Outbursts in China

By
Dr. Wang Kai
Visiting Professor

CSIRO Exploration and Mining
CONTENTS

1 Introduction
2 General understanding of OB
3 OB cases
4 OB prediction and control
5 Research status
6 Key issues
1 INTRODUCTION

- OB occurrence is very serious in China
- 1950.5.2, first recorded in China
- 1975.8.8, the largest OB in China: 12780t of coal, 1.4 M m³ of CH₄
- Marjory OB: CH₄ & Coal
- Minority OB: CO₂ & Rock, 1050t of rock, 240,000 m³ CO₂
Number of OB occurrence in state-owned coal mines in China from 1950 to 2000
Categories of OB occurrence: coal & gas bursting, coal bursting due to stress and gravity, rock bursting
1 OB VS Mining Depth

The depth occurred OB in China is from 50 to 600 m, different in various areas.
2 OB is associated with geological structures (faults, folds, volcanic rock intrusion and variation of coal seams such as thickness, dip and orientation) and structural stress.
3 In the zone of overlapping stress due to face and roadway extraction, OB risk is higher.
4. The higher gas pressure, the higher OB risk.

5. OB vs mining methods, shotfiring is the most risky.

采掘作业与突出的统计关系（样本数：6427）
6 Precursors of OB occurrence

- Audio- and non audio- precursors prior to OB occurrence
- Audio precursors include cracking, thundering etc
- Non audio- precursors include weighing of supports, rib and face cracking and falling, borehole heavily deforming, gas emission variation, irregular beddings, bursting while drilling, coal softening, coal dust increasing, etc.
4 OB PREDICTION AND CONTROL (GUIDELINE)

1 Implementation Procedures

煤层

区域预测

非突出层

突出层

区域预测

无突出危险区

威胁面

安全措施

推进30~100m

验证性工作面预测

危险区

工作面预测

无危险

安全措施

采掘作业

危险面

防突措施

措施效果检验

是

否

安全措施

采掘作业

威胁面

危险面

安全措施
## 2 Regional OB Prediction

### Single Index

<table>
<thead>
<tr>
<th>Index</th>
<th>Coal damage classifications</th>
<th>Initial desorption rate of coal (mmHg)</th>
<th>Coal strength coefficient $f$</th>
<th>Seam gas pressure (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>III, IV, V</td>
<td>$\geq 10$</td>
<td>$\leq 0.5$</td>
<td>$&gt;0.74$</td>
</tr>
</tbody>
</table>

### Composite Index

$$D = \left( \frac{0.0075H}{f} - 3 \right)(p - 0.74)$$

$$K = \frac{\Delta P}{f}$$

<table>
<thead>
<tr>
<th>$D$</th>
<th>$K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 0.25$</td>
<td>$\geq 20$</td>
</tr>
</tbody>
</table>

### Composite Index

<table>
<thead>
<tr>
<th>$D$</th>
<th>$K$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 0.25$</td>
<td>$\geq 20$</td>
</tr>
</tbody>
</table>
3 Coal face OB Prediction

Cross measure roadway - coal/rock face

- Composite Index;
- Coal Cuttings Desorption Index ($\Delta h_2, K_1$)

<table>
<thead>
<tr>
<th></th>
<th>Threshold Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta h_2$ (Pa)</td>
<td>$K_1$ (mL/g.min$^{1/2}$)</td>
</tr>
<tr>
<td>Dry coal: 200</td>
<td>0.5</td>
</tr>
<tr>
<td>Wet coal: 160</td>
<td>0.4</td>
</tr>
</tbody>
</table>
3 Coal face OB Prediction

**Inseam roadways - coal face**

a) Initial gas flow rate from borehole ($q$):

<table>
<thead>
<tr>
<th>Coal volatility $V_{daf}$ (%)</th>
<th>5~15</th>
<th>15~20</th>
<th>20~30</th>
<th>&gt;30</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_m$ (L/min)</td>
<td>5.0</td>
<td>4.5</td>
<td>4.0</td>
<td>4.5</td>
</tr>
</tbody>
</table>

b) $R$ Index ($R_m = 6$)

\[ R = (S_{max} - 1.8)(q_{max} - 4) \]

c) Coal cutting index

<table>
<thead>
<tr>
<th>Threshold value of coal cutting index</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta h_2$ (Pa)</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>
4 OB Prevention Measures (Regional/Local)

防治突出措施

区域防突措施
- 开采保护层
- 煤层瓦斯抽放
- 煤层注水
- 扩孔卸煤钻
- 金属骨架
- 高压注水
- 水力冲孔（冲刷）
- 超前钻
- 松动爆破（卸压爆破）
- 超前支护
- 掩护挡板
- 卸压槽（缝）
- 高压注水（疏松压出）
- 浅孔松动爆破

局部防突措施
- 高压注水
- 掩护挡板
5 Safety Protection Measures

- Shake Shotfiring
- Remote Shotfiring
- Underground Refuge
- Self Rescue System of Compressed Air
- Isolated Aerophore
1 Spherical disk failure theory of OB
煤与瓦斯突出的球壳失稳理论
THEORY OF OB OCCURRENCE
SPHERICAL DISK FAILURE

Mechanics conditions of OB occurrence

(1) Ground stress generates shear failure of coal, then form cracks in coal

\[ \sigma_\theta \geq \frac{1 + \sin \varphi}{1 - \sin \varphi} \sigma_r + \frac{2K \cos \varphi}{1 - \sin \varphi} \]
(2) Cracks expand under gas pressure, then form spherical disk

\[ P_{if} - P_2 \geq M_1 \frac{K_{1c} \sqrt{\pi}}{2\eta \sqrt{a}} \]
THEORY OF OB OCCURRENCE
SPHERICAL DISK FAILURE

