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Perspective

# Progress and prospects of mining disaster prevention techniques and equipment

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**Abstract:**
As mining operations delve deeper and mechanization and intelligence levels improve, coal mine disasters are becoming increasingly severe. Consequently, developing effective technology and equipment is crucial to ensure the safety of mining enterprises. This perspective summarizes the technical methods for preventing coal and rock dynamic disasters and controlling dust in coal mines. Furthermore, it provides insights into the future directions of mining disaster prevention techniques and equipment in this field. The aim of this paper is to offer effective disaster prevention strategies, enhance the efficiency and effectiveness of disaster control, and further safeguard the health and safety of miners.

## 1. Introduction

With the economic development of the world, the demand for mineral resources is increasing, leading to a significant rise in the number of high-intensity mining operations. High-intensity mining leads to more and more serious disasters such as rock bursts, coal and gas outbursts. It is urgent to develop targeted disaster prevention and control technology and equipment according to the latest mining technology to ensure the safe production of mines (Yin et al., 2024). Against this backdrop, this perspective summarizes the key findings in the 32$^{th}$ session titled "Advancements in mining disaster prevention technologies and equipment" at the first "Geo-Energy Frontier Forum" (Cai, 2024), to explore the latest advancements in the prevention and control of dynamic disasters and dust in coal mines.

## 2. Technologies and equipment for coal and rock dynamic disaster prevention and control

Coal and rock dynamic disasters represent a common and significant safety hazard in coal mining production. These disasters result from various complex physical processes, including the destruction of coal and rock mass, methane desorption and diffusion, stress changes and two-phase flow propagation within gas flow fields. In recent years, with the continuous updating and development of research methods, the focus of research on coal and rock dynamic disasters has

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gradually shifted from macroscopic regularities to microscopic mechanisms. On the one hand, experimental and simulation techniques are applied to analyze the stress, displacement, plastic zones, and changes in strain energy characteristics at specific locations during coal extraction. These research aims to explore the macroscopic mechanics and deformation characteristics of coal and rock mass. On the other hand, the application of microscopic research methods is becoming increasingly widespread. Among them, the successful application of atomic force microscopy provides a new means to observe the microstructure of coal. By combining three-dimensional surface morphology characterization with quantitative analysis, atomic force microscopy can more accurately describe gas adsorption and its resulting coal expansion behavior. Consequently, it elucidates the micro-evolution mechanism of coal and rock dynamic disasters, thereby offering essential insights for disaster prediction.

The ultimate goal of mechanism research is to establish explicit criteria for predicting mine disasters. Extensive long-term practice has demonstrated that the occurrence of mine disasters is accompanied by various macroscopic precursors. There is a significant correlation between the magnitude of various indicator parameters and the level of danger, playing a crucial role in predicting coal and rock dynamic disasters. By establishing an intelligent prediction model and a visualization platform for coal and rock dynamic disasters, the accuracy of predicting can be further improved.

In addition, the research of gas hydration curing anti-protrusion technology is also a key focus in current mine safety production. Continuous advancements in monitoring techniques will provide more effective guarantees for miner safety. The monitoring of acoustic emission signal is a reliable indicator for judging the risk of coal body protrusion, and it is also a potentially important indicator for judging the effect of gas hydration curing. Improving the mine disaster assessment model through multiple indicators is of great significance for the safe production of mines (Kang et al., 2024; Shen et al., 2024).

The continuous development of coal rock dynamic disaster prevention and control technology provides an important scientific basis for mine safety production. This contributes to reducing the likelihood of disasters, safeguarding the lives and property of miners, and fostering greater advancements in mine safety production efforts.

## 3. Technologies and equipment for mine dust prevention and control

Dust is one of the five major hazards in underground coal mining operations. Inhalation of respirable dust in coal mine may lead to pneumoconiosis. Besides, coal mine dust poses an explosion hazard, endangering the safety of coal mine production. Effective dust control technologies and equipment are of paramount importance in reducing dust hazards and ensuring mine safety. Currently, effective control measures include dust suppression through watering, chemical dust suppression, and personal protective equipment.

Dust suppression by watering refers to the process of increasing the wetness of dust by spraying water through nozzles, causing small dust particles to coalesce into larger ones, thereby enhancing dust density and ultimately achieving dust reduction. The structural parameters, operational parameters, and atomization performance of the nozzle can all affect the dust suppression effectiveness. With the continuous advancement of technology, dust suppression nozzles for mining applications are constantly being updated. The optimization of mining anti-clogging atomization nozzle systems has refined the internal structural parameters of single-water and air-water nozzles, resulting in novel single-water and air-water atomization nozzles tailored for coal cutting, repositioning, and other sources of dust.

Through the development of novel single-fluid and air-water dual-fluid atomization nozzles, utilizing the "natural fall" and "hydraulic impact" methods, the problem of mining face pollution is solved. Additionally, the invention of mining-specific anti-clogging atomization nozzles can solve the problems such as incomplete development methods and poor dust capture efficiency of the nozzles.

The supersonic dynamic micro-electrostatic mist dust collection technology combines electrostatic mist dust collection technology with supersonic coaxial atomization technology. The high-speed jetting process of gas mist reduces the energy accumulation between electrodes, thereby achieving the effects of arc extinguishing and explosion isolation. This technology effectively controls respiratory dust while avoiding the risk of combustible dust and gas explosions caused by generating sparks near the nozzle (Zhang et al., 2023).

Chemical dust suppression presents a more efficient method for dust control compared to water spraying. The common types of chemical dust suppressants include wetting agents, adhesives, and agglomerates. Typically, the surface tension of water is usually reduced by adding surfactants or by modifying specific groups through nucleophilic substitution to enhance water's wetting ability towards coal dust, thereby improving the effectiveness of spray dust suppression. Additionally, incorporating anionic and nonionic surfactants as components of composite wetting agents can effectively enhance the wetting properties of the wetting agents, thus achieving better dust removal results.

Dust removal technology and equipment play a crucial role in ensuring the safety of coal mining operations. In future, there is a need to intensify research efforts into novel dust control technologies and equipment, further enhancing their efficiency and applicability to meet the demands of mine safety production.

## 4. Conclusions

In addressing coal and rock dynamic disasters, continuous advancements in research methodologies have progressively unveiled the essence of processes such as coal and rock mass failure and gas migration, from macroscopic regularities to microscopic mechanisms. These revelations provide crucial foundations for predicting and preventing disasters. Simultaneously, the application of dust suppression through watering and chemical means, alongside the development of novel nozzles and wetting agents, has significantly enhanced the efficiency and standards of dust control, effectively safeguarding miners′ health and safety.

Looking ahead, it is imperative to further delve into the mechanisms and predictive technologies concerning coal and rock dynamic disasters, and continually enhance prediction accuracy and precision, thereby furnishing more reliable technical support for safe mining operations. Moreover, there is a pressing need to intensify efforts in the research and developing innovative dust control technologies and equipment, elevating their efficiency and applicability to meet the evolving requirements of safe mining practices.

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## Conflict of interest

The authors declare no competing interest.



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