

## Study on some solutions for enlarging the application scope of the fully mechanized longwall coal mining technology according to seam dip angle at underground coal mines in Quang Ninh coalfield

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**Abstract:** The paper summarizes the applied experience, the technical solutions to limit the adverse effects of slope angle in the mechanized longwall mining at underground mines in the world. The paper proposes some solutions for enlarging the application field of the fully mechanized longwall mining technology according to seam dip angle at underground coal mines belonging to Vinacomin. In the article exploitation methods of coal seams of medium to thick thickness with dip angle above 20° designed for mechanized longwall were presented.

### 1 Introduction

Currently, Vietnam National Coal – Mineral Industries Holding Corporation Limited (Vinacomin) is promoting the application of the mechanized coal mining technology, in order to improve capacity and labor productivity, meet the demand for the economy. In which, the process of applying mechanized technology to mining coal seams with dip angle  $\alpha \leq 35^\circ$ , solved the requirements of capacity, productivity and labor safety. However, in condition of some inclined seams with a dip angle  $\alpha > 20^\circ$ , the level of efficiency of the technology decreased sharply (equal 25-30% compared to the stable period). Although the device is designed with the ability to work when the angle is up to 25°, even to 35°. The results of assessment mechanization application process in coal mines in Quang Ninh in the past ten years show that: Stable working time of longwall accounts for 38% to 45% of total operating time [2]. The remaining time, the longwall often encountered trouble, in which the slope factor plays an important role (accounting for 17% of the total unstable operation time and accounting for 38.6% of the geological problems). Proportion of factors affecting the reduction of longwall production was presented on the Figure 1. If the dip angle is greater than 20°, the equipment in the mechanized longwall will work with low reliability, usually occurs sliding, must stop troubleshooting, affects the durability of the device and reduce exploitation efficiency. Therefore, study on some solutions for enlarging the application field of the fully mechanized longwall mining technology is necessary for underground coal mines

in the Quang Ninh coalfield. The behaviour of the rock mass in the post-exploration areas depends on the compressibility of the material filling the voids [9,10,11]. Particularly important issue that increases miners safety is the ability of monitoring of the longwall system and loading on the rock bolts [5,6,13]. In the longwall systems for which roadways are maintained, resin rock bolt support installed at various lengths plays a very important role [12]. Furthermore mining support should be designed for dynamic loading [7,8,14].

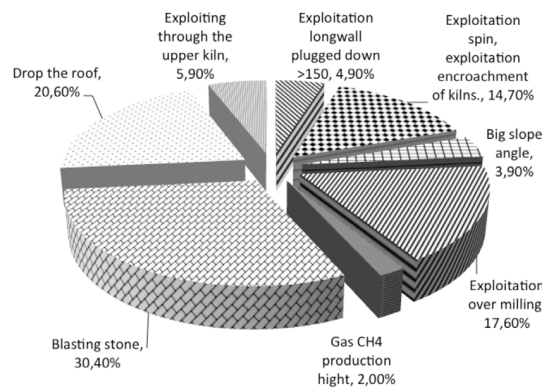


Fig. 1. Proportion of factors affecting the reduction of longwall production

## 2 Improving the structure of the support

This method link individual support units into clusters by the anti-topple jacks and face conveyor with power support by anti-slip device. The addition of large hydraulic jacks with thrust (or pull) along the direction of the dip angle of the longwall, linking the canopy and base of the single power support as above is quite effective in keeping the supports and face conveyor not fall over by the impact of the dip seam, thereby increasing the scope of application according to the working angle of the power supports and conveyor (Fig. 2a-2c).