Mechanics conditions of OB occurrence

(3) Spherical disk fails and thrown out under gas pressure

\[ P_{im} - P_2 \geq [1 - 0.00875(\phi_1 - 20^\circ)](1 - 0.000175 \frac{R_i}{t_i})(0.3E \frac{t_i^2}{R_i^2}) \]
According to the spherical disk failure theory, the key for OB to occur is the gas initial expansion energy.
Gas initial expansion energy
Measuring Apparatus
THEORY OF OB OCCURENCE
SPHERICAL DISK FAILURE

Test validation of spherical disk failure theory

OB in the test
Test validation of spherical disk failure theory (1)
Through increasing the air pressure in the model tunnel to prevent spherical disk from failure, OB can’t occur.
THEORY OF OB OCCURRENCE
SPHERICAL DISK FAILURE

Test validation of spherical disk failure theory (3)

Delayed- OB
The test results (OB or Non-OB) can be classified by the parameters of gas initial expansion energy and thickness of soft coal.
Test validation of spherical disk failure theory (5)

The variation in coal temperature in OB initiation is measured, the increase of temperature near cracks is 50 centigrade degree.
2 Regional OB Prediction method

Minimum gas pressure of OB occurrence
- statistically

\[ p_{\text{min}} = 5(0.1 + 0.017v^rf) \text{ MPa} \]

When \( v^rf < 5 \):

\[ p_{\text{min} \cdot kt} = 0.028(v^rf)^2 - 0.126v^rf + 1.02 \text{ MPa} \]

When \( 5 < v^rf < 8 \):

\[ p_{\text{min} \cdot kt} = 0.411(v^rf)^3 - 7.37(v^rf)^2 + 44.7v^rf - 89.5 \text{ MPa} \]
2 Regional OB Prediction method

Minimum gas pressure of OB occurrence

- statistical data of 26 mining areas in China
2 Regional OB Prediction method

Detection techniques of geological structures

- radio wave
- seismic
- geological radar
- Pulse ultrasound
3 Working face OB prediction

Acoustic Emission method

- In Nantong Coal Mine, the total AE events larger than 15 and its energy larger than 300 in 30 minutes after shotfiring are determined as the threshold values of OB.
3 Working face OB prediction

EmE (Electromagnetic Energy) radiation monitoring method

Measurement of EmE, $S$ and $q$ during tunnelling
3 Working face OB prediction

EmE (Electromagnetic Energy) radiation monitoring method

- When there is OB risk, EmE and its pulse number are higher (Fig. a)
5 RESEARCH STATUS

3 Working face OB prediction

\( V_{30} (V_{60}) \) and \( K_v \) Indices

- The quantity of gas emission per ton coal in 30 (or 60) minutes after shotfiring: \( V_{30} (V_{60}) \)

- The variation coefficient of gas emission in 30 (or 60) minutes after shotfiring: \( K_v \)

\[
K_v = \frac{1}{Q} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (Q_i - Q)^2}
\]
When $V_{30} > 9 \text{m}^3/\text{t}$ or $K_v > 0.72$, there is OB risk 2 ~ 5 m ahead of the face.
Nonlinear characteristics of face gas emission

When there is OB risk, the multi-fractal spectra of face gas emission dehisce obviously.
5 RESEARCH STATUS

4 Regional OB prevention technique

Mining protective seam- destressing and increasing permeability
Mining protective seam - destressing and increasing permeability

The effect of protective seam mining
4 Regional OB prevention technique

Seam gas drainage in advance
Gas drainage in advance – coal volume shrinks, stress reduces, permeability increases

![Diagram showing gas drainage in advance](image)

**Fig. 2** The arrangement of boreholes at No.9 crosscut

![Graph showing changing curves of several parameters during degassing](image)

**Fig. 3** The changing curves of several parameters during the degassing
Gas drainage in advance - coal volume shrinks, stress reduces, permeability increases
Large diameter (Φ500) destressing borehole in coal/rock face
Local OB prevention technique in coal/rock face

High pressure water injection for borehole enlarging
5 Local OB prevention technique in coal/rock face

Drilling + extraction
5 RESEARCH STATUS

5 Local OB prevention technique in coal/rock face

Slotting + Extraction

图 3-4-15 开卸压槽时掘进机工作状态

1—转载机构；2—司机座；3—水平回转油缸；4—升降油缸；5—推进油缸；
6—工作臂；7—截割头；8—中心钻；9—开卸压槽装置
5 Local OB prevention technique in cutting face

Hydraulic destressing ahead of mining face

- The coal ahead of the face can be destressed and extruded out.
- The distressed zone ahead of the face can be enlarged.
1. Low permeability coal seams – techniques to enhance permeability

2. In seam long hole drainage

**Key techniques:**

- Effectively remove cuttings
- Directional drilling
- Increase drilling power
- Minimize outbursting while drilling
- Increase borehole length
3 Continuous monitoring techniques of OB precursors and OB risk identification techniques

Precursor: gas emission rate (from borehole of face), EmE, etc.
Identification: extracting characteristics, AI, etc.

4 Evolution of OB hazards and its minimizing techniques

The spread mechanism of OB shock wave and gas, its influence on mine ventilation system, the evolution pattern of secondary disasters.
THANK YOU!