Applications of a Scaled Aerodynamic Model for Simulations of Airflows in a Longwall Mine

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NIOSH Mining Program
Outline

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- Measurement and Instrumentation
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- Development of LIAM
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Introduction

- Ventilation systems are complex and dynamic which makes it difficult to conduct accurate and detailed field experiments
- Simulate inaccessible areas of a longwall panel through physical modeling
- Simulating the performance of a ventilation system under controlled conditions
- A 1:30 scale Longwall Instrumented Aerodynamic Model (LIAM) was designed and constructed to simulate a portion of a longwall operation
- LIAM is built with critical details of the face and face machinery
**Layout and Design**

- Single panel with a three-entry headgate and tailgate configuration
- LIAM is 29 ft. long, 16 ft. wide, and is 2.75 ft. in height
- Face length is 24 ft., which represents a 720 ft. in full-scale with 127 shields
- Gob represents an early stage of mining for near face studies, before the gob is "squared up"
- Ventilated by a single centrifugal fan connected to a variable frequency drive
Visual Recording using Smoke

Bleeder Entries

Gob

Face

Tailgate

Headgate
Measurement and Instrumentation

- Velocity: 19 hotwire anemometers are located in different entries and 24 hotwire anemometers are located in the gob
- Pressure: Differential pressure across the face is recorded
- Temperature: Two thermocouple record air temperature
- Data Acquisition System: 45 sensors connected to the computer
- Smoke Generator: Theatrical smoke is used for visualization of airflow paths, eddy currents, and gob-face interaction
- Video: Each test is recorded using a ceiling mounted wide-angle camera that helps in validating the airflow patterns
## Scaling of Airflow

<table>
<thead>
<tr>
<th>Model</th>
<th>Specification</th>
<th>Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale for geometry</td>
<td>x $1/30^{th}$</td>
<td>3 inch high face in LIAM represents 7.5 ft face in full-scale. 24 ft face length in LIAM represents 720 ft in full-scale</td>
</tr>
<tr>
<td>Scale for velocity</td>
<td>x 0.56</td>
<td>280 fpm in LIAM represents 500 fpm in full-scale</td>
</tr>
<tr>
<td>Scale for flow</td>
<td>x 0.00062</td>
<td>62 cfm in LIAM represents 100 kcfm in full-scale</td>
</tr>
<tr>
<td>Turbulent dispersion</td>
<td>Reynolds number &gt; 6000</td>
<td>Similitude for turbulent dispersion. Reynolds number ~12000 in headgate entry.</td>
</tr>
<tr>
<td>Layer formation</td>
<td>Conservation of the Richardson number</td>
<td>Similitude for layering</td>
</tr>
</tbody>
</table>
Development of LIAM

- Construction of geometrically scaled model based on 1:30 scale
- Standard testing procedure and scaling of airflow using gob material of known properties
- Calibration of sensors by conducting baseline testing
- Calculation of porosities of various gob materials
- Experimental tests to simulate airflow in a longwall panel
Experiment Design

LIAM Tests

Fan Location
- Exhausting Ventilation (Negative)
- Blowing Ventilation (Positive)

Air Circuit
- U-Tube Ventilation
- Through-Flow Ventilation

Caving Characteristic
- Gob Material
- Void Space Behind Shields

Methane Control
- Bleeder
- Bleederless
### Test Conditions

- **Objective:** Measure the air velocities within the gob, quantify the gob-face interaction, and measure airflows on face.
- **LIAM offers the unique opportunity to easily modify and compare different ventilation systems.**
- **Bleeder System:** Exhaust on the tailgate side used to simulate a bleeder shaft.
- **Bleederless System:** Stoppings added around the gob.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bleeder</th>
<th>Bleederless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan speed</td>
<td>2400 RPM</td>
<td>2160 RPM</td>
</tr>
<tr>
<td>Velocity at Face (Headgate)</td>
<td>280 fpm</td>
<td>269 fpm</td>
</tr>
<tr>
<td>Intake Airflow</td>
<td>80.6 cfm</td>
<td>80.7 cfm</td>
</tr>
<tr>
<td>Stoppings</td>
<td>No stoppings</td>
<td>Stoppings added between the gob and back entries</td>
</tr>
<tr>
<td>Gob Material</td>
<td>Gravel and Styrofoam</td>
<td>Gravel and Styrofoam</td>
</tr>
</tbody>
</table>
Results from Bleeder System

- Air traveled in the gob right behind the shield line, and mixed with face air near the mid-face region
- ~21% air entered the gob near headgate in this system
- Higher fan pressure required to ventilate bleeder system
- Airflow higher in the tailgate side porous zone, compared to other areas of the gob
Results from Bleederless System

- Less movement of air from the face towards the back of the gob, when compared to the bleeder system
- ~15% higher airflow at the tailgate end than at the headgate side, as a large portion of air enters the gob
- Lower fan pressure required to operate bleederless system
- Air velocities within the gob lower than the air velocities in the bleeder system
Summary

- An aerodynamically and geometrically scaled physical model was successfully developed with critical details of a longwall panel.
- Scaling relationships were successfully derived to preserve the physical and dynamic similitude.
- Simulated airflow streams within the gob, gob-face interaction for bleeder and bleederless ventilation systems were demonstrated.
- Bleeder and bleederless ventilation systems were compared for the same mining configurations.
Future Work

- Complement field and numerical modeling studies
- Caving characteristics and void space behind the shields
- Mine specific studies to optimize and mitigate problems in a longwall mine
- Study of gas emission in the gob
SAVIE THE DATE

NIOSH Mining Webinar:
Improvement of Longwall Ventilation
September 21, 2017

For more information, contact Tom Dubaniewicz
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Thank you for your attention!

Questions?

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Aerial view of the NIOSH Pittsburgh Laboratory