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Solutions to prevent face spall and roof falling in fully mechanized longwall at underground mines, Vietnam

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Abstract

Purpose. On the basis of analysis and assessment of geological conditions, technological parameters and support methods of a longwall, the author has pointed out the causes and rules of the phenomenon of face spall and roof falling in fully mechanized longwall. From there, the author proposes some solutions to prevent this phenomenon to ensure the safety of the longwall.

Methods. The statistical, survey and analysis methods of actual field data are used to achieve research results.

Findings. The results of applying solutions to prevent the phenomenon of face spall and roof falling are relatively good. There are some effective solutions such as the technique of force-pumping chemicals directly into the coal seam to increase the connection among the coal masses, the solution of force-pumping water into the seam combined with enhanced support at the place of face spall and roof falling on a small scale.

Originality. There are many reasons and factors that cause the phenomenon of face spall and roof falling in the longwalls. In the present paper, the author focuses on 5 main causes and factors ruling face spall and roof falling in longwalls. On that basis, the author proposes 5 solutions that can be applied to prevent the face spall and roof falling in geological conditions of longwalls in Quang Ninh coalfield, Vietnam.

Practical implications. The research results presented in the article will help mines be proactive in production. These technical solutions, after being applied in actual production, allowed to achieve quite good results, and effectively handled the phenomenon of face spall and roof falling in the longwall according to each specific geological condition. Thus, it is possible to develop technical and technological solutions for troubleshooting in fully mechanized longwall at some current underground mines of Quang Ninh coalfield, Vietnam.

Keywords: *solution, face spall, roof falling, fully mechanized, longwall, underground mining*

1. Introduction

The face spall is the phenomenon of coal being separated from the original coal seam and overflowing into the space of the longwall, which affects the activities in the longwall [1], [2]. When exploiting coal seams with soft, loose, high pressure and unreasonable mining techniques, the phenomenon of face spall will occur more frequently and continuously. When the phenomenon of face spall occurs, the roof loses its support, if it is soft rock, it will tend to fall into the space of the longwall, which can cause impacts and incidents, this is called the phenomenon of the roof falling of the longwall during the mining process [1], [2]. This phenomenon occurs in a large space, leading to the hollow roof of the longwall, which affects the quality of the support, the shield may be tilted, even the shield will fall and become unsafe for longwall. In the longwall, the process of face spall may occur first, the next by the phenomenon of roof falling. When the longwall operates stably, the phenomenon of face spall and roof falling occurs in turn according to the process of the movement in the direction of the longwall.

The technology of fully mechanized longwall mining is constantly developing and improving in many countries around the world. Because this technology has many outstanding advantages, it is increasingly being researched and applied in actual manufacturing [3]. In Vietnam, in recent years, fully mechanized longwall mining technology has been applied in underground mines [4]. Currently, Quang Ninh coalfield, Vietnam is operating and exploiting 10 fully mechanized longwalls, specifically in these coal mines: Ha Lam coal mine, Nui Beo coal mine, Duong Huy coal mine, Ha Long coal mine, Quang Hanh coal mine, Mong Duong coal mine, Khe Cham coal mine and Vang Danh coal mine. In the next few years, fully mechanized mining technology will be researched and applied at Mao Khe coal mine, Nam Mau coal mine, Thong Nhat coal mine and some other mines with suitable geological conditions [5]. In the process of exploitation and assessment, it is initially shown that these longwalls have brought remarkable results. However, at these longwalls, there are also incidents due to many diffe-rent reasons, of which the most common problem is the phenomenon of face spall and roof falling. When the phenomenon of

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face spall, roof falling occurs in the longwall, it will disrupt the operation scheme, reduce labor productivity and efficiency as well as bring the problem of unsafety in production.

In order for the fully mechanized mining longwall to operate continuously and bring efficiency in the use and operation of synchronous equipment, incidents need to be handled quickly and promptly, in which it is very important to prevent the phenomenon of face spall, roof falling [6], [7]. In a fully mechanized longwall, due to the operation of many types of machinery and equipment, besides the changing and complex geological conditions of the longwall, it often has problems. Before proposing solutions to prevent incidents, it is necessary to clearly analyze the influencing factors, on that basis, to choose the right and timely solutions to keep the longwall safe [8], [9]. In the world, there are many countries that have technical and technological solutions to handle and prevent the phenomenon of face spall, roof falling, in which two solutions of force-pumping chemicals and force-pumping water into the coal seam are also relatively common [10]. However, in each specific geological condition, different mining technology, the application of each solution to prevent face spall, roof falling is also different. Through analyzing the characteristics of the mechanized longwall being exploited in some underground mines in Quang Ninh, the author also analyzes the influencing factors and the rules of the phenomenon of face spall in the longwall, from which proposes some effective solutions to handle. These solutions can be completely applied in mechanized longwalls in Quang Ninh coalfield, Vietnam, and contribute to improve the level of safety and good efficiency in the production process.

