Outburst Prevention

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1. INTRODUCTION

The physical model of outburst conditions as described by Kidybinski is very useful because it gives insight into almost all of the methods that are currently used in outburst prevention and control.

Kidybinski's model is based upon three zones ahead of the working coalface Figure 1.

(i) the abutment pressure zone, where the combination of virgin stress plus mining induced stress is sufficient to fracture the outburst-prone coal.

(ii) the high gas pressure zone, where gases desorb into the induced fractured coal, as the porosity is increased under reduced abutment pressures.

(iii) the protection zone, that acts as a permeable barrier allowing gas to permeate from the gas zone, but having sufficient strength to withstand the gas pressures acting therein.

Kidybinski considered three limiting conditions that must prevail if an outburst occurs when a cylindrical hole is drilled through the protection zone into the gas zone.

(a) In the abutment zone the induced stress is greater than the constrained strength of the coal

\[ k\gamma > \frac{c}{\Omega} \]

\( k \) is a stress concentration factor
\( \gamma \) is the specific weight of the overburden
\( \Omega \) is the depth
\( c \) is the compressive strength of the coal
\( L \) is the width of the protection zone (from the coalface to the high pressure gas zone)
\( M \) is the seam thickness

(b) As a hole of diameter \( D \) penetrates the protection zone into the high gas pressure zone an outburst will occur if

\[ (k\gamma + p)\frac{\pi D^2}{4} > \pi DL(c + \sigma \tan \psi) \sqrt{\frac{L}{M}} \]

i.e. the force acting on the end of the hole must be greater than the forces resisting shear on the cylindrical surface of the hole.

\( c \) is the natural cohesion
\( \tan \psi \) is the coefficient of the internal friction
\( \sigma \) is the normal stress at the shearing interface
(c) For an outburst to be sustained there must be a sufficiently high gas velocity to maintain fluid-bed flow. This in turn requires the appropriate quantity of gas commensurate with the diameter of the outburst hole. Since the free-gas in the coal pores is normally less than 10% of the total desorbable gas, a very high desorption rate is necessary.

2. OUTBURST PREVENTION AND CONTROL

If there is no gas present, or if the gas pressure in the coal is reduced below a certain threshold value for a given physical coal strength, then a gas outburst cannot occur. It may, however, still be possible to get a coalburst, i.e. a release of strain energy alone.

Most, if not all, outburst preventative measures are directed at reducing the gas content of the in situ coal, as discussed in the following:

(1) Seam Destressing by Mining.
This is the most common and probably the preferred method of outburst prevention where a number of seams of coal or other valuable minerals such as fire clay or iron-ore, are stratified in close proximity. The basic concept is to mine the seam with the least propensity to outbursting first, and thereby de-stress the area. Destressing increases the porosity and the permeability of the adjacent strata, which is then amenable to methane migration and drainage.

In selecting the least outburst prone seam due regard is paid to the following seam characteristics:
(a) Gas condition and desorption rate
(b) Physical Properties
(c) Relative position in the stratified deposits

Because of the influence of gravity the destressed distance above a mined seam is greater than that below. However, because most coal measure strata are anisotropic the zone of influence is much greater than for massive isotropic rock. From an outburst point of view it is better to mine a lower seam first even though it may have some detrimental effects upon general working conditions in the superadjacent seams.

Longwall mining with 100% extraction is normally preferred, so as to eliminate as far as possible highly stressed zones associated with remnant pillars.
Seam destressing by mining is practised at Ibbenburen Colliery in West Germany where seam 54 is mined below seam 53. As reported by Paul, 1980, based upon an equivalent coal production, the frequency of outbursts in seam 53 was twenty-four (24) times higher than in seam 54.

The desorbable gas content of the anthracite coal (6-7% vol.) is some 18-22m³/tonne and the gas yield from all of the mine averaged 100m³/tonne. Some 30-40% of the gas is diluted by the ventilating current and exhausted by the minefans. The remaining 60-70% is extracted by methane drainage and used as a fuel in the electrical power station at the mine surface.

In the Lower Silesian coalfield of Poland seam destressing by mining is also practised on a large scale at Nowa Ruda and Thorez mines.

At the Piast shaft of Nowa Ruda mine there are 9 mineable coal seams some 1 to 2 metres thick, of which 7 are extracted. There are 5 fire clay seams in the floor, 3 of which are mineable. Below this sequence there are intrusive gabbros. The Piast shaft is 600 metres deep and the general rule is to mine the least outburst prone coal or fire clay seam with a view to destressing the adjacent seams. The Upper Carboniferous strata that overlie the coal measures are predominantly very strong elastic sandstones. Thus, in selecting a destressing medium it is desirable to choose a seam at an horizon well below the overburden. At various times coal seams and fire clay seams have been selected, currently seam 412 is considered the best destressing medium.

At Thorez colliery, in the town of Walbrzych, seam 672 is generally mined as the destressing medium because of its central position in the sequence of workable seams.

(ii) Destressing with Boreholes.
In mines where single seams are mined, and also in developing the workings in the initial destressing coal seam, special care has to be exercised particularly when driving development roadways or gate roads in advance of long-wall faces.

