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Study on the Energy Law of Coal and Rock Mass Failure and the Influence of Coal and Gas Outburst under Geostress

Huiyue Wang

China Coal Science and Engineering Group Shenyang Research Institute Co., Ltd., Shenyang, Liaoning, China

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Abstract: In the process of coal mine production, with the increase of mining time and mining intensity, the mining depth of most mines continues to increase, most of which have exceeded 500m, and the coal mining environment is becoming increasingly complex. Coal and gas outburst disasters caused by in-situ stress, in-situ pressure, and complex gas storage conditions pose a greater threat to coal mine safety, coal and gas outburst suddenly and violently, resulting in more serious casualties and large economic losses. It has become the most serious disaster in the process of coal mine production. So far, people have not come to the real reason. Therefore, this paper explores the main causes of gas outburst disaster under the joint action of in-situ stress and gas. The interaction between coal and Gas Outburst under impact load is studied by means of theoretical analysis, impact dynamic experiment, and numerical simulation, to provide basis for the prevention and control of combined geo dynamic disasters of rock burst and gas outburst.

1. The Significance of the Study

Due to the continuous production and mining of renewable energy coal and the continuous reduction of shallow coal resources, the mining level of coal mines has been deepened. The mining depth of some mining areas has reached below 1000 meters. The mining conditions are becoming increasingly complex and harsh [1]. The risks such as gas, water, ground temperature, and ground pressure are increasing. The safety and efficient production of coal mines are seriously threatened, which adversely affects the health and stability of the national economic and social development. With the increase of mining depth, dynamic disasters such as coal mine, rockburst, and coal and gas outburst are on the rise, especially the severity of rockburst and coal and gas outburst is increasing, which is mainly manifested in the destructive, serious and random nature of disasters, and the safety environment of coal mining is at risk [2]. Dynamic disaster often occurs in coal mining activities, which is a major disaster in coal mine production. At present, it has a gradually increasing trend. In the event of dynamic disaster, the sudden release of elastic deformation energy of roadway or rock mass will lead to the destruction of coal and rock mass and gas emissions, gas waves, roof fall and wall caving, water permeability, coal and gas outburst, abnormal gas emission, support collapse and destruction, roadway blockage, ground vibration, casualties and other phenomena, with strong destructive power and danger [3].

Therefore, in order to ensure the safe and efficient production of coal mines, it is of essential theoretical and practical significance to study the mechanism of dynamic disasters, such as the prominent interaction between coal and gas and the damage law in the process of energy transmission of coal and gas which could lay a theoretical foundation for the prevention and control of power disasters and ensure the safe production [4].

2. Current Research and Development at Home and Abroad

Researchers Li Tie, Cai Meifeng, etc proposed that the occurrence of impact ground pressure in deep coal mining is closely related to gas, high-pressure gas, which participates in the gestation of impact ground pressure which could be a coupling effect of excavation and unloading and gas desorption expansion [5]. Taking Xin'an coalfield as the engineering background, they verified and deepened the theory that the "three soft" coal seam floor impact the ground pressure induced by coal and gas protrusion early development mechanisms [6]. Researcher Wang Zhen et al. analyzed the similarities and differences between ground pressure and prominently value of high-gas coal seams from the aspects of disaster occurrence conditions, energy sources, and destructive forms. The induced transformation mechanisms of the two disasters were discussed from the aspects of gas stress and physical and mechanical properties of coal rock [7]. At the same time, based on experimental research and theoretical analysis, the induced transformation conditions of two disasters at different stages of gestation, occurrence and development are proposed. The natural stress of rock is the fundamental force source that leads to coal and gas protrusion and impacts ground pressure, and the in-situ stress plays an essential role as a fundamental power source for the accumulation of natural elastic strain energy of gas seam, the potential expansion energy of gas, the stress in the process of gas protrusion, the gravity distribution, the unidirectional unloading and rupture of coal seam and top and bottom slate stratum, accompanied by elastic energy release, gas expansion energy release, gas desorption and other complex processes, as well as gas protrusion results, and acts on the whole process of gas protrusion [8].