2. Methods

2.1. Current status of fully mechanized longwall mining technology in Vietnam

Currently, in Quang Ninh coalfield, there are 10 underground mines, which apply fully mechanized longwall mining technology, specifically as follows:

1. Ha Lam coal mine has two longwalls, in which one is applied to exploit Seam 11 (from 2013), equipment includes: shield of type ZF4400/16/28, shield of type ZFG4800/18/28, shearer of type MG150/375-W, conveyor coded SGZ630/264, designed capacity 600 thousand tons/year; the other one is applied to exploit Seam 7 (in 2015), equipment includes: shield of type ZF 8400/20/32, shield of type ZFG9600/23/37, shearer of type MG300/730WD, conveyor coded SGZ 764/400, designed capacity 1.2 million tons/year [11].

2. Khe Cham coal mine has two longwalls, in which one is applied to exploit Seam 14-5 (from 2016), equipment includes: shield of type ZFY5000/16/28, shield of type ZFG-6200/17/30, shearer of type MG-150/375-WD, conveyor coded SGZ630/246, designed capacity 600 thousand tons/year; the other one is applied to exploit Seam 15-5 (in 2018), equipment includes: shield of type ZZ/3200/16/26, shearer of type MG150/375-W, conveyor coded SGZ 630/220, designed capacity 300 thousand tons/year [12].

3. Duong Huy coal mine hasone longwall, which is applied to exploit Seam 11 (from 2015), equipment includes: shield of type ZY3200/16/36, the shield of type ZYG3200/16/36, shearer of type MG300/700-WDK, conveyor coded SGZ 730/220, designed capacity 600 thousand tons/year [13] (Fig. 1).

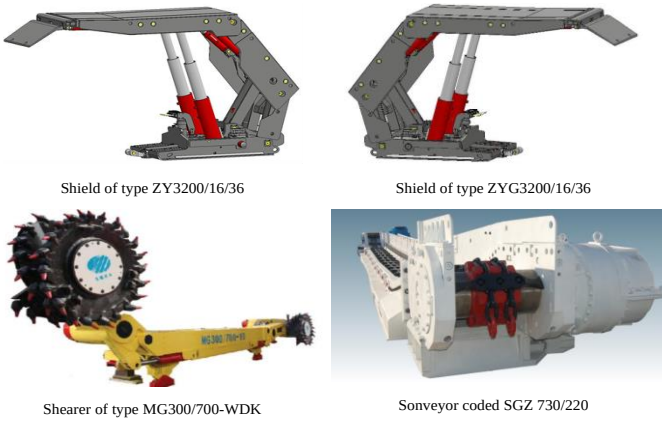

Figure 1. A group of equipment used in the longwall of coal Seam 11 – Duong Huy Coal Mine, designed capacity 600 thousand tons/year [13]

4. Quang Hanh coal mine has one longwall, which is applied to exploit Seam 7 (from 2015), equipment includes: shield of type ZY3000/12/26, shearer of type MG132/320-W, conveyor coded SGZ 630/220, designed capacity 180 thousand tons/year [14].

5. Vang Danh coal mine has one longwall, which is applied to exploit Seam 8 (from 2018), equipment includes: shield of type ZF4400/17/28, shield of type ZFG4800/20/32, shearer of type MG170/411-WD, conveyor coded SGZ 630/264, designed capacity 450 thousand tons/year [15].

6. Mong Duong coal mine has one longwall, which is applied to exploit Seam L7 (from 2019), equipment includes: shield of type ZF3000/15/24, shield of type ZFG3200/19/31, shearer of type MG160/380-WD, conveyor coded SGZ 630/220, designed capacity 300 thousand tons/year [16].

7. Nui Beo coal mine has one longwall, which is applied to exploit Seam 11 (from 2020), equipment includes: shield of type ZF4400/17/28, the shield of type ZFG4800/18/30, shearer of type MG160/391-WD, conveyor coded SGZ 630/264, designed capacity 600 thousand tons/year [17].

8. Ha Long coal mine has one longwall, which is applied to exploit Seam 11 (from 2021), equipment includes: shield of type ZY2400/14/32Q, the shield of type ZYG2400/12/32Q, shearer of type MG160/381-WD, conveyor coded SGZ 630/220, designed capacity 300 thousand tons/year [18].

Based on surveys at mechanized longwalls, during the coal mining process, the phenomenon of face spall, roof falling has occurred in most of the longwalls. Depending on the conditions of the longwall, the phenomenon occurs in a large or narrow area. It takes a relatively long time to stop the longwall to overcome the phenomenon of face spall, roof falling, affecting the output and production plan of the longwall and the whole company. Therefore, prevention and treatment solutions are extremely necessary.

