Sealing method and experimental study of large-diameter reverse circulation hole hammer

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Abstract: A reliable sealing structure is the key to achieving reverse circulation drilling technology for large-diameter reverse circulation down the hole hammers, and it is also a difficult point in the design of large-diameter reverse circulation down the hole hammers. The existing large-diameter reverse circulation down the hole hammers are designed based on the sealing structure of the bottom drilling tool body. This article proposes a joint sealing method for hole bottom and hole opening. Based on this sealing method, a bundle type reverse circulation down the hole hammer and hole opening sealing device with a diameter of 710/311mm were developed for hole expansion, and field tests were conducted with a double wall drilling tool with a diameter of 127/70mm. The method achieved good continuous reverse circulation slag removal effect, with an average mechanical drilling speed of 2.1m/h, which is 2.6 times higher than the conventional roller bit hole expansion method. The experimental results indicate that the joint sealing method between the bottom and the mouth of the hole is feasible and worthy of further promotion and application.

1. Introduction

In recent years, with the rapid increase in the construction volume of gas extraction holes, ventilation holes, strong drainage holes, cable holes, rescue holes, and other large-diameter drilling holes, the application of efficient drilling technologies such as gas lift reverse circulation drilling, large-diameter PDC drill bit drilling, and large-diameter down the hole hammer drilling has also been further promoted and developed. Among them, the large-diameter down the hole hammer drilling technology has received great attention for its efficient drilling speed, and multiple relevant units have conducted research and experiments on this technology to varying degrees [1-5].

The large-diameter reverse circulation down the hole hammer can be divided into two main types according to the structure of the drill bit: single type and bundled (or bundled). Currently, there are mainly two types of large-diameter reverse circulation down the hole hammers in China [2,5-10]: single head large-diameter wet reverse circulation down the hole hammer (FGC-15, FGC-15B), large-diameter through type down the hole hammer (maximum diameter of Ø 660mm), large-diameter combined bundled pneumatic down the hole hammer (FC-312), and bundled reverse circulation down the hole hammer (maximum reported diameter of Ø 660mm).

The sealing structure is an important part of the large-diameter reverse circulation down the hole hammer and is the key to its ability to form reverse circulation. At present, the sealing structure of the reverse circulation down the hole hammer is set on the bottom of the drilling tool body. It uses the narrow space between the outer diameter of the sealing disk of the drilling tool body and the diameter of the borehole to form damping for the upward return air, promoting the upward flow of slag carrying air from the slag discharge pipe. Possible issues include: due to the sealing structure having a smaller diameter than the drilling hole formed by the rotation of the drill bit, the gap area between the outer diameter of the sealing structure and the drilling hole wall will increase with the extension of drilling time; And during the drilling process of the drill bit, there is a certain expansion rate of the drilling diameter, so the amount of compressed gas returning from the annular gap formed by the sealing structure and the drilling hole will increase, which will affect the anti circulation slag discharge effect, and in severe cases, it may even fail to form anti circulation. Therefore, a method of joint sealing between the bottom of the hole and the hole opening is proposed to overcome the above-mentioned defects. Based on this method, a bundle reverse circulation down the hole hammer with a diameter of 710/311mm and a hole opening sealing device are designed, which is matched with a double wall drilling tool with a diameter of 127/70mm and tested on site.

2. Joint sealing method of hole bottom and hole opening

The joint sealing method of hole bottom and hole opening is proposed to address the problems existing in the sealing structure of large-diameter down the hole hammer hole bottom, as shown in Figure 1. When the bottom sealing structure of the hole cannot fully meet the requirements for establishing reverse circulation, that is, a large amount of gas returns from the annular gap formed by the large-

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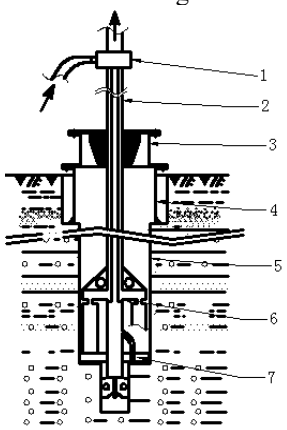
diameter down the hole hammer and the borehole, under the action of the orifice sealing device, the large annular space gap formed by the borehole and the double wall drill rod is a closed and limited space. When the gas pressure in this space reaches a certain level, it forces the compressed air at the bottom of the hole to enter the slag discharge channel of the large-diameter down the hole hammer and be discharged along the inner pipe of the double wall drill rod to the mud pit, thereby re establishing the reverse circulation channel.

