

Hazardous manifestation of gas-dynamic phenomena in the faces of coal mines

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Abstract. The statistics of coal and gas outbursts in the faces of the Russian coal mines is provided. The mining-geological and mining-engineering conditions for the occurrence of sudden outbursts during the coal mining are considered, and the distinctive features in the factors of their occurrence and behavior are discussed. The criteria for identifying the potentially hazardous zones with the help of geophysical measurements are given. It is shown that it is important to take into account the data on the actual occurrence of outburst hazard in overlying and underlying longwall faces and development workings, as well as the results of the current forecast when preparing the extraction area for mining, as it follows from the results of underground investigations. The features are noted and the concept of the mechanism causing sudden coal and gas outbursts of faces is formulated. According to this concept, the probability of a hazardous situation is minimal at the beginning of the face advancement before the primary roof collapse. After the primary caving, the outburst hazard increases with the face advancement from the place of caving due to increased stresses in the bearing pressure zone, strengthening of the restraint of the nearest roof support, and the formation of a low permeable bridge in the coal seam near the exposed surface of the coal massif, which increases the pressure and free gas volume behind this bridge. The maximum degree of outburst hazard in the cleaning face is reached at the time of secondary roof collapses.

1. Introduction

At the Russian coal mines, the largest number of sudden coal and gas outbursts, about 80%, was registered during the preparation works in the coal seams. Sudden outbursts during coal mining began to occur later and with a lower frequency than when the development of seams was started and development workings were carried in them. The lower outburst hazard of the cleaning faces is due to the peculiarities of the stressed-deformed state of the mountain massif in the vicinity of the mine workings, which will be considered below. However, by the present time, mining operations in the mines are conducted at the depths at which in most faces in the certain geological conditions and mining engineering parameters, an outburst hazard is possible.

The share of outbursts that occurred during the development works from the total number reached approximately 15%. At present, most of the faces work at the depths below the critical ones for sudden outbursts of coal and gas, that is why the problem of early assessment of the gas-dynamic hazard is urgent for them. It concerns mainly the mechanized faces in the flat and inclined seams mined at high speeds with the use of pillar method. In these faces the largest amount of coal is extracted.



2. Statistical data on the sudden coal and gas outbursts in the mines of Russia

The largest number of sudden coal and gas outbursts in the mine workings (47 outbursts) was registered in the mines of the Pechora Basin. Of them 31 sudden outbursts of coal and gas occurred in 1960-1964 at mine No. 1 at a depth 365-460 m from the surface during the development of the seam Dvoynoy. The outbursts intensity at mine No. 1 varied from 1.2 to 37 tonnes of coal, the gas intensity – from 65 to 3800 m³. The gas outburst reached an extremely high value – 295 m³ per 1 tonne of the ejected coal.

In the Primorsky Basin in 1970, 13 sudden outbursts of coal with associated gas release were recorded during the development of the seam Modestov II at the mine “Podgorodnenskaya” and the seam Nizhne-Kedrovyy at the mine “Tsentralnaya”, which, in accordance with the then in force “Instruction on the safe performance of works in the seams hazardous because of their sudden coal (rock) and gas outbursts” during the investigation of gas-dynamic phenomena were attributed to sudden coal and gas outbursts. The outburst intensity reached 35 tonnes of coal and 5000 m³ of gas.

The total number of sudden outbursts in the faces of the Pechora, Primorsky and Kuznetsk Basins amounted to 69 or 7.4% of the total outbursts in all types of workings, and in the Pechora Basin the share of outbursts in the mining face was 17%.

It should be noted that statistical studies on the mines of Donbass indicate that the greatest number of sudden outbursts in mining faces occurs at depths of 400-500 m [1]. This is confirmed by the manifestation of outburst hazard in the mines of the Pechora basin.

3. Methodological approaches to the establishment of probable zones of sudden coal and gas outbursts in the faces

As it is known, sudden outbursts of coal and gas occur in areas of tectonically disturbed coals in the area of disjunctive or plicative dislocations. Other geological factors that determine the possibility of identifying the outburst hazard zones are the degree of coal and host rocks metamorphism, the petrographic composition and coal seam thickness, the moisture content of the coal, the lithological composition and thickness of the host rocks.

