

## **The Application of Horizontally-Directional Long Drilling for the Bearing Mining in Dongjiahe Coal Mine**

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**Abstract** The hydrological conditions are extremely complex in Dongjiahe coal mine of Chenghe mining company. Glutinous clay- cement slurry has been used to strengthen and rebuild the target strata which is under coal seam 20-30m since 2005. This technique enabled the bearing mining technology had made a breakthrough progress, which improve the production environment of Dongjiahe coal mine, and the output increased from the 400,000 tons to the 1000,000 tons. Because of the accessing cost, it will use the horizontally-directional long drilling technology to strengthen and rebuild the target layer which is under coal seam 25-30m in continuation working face. This scheme had decreased a special grouting crossheading in each face, the number of drill fields had decreased 85%-90%, the period of water control was shortened to 50%, the cost of the water control had an average reduction of 10 million yuan-15million yuan in each working face, and reduced the loss of coal pillar between working face. It can carry out the grouting transform in a mining area, which will have obvious economic benefit.

**Keywords** horizontally-directional long drilling, bearing mining, floor strengthening, grouting transform

### **Geological and hydrogeological in Dongjiahe coal mine**

#### ***General geology***

The basic structure form of Dongjiahe coal mine is the monoclina structure with the strike to north-east-east and the inclination to north-north-west. The dip angle is between 3° to 25°, usually around 8° and the biggest is nearly 20°.

The variations are the gradual undulation in the strike and alternate steepness and slowness in the inclination. The fold and breakage construction are rather developed, and the fold is the main. The folds are mainly the closed short-axis anticline and syncline with the range between 5 m to 20 m. The faults are generally developed, and mostly are normal faults. Moreover, the fall of the faults is mostly below 4.5 m, the most of faults are nearly east-west direction and south-north direction developed. In addition to the fault, the layer slider of the No. 5 coal seam is so developed that it lead to the coal thickness varies rapidly.

In Dongjiahe coal mine, the exploitable index of No. 3 coal seam is 33% with fragmentarily exploitable. The thickness of coal seam is between 0 m to 1.28 m, the thickness is 0.71 m in the exploitable range. Furthermore, there is simple coal-bed structure, occasionally with a layer of dirt band, the buried depth of the No. 3 coal seam is between 308 m and 458 m, and the scale height of the base board of the coal bed is between +255 m and +298 m.

The No. 5 coal seam is the main exploitable, located in the roof of the Taiyuan formation with a stable. The exploitable index of 97.7% and thickness between 0 and 3.94 m, usually around 3.5m; with a complex construction of coal bed, it includes 1 to 3 layer of dirt band, usually 2 layers. Additionally, the buried depth of the coal seam is 182 to 420 m, and the floor level is +234 m to +380 m.

The thickness of the No. 10 coal seam is 0 to 3.94 m, generally about 1.44 m. The buried depth is 360 to 489 m, and the floor level is +212 to +252 m. At present, the No. 10 coal seam can't be exploited with the existing technology as the coal seam is all seated below the elevation of ordovician limestone hydrostatic level (the elevation of limes hydrostatic level in the mine zone is +370 m), and it is separated with the limestone surface by an aluminum mudstone as thick as 0.42 to 4 m. It cannot avoid the ordovician limestone water damage.

### Hydrogeological conditions

The hydrological conditions are extremely complex in Dongjiahe coal mine of Chenghe mining company. In 1970s, as the ordovician limestone karst water burst abandoned the +300 m level and +330 m level which was under construction, the level had to be risen to the existing +355 m coal-bearing strata. The division and main characteristics of the aquifers (aquifuges) in Dongjiahe coal mine are illustrated in fig. 1.