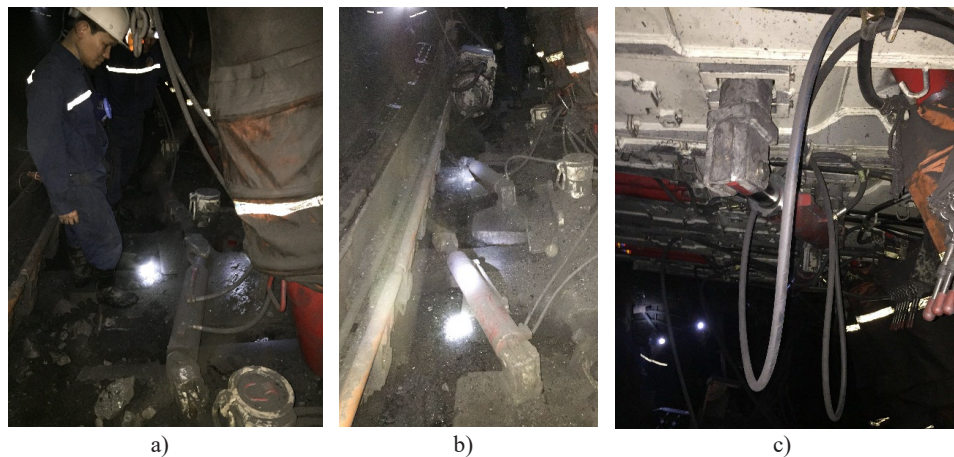


Fig. 2. Hydraulic jacks against drifting, anti-topple of face conveyor at mechanized longwall, Quang Hanh Coal Company; a) Anti-drift system of power support, b) Anti-drift system of face-conveyor, c) Anti-topple system of power support

This solution has been practically applied and highly effective in some mechanized longwall mining at the medium thick seams in Chinese underground mines such as Doanh Coc Son and Xuong Hung of Ban district - Guizhou; Dai Hung mine - Tao Trang; mine No. 10 - Binh Dinh Son - Ha Nam Province; Tuan Duc Mine - Hac Cuong Mine - Hac Long Giang Province .... The mechanized longwall have a length of 100 ÷ 150m, have coal output of 350,000 ÷ 600,000 tons/year, some favorable cases, the longwall capacity reaches 1.5 million tons/year, labor productivity reaches 20 ÷ 50 tons/work, the exploitation coefficient reaches 90 ÷ 95% [2]. In Quang Ninh region, the longwall CGH TT-6-1 located in the coal seams 6 of the Trung Tam area, Quang Hanh coal mine has been equipped with anti-drift hydraulic jacking system, the longwall relatively stable operation in sloping conditions of about 25°.

### 3 Solution of longwall mining in the direction of selling oblique to reduce slope angle

This solution set the coal face of longwall in the semi-oblique direction to reduce the dip angle of the longwall (Fig. 3). The degree of dip angle of the longwall  $\alpha_{lw}$  (compared to the true dip angle of coal seams  $\alpha_{cs}$ ) depends on the semi-oblique angle between coal face and the strike of the coal seams (or the line of dip)  $\gamma$ .

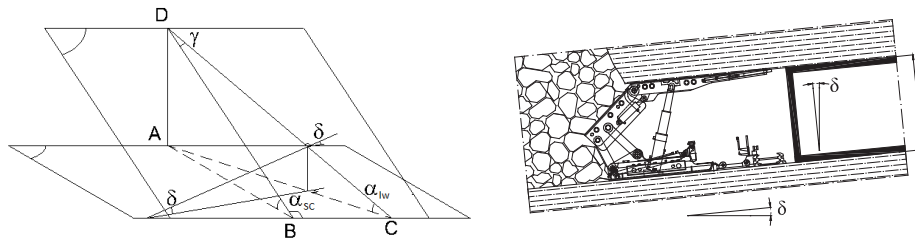


Fig. 3. Diagram to calculate the dependence of the dip angle of longwall  $\alpha_{lw}$  and the angle of the coalface into the semi-oblique angle  $\gamma$

The relationship between the dip angle of the longwall  $\alpha_{lw}$ , the true dip dip angle of the coal seam  $\alpha_v$  (Fig. 4), inclined angle of the coal face  $\delta$  with the semi-oblique angle of the coal face compared to the the line of dip  $\gamma$  (Fig. 5), is represented by the formulas:

$$\sin \alpha_{lw} = \sin \alpha_v \times \cos \gamma; \sin \delta = \sin \alpha_{cs} \times \sin \gamma \quad (1)$$