Since coal has reduced strength properties within the range of the hazardous portion, a redistribution of stresses occurs near it. The undisturbed part of the coal seam along the boundaries of the site is in a more stressed state. Therefore, when approaching the boundaries of the hazardous portion, sharp, abrupt changes in the velocity parameters of seismic waves are observed [2-4].

According to the results of the geophysical survey, areas with anomalously low values of the potential difference, with not less than two times less than the average values for the excavation column, and lowered not less than 20% values of the velocities of the formation waves belong to areas prone to hazardous outbursts [5]. At the boundaries of these sections, anomalous increases in the values of the potential difference are observed – approximately in 2 times compared with the average background and the increase in the seam waves velocities by 20%.

It is important to take into account the data on the actual outbursts manifestation in the process of contouring development workings and the results of determination of the outburst factor at the current forecast in these workings. This follows from the results of the studies [6]. Figure 1 contains the curve of the gradient change in the initial velocity of gas release from control wells g_n in face of longwall No. 3 of the seam Vladimirovsky at the mine “Severnaya” (in Kuzbass) at the approach to the alignment with the position of the face in the underlying longwall No. 2, where a sudden outburst of coal and gas occurred on August 08, 1978.

As it is known, this parameter is a reliable characteristic of the outburst hazard and is used in regulatory forecasting methods. The curve indicates that the maximum gradient was measured at a distance of 2 m from this alignment, that is, it indicated the entrance to the hazardous area.

The sudden coal and gas outburst that occurred at the same mine on April 11, 1970, when the same seam was mined by longwall No. 2, was preceded by seven outbursts in the cross-cut of the II parallel drift, driven for the preparation of longwall No. 2, six – when drilling wells ahead of the longwall. Their intensity for well outbursts was very high – 15-35 tonnes.

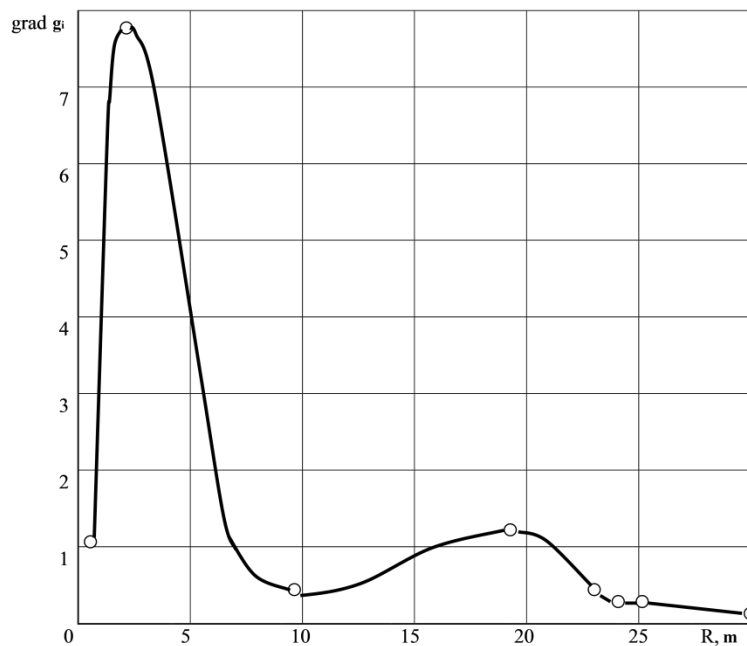


Figure 1. Change in the gradient of initial gas release from the holes in longwall No. 3 of the seam Vladimirovsky at mine “Severnaya”, depending on the distance to the alignment with the place of sudden outburst in the underlying longwall No.2.