2.2. Characteristics, influencing factors and rules of the phenomenon of face spall, roof falling in fully mechanized longwalls in Vietnam

2.2.1. Characteristics

Under the condition of unstable or moderately stable roofs, with cracks and soft coals, it will usually lead to front face spall, rear roof falling, followed by face spall and roof falling occurring alternately.

There are immediate roofs or the false roof that are broken or loose, collapsing, making the shield and the rocks in bad contact, leading to the formation of a local hanging roof.

If the equipment is damaged or the movement of the shield is not suitable, it can lead to the hanging roof again collapsing, causing the face spall and roof falling to occur on a larger scale, from small to large.

If the condition of coal and rock is soft, the broken and loose areas are large, it will easily lead to the phenomenon of face spall and roof falling, its characteristic is that the loose rocky area occurs the phenomenon of the roof falling continuously until the longwall completely passes through the loose roof.

Along with the process of unloading many times of the shield, the temporary equilibrium of the roof is constantly being destroyed, making the scope of the face spall and roof falling develop many times and spread.

2.2.2. Factors affecting

1. Mine pressure factor. The common factor of mine pressure is the pressure of the coal pillar or the pressure in the period of cyclic caving, which causes the mine pressure to appear abnormal, leading to the problem of face spall and roof falling. The reality of exploiting several fully mechanized longwalls mining in the Quang Ninh, Vietnam shows that a number of coal pillars are stored above the shield, thus affecting the coal mining in the longwall and causing relatively serious face spall. This is due to the influence of the pressure acting on the coal pillars, creating increased local stress during the mining process, which leads to the face spall of the longwall.

2. Geological factors. In areas with soft rocks and loose roof, it is easy to see the phenomenon of spall and roof falling. In the area close to the structure of the fault, the axis of the fold, especially in the condition that the roofs have small, stratified thickness and low intensity, this phenomenon is also likely to occur. Through the survey, it was found that the longwall in Seam 14-5 of Khe Cham mine, longwall in Seam 11 of Ha Lam mine and longwall in Seam 11 of Duong Huy mine are the softest coal longwalls, so the phenomenon of face spall and roof falling occurs more often. In some other mechanized mining longwall, faults and folds occurred, the phenomenon of partial face spall and roof falling occurred, which greatly affected the production process, took a long time to handle this problem.

3. Exposed width of roof. After the shearer has cut coal, the roof is exposed. If the shield does not move in time to support the roof or during the move, the shield does not lower to the required level but still makes certain contact with the roof, reducing the support quality of the shield. The distance from the shield to the longwall face exceeds the specified value, which causes the exposed distance of the roof to be large, and then leads to the hanging time exceeding the specified time limit. The working load and initial holding force of the shield do not reach the specified value, or the mining height is greater than the maximum support height of the shield, resulting in pressure on a large area concentrated on the roof, which causes the roof to bend and creates problems with the phenomenon of face spall and roof falling.

During the mining process, the movement of the longwall will cause the roof to be exposed, the larger the exposure interval, the higher the level of the collapse of the roof (Figure 2 shows the relationship between the degree of collapse *M* of the roof and exposed distance *S* of the roof).

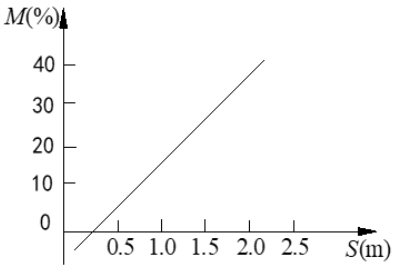

Figure 2. Relationship between the degree of collapse M of roof and exposed distance S of roof [19]

The actual exploitation shows that there are cases where the exposed distance of the roof is zero (the shield has come close to the longwall face) but there is still the phenomenon of the roof falling, which proves that the distance factor of the exposed roof is not the only factor affecting the phenomenon of the roof falling, but also related to many other factors.

4. The movement speed of the longwall. The level of the collapse of the roof and the movement speed of the longwall has a direct relationship. If the moving speed of the longwall is faster and faster, the timely support of the exposed roof will reduce the deformation of rock and coal, and at the same time minimize the degree of roof falling in the longwall (Figure 3 shows the relationship between the degree of collapse *M* of the roof and the movement speed *V* of the longwall).

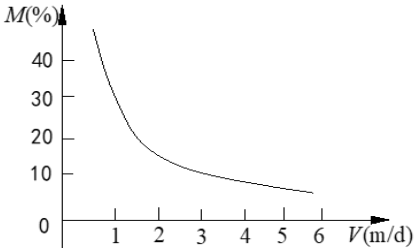

Figure 3. Relationship between the degree of collapse M of the roof and the movement speed V of the longwall

5. Initial support load of shield. During the operation of the shield, it is necessary to adjust the average working load of the shield to a reasonable level, which can reduce the problem of roof falling of the roof. In order to ensure the supporting load of the shield, it is necessary to first determine the initial support load of the shield, but in fact, it is shown that the reasonable ratio of the initial supporting load of the shield is to be determined only about 70% on average, due to the following main reasons:

– the time to supply lubricant to the shield is short, the initial support load has not been achieved but the lubricant has stopped pumping;

– the pressure of the pump station is not enough, the valve and the pipeline are leaking;

– the floor is soft and weak.

