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Research on Enhanced Gas Extraction Technology through Layer Drilling by Hydraulic Punching

FENG Wen-jun[1], ZHANG Yu-heng[2], XIE Jia-wei[2]
[1]*Henan Science and Technology Innovation Promotion Center, Zhengzhou 450003, Henan, China*
[2]*School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo 454003, Henan, China*

Abstract: As a coal and gas outburst mine, Zhongma Mine has poor gas permeability and low gas extraction efficiency, which affects the normal production schedule. Through the test of enhanced gas extraction technology in 27011 return air lane, the overall pressure relief of the coal seam in the unexcavated strip section of 27011 return air lane is realized. While flushing out coal and gas, the gas permeability of the coal seam is increased, and the gas extraction is strengthened, and the outburst risk in the driving is quickly eliminated.
Keywords: hydraulic punching; gas extraction; through layer drillings.

I. Introduction

The process of hydraulic punching[1-2] is the process of coal body damage and spalling, stress state change, and large amount of gas release. The high pressure water jet breaks the coal body, and a large number of coal bodies are flushed out within a certain period of time to form a larger diameter hole, thus destroying the original stress state of the coal body[3]. The coal body around the hole has a large displacement in the direction of the hole, which causes the stress state to be redistributed and the stress concentration zone to move forward. Secondly, the generation of new cracks in coal seam and the reduction of stress level break the dynamic balance of gas adsorption and desorption, so that part of adsorbed gas is transformed into free gas, while free gas is migrated and produced through cracks, greatly releasing the elastic potential and gas expansion energy in coal and surrounding rock, and significantly improving the gas permeability of coal seam[4]. Finally, high-pressure water moistens the coal body and reduces the desorption rate of the residual gas in the coal body[5].

II. Drilling Hydraulic Punching Equipment

The drilling equipment uses the self-developed hydraulic punching machine[6-7], the maximum working pressure is 45MPa, the maximum flow rate is 200L/min, and the high pressure water is transported by the continuous tubing with a diameter of 16mm, which ensures that the coal and rock powder of the plugging hole can be discharged from the annulus and can be continuously penetrated to any position in the drilling hole. The position of the nozzle in the hole, jet pressure and jet discharge can be adjusted by remote control, and the entire punching operation can be monitored in real time in the downhole or control room.

Figure 1. Drilling hydraulic punching equipment

III. Design of Hydraulic Punching Nozzle through Layer Drilling

The nozzle is the actuator of high pressure water jet, its function is not only to convert the static pressure of high pressure pump into the dynamic pressure of water, but also to make the jet have good dynamic and flow characteristics, shown in Figure 1. The optimization of high-pressure water jet nozzle[8] has become an important factor affecting the hydraulic punching effect. To simulate and optimize the nozzle parameters, it is necessary to set up an experimental scheme to simulate the nozzle parameters that affect the water jet effect.
In the nozzle design, the nozzle outlet diameter d depends on the jet flow and pressure, and the other parameters include nozzle contraction Angle a and so on. The inlet pressure of the nozzle was set at 40 MPa and the flow rate at 0.2 m³/min. The nozzle parameters were optimized by analyzing the high-pressure water jet structure. The change curve of the jet velocity along the axis of the nozzle with different shrinking angles was obtained by the simulation calculation.

