Simulating spon com

Looking at CFD modeling of spontaneous heating in longwall gob areas, by NIOSH's **Liming Yuan** and **Alex Smith**

In underground longwall coal mines, some coal may be left in the gob, either from the unmined roof, floor coal, gateroad pillars or from an overlying coal seam that caves into the gob. When exposed to the air, the coal may undergo low temperature coal oxidation resulting in spontaneous heating.

When the heat produced by the low temperature reaction of coal with oxygen is not adequately dissipated by the airflow, it will result in a net temperature increase in the coal mass. Under conditions that favor a high heating rate, the coal attains thermal runaway and a fire ensues.

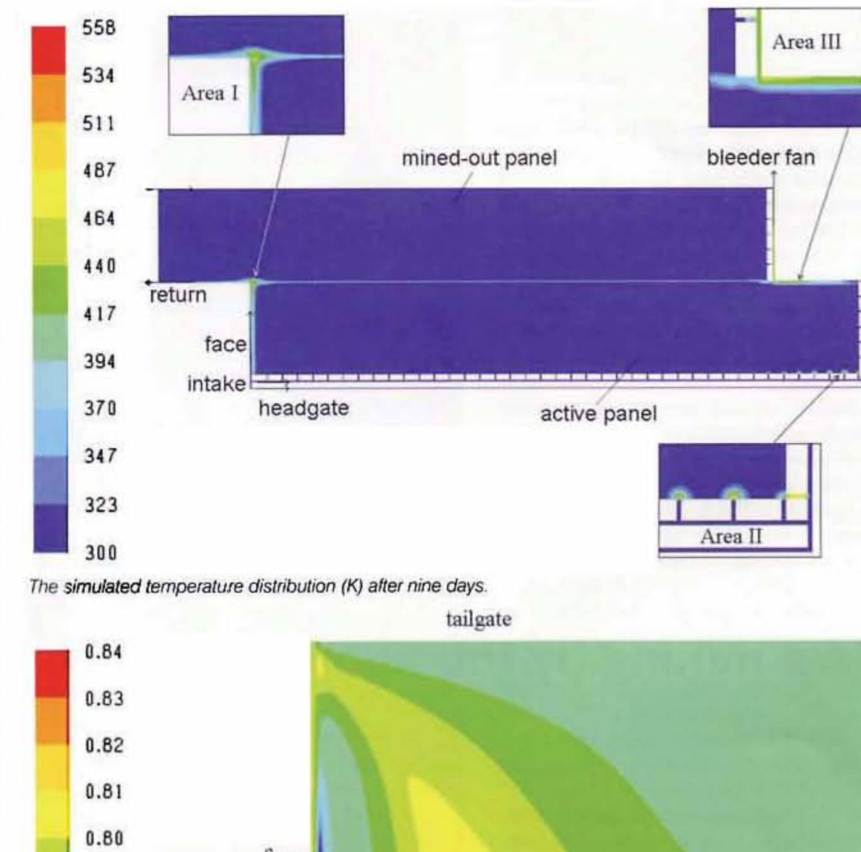
For the period between 1990 and 2006, a total of 25 reported underground coal mine fires in the US were caused by spontaneous combustion. The risk of an explosion ignited by a spontaneous combustion fire is also present in those mines with appreciable levels of accumulated methane. In fact, three of the mine fires resulted in subsequent methane explosions.

The spontaneous combustion potential of coals can be evaluated qualitatively in a laboratory and while the results are valuable, their extrapolation to the mining environment has not been completely successful because of complicated scaling effects that cannot be reproduced in small-scale experiments. In actual spontaneous heating events in longwall gob areas, much larger coal masses may be involved.

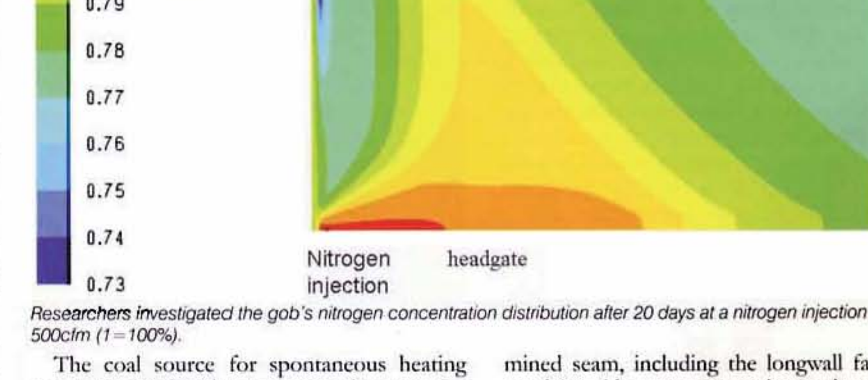
To reduce the fire hazard caused by spontaneous combustion in the gob, a computational fluid dynamics (CFD) study is being conducted by NIOSH to simulate the spontaneous heating of coal in the area.

