SOME CHARACTERISTICS OF THE STRONG OUTBURSTS OF COAL AND GAS IN COAL MINES IN CHINA

By S.N. Zhou

ABSTRACT

China has at least 200 collieries suffering from the problem of instantaneous outbursts of coal and gas. Strong outbursts often have occurred in geological tectonic zones and concentrated stress areas. There are some particular characteristics of these strong outbursts, including the effects of ground stress, gas pressure and the properties of coal associated with the outbursts.

INTRODUCTION

In China, almost all coal mines are gassy. The instantaneous outbursts of coal and gas have occurred in 17% of coal mines. About 10,000 outbursts, large and small, with up to 12,780 tonnes of ejected coal and stone have occurred in the last 35 years. Strong outbursts (more than 1,000 tonnes of coal and stone) occurred 24 times from 1958 to 1980. The total amount of coal and stone ejected in these outbursts was about 107,000 tonnes. These comprised 46 with 1,000 to 3,000 tonnes ejected, 25 with 3,000 to 5,000 tonnes, 2 with 5,000 to 10,000 tonnes and one greater than 10,000 tonnes.

The ejected gas is almost always CH4, with CO2 occurring only in two outbursts. However, the volumes of the ejected gas in all outbursts ranged from about 0.02 to 3.50 million m3. According to outburst characteristics (ejection distance, total angle and size separation of coal), these occurrences are typical outbursts. These are distinct from spontaneous falls and extrusions of coal, none of which exceeded 1,000 tonnes.

These strong outbursts are very dangerous in coal mining, because so much gas is released during the outburst. The gas flow can move back into the intake area for a long distance.

GEOLOGICAL CONDITIONS

Statistically, 85% of outbursts occurred in bituminous and anthracitic coal seams of the Carboniferous-Permian coal deposits. In Sichuan, Kwain, Hunan and Jiangxi Provinces, outburst-prone coal seams are always associated with a thick limestone bed with higher strength and lower permeability above the coal seams so that it can retain the high gas content in coal seams and strong elastic energy in the strata. In addition, almost all outburst locations had faults and other abnormal geological structures in the coal seams, which crushed the coal to form bands of mylonitic coal in some areas.

About 10% of outbursts occurred in long plane and bituminous coal seams of the Jurassic deposits. In Liaoning Province, magmatic intrusions were common in outburst-prone coal seams. Thus, not only have coal seams been subjected to folding, thinning and fracturing but they have become fragile or have become hard natural coke. Outbursts commonly occur in the fragile coal zone.

The strength of coal varies widely because of intrusions. When a heading is driven into such an area, it is easy for an abrupt change in gas pressure and ground stress to occur in front of the working face. This is an important factor in the initiation of outbursts. In effect, the prevailing geological conditions provide a basis for outbursting.

STRATA STRESS

In outbursts, the strata stress is the main energy for initiating outbursts. It consists of virgin strata stress and mining induced stress. As observed in measurements of ground stress in China, the horizontal stress is always greater than the vertical gravity stress in geological tectonic areas. It is 1.5 to 3.5 times and even 8 times as high as the vertical gravity stress. However, the difference between these decreases as the depth increases. (Liao, 1983).

There have been 3 strong outbursts recorded at a depth of less than 100m, 16 outbursts at 100 to 200m, 11 outbursts at 200 to 300m and 24 outbursts at more than 300m.

In Hunan Province, most strong outbursts occurred at a depth of less than 200m. At Zambell Colliery, a strong outburst with 1300 tonnes of coal and stone ejected, occurred at a cross-cut where the depth was only 95m, and no mining was involved during this occurrence.

It is reasonable to consider that this
outburst was initiated by the horizontal ground stress, because the vertical gravity stress was only 2.50MPa and not high enough for initiating an outburst.

The strong outbursts occur in geological structural zones associated with high pressures. For instance, on 8th August, 1975, in Sanhui No. 1 colliery, Sichuan Province, when the K1 coal seam was exposed by shock blasting at the main adit, a strong outburst with 12,780 tonnes of coal and stone as well as 1.5 million m³ of gas occurred.

There was a thrust fault and the coal seam had suffered strong pressure from the stress. As a result, the coal seam had been split and became thick and soft. The angle of dip of the coal seam changed from 32° to 59°, and the thickness from 2.5m to 5m.