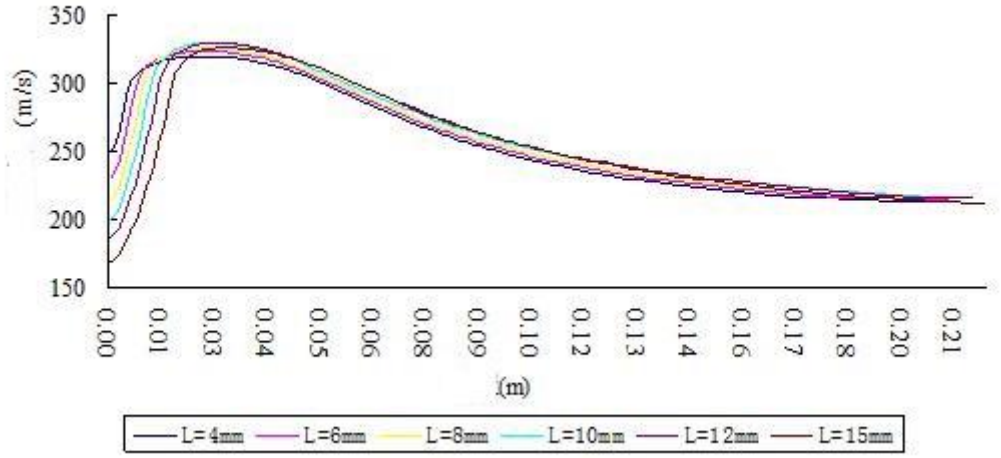

Figure 2. The changing curve of jet velocity alone axis in jet nozzle with different shrinking angle

It can be seen from Figure 2 that the velocity on the jet axis reaches its maximum value after accelerating through the nozzle, while it attenuates after leaving the nozzle due to momentum and energy exchange with the surrounding air. At the same time, it can be seen that the jet velocity distribution on the axis of the nozzle with different contraction angles is different. Although the nozzle outlet diameter is 4 mm, the local energy loss of the nozzle is different due to the different contraction Angle. When the injection pressure is both 40 MPa, the jet velocity of the nozzle axis with shrinking Angle a=30° is the smallest, the nozzle efficiency is the lowest, and the rock breaking ability is the worst. When the contraction Angle a=10~15°, the jet velocity of the nozzle axis is not different, and the nozzle efficiency is the highest.

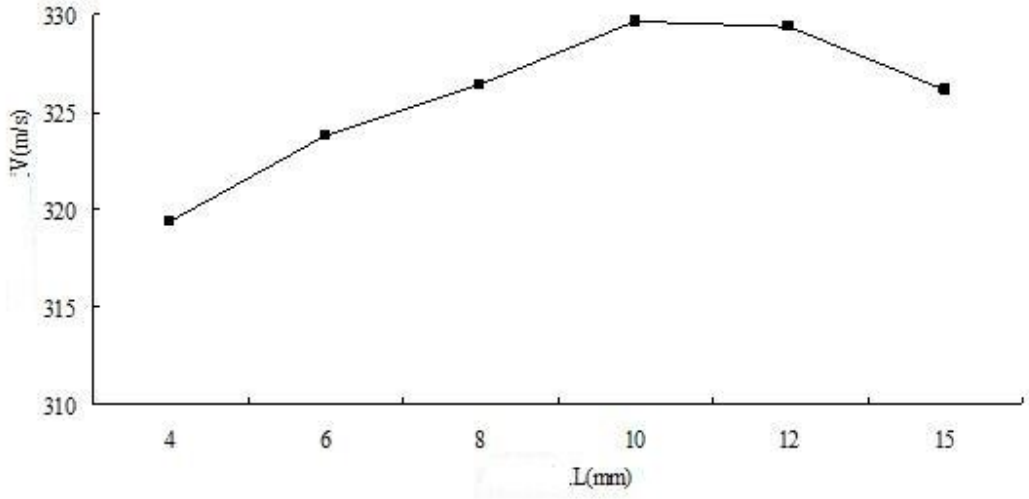

Figure3. The maximum value of jet velocity alone axis in jet nozzle with different length

The longer the nozzle, the larger the inlet diameter, the smaller the corresponding inlet velocity. With the increase of the nozzle length, the longer the jet acceleration length, the larger the maximum jet velocity will be. Meanwhile, the increase in the nozzle length leads to the increase in the nozzle energy loss, resulting in the decrease of jet velocity. It is 2.5~3 times the diameter of the nozzle outlet, shown in Figure 3.