3. Experimental Study of Coal and Rock Mass under In-Situ Stress Shock Load

The device used in the study is Hopkinson pressure rod (SHPB). The test system mainly includes N2 cylinder, power supply device, air cannon, bullet, incidence rod, transmission rod, absorption stem, buffer, optical velocimeter, strain gauge, experimental specimen, ultra-dynamic strain gauge, computer and other equipment. The schematic diagram of the test system is shown in Figure 1.

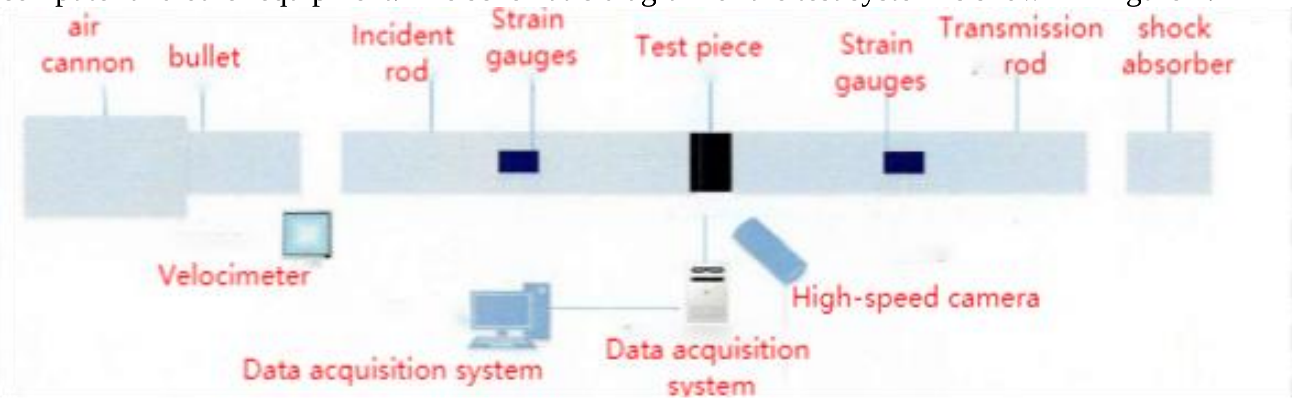

Figure 1: Schematic diagram of the experimental setup system

The coal and rock specimens used are directly drilled from large pieces of coal and rock samples by the drilling sampler, and the size of coal samples and rock samples is φ75mm and the height is 100mm. This experiment mainly studies the dynamic mechanical properties of coal-rock assemblies under different impact loads, and the coal-rock-coal combination is mainly studied in coal-rock combination as shown in Figure 2.

Figure 2: Structural model of cut coal and rock samples and coal-rock assembly

The experimental specimen is placed in the middle position of the incident rod and the transmission rod. When the pressure in the air cannon is increased to a certain degree within a gas cylinder, the high-pressure gas is instantly released, which pushes the bullet to impact one end of the incident rod at a certain speed, at this time the impact stress wave is generated in the incident rod and propagates at a certain speed, when the stress wave propagates to the junction of the end face of the incident rod and the specimen, part of the stress wave is reflected back into the incident rod, and the other part is propagated with the specimen into the transmission rod to form a transmission elastic wave, and the transmission rod hits the absorbing rod , absorbing the transmitted wave and finally being absorbed by the buffer [9]. The propagation of the incident wave passes through the test piece, and the test piece is deformed and destroyed, and the data acquisition system composed of strain gauges and ultradynamic strain gauges pasted on the incident stem and transmission rod is used to measure the incident wave, reflected wave and transmitted wave. The typical waveform diagram is shown in Figure 3.

