



Research Status and Review of Coal and Gas Outburst Mechanism

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Abstract: The continuous occurrence of coal and gas outburst accidents seriously affects the safe production of coal mines. This paper reviews the existing research results of coal and gas outburst mechanism at home and abroad. The historical development process and research status of coal and gas outburst mechanism are expounded. The shortcomings of these research results are analyzed. Based on the full text, the mechanism of coal and gas outburst has developed from single factor to multi-factor, and the comprehensive action hypothesis has been widely recognized. In addition, the preparation mechanism of coal and gas outburst, instability and balance mechanism, development mechanism, propagation mechanism and distribution law of coal and gas outburst zone are the directions that need to be further studied in the mechanism of coal and gas outburst, and also the problems that we need to face in the future.

Keywords: Coal and gas outburst; mechanism; research status

1. Background

Coal and gas outburst is a complex dynamic phenomenon that occurs under the mine. It is a serious and common natural disaster that threatens the safe production of the entire mine. Since the first coal and gas outburst accident in the world, the countries engaged in coal production in the world have invested a lot of manpower, material and financial resources to carry out research on coal and gas outburst, and have achieved a lot of results. For the mechanism of coal and gas outburst, scholars at home and abroad have put forward the hypothesis of gas leading role, ground stress leading role, chemical essential role and comprehensive role through long-term unremitting efforts, which basically qualitatively explains the phenomenon of coal and gas outburst, and provides a basis for the prediction of coal and gas outburst risk and the formulation and implementation of outburst prevention measures. However, the failure forms of coal and rock mass are diverse, and the occurrence and transfer of gas are complex, which leads to the unclear mechanism, process and details of outburst. With the continuous increase of mining depth, the in-situ stress and gas pressure are also increasing, which will lead to more coal and gas outburst mines, and more uncertain coal and gas outburst problems. Therefore, solving the problem of coal and gas outburst in mines is the key to achieving sustainable development of the coal industry.

The purpose of this paper is to make a general review of the current research status of coal and gas outburst mechanism at home and abroad, especially for the analysis of possible problems and accidents in the case of deep mining and put forward suggestions on the research direction of coal and gas outburst.

2. Mechanism of Coal and Gas Outbursts

Before the underground mining activities, the gas is buried in the coal seam in a free state or an adsorbed state [1]. Under the influence of mining, the original stress state of the gas is changed. The gas gushes instantaneously along the coal seam fracture or structural plane, and a large amount of coal is erupted in a short time, accompanied by huge impact force and sound, which is a violent mine dynamic phenomenon. When coal and gas outburst occurs, it will cause serious consequences. The resulting shock wave will cause collapse and



blockage of mine roadways, destroy ventilation systems and other mechanical equipment, and the toxic and harmful gases generated during outburst will also cause harm to the human body.

3.Characteristics of coal and gas outburst

Coal and gas outburst accidents are instantaneous and diverse [2]. In addition, they also have the following characteristics:

Coal and gas outburst accidents often occur in areas with complex geological conditions and complex rock structures, especially in areas where the working face is close to faults or where the thickness of coal seams changes greatly, coal and gas outburst accidents are more likely to occur. With the progress of mining work, the deeper the mining depth [3], the greater the pressure on the coal seam, the greater the probability of accidents. The danger of gas outburst is related to the solid coefficient of coal seam. When the coal seam is squeezed by mining, the lower the strength of the coal seam, the more likely the coal wall is to spalling, and the gas is more likely to gush out from the damaged coal wall. The mining relationship and mining sequence in mine production will affect the occurrence of coal and gas outburst accidents. The underground production experience shows that the probability of coal and gas outburst accidents increases when the underground mining is opposite. The occurrence of coal and gas outburst accidents is related to the gas content in the coal seam. When the gas content in the coal seam is large, the pressure of gas accumulation in each layer is also greater, and coal and gas outburst accidents are prone to occur.

3. Research Status at Home and Abroad

The research on the mechanism of coal and gas outburst can be summarized into the following four aspects: [4-11]

(1) Gas leading role hypothesis. The hypothesis holds that coal and gas outburst is mainly caused by the gas stored in the coal seam. During excavation, some low-permeability coal seams are affected by mining, and the permeability of the coal seam is enhanced, resulting in the instantaneous gushing of gas accumulated in the coal seam from the weak surface, resulting in accidents. This is a very short and continuous process.

