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Management of Major Influential Factors on Safe Coal Mining

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Abstract

A couple of factors affecting coal mining are investigated. These factors include but are not limited to thickness, structure and stability of coal seam, roof, floor as well as their stability, hydrogeology, gas and coal dust, temperature. How each of these factors affects coal mining is deliberated. Finally, the paper concludes that it is important to have these factors in mind when a coalmine proceeds with its mining operations and put them under control. Moreover, safety management plays an important role in work safety in coal mines.

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Keywords: coal mine; coal seam; floor; roof; gas; coal dust; safety management

1. Introduction

Technical conditions of mining for a coalmine influence its construction, production and safety. They comprise coal seam thickness, structure, physical properties of coal, occurrence and variation of coal seam, roof and floor of coal seam and engineering geological conditions, gas, coal dust as well as spontaneous trend of coal. With ever-increasing mechanization degree of coal mines, high demand on the technical conditions of mining and their research is rising. Therefore, it is of significance to strengthen exploration and research on the technical conditions of mining.

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2. Thickness, structure and stability of coal seam

According to the characteristics of mining techniques in general, thickness of coal seam can be divided into three levels, i.e., thin seam (113m), moderate thick seam (1131-3150m) and thick seam (>3150m). According to availability of stone band in the coal seam, coal seam is categorized as simple structure and complicated one. According to the changing margin of the thickness and structure of the coal seam in the coalfield, coal seam is categorized as stable, moderately stable, unstable and extremely unstable seam. Generally speaking, a coal seam that is thick and structurally simple has a large reserve and is easy to be mined. On the contrary, a coal seam that is thin, changes significantly and structurally complicated often includes non-mined area, or the coal seam frequently meets branching, which pose difficulty on the coalmine production[1].

The mechanical and physical properties of a coal seam are closely related to model selection of mining machinery and improvement of mining efficiency. Anti-brittle nature of a coal seam (i.e., brittleness) includes one-way compression strength, robustness of coal, cutting resistance coefficient and fissure of coal, etc. They are main components used to evaluate the physical properties of coal. Different mining machines are applicable to coal seam at different thickness.

3. Occurrence of coal seam

If a coal seam has gentle occurrence and slight variation in trend and tendency, design of a large shaft equipped with integrated mechanization can be considered. If a coal seam has steep dip occurrence, the folds of the coal seam is compact or fault structure is well developed, production will meet significant difficulties, mining mechanization be restricted, and production capacity is hardly improved. Medium and small shaft is generally suitable. Hence, the occurrence of coal seam, the development degree of its folds and faults, and influential degree of magmatic rock are major aspects of complicated degree of the structure. Accordingly, the complicated degree of the structure is divided into four categories: simple, moderate, complicated, extremely complicated. According to the dip angle of a coal seam, the coal seam is divided into gently inclined seam (dip angle <25°), inclined seam (dip angle ranging 25-45°), steep inclined seam (dip angle >45°). Traditionally, coal seam with a dip angle <5° is called closely horizontal seam; and coal seam with a dip angle >60° is called vertical seam. Effective coal seam control is a prerequisite for maintaining an efficient mining operation. If the strata in the vicinity of an opening are not controlled effectively, it is impossible to perform a safe, efficient and economical operation.

4. Roof and floor of a coal seam and their stability

4.1 Composition of floor and roof

According to the location of rock and coal seam and the difference of their collapse performance, the roof and floor can be divided into upper roof, immediate roof, false roof, false floor, immediate floor and main floor. As for a given coal seam, these six parts are not necessarily all developed[2].

(1) Upper roof: is located above immediate roof, alternatively, is thick and solid rock layer located above coal seam, generally consisting of sandstone, conglomerate and limestone. It can sustain a very large temporary controlling face but will not collapse with the immediate roof.

(2) Immediate roof: is one or several rock layers above false roof or coal seam, generally consisting of sandy shale, mudstone, siltstone, etc. that easily collapse. Its thickness can be a couple of meters. After mining operations, it automatically collapses with prop pulling, and sometimes needs manual collapse.

(3) False roof: is a very thin soft rock layer immediately above coal seam, generally consisting of
slightly strong and easily collapsed carbon mudstone. It has a thickness of 0.3-0.5m and falls simultaneously with coal body.

(4) False floor: is thin and weak rock layer located beneath coal seam, generally consisting of carbon mudstone and mudstone.

(5) Immediate floor: is rock layer located beneath false floor or immediately beneath coal seam, generally consisting of mudstone and claystone. If immediate floor is solid rock, it can serve as good base of the supports; if it is soft rock, it easily causes bottom heave and makes pillars collapse into the floor, or easily slides on meeting with water.

(6) Main floor: is located beneath immediate floor, or beneath coal seam, generally consisting of moderately solid and stable sandstone and limestone.

4.2 Categories of roof

The stability of coal seam roof means to what extent the roof rock layer deforms and fractures after coal seam is mined, which mainly concerns the control of coalmine pressure. Since the differences in the common roof rock characteristics and pressure in China’s coalmines directly determine the support type of stoping face and treatment method of goaf, the stability of roof is the most important.