Times		Spacing of layers		Columnar	Number of layers	Thickness (m)	Lithology	units-inflow (L/sm)				
the lower Permian series	the lower Shibezi formation	205.85 m	79.5m			$\frac{6.6-46.13}{29.80}$	mudstone, sandy mudstone, fine-grained sandstone	aquifuge				
					K middle	$\frac{1.8-27.68}{9.08}$	medium-grained sandstone	0.0013~0.0132				
					1 # 2 #		coal seam sandy mudstone	aquifuge				
					K *	$\frac{0-11.59}{4.98}$	fine-grained sandstone	Weakly Water-carrying layer				
	Shanxi formation		40.62m			12.83	siltstone	aquifuge				
					K 4	$\frac{3.34-33.84}{14.17}$	fine-medium grained sandstone	0.0000939~0.00481				
						$\frac{0-1.05}{0.8}$		aquifuge				
					5 #	$\frac{0-5.54}{3.44}$	coal seam					
				the upper of Carboniferous	Taiyuan formation	29.56m	20.3m		9 #	$\frac{11.68-32.80}{20.30}$	coal seam quartz sandstone, siltstone, sandy mudstone	aquifuge
									K 2	$\frac{0-4.15}{2.02}$	quartz sandstone, limestone	0.0316~0.732
	10 # K 1	$\frac{0.41-23.01}{7.24}$	coal seam aluminum mudstone					aquifuge				
middle Ordovician	Fengfeng formation				O2r <sup>2</sup>	147.3	limestone, dolomitic limestone, marl	0.2~1.51				

Fig.1 The aquifer and aquifuge in Dongjiahe coal mine

With the production to the deep, the coefficient of pressure-bearing of the extracting coal face constantly increase, threaten to further increase by underlying the Ordovician limestone karst water, and with the increase of production strength, slope length of the working face increasing, using original the bearing mining technology to transform bottom technology increased costs and workload, lengthened time limit for a project, seriously affected

production succeeded. So, using horizontally-directional long drilling technology was necessary and reasonable to do the bearing mining bottom renovation.

**Reinforcement scheme of the directional edgewise long drilling**

To meet the time requirements of production and reduce the cost of the mine drilling construction, 22517 working face and later 22511, 22513, 22515 working face proceeded grouting reconstruction reinforcement to under the coal seam bottom selected target by employing the directional edgewise long drilling craft, the drilling plan of the directional edgewise long drilling craft is fig. 2. Fig.3 is the drilling stereo space diagram, and fig.4 is drilling structure chart.

