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Research Paper

Laboratory Study on the Effect of Methane Degassing on the Instantaneous Coal Gas Outburst Phenomenon in the Tazareh Mine

Heidari Sheibani R.[1], Ataei M.[2*], Kakaie R.[2]

1- Ph.D Student, Dept. of Mining, Petroleum, and Geophysics Engineering, Shahrood, Iran
2- Professor, Dept. of Mining, Petroleum, and Geophysics Engineering, Shahrood, Iran

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Abstract: An outburst is a hazardous and complex phenomenon characterized by the sudden and violent release of large amounts of coal and gas within a short period. Such unexpected events can result in catastrophic consequences, including loss of life and considerable economic damage. Coal gas outbursts, driven by rapid and intense energy release, can significantly impact the surrounding environment. In the early stages of these events, coal fracturing and gas discharge are critical determinants of their onset and intensity. This study focuses on the K10 seam of the Tazreh coal mine and utilizes an advanced laboratory apparatus to investigate the energy dynamics involved in such occurrences. The critical energy release was measured at 30.66 mJ/g, with the corresponding threshold pressure for outburst initiation estimated at 0.35 MPa. To evaluate the effect of methane degassing, controlled experiments were conducted on coal samples from the seam using the custom-designed device. The results revealed that reducing the internal gas pressure by 20% through degassing effectively prevented outburst initiation. These findings represent a notable advancement in coal mine safety and offer practical insights for developing proactive risk mitigation strategies in similar high-risk mining environments.

Keywords: Coal outburst, Methane degassing, Energy release, Coal mine safety.

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*Corresponding Author Email: *ataei@shahroodut.ac.ir*

INTRODUCTION

Methane, a major component of natural gas, is one of the most potent greenhouse gases. It forms a transparent layer in the atmosphere—much like greenhouse glass—that traps heat and gradually raises the Earth's surface temperature. Excessive emissions of methane and other greenhouse gases are a primary contributor to climate change and various adverse environmental effects.

One of the most significant challenges facing coal mines worldwide, especially in developing countries, is the risk of explosions resulting from methane and coal dust accumulation. Far from diminishing, this threat has intensified in recent years.

The motivations for methane recovery in coal mines can be broadly categorized into three main areas:

1. Enhancing Mine Safety: Methane can accumulate to explosive levels in underground mines, contaminating the air and creating hazardous working conditions. Sudden methane releases drastically increase the likelihood of explosions, leading to potentially fatal consequences and substantial financial losses. Moreover, the release of other toxic gases during such events poses additional risks to human safety and the environment.

2. Economic Utilization: Methane captured through degassing systems not only reduces explosion risks but can also be harnessed as an energy source for internal mine operations or commercial use. This improves the mine's economic efficiency and opens new revenue-generating opportunities.

3. Environmental Protection: Beyond safety and economic benefits, methane recovery also serves ecological goals. Reducing methane emissions contributes significantly to mitigating climate change and improving air quality at both local and global levels.

In summary, the effective management of methane in coal mines enhances worker safety, increases economic productivity, and serves as a strategic step toward environmental sustainability.

The coal gas outburst phenomenon presents a critical safety hazard, particularly in longwall mining operations. Predicting methane levels is essential for mitigating this risk, as the danger intensifies with increasing mining depth due to higher gas emission rates from coal seams.

Studies have shown that variables such as gas pressure, low permeability, geological structures, and insufficient degassing are key contributors to gas outbursts. Proper identification and understanding of these factors can improve mine safety and reduce the occurrence of sudden gas releases [1].

Methane remains one of the most significant threats in coal mining. However, modern gas drainage techniques can transform this hazard into an opportunity. Methane drainage is typically performed via two methods: pre-mining and post-mining extraction. Variations in geology and mining conditions worldwide necessitate customized drainage strategies [2].

Gas pressure, gravitational forces, and mining-induced disturbances can weaken the rock mass, leading to the formation of fractures. These fractures alter the load-bearing capacity of coal seams and influence the probability of outbursts [3]. Simulated gas release using compressed coal briquettes has been widely applied to study the underlying mechanisms of instantaneous gas emission [4–7].

In 1998, Lama and Budzianowski identified gas pressure and coal seam permeability as crucial factors in coal gas outbursts. They found that high gas pressure combined with low permeability increased the likelihood of sudden emissions [8]. Similarly, in the Bowley mines in Australia, mining operations were halted due to high gas concentrations, as reported in a 1994 safety report [9].

In 2012, Skoczylas studied rapid gas diffusion under various methane pressures and uniaxial strengths [10]. Later, Zhai et al. (2018) investigated the effect of borehole diameter and lateral stress on gas discharge during drilling. Their findings suggested that larger and deeper boreholes subjected to stress could yield more accurate predictions of sudden gas emissions [11].

The coal gas adsorption-desorption process is considered a dynamic equilibrium. Due to the rapid kinetics involved, high-energy gas releases during explosions play a major role in initiating and propagating such events. However, pressure alone is insufficient to trigger an outburst. Shock tube experiments with CO_2 under high pressure (4–6 MPa) demonstrated only minimal impact on coal samples [12].

In 2022, Shu and colleagues developed a structural simulation apparatus to study the mechanical thresholds required for instantaneous gas release. Their lab-scale eruption tests helped validate a new model for outburst prediction [13].

Despite advancements, there is a lack of large-scale physical models that accurately replicate real mining conditions while evaluating the behavior of degassing under stress. This study addresses that gap by introducing a newly developed experimental device to investigate instantaneous gas release and the effect of methane degassing, with a specific focus on the K10 seam of the Tazreh coal mine.