Similar results were obtained in the Pechora and Primorsky Basins. At the same time, the non-hazardous behavior of longwalls in all these basins corresponded to the non-hazardous values to the outbursts hazard indicator in the development workings contouring them. The mining areas, the outburst hazard of which is confirmed by the gas-dynamic phenomena occurring on them near their borders, or by the results of the current outburst hazard forecast in the contouring development workings, are subject to compulsory mining with the help of regional methods to prevent sudden outbursts of coal and gas. The decision on the need to apply regional methods to prevent sudden outbursts in other areas with a disturbed structure is adopted depending on the values of the energy criterion of outburst hazard [6].

4. Consideration of the peculiarities of sudden coal and gas outbursts of the faces and the mechanism of their behavior

The founder of the theory of sudden coal and gas outbursts V.V. Khodot [7] notes the differences in conditions that cause sudden outbursts of coal and gas in the faces of development workings. He supplements the main factors that determine the occurrence of outbursts in the faces with the dynamic load on the coal seams on the side of the host rocks. Having carried out the research in the mines of Donbass, A.F. Shak and S.V. Mirer [8] confirmed that the poor caving of roof, contributes to the occurrence of a hazardous situation. Half of all sudden outbursts in the faces occurs in the lower and upper parts of the longwalls due to a sharp change in the ratio of the elastic and inelastic zones in them [9].

In the process of primary collapse, there is a transition of the type of roof loading from the beam scheme to the cantilevered. As a result, the zone of bearing pressure with a region of increased stresses and a clearly pronounced maximum is formed ahead of the face in the massif. In the coal seam ahead of the face, four zones [10] of the massif condition in the vicinity of the face in terms of outburst hazard are identified (figure 2).

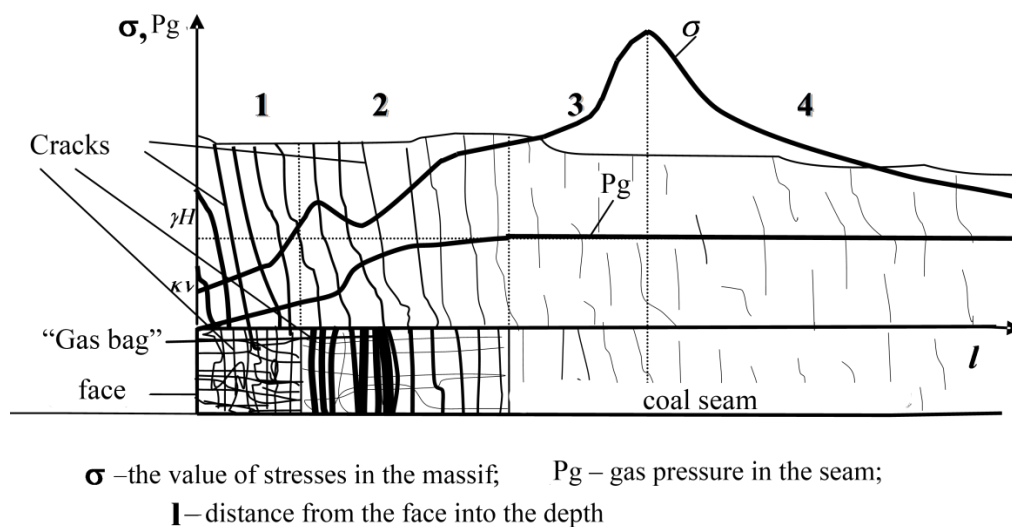


Figure 2. The scheme of formation of outburst hazard condition in the massif ahead of the face.

Zone 1, adjacent to the face, is composed of the most destroyed coal due to the destructive effect of the roof rocks. It has very low filtration properties, so the degassing process of the coal massif is greatly extended in time. Zone 2 is a system of roughly parallel to the face elements of the array, consisting of coal blocks, tightly pressed to each other by the host rock. In it, due to the low filtration capacity of zone 1, conditions are created for accumulating large volumes of free gas under pressure. In zone 3, which is the most remote from the face, the preparation of the massif for the transition from the elastic state to the elastic-plastic one takes place. Zone 4 is the undisturbed massif outside the area of influence of the face on the stress-strain state of the coal seam.

The outburst hazard of the mining faces occurs due to the formation of a “gas bag” in zone 2 because of the presence of a bridge pinched by the bent roof between zones 1 and 2 with a very low gas permeability [11].