At Nowa Ruda destress drilling for roadways consists of drilling 10 to 15 holes of 40-45mm diameter some 15 metres long to cover the advance and the flanks of the roadway. Often 0.5 to 0.7
tonnes of coal cuttings are obtained from a single hole. The holes are drilled by hand held augers, all miners wearing oxygen breathing apparatus. It was claimed that if 4 percent of the volume of coal outlined by drilling, was actually won by the drilling operations, then the outburst hazard was eliminated. Care was taken during drilling to incline holes such that all coal plies are intersected.

In terms of Kidybinski's model, this operation produces a destressed permeable safety zone that can withstand the stress and gas pressures outside the zone of influence.

For longwall faces, similar drilling operations are undertaken in holes some 4 to 5 metres apart. Under these situations winning of 2 percent of the available coal, as drill cuttings, was stated to remove the outburst danger.

Obviously for a given situation, with respect to coal strength and gas pressure, the smaller the diameter of the borehole the lower the risk of inducing an uncontrolled outburst. In fact, the emission of gas-borne particles from these holes during drilling was easily choked off by moving the drill in the hole.

Polish and British practice is to use small diameter holes, some 40-45mm diameter, when destressing outburst prone coal. On the other hand the German practice at Ilbenbüren is to use drills of some 95mm diameter. This of course may be a reflection on the strength and the physical conditions of the coal. Nevertheless, it must carry an increased risk of triggering an uncontrolled outburst. The term 'uncontrolled outburst' is used after due consideration because it would appear that the destress drilling process triggers small scale events that can be detected by sensitive seismic equipment.

(iii) Methane Drainage from the Undisturbed Seam.

We are all aware of the methane drainage project from solid coal at West Cliff. If this technique is to be successful in removing the outburst hazard then the in-situ seam gas pressure at all places must be reduced below some threshold value for a particular strength of coal and set of stress conditions. The more permeable the coal seam the greater the chances of success. Problems arise in multi-banded seams of varying lithology where the boreholes fail to intersect all sections of the seams. Ideally holes should have the greatest possible
resonance in the coal bands with the highest desorbable gas content. Paul (1981) describes some test work at Ibbenbüren in seam 53 where holes were drilled parallel to the face from advance gates and return roads. Holes 110 metres long, 10 metres apart and 95mm diameter were drilled from each roadway to cover the entire 220 metre length of face. The set of holes drilled from one roadway yielded drill cuttings in the range 61-124 litres per metre, while the set from the other roadway yielded 83-151 litres per metre. Boreholes were drilled when the distance from the face varied between 23 and 59 metres.

Gas emissions were measured by borehole anemometers once per week, the results being as shown in figure 2.

The calculated reduction in desorbable gas content of the coal, up to 2.8 metres$^3$ per tonne and averaging some 16 percent, was insufficient to reduce the outburst hazard as shown in figure 3 where subsequent outbursts were recorded.

Paul stated "in this case too it has again been confirmed that working of a seam to provide relief in a suitable adjacent seam is the most effective means of preventing outbursts".

(iv) Inducer Shot Firing.
This is one of the more common techniques of reducing the risks of uncontrolled outbursts, particularly when driving development roadways either in the coal seam or as cross-measures to intersect seams.

The basic concept is to use some of the blast energy to trigger incipient outburst zones and produce a safety zone around the excavation which will allow the safe desorption of seam gases. The design of the hole patterns and the quantity of explosive must obviously vary with local conditions which include seam strength, gas pressure and quantity. Some massive outbursts have been triggered using this technique as detailed below, hence it is important that the blasting operations should take place when few, if any, men are below ground and as recommended in the Cynheidre rules (S. Wales) each working face or development has its own return, i.e. no series ventilation networks.

At Victoria Colliery Lower Silesia I inspected an underground drivage 508m deep from the Barbara shaft workings, where on June 20th, 1981 a major outburst occurred. The outburst occurred where the cross-measure drift made contact with the inlined coal seam from the hanging wall side.
The burst occurred from the floor in the right hand side of the drivage. 120,000 cubic metres of gas (100,000 CO₂ 20,000 CH₄) were calculated to have been emitted in 4 minutes. In addition 1,600 tonnes of coal were outburst. The steel arched, force ventilated roadway, was filled with coal for some 170 metres. For 20 metres from the face all the steel arches were distorted and displaced. Forty metres from the face the mine cars were thrown over. There was a 7 metre long debris free zone at the face and a 1 metre high passage above the pulverized coal for some 100 metres from the face.

The heading was ventilated by a forcing fan passing 150m³ per minute. The outburst was of sufficient severity to reverse the ventilation in the nearby Victor shaft where the pit bottom water gauge was normally 20-30mm H₂O (Fan 80mm) with a volume of 2,500 m³/min.

In contrast at the Piast shaft of Nowa Ruda I made an underground inspection of a development roadway 660 metres below the surface in the No.3 fire clay seam. Some coal riders were visible in the roadway section above the fire clay. Outbursts are provoked regularly every 12-15 metres of advance, by blasting. Typically some 150 tonnes of debris is ejected in association with 12000-15000 m³ of carbon dioxide (80-100 m³/tonne).

References


Figure 1. Physical model of an outburst.
After Kidybinski

Figure 2. Gas flow from stress-relief and pre-drainage boreholes in an anthracite coal seam. After K. Paul

Figure 3. Stress-relief boreholes and outburst points in a working of an anthracite coal mine.