Research of Ventilation Dedusting Technology of Full Section and Rapid Excavation Working Face in Daliuta Coal Mine

Xin-lei LIU\textsuperscript{1,2}, Bin SHEN\textsuperscript{1,2,*}, Xian-li QIN\textsuperscript{1,2}, Hao YUN\textsuperscript{1} and Chun-sheng WANG\textsuperscript{3}

\textsuperscript{1}School of Safety Engineering & Technology, Heilongjiang University of Science & Technology, Harbin 150022, China
\textsuperscript{2}National Central Laboratory of Hydrocarbon Gas Transportation Pipeline Safety, Heilongjiang University of Science & Technology, Harbin 150022, China
\textsuperscript{3}Shenhua Shendong Coal Group Co. Ltd, Erdos, 719315, China

*Corresponding author

Keywords: Rapid excavation, Ventilation mode, Dust removal technology, Dust reduction measures, Dust concentration.

Abstract. According to potential safety hazards of unreasonable ventilation and overrun dust concentration caused by the high degree of mechanization and the quick tunneling speed in the “long-distance & full-section” working face used in Daliuta coal mine of Shenhua coal group corporation limited, this paper studied the FPNA (far pressing near absorption ventilation) ventilation dedusting technology to solve the problems. This technology includes measures of simulation analysis on dust distribution, reasonable selection of the dust removal fan, adopting dynamic hanging technology to extending blower to the front of tunneling working face, setting up dust preventing board in front of tunneling machine and dust suppression by spraying. Field practice shows that the average dust concentration of working face is reduced by more than 50%, and achieved good results. The improved ventilation dedusting technology has been promoted and applied in Shenhua coal group corporation limited.

Introduction

The industrial test of full section rapid excavation system in Daliuta coal mine of Shendong Coal Group shows the driving section reached 25 m\textsuperscript{2}, driving speed exceeds a new record of 150 m per day and 4000m per month. Compared with the traditional excavating equipment, the new system realizes the efficient integration operation about parallel operation of driving and bolting, the multi arm efficient support, continuous breaking and transportation, and intelligent remote control. The mining efficiency is improved by 10 times, but it brings the problem of ventilation difficulty and excessive dust concentration\textsuperscript{[1-2]}. It is difficult to arrange the dust removal system in integrated mechanized driving face, because of its fast moving speed and large equipment in it, which makes ventilation dedusting technology become the most basic technical means. Compared with other excavation ventilation system, the FPNA ventilation system of full-section and rapid excavation working face has four typical characteristics\textsuperscript{[3-6]}. First, the pressed air duct is arranged behind the ten arm anchor machine from the working face up to 45 m; second, the draw out air duct is located on the ten arm anchor machine from the working face up to 30 m; third, it has a large section of over 25 m\textsuperscript{2}; fourth, large excavation equipment has a greater impact on the airflow distribution. Yang Mingrong\textsuperscript{[7]} et al. studied the distribution law of wind field in long distance large section driving face, believed that the velocity of medium pressure jet in large section tunnel attenuates rapidly, and the effective range is about 13m. Shen Bin\textsuperscript{[8]}, Liu Yongli\textsuperscript{[9]} et al. have studied the law of airflow and dust distribution in full section and rapid excavation working face by numerical simulation, they thought that the suction outlet of absorption air duct is located in the effective range of the pressing air duct, resulting in poor dust
removal. On the contrary, when the suction outlet of absorption air duct extends to the driving machine, the dust removal effect can be effectively improved. Qin Xianli et al. have preliminarily put forward the hanging technique of the air duct of a single lane long distance rapid excavation ventilation system, and proved its feasibility.

On the basis of the author's previous research and combined with the engineering practice, a new type of ventilation dedusting technology based on the dynamic hanging of the air duct is further developed. The key parameters of its engineering implementation are determined, and industrial tests are carried out at the 52501 heading face of Daliuta coal mine.

Project Overview and Problems

Daliuta coal mine of Shenhua coal group corporation limited uses full section rapid excavation system on the construction of mining roadway, the system consists of QMJ4260 full face driving machine, CMM10-30 straddle type ten arm anchor machine and DZY100/160/135 automatic tape machine, parallel operation such as digging, loading, supporting and transporting, as shown in Figure 1. The large amount of dust produced cannot be effectively managed due to the fast speed and large cutting area. The total dust concentration of the working face was over 27.3 mg/m³, and the concentration of respiratory dust exceeded 7.0 mg/m³. The poor working environment has affected the health and the working view of the workers, which has caused a great danger to the safety production.

The anchor machine of the full section rapid excavation system (Fig. 1, 3), is about 20~40 m of the distance from the heading face. The equipment in this range is dynamic and has no support which resulting in artificially unable to erect air duct. The air inlet of the press in type air duct can only be extended to the tail section of the ten arm anchor (Fig. 1, 7). The dust removing air duct can only be positioned at about 2 m of the front of the anchor machine (Fig. 1, 9). This leads to the presence of no wind or breeze at the front of the anchor machine.