In addition, in the coal massif in the zone influenced by mining the pressure of free gas in the process of hysteresis of methane sorption by coal increases, caused by low-frequency oscillations of the roof above the seam during its step-by-step caving established by the authors of the work [12, 13].

5. Conclusions

Summarizing the above, we can formulate the following concept of occurrence of sudden coal and gas outbursts in the face. The probability of a hazardous situation is minimal at the beginning of the face advancement. The process of reducing stresses in the seam in the zone, corresponding to the bending zone of the roof, and the formation of a “gas bag” in it is not pronounced due to the stable condition of the roof. Apparently, a sudden outburst in the face before the primary step of caving is possible only when the face encounters a large local tectonic disturbance of a closed type with large gas reserves. However, there is a high probability of outburst at the moment of roof caving because of a sharp decrease in the cohesion forces between the coal seam and the host rocks and coal layers.

After the primary step of caving, the outburst hazard increases as the face advances from the place of caving due to the rise in the stresses in the bearing pressure zone (the intensity of formation of the outburst hazardous cracks and the amount of free gas enclosed in them increases), the formation of a zone of low stresses due to the roof bending (a “gas bag” appears), increased strengthening of the restraint of the nearest roof support (formation of a low permeable bridge in the coal seam near the

exposed surface of the coal massif formed, which contributes to an increase in pressure and a free gas volume in the “gas bag”).

If the roof collapses at this stage of the massif behavior, then the nearest roof support (coal bridge) will collapse with the sufficient pressure and gas volume in the gas bag, a sudden coal and gas outburst will happen, and at a high gas pressure gradient it will transit to the stage of gas crushing of coal. The process will be strengthened by the fact that instantaneously due to the hysteresis of methane sorption by coal the volume and pressure of the gas in the “gas bag” will increase.

If, however, the advancement from the face will increase and there will be no roof caving, then starting from a certain moment, the process of cracks formation, oriented in a direction close to the perpendicular plane of the layering, begins, but due to the roof bending they will be directed to the gob. Through these cracks the gas from the “gas bag” will begin to flow into the gob, the pressure and the volume of the gas and, consequently, the outburst hazard of the of face in it will begin to decrease. The outburst hazard from this point onward with the face advancement will also decrease. The same will happen after the next cavings.

Thus, from all that has been said, it follows that the maximum degree of outburst hazard in the face is reached during the roof collapses. The degree of hazard is especially great if, by this time, no cracks have already appeared that penetrate into the gob and degasify the zone of intense crack formation 2 (figure 2) with large gas reserves under pressure between the layers of coal massif divided by the cracks quasi-parallel to the face, including the so-called “gas bag”, that is, when the formation of zone 2, which is the “driver” of the sudden outburst, reaches the maximum degree of hazard.

According to [10], the face might be hazardous because for its sudden outbursts if $F_a \geq F_o$ and $l \geq \Delta x$, where F_a – is the resultant of the active forces tending to eject coal; F_o – is the resultant of the limiting obstructing forces; l – the depth of penetration; Δx – the value of the degassed coal zone. The values of these parameters are determined depending on geological conditions and mining engineering parameters. However, this model needs to be clarified, since it does not take into account the processes of hysteresis of methane sorption by coal and the formation of a zone of low stresses ahead of the face at the place of roof bending and, consequently, changes in the degree of outburst hazard depending on the amount of face advancement from the caving site.

To take into account the first process, an amendment was made to the model during the development of instructions [2], according to which the value of the gas pressure P_k used in the model for the face advancement intervals in the zone, where the roof collapse is possible, is determined from the expression $P_k = P_0 + \Delta P$, where: P_0 – is the seam pressure of gas; ΔP – increase in gas pressure due to the phenomenon of hysteresis of methane sorption by coal. The value of ΔP is determined by the diagram given in the instructions.

In order to take into account the influence of the roof bending on the outburst hazard, a considerable amount of experimental research is required, and the model of sudden outbursts occurrence in the faces should be elaborated on the basis of these research results.

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