2.2.3. The rules of face spall and roof falling in the longwall

2.2.3.1. Dividing the deformation area of the coal in front of longwall face

According to the movement of the longwall, after the coal was split, the roof behind the longwall was split, deformed, cracked and collapsed. When the inside of the soil and rock form a balanced structure with a certain height, the roof around the longwall appears to redistribute the stress, so that

concentrated stress appears in front of coal block of the longwall, becoming pressure.

Under the effect of this pressure, inside the coal mass in front of the longwall face, plastic deformation and destruction appear, forming a collapse zone and a plastic zone. From there, leading to the phenomenon of face spall and roof falling. As for deep into the coal mass, the coal mass gradually turns into 3 zones of stress state, improving the expression of pressure, forming elastic zone, collapse zone and plastic zone [20]-[22]. The deformation area of the coal mass in front of the longwall is shown in Figure 4. The size of the plastic zone and the collapse zone is mainly determined by the pressure acting on the coal mass and the deformation process of the self-weight of the block and its structural relations.

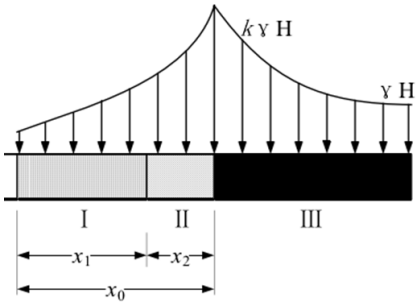

Figure 4. Deformed area of coal block in front of the longwall: I – breaking zone; II – plasticity zone; III – elastic zone; x_1 – width of breaking zone; x_2 – width of plasticity zone; x_0 – non-elastic area width

2.2.3.2. Forms of coal face spall

1. The face spall in the form of cut break. The face spall in the form of cut break is shown in Figure 5a, for soft coal seams, under mine pressure, in the coal appears horizontal tensile stress, because the cut stress in the coal is larger than the strength of cut resistance, thereby causing the form of cut break. In fact, the shear surface is mostly curved, when the height of the longwall face and the height of the face spall is not large.

2. The face spall in the form of tensile break. Figure 5b, c shows the face spall in the form of tensile break, this break is common in brittle hard coal, this type of coal mass has a small amount of deformation. The cause of face spall is mainly due to the impact of rock pressure, causing the coal to appear tensile stress in the horizontal direction, but the horizontal tensile force cannot be through the deformation of the coal mass to release or slow down, so that when it is greater than the tensile strength, the coal is broken, and there is usually a cracking sound when it is broken.

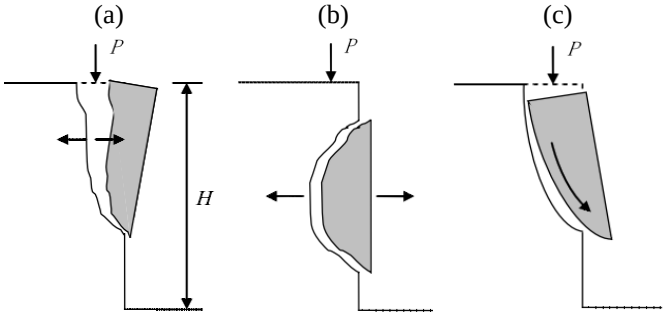

Figure 5. Forms of coal face spall

From the above analysis, it can be seen that the mechanism of face spall mainly occurs in two forms, namely, the face spall in the form of cut break and the face spall in the form of tensile break. The causes of face spall are mainly related to the roof pressure, shear strength, tensile strength and some other properties of coal. Therefore, the research to minimize the mine pressure on the longwall face or change the mechanical properties of the coal is the main research to prevent the coal face spall.

2.2.3.3. Structural relationship and destructive deformation of coal mass

Using a hardness tester to test the compressive resistance of the coal mass and observing the field have both proved that the deformation collapse of the coal is a complicated process. Most of the experiments prove that the stress-improvisation graph of the coal mass can be simplified as a soft model with ideal plasticity and elasticity. The deformation process of coal is classified into elastic deformation, plastic deformation and plastic fluidity (residual deformation stage). Figure 6 shows the division of 3 zones as mobility, softening and elasticity respectively called elastic zone, plastic zone and collapse zone [23], [24].