There are 11 hypotheses about the leading role of gas, such as ' gas bag ' theory, powder coal belt theory, uneven coal gap structure theory, outburst wave theory, crack blockage theory, closed gap gas release theory, gas expansion theory, pressure relief gas theory, volcanic gas theory, geological damage zone theory, gas desorption theory and so on.

(2) The dominant role of ground stress hypothesis. The hypothesis holds that coal and gas outburst accidents are dominated by ground stress. Under the influence of mining, the stress around the surrounding rock is released and redistributed, which breaks the coal body and causes a large amount of coal and gas to gush out.

The main hypotheses of the dominant role of ground stress are: rock deformation potential theory, stress concentration theory, plastic deformation theory, impact approach theory, tensile stress wave theory, stress superposition theory, blasting outburst theory, roof displacement uneven theory and so on.

(3) Chemical nature hypothesis. The hypothesis holds that under the condition of high temperature and high pressure, a certain chemical reaction will occur inside the coal seam, forming high pressure gas and other gases. Under the influence of mining, high pressure gas gushes out from the weak surface of the coal seam, causing coal and gas outburst accidents.

The hypothesis of the dominant role of chemical nature mainly includes three hypotheses: gas hydrate theory, geochemical theory and nitro compound theory.

(4) Comprehensive effect hypothesis. The hypothesis holds that coal and gas outburst accidents are affected by many factors, such as ground stress, geological structure, coal seam properties and gas analyticity. However, there is no unified conclusion on how each factor works in the coal seam.

The comprehensive action hypothesis mainly includes six hypotheses: vibration theory, layered separation theory, failure zone theory, free gas pressure theory, in-situ stress non-uniformity hypothesis, and energy hypothesis.

4. Problems and Analysis

At present, although the mechanism of coal and gas outburst can make qualitative explanation and approximate quantitative calculation of the cause, condition, process and energy source of the accident, it is difficult to



explain all the mine outburst phenomena with a certain hypothesis because all kinds of hypotheses are put forward for a certain kind of specific conditions, and the actual data show that they have certain limitations. And with the development of mining activities, more and more problems will be encountered in deep mining. Under the condition of deep mining, high stress, high ground temperature and high gas are undoubtedly the problems we face. If the geological characteristics and laws under the condition of shallow mining are used to analyze and deal with the deep problems, it is undoubtedly far from enough and contains great risks.

For the problem of coal and gas outburst under deep mining conditions, it is necessary to strengthen deep geological work. Fully understand the complex and changeable characteristics of coal and rock mass, the distribution of gas, water and other disasters, the spatial structure of faults, the stability of surrounding rock and the relationship between surrounding rock and roadway engineering, so as to provide basic conditions for taking effective schemes or technical approaches. In addition, the surrounding rock control technology should be improved to limit the deformation and failure of surrounding rock. Surrounding rock support methods are divided into active support and passive support. Active support is aimed at strengthening surrounding rock, and the self-supporting ability of surrounding rock is used to control the deformation and failure of surrounding rock. Passive support is to limit the deformation and failure of surrounding rock and protect and control the loose rock. Deep surrounding rock may develop into cataclastic body or loose body after a few hours of excavation, and the supporting object is the dilatancy deformation surrounding rock after fracture. Therefore, in the deep area, the active support method of anchor net cable is adopted to improve the strength of anchor net cable support system and improve the characteristics of surrounding rock, which may achieve better support effect. The composite support effect in poor geological areas may be better, and should be adapted to local conditions.

5. Prevention Measures of Coal and Gas Outburst

The prevention and control measures of coal and gas outburst can be divided into regional outburst prevention measures and local outburst prevention measures. Regional outburst prevention measures mainly include mining protective layer and pre-drainage of coal seam gas. Local outburst prevention measures include advanced support, deep hole pre-splitting blasting, metal skeleton, coal seam water injection, pressure relief groove, etc. Among them, the mining of protective layer is the most effective and economical outburst prevention measures.

Regional outburst prevention measure:

(1) Mining protective layer. In the mining of high gas mines, the protective layer should be mined first to destroy the original stress equilibrium state of the rock mass in the protective layer, reduce the internal gas pressure, increase the permeability and compressive strength of the coal rock, so as to achieve the effect of reducing or eliminating coal and gas outburst.

(2) Pre-drainage of coal seam gas. When there is no protective layer or a single outburst dangerous coal seam in a high gas mine, pre-drainage of gas can be used to reduce the gas content in the coal seam to achieve the purpose of reducing the risk of accidents. The pre-drainage gas technology is divided into ground drainage and underground drainage. The appropriate drainage method should be selected according to the actual production situation, so as to achieve the safe production of the mine.

