Study on application of high speed cross belt auger drilling machine in fragmentized coal seam

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Abstract: In order to extract gas efficiently in soft outburst coal seam with belt haulage roadway, a ZDY2800LG full hydraulic drilling rig with high drilling rate, cross-belt construction ability and strong adaptability of technology was developed. The whole process of industrial test of drilling machine is introduced in detail through three stages of formation groping, breakthrough seeking and efficient drilling.

1. Introduction

Gas control is the fundamental measure to reduce and eliminate the occurrence of gas accidents, and the key and focus of gas control lies in the construction of gas extraction drilling [1]. China’s soft coal seams are more widely distributed, accounting for about 42% of total coal output. This kind of coal seam has low intensity, fast gas desorption speed and relatively high gas content, and belongs to coal and gas outburst [2-3]. It is found in the study that in the construction of gas extraction in soft coal seam, the spiral drilling technology is adopted to conduct the spiral drilling, and the hole forming effect is good, which is an effective drilling construction method [4-5]. The screw drilling process is adopted for drilling. When the rotating speed of the drill is relatively high, the powder discharge effect is good, which can effectively reduce the resistance inside the hole, thus improving the drilling efficiency and drilling depth [6].

At present, the domestic most of the coal mine gas extraction drill due to factors, such as drilling machine structure is more suitable for in the absence of a belt conveyor roadway in homework, while working into a belt conveyor roadway drill cannot effectively across the belt operation, so that reduces the working efficiency, also increased the labor intensity of workers [7].

ZDY2800LG type coal mine crawler full hydraulic tunnel drill is a kind of full hydraulic tunnel drill with high speed, large torque, which can carry out the construction across the belt. It is mainly applicable to the construction of gas extraction hole across the belt in coal mine. This drill has advanced technical performance, strong adaptability, safety and reliability, and is convenient for moving and moving.
2. Drilling rig structure and parameters

1. Electromagnetic starter 2. Radiator 3. Pumping station 4. Hang lifting device 5. Manipulator 6. To stabilize the angle adjustment device 7. Host 8. Seat 9. Foot body

Fig 1. Diagram of the rig structure

As shown in Figure 1, the rig is organized as a whole. It consists of nine parts: an electromagnetic starter, a radiator, a pumping station, a lifting device, a console, a solid angle adjustment device, a host, a seat, and a track body. Each part is connected by a high-pressure hose and bolts. Compact structure, high reliability.

The ZDY2800 LG crawler type full hydraulic tunnel drill is mainly suitable for the construction of gas pumping holes across the belt under the coal mine, which meets the requirements of high speed, large adjustable range of drilling angles, flexible operation, and strong technological adaptability. The main performance parameters of the rig are as follows:

Table 1. Basic parameters of the ZDY2800 LG rig

| Name                        | Number of parameters |
|-----------------------------|----------------------|
| Rated torque / N.m          | 2800〜400             |
| Rating speed /(r/min)       | 200〜800              |
| Rating speed /(r/min)       | -20〜20               |
| Maximum entry/pull / kN     | 120/160               |
| Give in/out stroke / mm     | 1800                  |
| Motor rated power / kW      | 90                    |
| I/II/III pump displacement / (ml/r) | 145/28/10         |
| Climbing ability / °        | 15                    |
| Maximum walking speed /(km/h) | 2.5                |
| Shape Dimension/m           | 5130×1200(3380)×2060  |

3. Industrial tests

In August 2015, the ZDY2800LG rig passed the performance test at the Xi'an Exploration Equipment Testing and Inspection Center of the National Safety Production. All the indicators meet the design requirements. The field industrial test is located at the work face of the auxiliary wind back lane at the Wangpo Coal Mine of Tiandi Science and Technology Co., Ltd.

3.1. Overview

The amount of gas gushing out of the main coal seam of Wangpo mine is 19.22 M /t, which belongs to the high gas mine. In the test area, the coal seam of the auxiliary wind back lane at 3316 is 3 # coal, the thickness of the coal seam is 4.20 to 7.89 M, the average hardness coefficient of the coal seam is 5.82 M, and the hardness coefficient of the coal seam is about f = 0.32. Most areas are soft and broken, and the gas content is high and easy to spray holes., joint crack development, The coal seam structure generally contains L to 2 layers of single layer thickness of 0 to 0.4 M, coal seams contain water.

The test rig is a spiral drill rod with a spiral angle of 28.5 °, a pitch of 100mm, and a drill rod length of 1.5 M and 1M. The drill rod adopts a hexagonal interconnect connection. Through U-shaped pin
fixation, positive and reverse construction can be carried out. The drill rod structure is shown in Figure 2.

![Fig 2. Spiral drill pipe for test](image)

There are two structural forms of three-wing cemented carbide bit and four-wing concave bit in the test. The bit structure is shown in Figure 3.

![Fig 3. Test drill bit](image)

The field industrial test is divided into three stages according to the degree of progress of the test. The first stage is the stage of familiarity with the strata, groping equipment and drilling tools, and the stage of technological adaptability. The second stage seeks the average hole depth and drilling efficiency on the basis of the previous stage. Data breakthrough stage. The third stage is based on the previous two stages, according to the stratigraphic reasonable selection of drilling tool grading relationship, the pursuit of efficient drilling.

