion hydrodynamics and incorporate the capability of modeling of laminar and turbulent burning velocities including the consideration of dust particles. The model will account for such a state-of the art effects of turbulent combustion as flame-flow feedback, burning along the turbulent vortex axes, and turbulence-instability coupling. To complement the numerical modeling, we shall construct an experimental platform to validate the input parameters for the modeling efforts. Specifically, extensive experimental data of laminar and turbulent burning velocity for gaseous and particle-air flames as a function of particle type, size, concentration, turbulent intensity and length scale will be generated during this study. Consequently, in this project we shall bridge the gap between the turbulent flame formulations, based on the empirical considerations, and that obtained from the fundamental principles of combustion