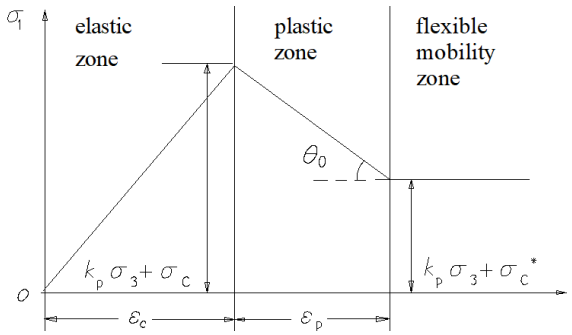

Figure 6. Ideal model for the softness and elasticity of coal

The coal mass in the structural relationship of the deformation stages is as follows:

1. Flexible mobility stage:

$$\sigma_1 = k_p\sigma_3 + \sigma_c^*, \quad (1)$$

where:

σ_1 – biggest main stress;

σ_3 – smallest main stress.

$$k_p = \frac{1+\sin\varphi}{1-\sin\varphi}, \quad (2)$$

where:

φ – internal friction angle of coal;

σ^*_c – residual (excessive) strength when stretching along the single axis of coal.

2. Plastic deformation stage:

$$\sigma_1 = k_p\sigma_3 + \sigma_c - M_0\varepsilon_p, \quad (3)$$

where:

σ_c – uniaxial pressure resistance strength of coal;

M_0 – softening modulus of coal ($M_0 = \tan\theta_0$, θ_0 – softening angle of coal);

ε_p – soft deformation of coal.

3. Elastic stage:

$$\sigma_1 = k_p\sigma_3 + \sigma_c. \quad (4)$$

2.3. Solutions to prevent face spall, roof falling in a fully mechanized mining longwall in Vietnam

Derived from the analysis of the influencing factors and the law of the phenomenon of face spall, roof falling, the author proposes solutions to prevent this phenomenon. Each solution is selected and applied in specific geological conditions.

2.3.1. Using chemicals to reinforce the longwall face

The solution of using chemicals to reinforce the longwall face is one of the most technically effective solutions. In some countries such as China, Poland, Australia, this solution is widely and popularly used to solve the problem of face spall and roof falling, this solution is not only used to handle face spall and roof falling in the longwall, but also used to handle the problem of the roof falling when digging the roadway in the soft coal seam and rock. The essence of the solution is to force-pump chemicals directly into the longwall face through drilled holes, from which chemicals pass through the cracks in the coal mass and bond into a solid block.

At the mechanized longwall in the coal area of Quang Ninh, Vietnam, in order to handle the roof and coal with face spall and roof falling, drill rows of holes with a diameter of 42 mm in the section of the longwall need to be reinforced, each hole is drilled from 2.5 m deep, the distance of the holes drilled in the slope direction is 3 m, then the chemical mixture is force-pumped through the drilled holes into the cracks for reinforcement. After each force-pump chemical, the longwall face will be stable for about 5 web cuts, equivalent to 3.15 m (the depth of one web cut at the fully mechanized longwall is 0.63 m). Currently, the chemicals used to reinforce longwall face have many different types and their prices are also different. The mechanized longwall in Quang Ninh coalfield often uses Chinese chemical DMT-601A/B or some longwalls use Polish chemicals to reinforce. Figure 7 shows the layout diagram of the chemical pumping equipment in the longwall.

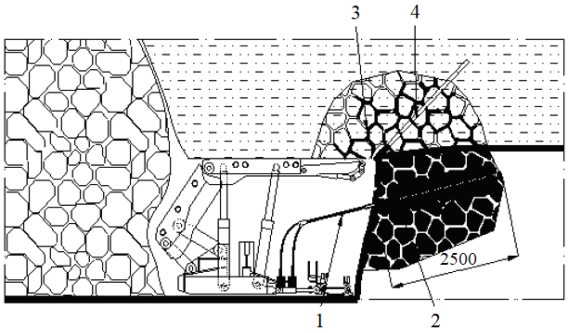

Figure 7. Principle diagram showing the force-pump chemical to reinforce the roof to prevent the phenomenon of face spall, roof falling [25]: 1 – chemical pump hose; 2 – chemicals that bind coal in the longwall face; 3 – chemicals that bond rock blocks on the roof; 4 – chemical pump borehole

Some advantages and disadvantages of the solution:

1. The construction is simple, the curing time is short (from only a few tens of seconds to a few minutes), so it is possible to quickly restore the excavation and mining (after 20 minutes of pumping the chemical mixture can start mining), thereby reducing the interruption time and improving the production efficiency.

2. Small pumping equipment, only about 50 kg with hydraulic driven pump, 100 kg with pneumatic-driven pump, so it is easy to move in the underground mines. In addition, the energy source for pumping equipment (hydraulic or pneumatic) can be obtained from the existing system of the mine, thus increasing the initiative in treatment.