### 3.2. Stage of stratigraphic exploration

At this stage, a 1.5-m long spiral drill rod and a 120mm three-wing cemented carbide drill bit are used. A total of 51 boreholes, a total length of 3135.5 M, and a maximum borehole depth of 201m are used. The normal comprehensive drilling efficiency reaches 42 m/h or more. See table 2 below for borehole information.

| Number boreholes (pieces) | Construction cycle (shifts) | Portable ratio (%) | Maximum holedepth (m) | Average holedepth (m) | Average efficiency (m/d) | Depth 100m ratio(%) |
|---------------------------|-----------------------------|--------------------|-----------------------|-----------------------|-------------------------|-------------------|
| 51                        | 42                          | 65.9               | 201                   | 78.8                  | 190.5                   | 24.1              |

It can be seen from the table that the proportion of holes, the maximum depth of holes, and the drilling efficiency are all unsatisfactory. After exploration by the project team, it is speculated that the three-wing cemented carbide bit has a poor straightening effect in soft coal drilling, and it is easy to enter the top and bottom plate prematurely.

Using YZG7 borehole track measuring instrument, the borehole trajectory of one of the three-wing cemented carbide bit construction drilling and two four-wing concave drilling bit construction drilling are remeasured, and the trajectory trend of the two kinds of drilling bits into holes is also mastered.
It can be seen from Figure 5 that 1 # hole uses a three-wing scraper bit after 65 meters, the trajectory begins to sink rapidly, and prematurely touches the bottom plate, while 2 # and 3 # drilling using a four-wing concave drill bit have better straightness. The reason for the analysis is that the three-wing scraper drill bit does not have a good support during the drilling process. The tight connection of the drill pipe provides a certain degree of straightness in the early drilling period. When entering a certain depth, the accumulation of connections between the drill rods cannot provide the drill bit with straightness. Drilling is easy to enter the bottom plate prematurely. The four-wing concave drill bit has formed a better support between the four-wing and the hole wall, so the straightness is good. The project team decided to replace the drill bit with a four-wing concave drill bit.

3.3. Search for Break-through Phase
At this stage, a 1.5 m long spiral drill rod and a 120mm four-wing concave drill bit are used to complete a total of 66 effective drilling scales, an effective total drilling scale of 60877m, an average drilling depth of 92.2 M, and an average comprehensive drilling efficiency of 45m/h. The total drilling speed is up to 60m/h, with an average daily rate of 265 M. The following table compares the construction of the drilling of the ZDY2800 LG rig and the 3316 auxiliary wind return lane to other types of drilling rigs in use nearby.

| Number | Rig         | Plan footage (m) | Maximum depth (m) | Average depth (m) | Average Efficiency (m/d) | Depth 100m ratio(%) |
|--------|-------------|------------------|-------------------|-------------------|--------------------------|---------------------|
| 1      | ZDY2800LG   | 3000             | 190               | 92.2              | 265                      | 33.3                |
| 2      | ZYWL6000    | 3000             | 165               | 74.17             | 264                      | 12.9                |
| 3      | ZDY1900L    | 3000             | 55                | 48.68             | 204                      | 0                   |
| 4      | ZYWL6000    | 1000             | 66                | 48.31             | 149                      | 0                   |

It can be seen from the table that the data such as total flow gauge, maximum hole depth, average hole depth, average drilling efficiency and 100 m hole depth drilling ratio are obviously superior to other drilling rigs used at the same time in the mine. The high speed of the drilling rig The performance of the cross-belt is reflected.

3.4. Efficient drilling phase
At this stage, a 1M spiral drill rod with a long 1mm four-wing concave drill bit is used to complete a total of 32 effective drilling scales, a maximum hole depth of 137M, an average drilling depth of 98.8 M, and an average integrated drilling efficiency of 296.4 m/d. Table 4 shows the data for the drilling of the ZDY2800 LG rig during the high efficiency drilling phase.

| Number boreholes (pieces) | Construction cycle (class) | Maximum hole depth (m) | Average hole depth (m) | Average drilling efficiency (m/d) | Depth 100m ratio(%) |
|---------------------------|-----------------------------|------------------------|------------------------|----------------------------------|---------------------|
| 32                        | 32                          | 137                    | 98.8                   | 296.4                            | 65.2                |
The goal of this stage is no longer to pursue the maximum hole depth, but to focus on the hole depth of 100 meters in the hole rate. From the data in the table, it can be seen that the hole formation rate, the average hole depth, the average drilling efficiency, and the proportion of the hole depth 100M are all higher than those in the search for a breakthrough stage. In particular, the ratio of the hole depth 100m has a qualitative improvement over the previous stage.

3.5. Summary
Stratigraphic exploration, seeking breakthroughs, and high-efficiency drilling into the three stages of hole formation ratio, average hole depth, average drilling efficiency, and average hole depth of 100M are shown in Table 5:

| Stage                  | Portable ratio(%) | Average hole depth (m) | Average drilling efficiency (m/d) | Depth 100m ratio(%) |
|------------------------|-------------------|------------------------|----------------------------------|--------------------|
| Stratigraphic exploration stage | 65.9 | 78.8 | 190.5 | 24.1 |
| Search for Breakthrough Phase | 86 | 92.2 | 265 | 33.3 |
| Efficient drilling phase | 100 | 98.8 | 296.4 | 65.2 |

It can be seen that the data for the three stages of stratigraphic exploration, exploration and efficient drilling are steadily improving, with the average drilling efficiency at the efficient drilling stage reaching 296.4 m/d and the ratio of hole depth to 100 m reaching 65.2 %. The industrial test of the ZDY2800LG rig was successfully completed.

4. Conclusions
(1) The capability of the drilling rig has been tested.

The ability of the drilling rig was fully tested through an effective feed gauge of more than 20,000 meters in the past 5 months. The advantages of high-speed cross-belt drilling were fully reflected. The fan cooling hydraulic oil was used to improve the drilling efficiency.

(2) Explore a new process method for soft coal drilling

Wangpokuang is recognized as a difficult to drill complex strata. Through experiments, he explored a technical method to solve the gas drilling hole in Wangpokuang's special strata, and solved the construction difficulties of the gas pumping hole in Wangpokuang's broken coal seam.

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