The first outburst took place at the fault footwall. After the adit crossed the fault plane into the fault hangingwall, the preventive measure of hydroboring was taken and 450 tonnes of coal and 25,000m³ of gas were ejected from the boreholes. Under the protection of hydro-boreholes, 27% of drivage was undertaken safely in the coal seam. Meanwhile the roof was exposed at the top of the adit. However, the second strong outburst with 2,807 tonnes of coal and stone occurred as soon as the end of the hydro-boreholes was reached. It is considered that there was not only the strong ground stress but also the abutment stress from the first outburst, as shown in Fig. 1.

![Fig. 1. Two outbursts, 1 - 8.8.75, 2 - 5.7.76, San-Hui No. 1 Colliery.](image)

After mining, the strata stress is redistributed in front of the heading face, the abutment stress is 2 to 3 times as high as the virgin stress. When the effect results from double mining stresses, the increment of stress could reach 4 to 5 times that of virgin stress, creating a dangerous situation.

For instance in Nantong No. 1 colliery on 20th January, 1968, a strong outburst with 5000 tonnes of coal occurred in a heading during driving into the abutment of the upper protective seam as shown in Fig. 2.

As mentioned above, it should be emphasized that the ground stress is the key to outburst initiation.

Fig. 2. Outburst site, 20.1.68, in Nantong No. 1 Colliery.

**GAS PRESSURE AND GAS CONTENT**

The potential energy of gas contained in coal seams is the main energy producing outbursts. It has an important effect on crushing, ejecting and transporting coal in the process of outbursting. As observed in practice, the gas pressure of outburst-prone coal seams is always more than 1.0MPa. In China, the highest gas pressure measured in Beipiao Mining Area was 8.26MPa. Under this pressure the gas content of coal seams is about 15 to 30m³/t.

At the same depth, the gas pressure is approximately equal in a small area. To date the location could not be found where the gas pressure is abnormally high. However, the relative gas emission (m³/t) from outbursts is much larger than the gas content of coal seams. According to statistics, the average relative gas emission during outbursts is 200m³/t. The largest is about 700m³/t.

It is expected that the amount of gas is not only from the ejected coal in outbursts but also from the coal seam around the outburst cavity where the permeability of the seam is increased significantly by destressing. Sometimes the width of relaxation zone around the outburst cavity is greater than 10m.

By measuring the velocity of gas desorption from coal grains (0.2 to 0.3mm), the rate of gas emission from coal grains in the first minute are 2-21% of the total. As the degree of crushing of coal increases, the velocity of gas desorption is also increased, as shown in Fig. 3 (Hang, 1980). The degree of coal maceration increases from 1st to 5th column as shown in Table 1.

As observed in practice, a strong outburst always consists of several lesser outbursts. The process of every outburst may last from several to ten seconds. There will be a relative quiet interval between two ejecctions. That is proved from outburst records. This process is able to be repeated several times until ground stress and gas pressure are not enough for initiating another outburst. The total time for all outburst processes may last in excess of 10 minutes.

The gas energy of the first outburst comes from the free gas in the coal seam. The occurrence...
TABLE 1

<table>
<thead>
<tr>
<th>Parameters</th>
<th>First</th>
<th>Second</th>
<th>Third</th>
<th>Fourth</th>
<th>Fifth</th>
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<tr>
<td>Cohesion C, MPA</td>
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<td>1.73</td>
<td>1.05</td>
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<td>Angle of friction, °</td>
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<td>33.3</td>
<td></td>
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<tr>
<td>Coefficient of strength, J</td>
<td>0.69-2.20</td>
<td>0.25-1.33</td>
<td>0.13-0.52</td>
<td>&lt;0.1-0.33</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Porosity, cm³/g</td>
<td>0.0121</td>
<td>0.0131</td>
<td>0.0216</td>
<td>0.0314</td>
<td>24.6</td>
</tr>
<tr>
<td>Constant of desorption, %</td>
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<td>5.1</td>
<td>4.8</td>
<td>10.6</td>
<td>16.7-22.1</td>
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<td>ΔP</td>
<td>0.5-2.8</td>
<td>0.5-8</td>
<td>1-19.3</td>
<td>3.8-21.7</td>
<td></td>
</tr>
</tbody>
</table>

3. Gas energy

It is considered that the physical process of gas expansion was in effect insulating, because the duration of the outburst was only 39 seconds. Therefore it is assumed that only free gas was involved in the outburst. The free gas content was 1.63m³/t.

$$W_3 = 0.098 P^2 V_1 \frac{P}{\eta} \left( \frac{n-1}{n} \right)$$

where
- $P_0$ = gas pressure in coal seam = 1.95MPa
- $P$ = gas pressure in mine heading = 0.1MPa
- $V_1$ = quantity of free gas = 1336m³
- $\eta$ = insulation exponent = 1.31

The gas energy, $W_3 = 422.35$ MJ

The gas energy is about 88% of all the energy in the outburst. From this analysis, it is considered that the gas energy is the main outburst energy, while the elastic energy of coal, roof and floor is the main energy associated with the crushing of the coal seam.