3. Chemicals in the form of a liquid solution have a better spread than cement, can be used in all conditions, have good quality of the reinforced rock mass and also have high stability. However, it also has the disadvantage of high cost, so in the mining of coal seams through destructive zones or large water reservoirs, the reinforcement radius cannot be controlled, the application of this solution will be very expensive compared to other methods. This is a big challenge for the current conditions of Vietnam's underground mines.

2.3.2 Using the method of pumping water into the coal seam

One of the effective solutions to handle the phenomenon of face spall is to force-pump water through the drilled holes into the coal mass in the longwall, this is a very effective solution in terms of economy, however, in locations where the phenomenon of the face spall and roof falling are heavy and strong, this solution cannot be handled. The essence of this method is to drill holes (short, medium and long) into the coal seam and use those holes to force-pump water into the coal seam to increase the humidity of the coal until it reaches the limit request. The scientific basis of this method is that when the humidity of coal increases to a certain extent within the limit of unsaturation, it will change the physical and mechanical properties of the coal such as the adhesion force between coal particles increasing, the plasticity of the coal increases, the brittleness of coal decreases, so when force-pump water into the coal seam, it will be effective for maintaining the monolithic nature of coal.

Currently, the longwall in Seam 14-5 of Khe Cham III coal mine and the longwall in Seam 7, the Seam 11 of Ha Lam are using this solution. The evaluation shows that, if the phenomenon of face spall in the longwalls does not occur too much, this solution is relatively effective. See Figure 8 and 9.

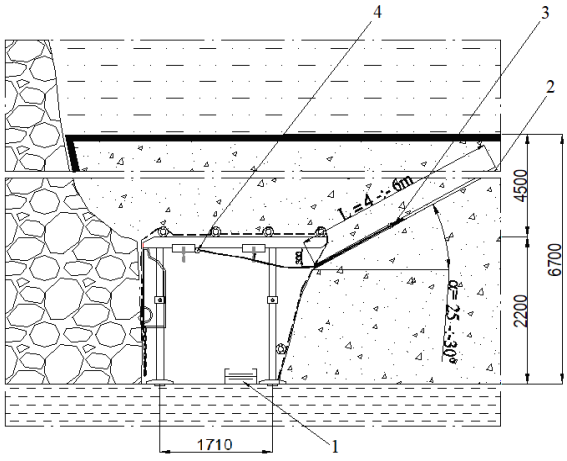

Figure 8. Arrangement of boreholes in the longwall to prevent face spall by force-pumping water: 1 – scraper conveyors; 2 – water pump borehole; 3 – water pump hose; 4 – water supply pipe

The advantage of this method is that the construction is simple, can use the available equipment and materials of the mine, does not require high water quality, and has a low cost.

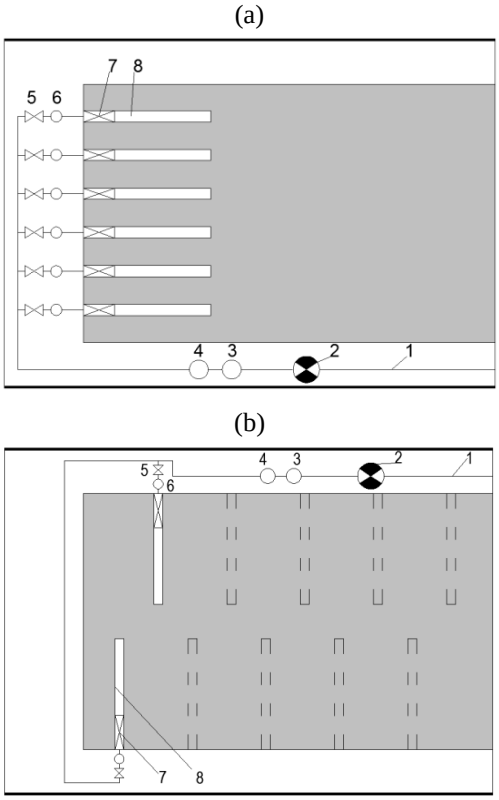

Figure 9. Principle diagram of force-pumping water solutions: (a) pumping water with medium borehole; (b) pumping water with a long borehole; 1 – water pipe; 2 – pump; 3 – flow meter; 4 – pressure meter; 5 – valve; 6 – pressure meter; 7 – borehole plug; 8 – borehole

In addition, when force-pumping water into the coal seam, it also contributes to improve the microclimate and environment at the mining such as reduced temperature and reduced dust concentration. The disadvantage of the method is that the effectiveness of preventing face spall is not as high as that of force-pumping chemicals.