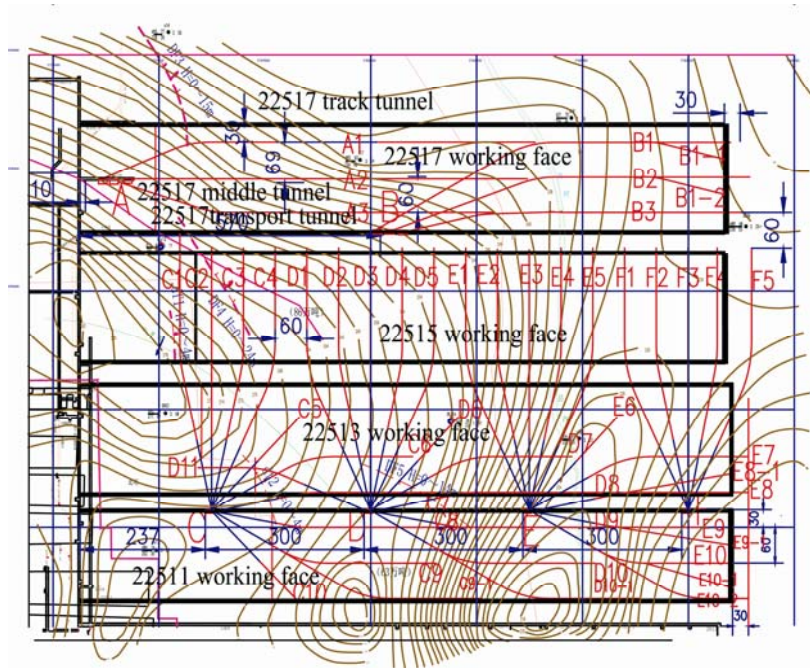


Fig.2 The drilling plan of the directional edgewise long drilling craft

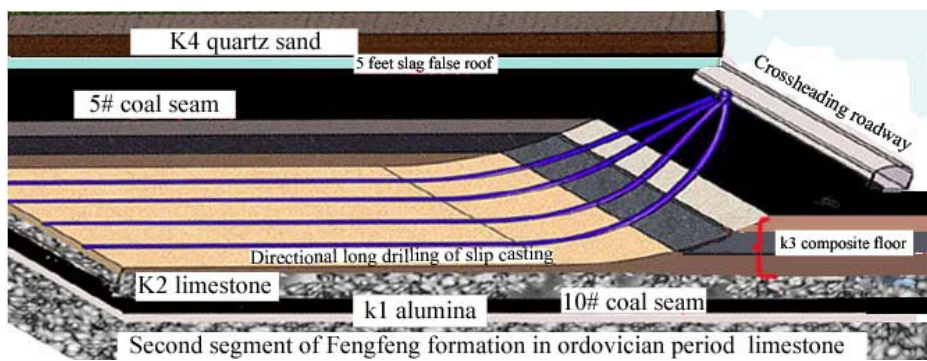


Fig.3 Drilling stereo space diagram

At present, if we don't consider continue intension and firstly continue 22517 working face, the four working faces (22511-22517) can only construct four drill sites in the 22517 track tunnel or 22515 transport tunnel. The four working faces (or a mining area) were strengthened and transformed one time. After this, the costs can be reduced relative to the original reinforcement retrofit scheme which working face were transformed one by one or

widened the middle construction grouting tunnels. Retrofit scheme of the four working faces is fig.5.