The joint sealing method between the bottom of the hole and the hole opening greatly reduces the requirements for the design of the bottom sealing structure and its sealing effect. That is, the gap between the bottom sealing structure and the drilling hole can be appropriately increased, which can reduce the difficulty of designing the bottom sealing structure and improve the ability of the reverse circulation down the hole hammer to deal with complex situations inside the hole, thereby achieving the goal of safe and efficient drilling.



1. Gas box; 2. Double walled drill pipe; 3. Orifice sealing device;4. Soil layer casing; 5. Drilling; 6. Large diameter down the hole hammer;7. Large diameter down the hole hammer sealing mechanism

Figure 1 Schematic diagram of joint sealing method for bottom and hole openings

3. Bundle reverse circulation down the hole hammer and matching hole sealing device for expanding holes with a diameter of 710/311mm

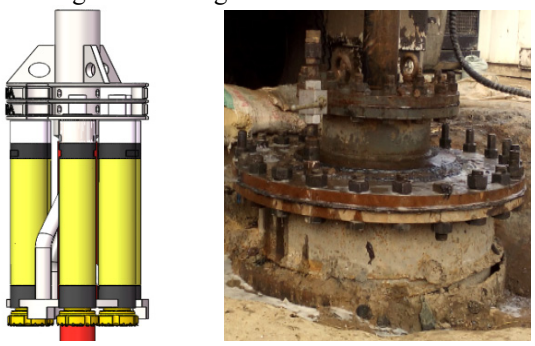
It is particularly important to ensure the reliability and safety of the coal bed methane vehicle mounted drilling rig's lifting and lowering gripper used in drilling and lowering operations. This article selects the joint body of the main structural components of the drilling gripper for strength analysis to ensure that its structural strength meets the design requirements[6-7].

3.1. Bundle anti circulation down the hole hammer for expanding holes with a diameter of 710/311mm

A bundled anti circulation down the hole hammer with a diameter of 710/311mm was developed based on the design principle of joint sealing between the bottom and the hole opening. It is a method of uniformly distributing three conventional Ø 216mm down the hole hammers on the same circumferential surface and using connection structures such as upper and lower pressure plates. The main structures include double wall joints, air distribution chambers, air down the hole hammers, slag discharge pipes, hole bottom sealing plates, and guide heads, as shown in Figure 2. Before drilling, connect a conventional roller drill bit with a diameter of 311mm at the front end of the guide head[8-9].

3.2. Orifice sealing device

The orifice sealing device is an important device in the joint sealing method between the bottom of the hole and the orifice. The structural design of the orifice sealing device should comprehensively consider various factors such as the structural characteristics of the drilling rig orifice worktable used in construction, the external characteristics of the matched Ø 127/70 mm double wall drill pipe, the large-diameter down the hole hammer and its drilling speed, air pressure, and the environmental conditions of loading and unloading operations. It mainly consists of a conical sealing core and an outer shell, which are connected to the drilling casing in a flange manner, as shown in Figure 2 and Figure 3.



1. Sealing rubber core outer shell 2. Cone shaped sealant core

Figure 2 Sealing Rubber Core Body

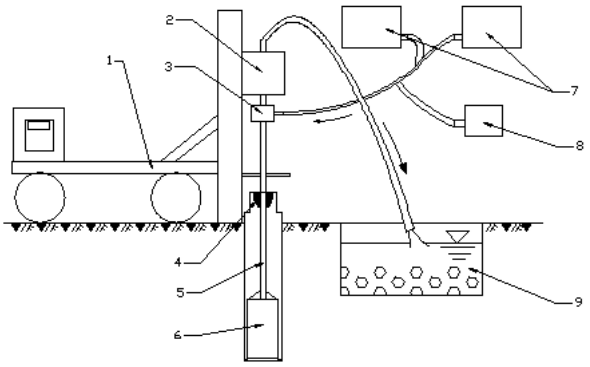
3.3. Establishment of the anti circulation channel in the hole of the 3-bundle anti circulation down the hole hammer

The channel formed by the reverse circulation inside the hole of the bundle type reverse circulation down the hole hammer used for the expansion of the Ø 710/311mm hole is as follows: the compressed air generated by the air compressor enters the gas box through the ground injection pipeline, descends along the annular gap between the inner and outer pipes of the double wall drill rod, enters the air distribution chamber through the annular gap between the inner and outer pipes of the double wall joint and the small hole set at the lower end of the outer pipe, and then enters the single down the hole hammer to drive the down the down the hole hammer to work. The exhaust gas is sprayed out from the center hole of the drill bit. Under the dual action of the bottom sealing disk and the hole sealing device, the exhaust gas is enclosed under the bottom sealing disk of the hole, carrying broken rock fragments and rock powder into the

slag discharge pipe, enters the inner pipe of the double wall joint through The pipeline goes up and is discharged to the slag storage tank through the gas box, power head center through-hole, and ground slag discharge pipeline[10-12].