2.3.3. Raise the working load and the initial support load of the shield

From the hypotheses and reasoning of roof control, it is shown that the initial support load of the large shield can control the roof, not only beneficial to prevent the layering phenomenon of the roof. but also beneficial to the stability of the shield. The ability of the shield to stretch is large, and the reliable support load can reconcile the pressure of the roof, which can be based on the design requirements, reliably ensuring control for the roof. Therefore, in order to improve the working load and the initial support load of the shield, it is necessary to do the following well:

1. First, it is necessary to improve the emulsion supply capacity of the pump station or select the emulsion supply system of the high-pressure pump station, trying to minimize the phenomenon of emulsion leakage of the system and the danger of the service supply system in the longwall, thereby reducing the incidents of face spall and roof falling.

2. Correctly operate the shield, after moving the shield, it is not necessary to immediately adjust the shield to the original position (position 0) to improve the initial support load for the shield.

3. Make good use of the initial support load of the shield to prevent the retaining roof in a timely and effective:

– moving the shield against the pressure of the big roof needs to be controlled for the height of the shield's leg to drop below 100 mm, after the shield's leg is stable, it is necessary to control the shield to raise the setting load;

– promote the rotating effect of the hydraulic jack, ensuring that the roof canopy of the shield is always in a state of balance, and at the same time, it must also ensure that the roof canopy is higher than the rear canopy to prevent the rock sliding towards the longwall face;

– flexible and timely handling, the number of anti-moving shields at the back of the shear must not exceed 5 hields and not less than 3 shields, otherwise the shear must stop working to move the shield;

– if the height of the face spall is more than 500 mm, the timber cog must be immediately placed above the roof canopy of the shield to prevent the development and spread of the phenomenon of face spall and roof falling.

2.3.4. Improve manipulating techniques and fully mechanized mining technology, at the same time strengthen equipment management in the longwall

It is necessary to prevent mining heights from exceeding design requirements. Because the mining height of the design is determined by many factors such as general geological conditions, mine pressure, etc. If the mining height exceeds the design requirements, there will be problems especially the setting load of the shield does not meet the specified requirements, but it is in contact with the non-enclosed roof, creating the layering process of the roof, under the influence of the stress, which causes the phenomenon of face spall. At the same time, it also leads to an increase in the distance of the exposed area of the roof, and the hanging time of the roof is too long, leading to the phenomenon of roof falling.

When the roof and coal mass are loose and broken, try to minimize the time and exposed area of the roof at the location where the shear passes. Time and exposed area of the roof are the binding factors for the formation of rocks near the broken, loose longwall face. Therefore, the time and size of the exposed area of the roof at the position where the shear passes are determined by the moving speed and the cutting depth of the shear. Therefore, in practice, it is necessary to base on the specific geological conditions and production conditions to choose a reasonable cutting speed and depth of the shear, minimizing the time and exposed area of the roof. Thus, it is possible to reduce the load of the shear, operate stably, fast speed, and at the same time make the expression of roof pressure relatively balanced, rock collapse with small area should be avoided the incident of the phenomenon of face spall and roof falling in the longwall.

Strengthening the management of electromechanical in the fully mechanized mining longwall. Improve the quality of equipment inspection and maintenance, operations for equipment need to meet standards, the transportation system also needs to be ensured including scraper conveyors, conveying machines, belt conveyors in good condition, ensuring normal transport capacity, continuous transport. The shear needs to be properly maintained to be able to cut well and improve the efficiency of its. Enhance the quality of inspection of the emulsion pumping station, so that the pumping station operates with high reliability, stable emulsion supply, yield load is achieved, and at the same time ensure the setting load of shield, after the shear cut coal, the shield can hold the roof in time, this avoids or minimizes the problem of face

spall and roof falling, thereby ensuring the quality of the work of the longwall, making the production process proceed continuously, stably and in balance.

2.3.5. Improve the movement speed of the longwall

The vast majority of practice proves that, when the time of face spall of the longwall is long, the longwall will also stop production, at this time, the face spall be more serious. Accelerating the movement speed of the longwall can reduce the influence of the pressure on the coal mass in front of the longwall face, reduce the time of influence of the pressure on the block, thereby reducing the extent of face spall or preventing face spall.

3. Results and discussion

Through monitoring, evaluating the results of force-pumping chemicals to reinforce coal blocks to serve the exploitation process at a number of longwall in Quang Ninh coalfield shows that the longwall after reinforcing with chemicals quality good, there is no face spall aspect as before the pump, the mining process then takes place favorably, ensuring safety, the speed of exploitation has been raised. However, due to non-production chemicals in the country but must be imported so it is high.

From statistical results showed before applying pump water solutions at longwall in Seam 14-5 of Khe Cham Coal Mine, longwall in Seam 11 and longwall in Seam 7 of Ha Lam Coal Mine, the face spall and roof falling are relatively frequent. The scope of phenomenon of face spall accounts about 40-60% of the length of the longwall, the depth of the face spall is usually from 1.0-1.5 m, the height of roof falling is from 0.5-0.8 m. Time to handle the face spall is often prolonged, after 8-12 shifts completed a mining cycle. After applying the solution of pump water into coal seams to increase the coal bonding, the face spall status in the longwall is reduced. From the statistics in Table 1 shows the scope and depths of face spall after the pump water is lower than before pump water. Thus, pump water solutions have been effective in increasing coal bonding, so the level of face spall decreases. The result compares the level of face spall before and after pumping water at some longwalls see Table 1.