Researchers developed a CFD model of the spontaneous heating process in a two-longwall-panel district using a bleeder ventilation system with a stationary longwall face. The spontaneous heating was modeled as the low-temperature coal oxidation in the gob using kinetic data obtained from previous Bureau of Mines laboratory-scale spontaneous combustion studies.

In the model, heat generated from coal oxidation was dissipated by convection and conduction, while oxygen and oxidation products are transported by convection and diffusion. Each simulated gob area is 2000m long, 300m wide and 10m high starting from the bottom of the coal seam.



The simulated temperature distribution (K) after nine days.



Researchers investigated the gob's nitrogen concentration distribution after 20 days at a nitrogen injection rate of 500cfm (1=100%).

The coal source for spontaneous heating was a 1m-thick rider sequence that was 1m above the main seam. The rider seam was modeled as caving into the bottom of the gob after the main seam was completely mined out. The effect of methane emissions from the mined seam, including the longwall face and overlying rider seam reservoirs on the gob gas distribution was considered.

Simulations demonstrate that temperature increases occurred in three areas, the first being Area I – close to the active tailgate and around the return. Area II was the area near the crosscuts close to the back end of the active panel, and Area III was near the middle entry at the back end of the mined-out panel. There was very little or no temperature rise in areas other than I, II and III.

CFD simulations were then conducted to model the spontaneous heating in the longwall gob area with a bleederless ventilation system. In the US, bleederless ventilation systems may be approved by the Mine Safety and Health Administration to serve as a spontaneous combustion control method in mines with a demonstrated history of spontaneous combustion.

Currently, three US coal mines are utilizing bleederless ventilation systems. A simple "U" ventilation scheme was modeled with a stationary longwall face, and the simulation results show that the temperature rise is much lower and only occurs in the corner of the gob between the face and the intake entry.

Under conditions used in the study, the maximum temperature was only 302.8 K after 20 days with the bleederless system, while the maximum temperature reached 500 K in eight days with the bleeder ventilation system.

The effectiveness of nitrogen injection to prevent spontaneous heating in the gob with a bleederless ventilation system was also examined. The nitrogen was injected at the corner of the intake entry with two different nitrogen flow rates: 500 cubic feet per meter and 1000cfm.

This served to dilute the oxygen concentration of the air flowing into the corner of the gob. Nitrogen was then forced to flow in the direction of ventilation air at the corner of the intake entry.

In one study case, time to reach a thermal runaway was increased about two days with the 500cfm injection rate, and this time was increased to about five days at 1000cfm. The location of the maximum temperature rise with nitrogen injection remained near the corner of the intake entry.

CFD simulations were also conducted to investigate the effect of longwall face advance on spontaneous heating of coals in the longwall gob area. One panel with a three-entry bleeder ventilation system was simulated, the width of which was 300m and length was 2000m.

The longwall face was first modeled at location number one, 1000m from the start line of the panel. It was assumed that the face advanced at a daily rate of 20m from that location.

The face advanced 100m in five days to reach locations two, three and four, respectively. The face advanced 200m in 10 days to reach location five.

Simulation results demonstrate that under typical three-entry bleeder ventilation conditions, that face advance can quickly reduce the maximum temperature in the gob developed during face stoppage. In our study, the maximum temperature in the gob was reduced from 203C to 72C when the face advanced to location two.

The maximum temperature was further reduced to 52C, 47C, and 42C when the face was advanced to locations two, three and four, respectively. The maximum temperature decrease followed three stages: fast decrease, moderate decrease and slow decrease.

Once the maximum temperature is in the slow decrease stage (below 57C in this study), the face advance no longer has a significant effect. It was also found that the value of the maximum temperature prior to the face advance has no effect on the pattern of maximum temperature decrease.

NIOSH is now working with several US mines to validate the model results and improve the CFD model to provide insights for the optimization of ventilation systems for the nation's underground operations facing both methane control and spontaneous combustion issues.