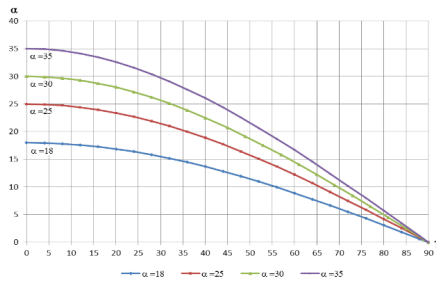


Fig. 4. Chart of the dependence of the dip angle  $\alpha_{lw}$  in the semi-oblique angle of longwall  $\gamma$

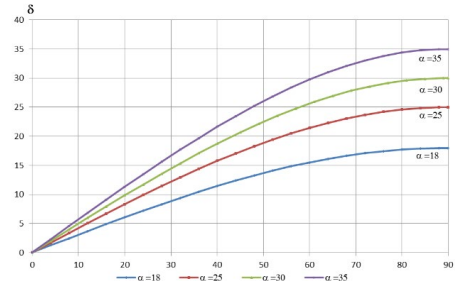


Fig. 5. Chart of the dependence of the inclined angle of the coalface  $\delta$  to the semi-oblique angle  $\gamma$

Based on the chart in Figure 4, Figure 5 can be seen in the case of the longwall kiln perpendicular to line direction of coal seam (semi-oblique angle  $\gamma = 0^\circ$ ), the slope angle of the longwall will be equal to the slope of coal seam. For example, if coal seams have dip angle  $\alpha_{cs} = 25^\circ$  and the semi-oblique angle  $\gamma = 35^\circ$ , the dip angle of the longwall will be  $20^\circ$ , corresponding to a decrease of  $5^\circ$  compared with the seam dip angle. However, if set the conveyor gateway area of the longwall go ahead the air-return gateway area, we will create a semi-oblique angle as above, the coalface of longwall will tilt accordingly at an angle of about  $\delta = 13 \div 14^\circ$ , easy to happen risk, for example, failed roof, coal falling. Thus mining operations may stop and major reinforcement begin immediately. To avoid this phenomenon, we can set the coal face in the opposite direction, The head area of longwall is over the foot are of the longwall (Fig. 6b) or the foot areas are still advanced ahead of the longwall but the coal face is straight (Fig. 6a).

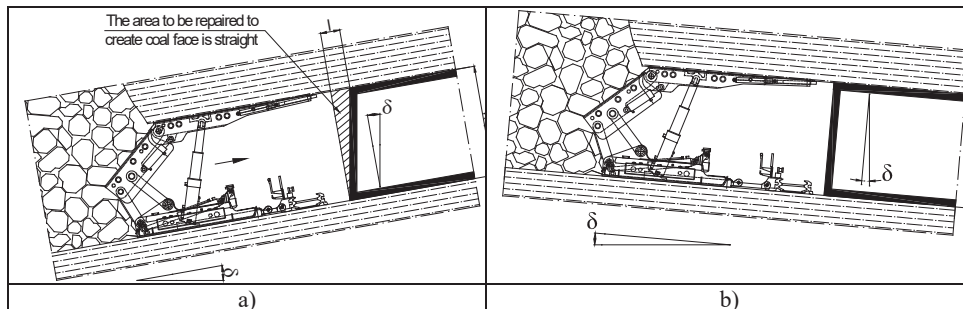


Fig. 6. The type of coal face in a semi-obliques longwall, a) support case of longwall legs first, b) support case of longwall head first

Along with the layout of semi-obliques longwall, the arrangement: supports - face conveyor (Fig. 7a) is often preferred over the oblique form (Fig. 7b) because the structure of the link between the face conveyor and the hydraulic anti-topple jacks (or hydraulic anti-slip device) is simpler, easier to fabricate and more durable, as well as the supports structure of the supports can be reduced significantly less.