THE PROPERTIES OF COAL SEAMS

In 54 strong outbursts, 3 outbursts occurred in coal seams with thickness of less than 1m; 8 outbursts occurred in coal seams of thickness 1 to 2m; and 43 outbursts occurred in coal seams of thickness more than 2m. 15 outbursts occurred in coal seams with less than 30° angle of dip; 19 outbursts in seams of dip 30 to 45°; 20 outbursts in seams of dip more than 45°.

The strength of coal is a resistance to outburst and that is an important factor. In China, coal has been divided into five categories according to its strength. In Beipiao Mining Area, some properties of coal as shown in Table 1 were measured.

As the degree of maceration of the coal increases, its strength is decreased. It makes the coal seam crush more easily. All strong outbursts occurred in the fourth and fifth categories of coal. To date no outburst has occurred in the first and second coal categories.

The third category of coal is similar to slack in appearance. Both fourth and fifth...
categories are similar to soils, and are the most dangerous gassy coal.

Generally speaking, the permeability of outburst-prone coal seams is very low (less than 0.05 milli Darcy). In some well-known outbursting coal seams, it is less than 0.005 milli Darcy. Thus it is easy for a high gas pressure gradient to exist in front of the coal surface to initiate an outburst during mining.

Particularly outburst-prone coal seams contain much gas and are under high stress and have obvious fluidity. Therefore after an outburst, the volume of the outburst cavity is always much smaller than that of the coal and stone ejected from the outburst and sometimes the outburst cavity could not be found after an occurrence.

Having used hydroboring in outbursting coal seams, the hydrobored holes had diminished in size and were filled by slack as shown in Fig. 4.

![Fig. 4. Flowability of coal](image)

**a - just hydroboring**
**b - after hydroboring for a long time**

The property of flowability is very important for initiating and promoting outbursts and it increases greatly the magnitude of the outburst as well as the quantity of gas emission in the outburst. Therefore, for the same conditions, the intensity of outbursting might increase with the thickness of outburst coal seams.

**MINING GEOMETRY AND ACTIVITIES**

Of these 54 strong outbursts, 2 occurred in raises, 11 in headings, and 41 in cross-measures. 75% of strong outbursts occurred in cross-measures during exposing or cutting through the outburst coal seams.

During exposing, the ground stress and gas pressure vary substantially and it is easy to induce a strong outburst. In addition, the section of cross-measures is generally larger, and convenient for movement of coal released under pressure. Thus a barricade of slack coal is difficult to establish.

After exposure, in the process of cutting through the outburst coal seam, the gas concentration in the air-flow is always smaller, because the permeability of the coal seam is very low. Strong ground stress and high gas pressure still surround the cross-measure. The drivage work thus becomes dangerous. Thus in China, all preventive measures are enforced in drivage from 2m prior to coal seam exposure to 2m after passing through the seam.

Of these 54 outbursts, 51 were caused by shock blasting, which accounts for 94.4%. It is understood that the vibration effect of blasting assists greatly in inducing outbursts. The largest amount of explosives used in inducing outbursts was 23kg, the smallest was only 0.6kg.

In a hazardous area, if the coal seam was not relaxed to form a distressed zone with 5 to 8m width around the cross-measure, it would be easy to initiate a strong outburst.

The ground stress fractures the coal seam, and this requires a certain time period. In general an outburst has a delayed action for several seconds to ten seconds, even ten minutes in some cases.

Sometimes where the ground stress is very strong, the gas pressure is high, and the strength of coal is low, an outburst is able to occur in general operations without blasting.

**CONCLUSIONS**

The problem of outbursts is serious in China. In 1958 to 1980, the strong outburst with more than 1,000 tonnes of coal and stone occurred 54 times. They had the following characteristics.

1. The strong outbursts occurred in an area of geological structure and associated with abutment zones. The ground stress was the key to the outbursts.
2. In strong outburst-prone coal seams, the gas pressure was greater than 1MPa. Gas energy was the main energy in outbursting.
3. There are 5 categories of coal in decreasing order of strength, the strong outbursts occurred in the fourth and fifth categories.
4. The flowability of coal had an important effect on outbursts. The gas absorbed and mechanical properties of coals were the basis for initiating outbursts.
5. Most strong outbursts occurred at cross-measures. The shotfiring had a strong effect on inducing outbursts.

**REFERENCES**