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Combined Drilling and Sieve Tube Borehole Protection in Soft and Outburst-prone Coal Seams

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Summary

Soft, outburst-prone coal seams in China have poor stability, high gas content, and high pressure, which result in drilling accidents as well as borehole collapse during the gas drainage process."Dry-style" spiral drilling and single-air drilling techniques were unsuccessful. This paper discusses auger-air combined drilling and sieve tube borehole protection technology. These may offer possible solutions to problems frequently observed during soft and outburst-prone coal seam drilling and gas drainage.

Introduction

Gas explosion is one of the most serious disasters in coalmining in China currently; the practice is to drain gas before the mining process, as an effective means to curb the number of gas-related accidents. Gas drainage is an effective method to avoid these accidents. This method is widely used in underground coal mining and has become the primary method of ensuring mining safety. However, two problems have appeared when dealing with the soft and outburst-prone coal seams that comprise a great proportion of active coalmines in China.

One problem in drilling in soft and outburst-prone seams is extremely difficult to deal with since the Protodyakonov Coefficient (f) is less than 1. Mud drilling (using water or mud as drilling fluid) will lead to drilling accidents such as borehole collapse and drilling tool jam. Auger drilling can reduce drilling disturbance of the coal seams because there is no drilling fluid ("dry-type" rotary drilling method).This is suitable for drilling boreholes in the soft and outburst prone coal seams; however, drilling depth is limited(usually to less than 150m) by the high rig capacity requirement. Air drilling is another possible drilling method. Some positive effects have been observed after using compressed air as a drilling fluid. However, since the air flow is unstable and the pressure is low, this leads to frequent jamming of the drilling tool and restricts the drilling depth.

Another problem is that the borehole may collapse under coal seam stress during the gas extraction process, resulting in low gas extraction efficiency. The gas extraction will begin after the drilling pipes are removed. This process will last several months until the gas content reach a safe percentage. If the borehole collapses, the gas extraction channels will be blocked which causes extraction failure.

Auger-air combined drilling

The auger-air combined drilling technology uses specially designed spiral drill pipes as the drilling string, and compressed air as the drilling fluid. The technique combines the advantages of "dry style" auger drilling and air drilling. There are several basic advantages to auger-air combined drilling in soft and outburst-prone coal seams.

- Less formation damage compared with traditional hydro positive circulation drilling and "dry style" auger drilling.
- More efficient drilling bit cooling compared with "dry style" auger drilling.
- Better drilling cuttings removal ability compared with air drilling.

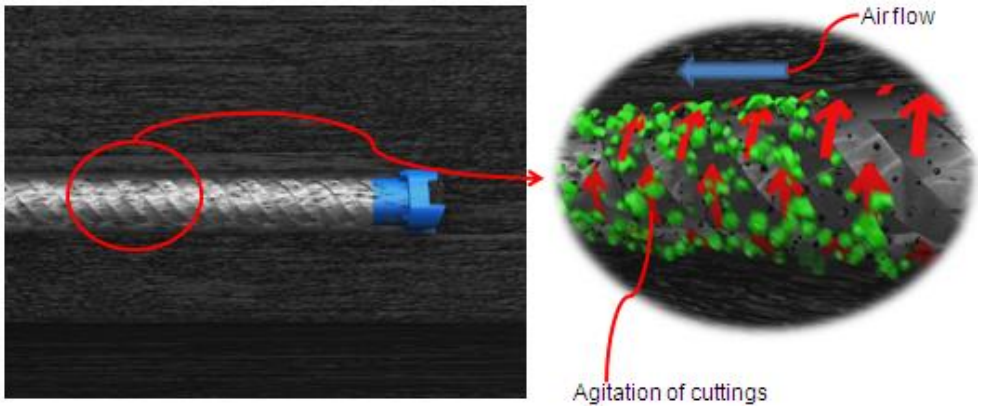


Figure1. Auger-air combined drilling simulation

The complete equipment consists of wide-blade spiral drill pipe, ZDY3200L drilling rig, jet flow dust collector and other components.

Compared with traditional spiral drill pipe (Figure2) used in “dry style” auger drilling, wide-blade spiral drill pipe (Figure3) has a different blade structure and manufacturing method. Its blade is much larger in width and shorter in height. Instead of being constructed through welding, wide-blade drill pipe is formed by milling. Due to the special structure, wide-blade spiral pipe has the following advantages.

Figure2. Traditional spiral drill pipe

Figure3. Wide-blade spiral drill pipe

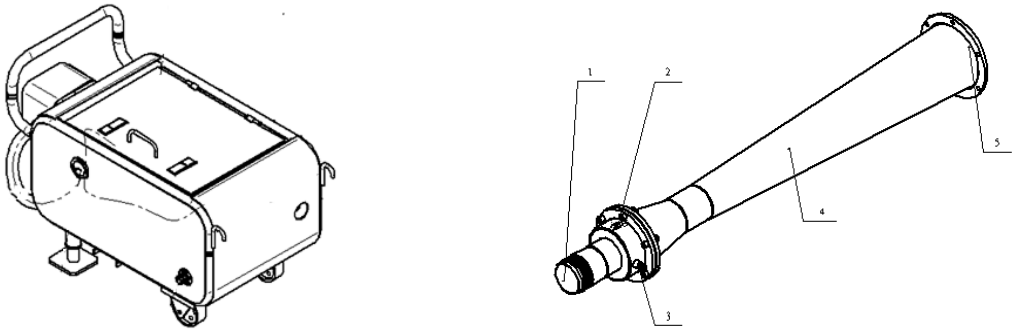
- The continuous rotation of the spiral blade can keep cuttings in a state of motion and force them out of the borehole.
- The spiral blade can stir up large particles of coal; this will allow large particles to be removed smoothly under the flow of compressed air; it removes cuttings more efficiently which can prevent borehole accidents.
- Wider and shorter blades can reduce borehole scraping and lead to a lower probability of drilling blockage.
- The wide-blade structure allows the pipe to be screwed on and off mechanically, therefore decreasing labor demands.
- Extending the inner hole can reduce air flow pressure loss.