The stability of roof mainly depends on different lithological characters and their fracture (especially the rock layer of immediate roof about 2m immediately above coal seam), as well as availability of false roof. According to such indicators as layer thickness of rock layer of coal seam roof, development degree of fissure and one-way compressive strength of rock, roof is categorized as unstable roof, moderately stable roof, stable roof and solid roof.

(1) Unstable roof: means carbon mudstone, clay rock, shale and fissure-developed sand shale having a layer thickness less than 2m. The one-way compressive strength of rock is less than 29.42 Mpa, there are generally more than three groups of fissures having average interval of less than 0.3m.

(2) Moderately stable roof: means shale, sand shale and fissure-developed sandstone having layer thickness ranging 2-5m. The one-way compressive strength of rock is 29.42-49.03 Mpa, there are generally 2-3 groups of moderately-developed fissures having average interval of 0.3-1m.

(3) Stable roof: means sand shale and sandstone having a layer thickness of 5-7m. The one-way compressive strength of rock is 49.03-78.45 Mpa, there are 1-2 groups of under-developed fissures having average interval of more than 1m.

(4) Solid roof: hardly has immediate roof, its main roof is thick layered sandstone and conglomerate.

5. Hydrogeological conditions

In conducting general survey and exploration of a coalfield, investigation and research of hydrogeological conditions should be well performed. By analyzing the water-filled factors of coal bed, predicting the amount of water inflow of mine shaft (open), necessary hydrogeological data is provided for design of mine shaft, suggestions are proposed for control and comprehensive utilization of underground water and environmental and hydrogeological and engineering geology possibly occurring in the mine area.

The size of water inflow of a coal shaft can be represented by absolute water inflow Q, which means total water amount flowing into the coal shaft in unit time at m³/h. Coal shaft is categorized according to absolute water inflow. In addition, the size of water inflow of a shaft can be represented by relative water inflow (alternatively, by water-containing coefficient K* of the shaft), meaning the ratio between the amount of water discharged from the shaft and the mined coal amount on the same period.

In many coal mines, limestone-confined aquifers underlie coal seams. During coal extraction from these mines, water inrushes occur frequently with disastrous consequences. This paper introduces the hydrogeological conditions of the coal mines and the potential water inrush disasters from aquifers under coal seams. It then presents the water inrush mechanism. The main factors which control water inrushes include strata pressure, mining size, geologic structures and the water pressure in the underlying aquifer. Analysis shows that reduction of confinement due to mining is the major cause of the water-conducting
failure in the floor strata. The depth of the failure zone is strongly dependent on the mining width. This paper also presents field observation results of the water-conducting failure in the floor strata, and applies the finite element method coupled with stress-dependent permeability to analyze hydraulic conductivity enhancement due to coal extraction. Finally, theoretical and empirical methods to predict water inrushes are given, and technical measures for improving mine design and safety for coal extraction over aquifers are presented. These measures include fault and fracture grouting and mining method modification such as changing long-wall to short-wall mining.

Water pressure in the aquifer that underlies the coal seam plays an important role in water inrushes during mining. Acting as a kind of stress on the bottom of the floor, water pressure makes the floor strata much more apt to expand into the exposed space of the mined area. Therefore, the higher the water pressure is, the easier the water inrush. This is the reason why some mines use water pressure as one of the important parameters to estimate potential water inrushes. In China, the water inrush index or coefficient is applied, as a rule of thumb, for preliminary evaluation of water inrushes in some coal mines. The water inrush index is defined as the water pressure bearing capacity per unit thickness of the floor strata.

6. Gas

Gas in a shaft is a generic term of all harmful gases emitting from the coal body and surrounding rock in the shaft and generated during production. Gas was generated in the process of coal forming, currently referring to the gas emitted from coal body and surrounding rock. Main ingredient of gas is methane, a non-toxic gas suffocating someone to death. When the methane in the air reaches a certain volume fraction, it tends to explode on meeting fire. So, gas poses a grave threat to the work safety of both peoples and coalmines.

As prescribed in the Safety Rules of Coalmines, in a coal shaft, if only coal and gas outburst is found once in a coal seam or rock layer, the shaft is considered a gas outburst-prone shaft. It will be managed according to the work rules on methane registration in coal shafts. Evaluation indicator mainly refers to relative gas emission, i.e., gas emission of 1t coal produced per day on average under normal production. The Safety Rules of Coalmines promulgated in 1986 in China provide that, the level of methane in coal shafts is divided into three levels: low-methane shaft is 10m³ and less; high-methane shaft is over 10m³; coal and gas outburst-prone shaft.

Because relative gas emission of a shaft can in no way be decided when resource is explored, only the gas content of coal seam can be evaluated, and future gas emission of the shaft be evaluated and predicted respectively so that the level of methane in the shaft is determined in the design task of the shaft.