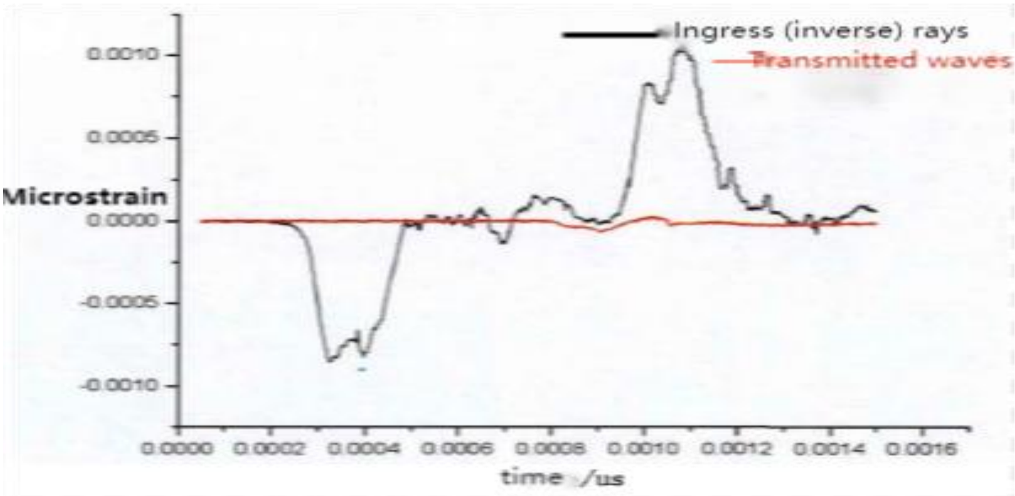

Figure 3: Typical waveform diagram

4. Study on Stress and Energy Dissipation Law of Coal and Rock Mass Failure under In-Situ Stress

From the perspective of energy, the generation and propagation of cracks in materials require dissipative energy, and the energy required for the formation of new cracks is far greater than the energy required for crack propagation, so under the action of low strain load, the fracture of rock materials is mainly formed by the expansion and penetration of inherent microcracks. And only those microcracks with less energy consumed by expansion have a practical effect on the crushing of materials, because before the absorption energy is increased to make other microcracks crack, the expansion and penetration of these microcracks have already caused the material to split and destroy, at this time the number of microcracks that play is less, the degree of fragmentation is relatively large, and the critical stress value of crushing is lower, that is, the compressive strength is low. With the increase of strain rate, before the breakthrough of microcracks that can be cracked at lower strain rates, the energy absorbed by the material reaches a higher level, so that more microcracks can expand and participate in the crushing process, and the number of new cracks produced is larger, so more energy needs to be dissipated, resulting in smaller fragmentation of the material, higher critical stress value of the material reaching crushing, so the strength of the material under high strain rate also increases [10]. Coal and gas outburst is caused by the combination of gas expansion energy and sudden loading (such as mining, cannon firing, structural stress, surrounding rock should be, etc.). Under certain low gas, high stress, or strong disturbance conditions, sudden loading can become the main energy source for critical damage to coal, or even crushing and throwing. Taking the working face as the research object, the failure characteristics of the coal body under the action of external sudden load during the process of working face advancement are simulated, and an observation point is set every 0.6m from the working face to analyze the damage of different parts of the coal body under different intensity sudden load conditions.

According to the relevant researches, the wave propagation caused by the shock load should be reduced to a pulse load after a period of time, as shown in Figure 4. Therefore, by changing the peak load of different waves; the degree and form of stress waves of different intensities on coal seam failure damage are studied. The dynamic constitutive equations of coal are embedded in large-scale finite element analysis software, and the damage of coal under sudden loads of different strengths PMAX=30MPa, 50MPa, and 70MPa is numerically simulated. Aiming at the numerical analysis of the impact effect of different peak intensity stress waves on coal, the evolution process of splitting cracks in coal under different impact loads was effectively studied. Under the impact load, the coal body has two forms of splitting damage, namely, one is the "leaping" damage splitting dominated by strong tensile stress, and the other is the "stepped" damage dominated by the accumulation of tensile-shear-shear damage is shown in Figure 5.