Table 1. The result compares the level of face spall before and after pumping water at some longwalls in Quangninh coalfield

No.	Content	Before pump water into coal seams	After the pump water into coal seams
1	Scope of face spall	Occupy about 35-45% of the length of the longwall	Only about 10-15% of the length of the longwall
2	Depths of face spall	Usually from 1.0-1.5 m even there is up to 2.0-2.5 m	Reduce to about 0.5-0.8 m
3	The level affects the period of regular mining	Effects up to 40% of production time per shift	Effect about 10-15% of production time per shift

4. Conclusions

Analysis of the causes and rules of the phenomenon of falling mirror when mining at soft coal seams shows that, this phenomenon is mainly due to the effect of self-weight and mine pressure on the coal mass in front of the longwall face, causing the form of cut break and the form of tensile break. Therefore, the study of minimizing the influence of mine pressure or changing the mechanical properties of the coal mass in front of the longwall face are the two main research to reduce the incident of face spall and roof falling. The force-pump of water, the force-pump of reinforcing chemicals into the coal seam are two of the effective solutions to prevent face spall because water and reinforcing chemicals can increase the cohesion and reduce the brittleness of the coal mass, so it improves the stability of the coal seam.

The above solutions are applied to the actual fully mechanized longwalls in Quang Ninh, Vietnam. Applicable results have also affirmed that force-pump of water and the force-pump of chemical solutions reinforced on coal seams meet the requirements of the ability to prevent face spall, roof falling. In addition, the application of these solutions also contributes to improving mining output and labor productivity and improving working conditions in the longwall.

In exploitation, the problem of increasing the linkage of coal mass is mainly done by force-pump chemical methods and recently the force-pump water method. In these methods, the method of force-pump water into coal seams to increase the coal's association although effective is not high with force-pump chemical, but it has many advantages such as simple construction work, can be used available equipment and supplies of mine for implementation, low cost, can contribute to improving working environmental conditions.

For longwalls with mirror surroundings, rendering large, frequent, frequent occurrence, solutions of the force-pump water into coal seams is not effective, the method of the force-pump of chemical must be applied in order to ensure safety for longwall, although the cost of this method is relatively high for the conditions of underground mines in Vietnam today.

Combined solutions such as increasing the speed of moving the shear, the longwalls are supported promptly, force-pump water and force-pump chemical reinforcing into coal seams are also applied in mechanized longwall to increase the effect of preventing the phenomenon of face spall, roof falling.

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Способи запобігання відколюванню вибою та обвалу покрівлі в повністю механізованій лаві на підземних шахтах В'єтнаму

T.T. By

Мета. Вивчення причин і закономірностей відколювання вибою та обвалення покрівлі у повністю механізованій лаві на основі аналізу й оцінки геологічних умов, технологічних параметрів та способів кріплення лави, а також розробка рішень щодо запобігання даному явищу для забезпечення безпеки вибою.

Методика. Для отримання результатів у дослідженні використовуються статистичні, оглядові та аналітичні методи обробки реальних польових даних. Виконано аналіз причин і факторів, що викликають явище відколювання вибою та обвалення покрівлі у лавах.

Результати. Визначено, що застосування розчинів для запобігання відколюванню вибою та обвалу покрівлі дає відносно позитивні результати. Рекомендовано нагнітання води та армуючих хімікатів у вугільний пласт – два ефективні рішення для запобігання відколювання вибою, оскільки вода та армуючі хімікати можуть збільшити зчеплення й зменшити крихкість вугільної маси, тому підвищується стійкість вугільного пласта. Прикладні результати також підтвердили, що нагнітання води та хімічних розчинів, що зміцнюються на вугільних пластах, задовольняє вимогам щодо здатності запобігати сколам вибою та обвалу покрівлі.

Наукова новизна. В умовах вугільного родовища Куангнінь вивчено основні причини, фактори та закономірності відколювання вибою та обвалення покрівлі у лавах.

Практична значимість. Результати дослідження, що представлені у статті, дозволяють шахтам самим вирішувати виробничі проблеми. Ці технічні рішення, застосовані у реальних умовах видобування вугілля, показують позитивні результати та ефективно справляються з відколюванням вибою та обваленням покрівлі у лаві, з урахуванням конкретних геологічних умов. Застосування рекомендованих рішень також сприяє підвищенню продуктивності гірничих робіт та покращенню умов праці у лаві.

Ключові слова: *рішення, відколювання вибою, обвалення покрівлі, повністю механізована лава, підземний видобуток*