Local prevention outburst measure:

(1) Advanced support. A certain number of gas exploration holes are arranged in the front of the roadway excavation face to discharge coal seam gas and reduce gas content and pressure in the coal seam, but they are only suitable for coal seams with good occurrence conditions.

(2) Deep hole pre-splitting blasting. It is to use the drilling rig to drill a certain number of deep holes in the stress concentration range of the coal and rock mass, and use the blasting technology to loosen the coal body through the impact vibration to release the gas, reduce the gas pressure, and transfer the stress concentration area to the deep, thus forming a gas pressure relief zone.

(3) Metal skeleton. When the crosscut is excavated to the surrounding area of the coal seam, the steel pipe or rail is used as the metal skeleton to insert into the coal seam borehole drilled in advance, and the vibration is used to break the coal seam and release the gas pressure.

(4) Coal seam water injection. Using high-pressure water to inject water into the coal seam with self-spraying capacity, the coal body is wet, the brittleness becomes smaller, the plasticity is enhanced, and the initial velocity



of gas dissipation in the coal body is slowed down. At the same time, the gas pressure in the coal body is released, which reduces the possibility of sudden breakage of the coal body and achieves the purpose of eliminating the outburst.

(5) Pressure relief groove. A certain width of the groove is sorted out along the side of the roadway, and a certain advance is maintained to make the coal body fall off. Mining and tunneling are carried out within the protection range of the pressure relief groove to prevent gas outburst.

6. A Review of The Existing Research Results

At present, the mechanism of coal and gas outburst has developed from single factor to multiple factors, and the comprehensive action hypothesis has been widely recognized, which provides a theoretical basis for the prediction of outburst risk, the selection of outburst measures and the test of outburst prevention effect. Coal and gas outburst is the result of the combined action of physical and mechanical properties of coal, ground stress and gas. It is the high-speed release of a large amount of energy accumulated in surrounding rock and coal. Among them, high gas plays a decisive role in the development of outburst. The sudden change of ground stress and the disturbance of mining activities are the factors that stimulate outburst, while the physical and mechanical properties of coal are the factors that hinder outburst.

Under the condition of deep mine, the effect of ground stress and gas on outburst, as well as the evolution of coal and gas outburst and rock burst, lack of in-depth and systematic research. In deep mining, the content of gas is relatively high, which is mainly manifested in two aspects. First, in deep coal mining, the amount of gas emission is large, followed by the high frequency of gas emission in the process of mining. This requires coal mines to pay more attention to the problem of coal and gas outburst in deep mining. Find and solve problems in time to reduce the occurrence of coal mine safety accidents. It is generally required that in the process of coal mine development, priority should be given to the problem of outburst prevention in the region, and then the local small area outburst prevention should be supplemented, and the principle of not excavating the outburst head and the outburst surface should be adhered to. At the same time, in order to improve the safety of coal mining, coal mining enterprises should also strengthen the improvement of gas prediction technology, so as to form a higher quality monitoring of gas and reduce the possible harm situation. In addition, in the process of completing the operation, if the underground miners lack good safety awareness, it is easy to have various bad operation phenomena, which will cause gas disasters. To this end, coal mining enterprises also need to implement the concept of safety management to the absenteeism, prompting them to correctly understand which of their operations are prone to gas disasters, and set up corresponding on-site supervisors to ensure that the overall mining process has high safety.

7. Conclusion

Coal and gas outburst is a complex mine gas dynamic phenomenon. After a long period of observation and research on a large number of coal and gas outburst phenomena in mines, the causes, conditions and processes of outburst have been basically mastered. It is clear that the coal, rock, gas and stress field involved in outburst are a unified system; the elastic strain energy and gas internal energy accumulated in coal and rock mass are the energy of outburst, and the sudden change of ground stress and the disturbance of mining activity are the factors that stimulate outburst.

The study of outburst mechanism still stays in the hypothesis stage of qualitative explanation and approximate quantitative calculation, and it is necessary to study its physical essence more deeply, so as to describe the outburst phenomenon quantitatively. In particular, it is necessary to study the preparation mechanism, instability and balance mechanism, development mechanism, propagation mechanism and distribution law of coal and gas outburst zones, to determine the time-space energy coupling relationship and dynamic evolution law between coal body, rock mass, gas and stress field, to determine the excitation conditions and equilibrium termination conditions of outburst instability, and to quantitatively evaluate the danger of coal and gas outburst.

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