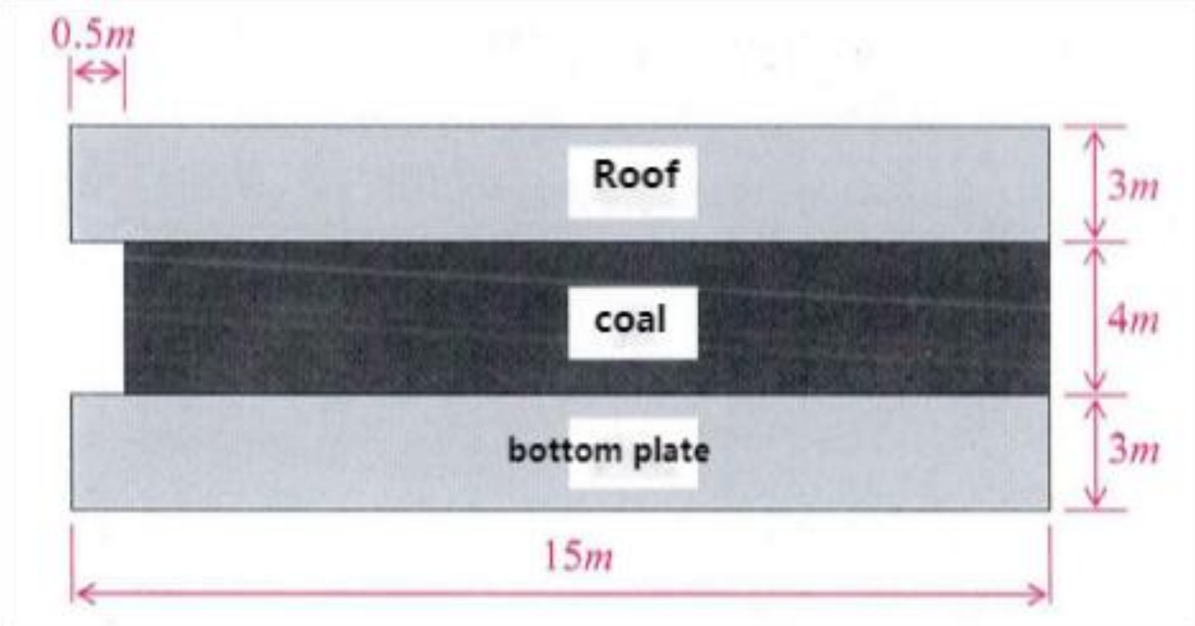

Figure 4: Numerical model size 1

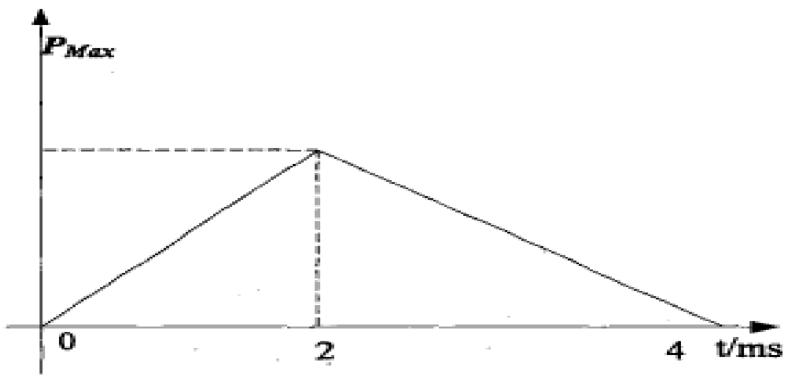

Figure 5: Load time history curve

5. Conclusions

Coal and gas protrusion is caused by the combination of gas expansion energy and sudden load input energy. Under certain low gas, high stress, or strong disturbance conditions, sudden loading can become the main energy source for critical damage to coal, or even crushing and throwing.

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