In order to reduce drilling accidents and obtain deeper drilling depths, drill rigs must have enough torque and high feed/pull capability. Since a single-hole is usually less than 200m and requires little construction time, frequent rig relocation is possible. Furthermore, coal mine tunnels have limited space. All the above facts should be taken into consideration when choosing drill rigs. ZDY3200L drill rig (Figure4) is specially designed to drill in soft, outburst-prone coal seams. The rig, which consists of mainframe, power stations, support device, crawler bodywork and control panel, has several significant advantages, including high drilling capacity, convenient in-field transportation and relocation, and small overall dimensions (the width is less than 1.5m).

1. Mainframe 2. Power stations3.Support device 4. Crawler bodywork 5.Control panel

Figure4. ZDY3200L drill rig

Cuttings and dust dispersal in the tunnel is harmful for the workers' health and floating dust may increase the risk of explosion. A jet flow dust collector has been designed to avoid air pollution caused by drilling. The dust collector includes a pump and water jet device. High-pressure water is sprayed into a tube though nozzles. It produces a vacuum in the entrance area, so that air and dust can be sucked into the tube. Then the dust is captured by the fine spray and divided from the air.



Pump Water jet device

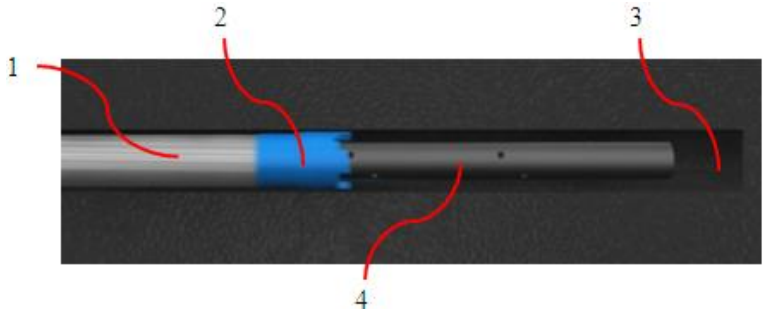
Figure5.Jet flow dust collector

An air supply system is required during the drilling process. Generally speaking, the main air supply system (usually the maximum air pressure is less than 0.7 MPa in the drilling site) can be used when the depth of the borehole is less than 100 meters; a dedicated air supply system, which consists of an explosion-proof air compressor, pipes, and joints, is required if the depth is more than 100 meters. The reason is that a dedicated air supply system can provide a sufficient amount of compressed air and enough pressure.

A detection device is assembled at the entrance of the drilling pipe to detect flow rate and air pressure. It can provide guidance for drilling construction.

Sieve tube borehole protection

Sieve tube borehole protection technology is used to solve borehole collapse and drainage passage block problems in soft outburst-prone coal seams. The sieve tube will be mounted through the inner hole of the drilling pipes. Then the drilling pipes will be removed and the sieve tubes will be left in the borehole to provide gas extraction channels.



1. Drilling pipe 2. Inner core detachable drill bit 3.Borehole 4. Sieve tube

Figure5.Sieve tube borehole protectionsimulation

An inner core detachable drill bit was designed to meet the requirements for sieve mounting into the borehole. The drilling bit consists of two parts, bit body and inner core. They are fixed together though a spring and position ball. In normal drilling, the drill bit body and the inner core cut coal together. After drilling is completed, the inner core of the bit is taken off under the axial force of the sieve tube to allow the drill pipe be taken out.

Examples

In field testing, the auger-air combined drilling system achieved the maximum borehole depth of 238.5 m in a seam where 0.5<f<1, which created the deepest underground drilling record in soft outburst-prone coal seam. The system achieved the maximum borehole depth of 120 m in a seam where 0.2< f <0.5. The most significant drilling depth improvement happened in the Luling Coal Mine where f < 0.45. The depth of the borehole was less than20meters when using “dry-style” auger drilling technology. After auger-air combined drilling technology was utilized, the average depth of the borehole increased to about 70 meters. During the field test, the sieve tubes were successfully installed.

The complete equipment and related technology have been used in more than 10 mining areas. Feedback suggests that the equipment and technology have improved the borehole depth and drilling efficiency effectively. Good economic and safety benefits have been achieved.

Conclusions

Auger-air combined drilling technology provides a new method for soft and outburst-prone coal seam drilling. According to the on-site testing, this technology can improve borehole depth and drilling efficiency significantly. Its drilling effect is much better than traditional “dry-style” auger drilling and single air drilling. The sieve tube borehole protection method can avoid gas extraction channel blockage that is caused by borehole collapse. This will lead to an increase in gas drainage efficiency.

Because of the diversity of the geological conditions, more research should be done in order to improve the adaptability of this technology. However, with steady improvement, this technology will be widely used in soft and outburst-prone coal seams in China.

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