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A new method of combined rock drilling

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ABSTRACT

Based on the technologies of traditionally mechanical drilling and water jet, we propose a new method of abrasive water jet in combination with rock drilling, and establish a combined rock drilling system for the gas pre-drainage. This study chose the common sandstone and silicon limestone as the rock sample. A series of experiments were completed in the case of dry drilling, existing technology drilling, combined drilling with high pressure water jet and combined drilling with abrasive water jet, respectively. The drilling efficiency and performance were contrasted and analyzed in detail. The results indicate that it is better to choose the method of combined drilling with the high-pressure water jet for soft rocks. The method of combined drilling with abrasive water jet is feasible for the hard rock drilling and has higher drilling efficiency and performance. In this paper, compared with the existing technology, the drilling depth has increased by about 65%, the axial force and torque have reduced by about 14% and 17%, respectively, and the drill wear reduces obviously in the same conditions.

1. Introduction

China is one of the countries with serious mine disaster in the world, especially in the coal and gas outburst, and it has brought a great physical and psychological damage to people [1–6]. In order to control the gas outburst during coal mining, many scholars at home and abroad have taken extensive studies, and many outburst prevention measures, such as dens holes, protection layer mining and hydraulic cutting seam, have been studied [7–12]. The drilling technology is the key one that constructs these measures, because the implementation of these measures all needs a lot of holes through the roof and floor, and the drilling efficiency and performance have an important influence on the cycle and effect of protection against outburst [13–15]. Drilling efficiency is mainly determined by the drilling method and rock sturdiness, and current applications show that there will be a slow drilling speed and a serious drill wear when the conventional technology is used for the gas drainage hole in the hard rock whose uniaxial compressive strength is more than 80 MPa. Especially, for the hard rock whose uniaxial compressive strength is more than 100 MPa, such as the siliceous limestone with pyrite nodules for most of coal seam roof and floor rock in southwest China, the traditional technology almost has no drilling ability on them, and it greatly prolongs the cycle of the outburst prevention and affects the coal mine safety and normal alternation of production.

In order to improve the drilling efficiency, scholars at home and abroad have done a lot of studies on the rock-breaking tool materials and rock breaking method. In the rock-breaking tool materials, various polycrystalline diamond composite (PDC) tools were made for the rock breaking [16–18]. The bits, however, are still worn seriously when the PDC bits are used for the hard rock [19–21]. Thus, construction costs greatly increase because of the high-price of PDC bits. In the rock-breaking method, since 1970s, rock breaking combined with water jet has been considered as the most promising combined rock breaking technology with water jet being introduced to assisting the mechanical tools to break the rock [22–26]. However, the combined effect of the water jet is closely related to the jet pressure and rock properties. For soft rocks whose uniaxial compressive strength is less than 60 MPa, the common water jet can make a good combined effect, but for the hard rock whose uniaxial compressive strength is up to 200 MPa, it is a huge challenge for the water jet generating device and cost in use. Thus, the application of the conventional water jet is restricted in hard rock breaking.

Abrasive water jet (AWJ) is a new technology developed in modern times, and it is a kind of liquid–solid two-phase media jet formed with the mix of abrasive and high speed water [27]. Because of the high-frequency shock and grinding effect, AWJ can break hard and super-hard materials in lower pressure [28,29]. This paper plans to verify the feasibility and superiority of the abrasive water jet combined hard rock drilling, and apply

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foundation for the further research based on a series of experiments completed in the State Key Laboratory of Coal Mine Disaster Dynamics and Control.

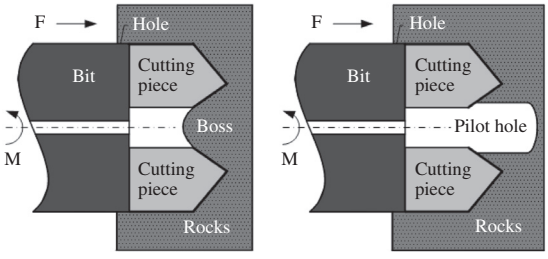
2. Principle of combined rock drilling

According to many drilling experiments using different kinds of mine-used rotary bits, it is clear that a "boss" easily forms in the bottom of the hole for the traditional mechanical drilling (as shown in Fig. 1a). The "boss" is a dense rock, which will wedge into the blank area between the two cutting pieces, like a conical wedge in the process of rock drilling. Only when the bit overcomes the rock uniaxial compressive strength, the "boss" can be broken in the manner of extruding and grinding, which makes the axial force and torque increase rapidly. The stress and temperature will be highly concentrated for the cutting edges. In the continuous super load, the cutting edges will be worn out gaps easily. Then the drilling condition of bit will be worse rapidly. So, if we can take a kind of effective tool and method to crush the "boss" for a "pilot hole", it is able to achieve the efficient drilling and low wear of the bit (Fig. 1b).