METHODS

In dimensional analysis, physical problems are simplified by converting variables into dimensionless numbers, rather than analyzing each variable independently. This technique reduces complexity and minimizes the number of experimental variables affecting a given physical phenomenon. The primary objective of dimensional analysis is to consolidate and reduce variables into meaningful, dimensionless forms.

It serves as a powerful tool for problem-solving, enabling the interpretation of physical systems through dimensionless parameters. Dimensional analysis supports transitions between unit systems, decreases the number of experimental parameters, guides model design through similarity principles, determines scaling rules for fluid properties and structural dimensions, and enhances physical insight by helping derive governing equations.

When the influencing variables of a phenomenon are known but their interrelations are unclear, dimensional analysis can express the system using a reduced number of dimensionless groups. These groups are typically fewer than the number of original variables, thereby reducing the number of experiments required to establish their relationships and often leading to simpler and more cost-effective testing.

In this study, a custom-designed laboratory apparatus was developed based on the principles of dimensional analysis and physical similarity to investigate coal gas outbursts and the effect of methane degassing.

The apparatus includes the following main components:

- A structural support frame
- A high-pressure test chamber (cylindrical)
- A hydraulic cylinder
- A vacuum pump
- A gas capsule
- Pressure sensors
- Solenoid valve and pneumatic valve system with connecting pipes
- An electrical control panel with PLC and HMI interfaces

The test cylinder is designed in accordance with ASME standards—recognized globally as key design codes for pressure vessels. The cylinder has a length of 1 meter, an internal diameter of 500 mm, and a wall thickness of 20 mm. The design specifications allow for a maximum intended gas pressure of 80 MPa, with an operational temperature range from 10°C to 55°C. A safety factor of 5 was incorporated into the design to ensure operational reliability.

FINDINGS AND ARGUMENT

Figure 1 presents the energy-time graph, which indicates that the highest energy recorded from the coal gas outburst test is 30.66 mJ/g. In this experiment, the suction pump first generated a vacuum within the cylinder after 328 seconds. Subsequently, gas was injected, and the hydraulic jack was activated to replicate the earth stress conditions acting on the coal, thereby increasing the chamber pressure. When the pressure reached 0.35 MPa, a sudden gas release took place. The valve of the instantaneous release system was opened for 10 seconds, leading to a pressure drop and a rise in temperature within the system. At the start of the test, the initial temperature at the valve of the device's instantaneous discharge system was 29 °C. When the instantaneous discharge occurred, the temperature rose to 33 °C.

CONCLUSIONS

The extraction of coal resources—predominantly conducted via underground mining methods—requires strict adherence to engineering principles, safety protocols, and industry standards. At present, most coal mining activities take place in gas-bearing zones, and as operations expand to greater depths, the frequency and severity of gas-related issues are expected to increase. Therefore, minimizing these risks through the application of modern technology, scientific knowledge, and available resources is essential.

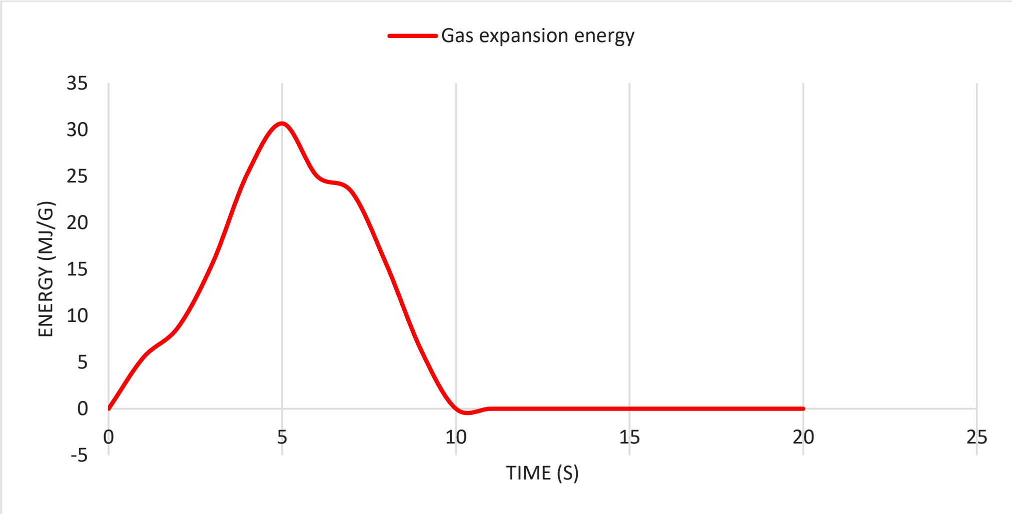

Figure 1. Energy versus time graph generated from the simulation of the outburst process for the K10 layer sample from the Tazareh mine

Methane degassing plays a vital role for three main reasons:

(1) it reduces greenhouse gas emissions,

(2) it provides a renewable energy source with economic potential, and

(3) it significantly enhances mine safety by mitigating the risk of dangerous outbursts.

This study introduced a novel laboratory apparatus, designed and constructed based on physical modelling principles, to investigate the coal gas flashover phenomenon and assess the effects of methane degassing on this event—specifically focusing on the K10 seam of the Tazreh coal mine.

The experimental results demonstrated that at a flashover pressure of 0.35 MPa, the energy release reached 30.66 mJ/g. Additionally, the system recorded a temperature increase of 4°C during the outburst event. In the degassing test, reducing the internal pressure by 20% through suction successfully prevented the flashover, demonstrating the effectiveness of this method in enhancing safety.

This innovative apparatus—developed for the first time in Iran—offers robust capabilities for analyzing and simulating conditions related to coal gas outbursts. It serves as a practical tool for optimizing methane degassing strategies across coal mines, contributing to both improved safety and environmental sustainability.

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