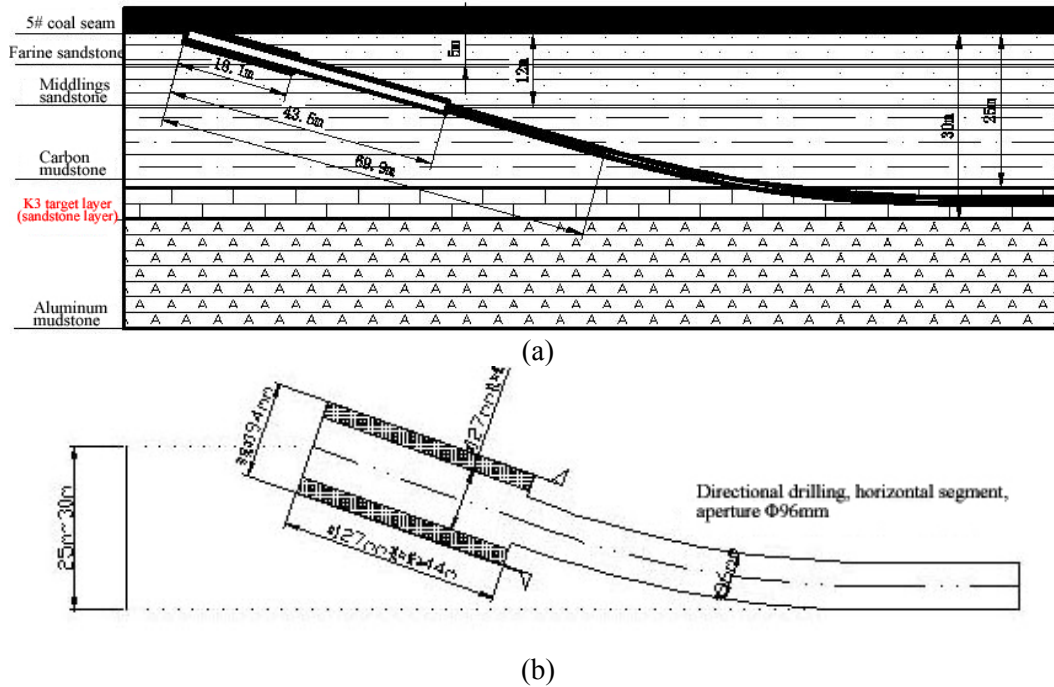


Fig.4 Drilling structure

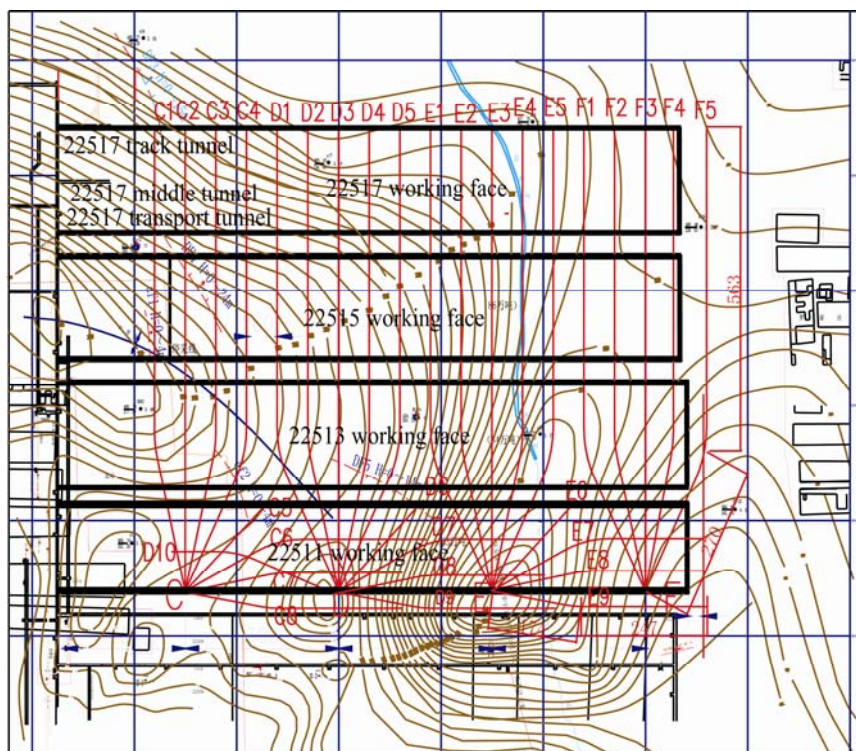


Fig.5 Retrofit scheme of the four working faces



Reinforcing serous still used cement soil+ cement+ aggregate (when it is necessary to add), grouting still used the automatic grouting station which have been completed. The principle and main parameters of the design scheme:

- (1)The bottom should be comprehensive principle of the grouting reinforcement and reconstruction without grouting blind spots.
- (2) The horizontal spacing of the bottom grouting drilling was 60~80 m, diffusion radius was 30~40 m less than before 50~60 m. Waterproof effect will be better after transforming.
- (3) The reinforced and reconstructive target horizon was selected under the sandy mudstone of the bottom 25~30 m, can construct along the top layer, the drilling path was changed from shallow place to target horizon when the drilling constructive process encountered aluminum mudstone K1 of the 10# coal seam bottom.
- (4) The order of the drilling construction was from external to internal, A, B, C, D, E, F. Using several drills to run at the same time.
- (5) The size of the every drilling field was 8 m×5 m.
- (6) The drilling was employed level 2 or level 3 installing telescopic scheme. The depth of the level 1 hole sealing was tunnel bottom coal and fake bottom, the vertical depth was around 5 m. The depth of the level 2 installing telescopic was the dynamic pressure influence depth, the vertical depth was around 12 m. The depth of the level 3 hole sealing was confirmed on the basis of the lithology, can reach the around target layer. Every sleeve must do a bulge test when it was installed.

### **The construction scheme**

- (1) The construction equipment and drill was adopted ZDY6000 underground tracked drill and YHD2-1000 MWD system.
- (2) According to the rock strata, the drilling construction was adopted the combination of the rotary drill and directional drill.
- (3) Using the ground grouting station (fig. 6) produced double seriflux to drilling poured when drilling external water yield come to particular extent or the drilling depth was equal to the length of the grouting.



*Fig.6* Ground grouting station

(4) According to the previous experience to confirm grouting quantity and pressure, until bottom water pouring out in the drilling, the pressure of the final drilling reached to 5-6 MPa.

### Analysis on economic benefits of technology

Before 2013, we always adopted the relevant states which had been the successful first confined recoverable experiments. According to the diffusion range of seriflux, the working face length of incline section of the long wall face along strike usually was less than 120 m, the layout plan of drilling is fig.7.

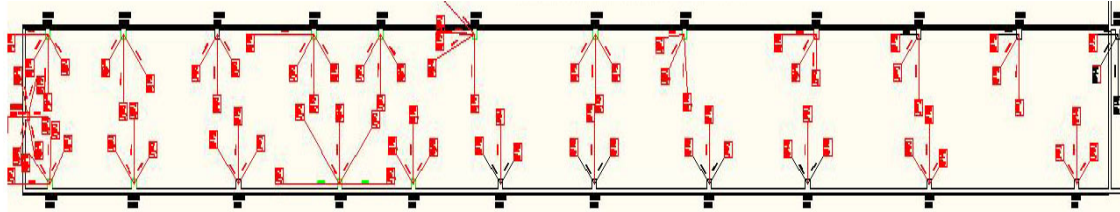


Fig. 7 Layout plan of drilling

In 2013, with increasing recoverable strength, it needed to increase the slope length of the working face. The 180 m slope working face was constructed a special grouting tunnel in the middle of the two tunnels. The arrangement of the working face is shown in fig 8.