Fig. 2 shows the system structure. This system structure comprises an abrasive water jet generating system and a mine-used hydraulic drilling system. A set of combined rock drilling system with abrasive water jet was designed. The abrasive water jet generating system mainly consists of pump, abrasive tank, valves and so on. Its main functions are to form high-energy abrasive water jet and control the supplement and concentration of the abrasive. The mine-used hydraulic drilling system mainly includes rotary sealing conveyance device, hydraulic drill, sealing drill pipe, hard rock breaking bit, etc. Its main functions are to provide enough power for the bit to drill into rocks and control the drilling and rotating speed of the bit.

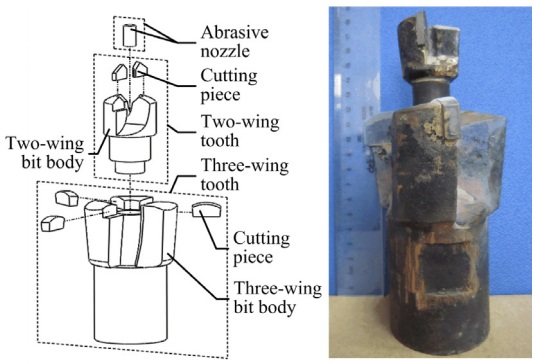
The research team designed a hard rock breaking bit made up of a abrasive nozzle, a second two-wing tooth and a third three-wing tooth, as noted in Fig. 3.

The abrasive nozzle is arranged along the two-wing tooth, fixed by brazing. The abrasive water jet will be generated from it to erode the target rock and form a first pilot hole. The two-wing tooth consists of two cutting pieces and a two-wing bit body. The cutting pieces are placed along the circumferential direction of the two-wing bit body with 180° to each other, fixed by brazing. Because of its action, the rock around the first pilot hole will be broken to form a second pilot hole. The three-wing tooth is composed of three cutting pieces and a three-wing bit body. The cutting pieces are placed along the circumferential direction of the three-wing bit body with 120° to each other, fixed by brazing. With its action, the rock around the second pilot hole will be broken to form the final hole. The materials of the cutting pieces are YG8 cemented carbide. The two-wing tooth connects with the three-wing tooth by screw thread.



(a) "Boss" existing (b) "Boss" eliminated for "pilot hole"

Fig. 1. Drilling diagram of rotation bit.



(a) Schematic diagram (b) Factual picture

Fig. 3. Hard rock breaking bit.

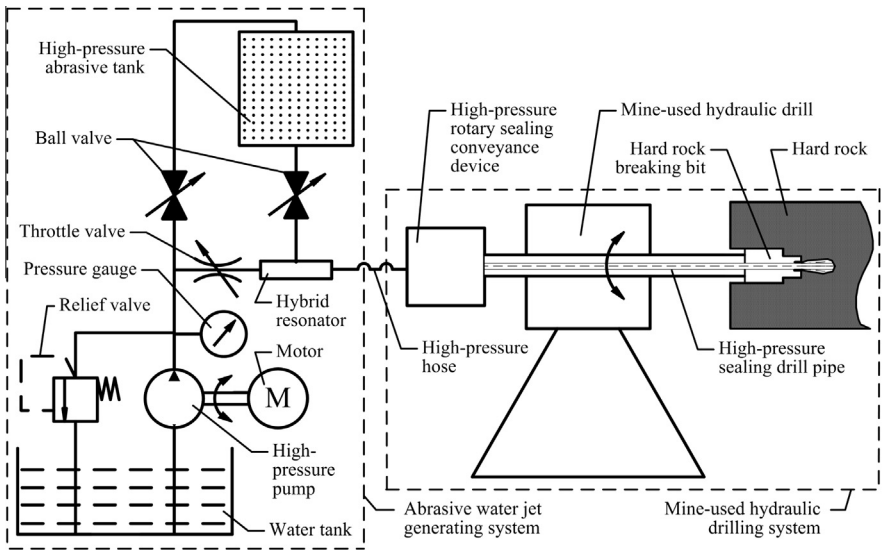


Fig. 2. System structure of combined drilling system.