IV. Gas Extraction Technology through Layer Drilling

The special expansion sealing cement slurry or other sealing materials are used to seal the holes, and the two bags are "double blocked" first, and the sealing grouting pump assembly is controlled by the PLC controller to start grouting. The check valve in the left and right bag is opened, and the sealing grouting pump assembly extracts the slurry in the liquid storage tank and fills it into the left and right bag, and the left and right bag expand radially. A number of sealing convex strips generate top pressure with the wall of the borehole through the wear-resistant elastic cloth sleeve. When the sealing slurry pressure in the left and right pocket reaches the specified value, the left and right pockets at the left and right ends of the hole sealing section will seal the borehole firmly, completing the "two blocks".

Then "one injection" is made to the grouting seal section, and the hole sealing grouting pump assembly continues to pressurized grouting. Due to the pressure action, the blasting valve in the grouting seal section is opened, and the hole sealing grouting pump assembly begins to inject grouting into the grouting seal section. During the grouting process, the manual ball valve on the recovery pipe is always closed, which is the stage of grouting with pressure. When the pressure on the grouting pipe is 2 ~ 2.5 times the pressure of the coal seam and the pressure is stable, the PLC controller closes the solenoid valve and the sealing grouting pump assembly, stops the grouting and completes the "one injection".

V. Hydraulic Punching Engineering Test and Effect Analysis

There have been several gas dynamic phenomena in 27031 return air lane and 27041 return air lane belonging to the 27 mining area of coal and gas outburst mine in Zhongma Cun Mine of Coking Coal Group. Although the strip gas of 27011 return air lane has been extracted by cross-layer drilling in East secondary Lane, the low extraction efficiency of soft coal has seriously affected the normal excavation due to its low permeability and difficulty in forming holes. During the driving process of 27011 return air lane, gas emission is large, and gas dynamic phenomena such as drilling jet holes and sticking often occur. Although the gas extraction measures have been adopted, it is still difficult to draw up to the standard in a short period of time, resulting in slow driving speed and affecting the production progress of the work face.

In order to accelerate the speed and intensity of gas extraction through hydraulic strengthening technology, three cross-layer boreholes with spacing of 20 m and 35 m were designed and implemented in east secondary lane, and hydraulic punching strengthening method was adopted to carry out operation and construction, with the purpose of rushing out soft coal as much as possible, realizing the overall pressure relief of coal seam in the unexcavated strip section of 27011 return air Lane. Increase the permeability of coal seam, strengthen gas extraction, and quickly eliminate the outburst risk during excavation.

Table 1 Construction parameters of through-layer drilling

Hole number	Azimuth (°)	dip angle (°)	hole depth (m)
ZM27C01	53	33	65
ZM27C02	30	8	87
ZM27C03	40	5	110

The influence range of this hydraulic strengthening is determined according to the location of the water outlet point and the coal outlet point during the hydraulic strengthening operation, as shown in Table 1. It can be seen from the table that the influence range of hydraulic strengthening operation is at least 35 m and at most 63.3 m, both of which exceed 15 m.

Drilling ZM27C01 hydraulic strengthening operation punching coal of about 15 tons, drilling ZM27C02 hydraulic strengthening operation punching coal of about 60 tons, drilling ZM27C01 hydraulic strengthening operation punching coal of about 2 tons, the cumulative amount of coal flushed out of about 77 tons, accounting for 0.33% of the coal volume in the control area.

After hydraulic intensification, gas extraction from 33 groups of 168 boreholes in the affected area was doubled, lasting for more than 30 days. Within 40 days, the total gas retractable quantity was 46181.55 m^3, and the average daily gas retractable quantity was 1141.42 m^3/d, which was 11.6 times of the 98.4 m^3/d before the over-hydraulic strengthening.

VI. Conclusion

(1) The nozzle parameters were simulated by Fluent numerical simulation, and the optimal nozzle contraction Angle, nozzle length and linear section length were obtained.
(2) The hydraulic punching machine independently developed was used to carry out hydraulic punching test on 3 perforating holes, and the accumulated coal output was 77 tons, accounting for 0.33% of the coal output in the controlled area.
(3) After hydraulic punching, the gas extraction of 168 boreholes in the affected area achieved remarkable results, and the pure gas extraction increased by 11.6 times within 40 days.

VII. Acknowledgement

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