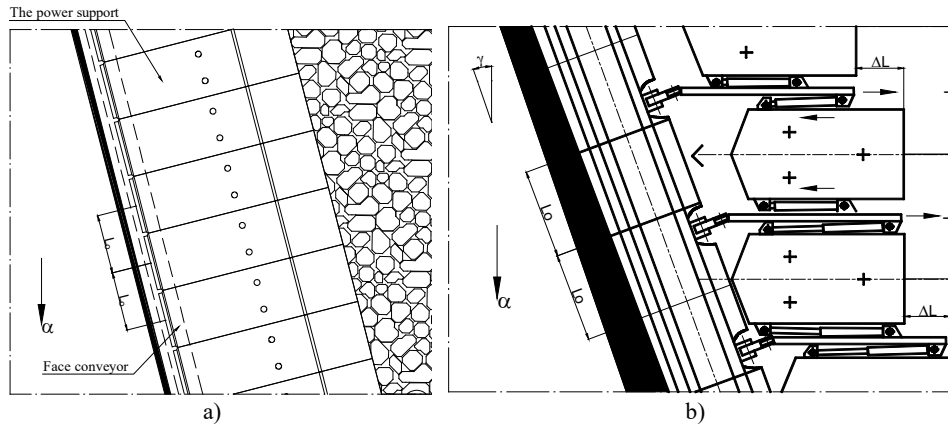


Fig. 7. The arrangement of the power support – face conveyor in a semi-oblique longwall; a) the power support - face conveyor are perpendicular in a semi-oblique longwall, b) the power support - face conveyor are oblique in a semi-oblique longwall

However, the arrangement of mining in the form of the first part of the longwall goes ahead, the major disadvantage is that according to the mining schedule, the support system and the face conveyor will automatically move down, although it is not affected (or subjected to little) impact by the dip angle. Meanwhile, the coal face of the longwall has legs ahead, often with the opposite direction of movement, the support and the face conveyor move themselves upwards according to the progress of mining and effectively overcome the drift downwards [3,4]. With the above arrangement, combined with the solution of using hydraulic system, anti-topple jacks and anti-drifting, the longwall has made relatively good exploitation, avoiding impacted slippery due to the influence of seam dip angle. Underground coal mine applied simultaneously with the above two solutions bring good results. For example, the Tuan Duc mine, Heilongjiang province, China used support HY-300, the KYBLK-70 scraper with combine machine KWB-3RW exploiting coal seams with average thickness of 2.75m, the 35° dip angle gives mining capacity of 350 thousand tons/year, labor productivity of 10 tons/work or Dong Vinh II mine, Hac Long Giang province using support ZZ4800 / 15/30, SGZ-764/2 × 200 and shearer MG250 / 601QWD in the longwall length of 114m to exploit coal seams with thickness 2.7m, dip angle 34° for a capacity of 1.580,000 tons/year, labor productivity reaches 45 tons/work shift [2].

#### 4 Solution to organize diagrams of mechanized mining coal face in longwall

This solution use a shearer in one direction from top to bottom (Fig. 8). The movement direction of the machine from bottom to top is done in the form of no-load movement. The control of shearer in the direction from top to bottom has create the device thrust upward reduce the slippage effect of the face conveyor indirectly to reduce the slippage effect of the support because the support and the face conveyor are always linked together.