4. Large diameter reverse circulation drilling test

The full hole reverse circulation drilling of the double wall drilling tool system this time uses a φ710/311mm bundled air down the hole hammer, and the double wall drill rod is a φ 127/70mm double wall drill rod. The drilling tool combination used is: φ710/311mm bundled air down the hole hammer+cross joint+φ127/70mm double wall drill rod+double wall protection joint+air box. During the test, the reverse circulation drilling process parameters such as rotation speed, injection pressure, and injection air volume are recorded every 1m of footage: injection air volume of 35m3/min, rotation speed of 26r/min to 35r/min, injection air pressure of 1.0MPa to 1.2MPa, and injection water volume of 30 m3/h (using a long rod pump to intermittently inject clean water from the annular space). The main equipment connections used in the on-site test of the reverse circulation drilling process with the bundled down the hole hammer are shown in the Figure 3.



1. Drilling rig; 2. Power head; 3. Gas box; 4. Orifice sealing device; 5. 178/113mm Double walled drill pip; 6. Ø 311mm air hammer; 7. Air compressor; 8. Water injection pump; 9. Mud pit

Figure 3 Schematic diagram of on-site equipment connection

Experimental results as shown in Table 1: The maximum depth of drilling reached 295m, with a mechanical drilling speed of 1.88m/h to 6.0m/h, an average mechanical drilling speed of 2.1m/h, and a pressure drop of 0.02MPa/m, which can meet the construction requirements of surface horizontal wells in coalbed methane mining areas.

In the remaining hard rock sections of the borehole, two types of roller cone drilling bits with specifications of φ550/311mm and φ710/550mm were used, and conventional mud rotary drilling technology was used to complete the construction. The average mechanical drilling speed was 0.8 m/h. Compared with the conventional mud rotary drilling process, the mechanical drilling speed of the large-diameter bundled reverse circulation down the hole hammer is 2.6 times higher.

Table 1 Statistics of Main Drilling Parameters and Mechanical Drilling Speed

Hole depth /m	Gas injection /m3/min	Gas injection pressure/MPa	Speed/rpm	Duration /min	drilling speed/m/h
267		1.2	35	20	3
268		1.2	35	19	3.16
269		1.1	35	15	4
270		1.1	35	20	3
271		1.2	35	25	2.4
272		1.2	35	25	2.4
273		1.3	35	15	4
274	35	1.2	35	13	4.62
275		1.1	35	12	5
276		1.2	35	15	4
277		1.2	35	12	5
278		1.2	35	10	6
279		1.2	35	15	4
280		1.2	35	20	3
281		1.2	35	19	3.16

Figure 4 Effect of reverse circulation slag discharge

5. Conclusion and Suggestions

In response to the characteristics of reverse circulation drilling with large-diameter down the hole hammer,as shown in Figure 4, this paper proposes a joint sealing method for the bottom and orifice of the hole. Its feature is that when the bottom sealing mechanism cannot fully meet the needs of establishing reverse circulation, a large amount of compressed air from the bottom of the hole will enter the large annular space gap. Under the action of the orifice sealing device, the compressed air from the bottom of the hole can be forced to enter the large-diameter down the hole hammer slag discharge pipe and be discharged to the ground along the double wall drill pipe. This method can reduce the design difficulty of the bottom sealing structure of the hole and improve the ability of the reverse circulation down the hole hammer to deal with complex situations inside the hole.

The design principle is based on the joint sealing method of hole bottom and hole opening, and a bundled reverse circulation down the hole hammer and a dedicated hole opening sealing device for expanding the hole with a diameter of 710/311mm have been developed. The ZMK5530TZJ60 (A) vehicle mounted drilling rig was used to conduct on-site drilling tests in hard rock sections, equipped with a Ø 127/70mm double wall drilling tool. During the test, the sealing effect was good, and a good reverse circulation slag removal effect could be formed. The average mechanical drilling speed was 2.1 m/h, which was 2.6 times the average mechanical drilling speed of the conventional mud rotary drilling process. The preliminary experimental results indicate that using the joint sealing method of hole bottom and hole opening as the basic design principle for designing large-diameter reverse circulation down the hole hammer is an effective method, which is worthy of further expansion of experiments and research and promotion.

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