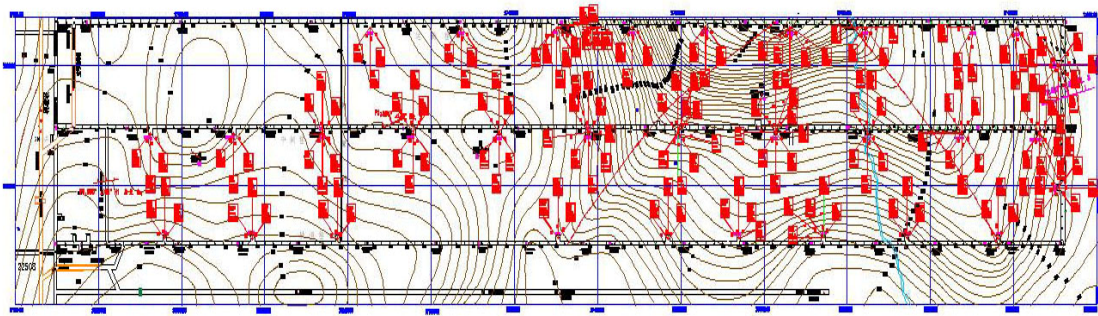


Fig. 8 Layout plan of drilling

The original scheme, special grouting tunnel scheme, the directional edgewise long drilling scheme, engineering quantity, grouting quantity, the cost of prevention and control water each ton were seed attached table 1.

From table 1, we can see which the directional edgewise long drilling had obviously economic advantage in the three schemes and reduce the costs of prevention and control water from original 46.6 yuan to 13.6 yuan. However, the directional edgewise long drilling scheme needed large initial investment, high technical requirements and difficult construction, especially, the construction difficulty of the target layer was great difficult when it came to the complex structure of the coal seam bottom, uneasy the thickness of target layer, much fold, lesser amplitude of fold or the easy to collapse hole soft rock. These questions which were repeatedly collapse hole, invalid branch hole and more footages have occurred in the construction process of A1 and A3 drilling, those have produced some effects to construction stage.

### Existing problems and points for attention

(1) At present, the screw motor torque of the directional drill was smaller. The construction speed was slower when it came to hard target layer. So, the bit needs further improve.

(2) The drilling construction should consider adopting floral or mud to protect drilling when construction was in the soft rock.

(3) To the complex construction aquifuge, uneasy the thickness of target layer, much fold, lesser amplitude of fold, we can consider adopting the method of the wear layer drilling, or directional and revolving drill to alternate construction.

(4) According to the practical construction fact, we known that construction speed of limestone was faster, construction speed of quartz sandstone or soft rock (bauxite, argillaceous, and so on) was slower, higher technical requirements and difficult construction technology.

(5) We must adequately argument the important conditions, such as the hardness of target layer, the stability of layer thickness, thickness, strata fold and amplitude before adopting the scheme.

*Table 1 The cost comparison on the original scheme, big working face scheme and new craft scheme*

No.	Schema name	Drilling project		Grouting project		Auxiliary project			Subtotal	Investment (Yuan/ton)
		Project quantity (m)	Cost (million yuan)	Quantity (m <sup>3</sup> )	Cost (million yuan)	Drill site(unit)	tunnel	Cost (million yuan)		
1	the original scheme(22508 face)	92/2300	5.95	52596	9.993	24×5 120 m		0.48	1643	35.2yuan/ton (0.466 million ton)
2	big working face scheme(22509 face)	130/5557	11.71	29771	5.6564	42×5 /210 m	1200 m	4.44	2181	32yuan/ton (0.068 million ton)
3	new craft scheme (four faces)	21330, 53320	31.99	40000	7.6	5× 40 m		0.16	3975	13.8yuan/ton (2.88 million ton)
4	one time construction scheme(four faces or a mining area)	21000	31.5	40000	7.6	4× 32 m		0.13	3923	13.6yuan/ton (2.88 million ton)