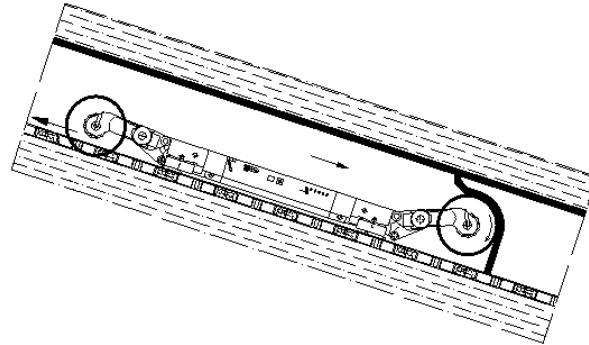


Fig. 8. Diagram of shearer mining coal faceshearer

This solution has been applied at the longwall 10121, 12 mines of Lao Oc Co mine, Quy Chau province (China), exploiting seams with thickness  $1.5 \div 5.5$  m, average 3.5 m, dip angle  $32 \div 45^\circ$ . Synchronous equipment includes the ZFQ4000/15/26 power support, combine MXG-250/600QWD and the SZ730/400 face conveyor for a 190,000 tons/year capacity. In order to reduce the influence of the seam dip angle, the coal mine has organized a mining diagram in one direction from top to bottom, the direction of the moving upwards is done in the form of no-load. Accordingly, when the coal face is cut, the previous cutting drum of the shearer cuts off the top coal, the next one cuts the flat coal, each one arranges a driver. Due to the steep angle of the longwall, during the time of coal mining, the machine operator must stand inside the column of anti-rig pillars, use the control to manipulate the control of the machine to avoid falling coal and rock. Due to the longwall dip angle is large, after cutting coal, the moving position of the support is at least 20 m from the combination of the shearer, to prevent rolling rock from causing accidents for workers at the time of moving the support apply the sequence from bottom to top.

### 5 Solution top coal caving and reduce the dip angle of the conveyor gateway area of the longwall

This solution is only applied to mechanized longwall top coal caving (Fig. 9). Characteristics of the mechanized longwall top coal caving is that after the recovery, the exposed area of the support on the top coal is significantly reduced and under the influence of the dip angle, the rear base of power support tends to drift downwards in steep direction, making the support less stable. In order to overcome this phenomenon, it is possible to arrange a conveyor gateway located on the side of the roof to create the scope of the foot of the longwall create a segment with a low slope angle (Fig. 9). At the same time, increasing the recovery progress of coal (usually, after about 2 steps of exploiting and executing the recovery of coal down). This solution can improve the stability of the support by indirectly increasing the contact area of the support with the top coal and a part of the foot of the longwall with a low, almost non-slip slope will create a base for the support will not drift down.

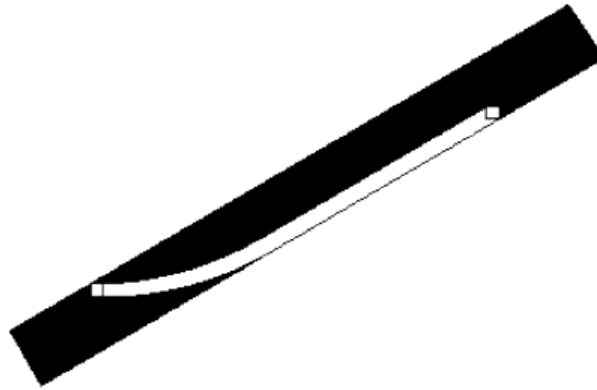


Fig. 9. Preparation diagram to reduce slope angle at the foot of the longwall

This solution has been applied in the longwall 44407 at Vuong Gia Son coal mine - Noi Mong area to exploit soft coal seam ( $f = 1$ ), thickness of  $13.5 \div 23\text{m}$ , dip angle  $38 \div 49^\circ$ . The length of longwall is  $145\text{m}$ , located at a depth of  $260 \div 320\text{m}$  compared to the topographic surface with longwall height is  $2.4\text{m}$  (the remaining coal is lowered to the ceiling) with a capacity of  $53,000$  tons/month. In addition, at the longwall 5335 U Lan mine - Noi Mong area has also applied mining mechanization technology in very soft coal seam conditions ( $f = 0.6 \div 1.2$ ), average coal seam thickness  $8.0$  m, dip angle from  $25 \div 35^\circ$ . The length of the longwall according to the line of dip is  $110$  m, the depth of exploitation is  $-350$  m compared to the topographic surface, the longwall output reaches  $70,000 \div 80,000$  tons/month.

## 6 Summary

Some solutions for enlarging the application scope of the fully mechanized longwall mining technology at underground coal mines as above, limiting the adverse effects of seam dip angle has been drawn from practical experience in underground mines around the world. The consideration of the application of the above solutions may help mechanized longwalls at Quangninh underground coal mines to improve the exploitation efficiency.

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