7. Coal dust

Coal dust means coal particles generated in the production process of the shaft. Harms of coal dust is mainly manifested in its combustion and explosions. In addition, coal dust also pollutes the air, and seriously affects human health. About 80% of the coalmines in China risk coal dust explosions. Coal dust suspended in air is explosive - coal dust has far more surface area per unit weight than chunks of coal, and is more susceptible to spontaneous combustion. As a result, a nearly empty coal store is a greater explosion risk than a full one. The worst mining accidents in history have been caused by coal dust explosions, such as the disaster at Senghenydd in South Wales in 1913 in which 439 miners died, the Courrieres mine disaster in Northern France which killed 1099 miners, the Lusenthal Mine disaster in Germany, which claimed 299 lives in 1962, and the worst: the explosion at Benxihu Colliery, China, which killed 1549 in 1942. Such accidents were usually initiated by firedamp ignitions, the shock wave of which raised dust from the floor of the mine galleries to make an explosive mixture. The problem was
investigated by Michael Faraday and Charless Lyell in the explosion at the colliery at Haswell County Durham of 1844, but their conclusions were ignored at the time.

Major factor that affects coal dust explosions is volatile content of coal. The higher the volatile content, the easier coal dust explosion. Therefore, volatile content can be the indicator to preliminarily evaluate coal dust explosion, i.e., Vdaf is less than 10% is non-explosive coal seam; Vdaf 10%-15%, is weak explosive coal seam; Vdaf more than 15% is the coal seam of which explosion risk suddenly intensifies. Besides, other indicators used to evaluate coal dust explosions are ash content, moisture, coal granularity and the lithotype of coal.

The main attempts at prevention include using safety lamps, adding stone dust coffers to mine galleries, watering workings and ensuring efficient ventilation of all the workings\cite{3}.

8. Geothermal and geological conditions

Geothermal temperature increases with mining depth. When abnormal geothermal zone appears in a coalmine, in order to control thermal harm, during exploration period, the geothermal distributions should be found out in the mine area or coalfield, analyze and understand the geological factors that contribute to geothermal temperature increase, discover the thermal source so as to provide design grounds for temperature decrease and ventilation of the shaft. Hence, Main indicators evaluating geothermal temperature are geothermal gradient and the depth and scope of thermal harm zone.

A region of which geothermal gradient is less than 3°C P100m is normal temperature increase region; more than 3°C P100m, is abnormal temperature increase region. A region of which geothermal temperature is 31-37°C is level-I thermal harm region; more than 37°C is level-II thermal harm region.

9. Safety management

Safety management plays an important role in proper control of coal mines. Traditional approaches on the prevention of accidents/injuries in mines reached its limit of effectiveness in improving safety performance and a fresh approach is utmost required. Behavioral safety analysis has been identified as an effective alternative in many industries. Therefore is should be to seek to examine the role of behavioral factors on the occurrence of mine accidents and injuries through a case study. Data should be collected to explore the differences between behavioral characteristics of accident involved (case) and non-involved (control) workers. How these differences could cause accidents/injuries in mines? The case study results show that accident group of workers (cases) are more job dissatisfied, negatively affected, and highly risk taking compared to the non-accident group of workers (controls). The accident model path analysis shows that negative affectivity, job dissatisfaction, and risk taking behaviors predict an increased number of injuries in mines. Apart from direct influences to work injuries, negative affectivity and job dissatisfaction make workers to take more risks and behave unsafely. These findings contribute to the design of safety programs including safety training, which should be behaviorally motivated. Mine safety management of the case study mines should outskirt their age old belief that accidents/injuries are due to hazardous nature of mining and only engineering control and regulatory monitoring are sufficient for improving safety of the mines.

10. Conclusions

(1) The thickness, structure of coal seam and its changes can affect selection of coal mining method and layout of mining area, as well as the production capacity of the shaft and the quality of coal.

(2) The occurrence of coal seam is of paramount significance to the design, construction and production of a coalmine. It is the basic ground for work out the exploration scheme of shafts and selection of coal mining method and machinery.
(3) The composition of the rock stratum of coal seam roof and floor is closely related to the stability of coal seam roof.
(4) The hydrological condition of coal deposit is one of the important factors that determine the exploitation and exploration conditions of the deposit.
(5) Gas affects the design, construction and production of a coalmine in many aspects. Among them the most important is that gas is important ground for design of ventilation of the shaft and determination of the gas management regulations.
(6) Coal dust somewhat affects the ventilation design of the shaft. When a shaft risking coal dust explosions is mined, wind speed should be strictly controlled to prevent fall dust floating. The Safety Rules of Coalmines stipulate that, detailed survey geological report must include the appraisal data on the coal dust explosion of all coal dust to facilitate the design and construction of the shaft.
(7) Geothermal temperature affects the work safety of the coalmine and the health of miners. The Safety Rules of Coalmines stipulate that, the allowable temperature in the shaft is 26°C, and if beyond this temperature, appropriate temperature decrease measure should be taken.

References