![Figure 1. Full face rapid tunneling system.](image)

New Ventilation Dedusting Technology Based on Dynamic Hanging of Air Duct

Improvement of ventilation Mode

On the basis of comprehensive analysis of the ventilation dedusting technology used in heading face at home and abroad, and the distribution law of dust and airflow in single-lane long distance fast heading work face, the new ventilation method defined as "far pressing near absorption" is adopted in which the suction outlet of absorption air duct is extended to the driving machine. Fig. 2 and Fig. 3 are the simulation results of airflow and dust distribution by Fluent. It shows that the extension of the absorption air duct changes the distribution of the airflow field and improves the dust removal effect.

The key technologies for the application of the new ventilation dedusting technology include reasonable selection of the dust removal fan, the dynamic hanging technology of extending dust removal ram to the front of tunneling working face, the extension mode of the air duct on the driving machine.
Selection of Dust Removing Fan

**Air Quantity Calculation.** The coal mine gas rank of Daliuta coal mine is low gas. In order to prevent the gas gathering, the air demand of the air return tunnel is calculated according to the minimum wind speed requirement.

\[ Q_j = V \times S_t \times 60 = 356m^3/min. \] (1)

Where \( V \) is minimum wind speed in Coal Roadway (0.25m/s), \( S_t \) is effective ventilation section of the roadway (23.7m²).

The FBDY No. 7.5/2 * 55Kw local fan with air supply volume of 720m³/min is chose as the pressing type fan. According to the suction ratio, the exhaust volume of the dust removal fan is 360 m³/min and the air leakage is ignored for the short distance.

**Fan Resistance Calculation.** The spiral spring skeleton flexible air duct with diameter Φ 800mm is selected. According to the measured friction coefficient of the air duct and the air resistance of the iron channel of the anchor machine, the ventilation pressure of the dust blower is calculated as shown in Table 1.

<table>
<thead>
<tr>
<th>Pipe material</th>
<th>Length of air duct L(m)</th>
<th>Coefficient of frictional resistance α (N·s²·m⁻⁴)</th>
<th>Perimeter U (m)</th>
<th>Sectional area S (m²)</th>
<th>Duct flow Q(m³/s)</th>
<th>Frictional resistance hf(Pa)</th>
<th>Iron duct drag R (N·s²·m⁻⁸)</th>
<th>Resistance of iron channel hj(Pa)</th>
<th>Total resistance of air duct h (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible skeleton</td>
<td>100</td>
<td>0.005077</td>
<td>2.45</td>
<td>0.48</td>
<td>6</td>
<td>405</td>
<td>4.165</td>
<td>150</td>
<td>555</td>
</tr>
</tbody>
</table>

**Dust Removing Fan Select.** According to the wind pressure characteristic curve of dust removal fan, KCS-700D wet dust removal fan can meet the requirements. The fan performance parameters are shown in Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Motor model</th>
<th>Rated speed motor (rpm)</th>
<th>Rated power (Kw)</th>
<th>Blowing rate (m³/min)</th>
<th>Total head (Pa)</th>
<th>Efficiency of dust collection (%)</th>
<th>Liquid gas ratio (L/m³)</th>
<th>Water pressure (MPa)</th>
<th>Maximum total pressure efficiency (%)</th>
<th>Noise (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KCS-700D</td>
<td>YBF2-250S-6</td>
<td>980</td>
<td>45</td>
<td>700~300</td>
<td>300~800</td>
<td>≥99</td>
<td>≤0.2</td>
<td>≥0.8</td>
<td>≥80</td>
<td>≤85</td>
</tr>
</tbody>
</table>
Dynamic Dedusting Duct Hanging Technique

The simulation of dust distribution law shows that the air suction duct extends to the driving face can significantly improve the dust removal effect\[7\][8]. Considering the effective integration with the whole driving system, the extending of dust suction inlet needs to solve these problems as follow.

The Method of Connecting Iron Bridge Wind with Front and Rear Dust Removing Air Duct of Ten Arm Anchor Bolt Machine. In order to avoid the noise of exhaust dust fan, dust removal fan should be set on tail of self moving belt conveyor, and the inlet scoop of retractable skeleton corkscrew negative duct should be extend to the front of roadheader. Because of the limited operation space, the dedusting duct can not be directly through anchor machine, therefore, an iron channel with an section area of 0.4m\(^2\) is bridged at the lower side of the anchor machine. The setting effect of the iron air duct is shown in fig.4.

![Figure 4. Figure headings.](image)

Dynamic Hanging Method for Front and Rear Dedusting Air Tube of Ten Arm Anchor Bolt Machine. The constant tension hydraulic winch wire rope pre tightening device can realize the dynamic hanging extension of the front and rear air duct of the anchor bolt machine. Hydraulic constant tension winches are installed at the top and rear of the iron air duct which hydraulic power is supplied by the anchor bolt machine. The detailed structure is shown in fig.5.

![Figure 5. Hanging principle of dust removing air duct for front and rear telescopic section of anchor machine.](image)

1—Roadheader 2—Crusher 3—Iron duct 4—Anchor machine 5—Retractable skeleton duct 6—Hydraulic wireline winch 7—Pulley 8—The "door" bracket

According to the calculation results of the mechanical model of the air duct suspension\[10\], the IYJ2.5-15-55-13 constant pressure hydraulic is selected with the rope capacity no less than 50m and 13mm (1 x 37) of the wire rope diameter.

Extension of Suction Head of Upper Air Duct of Roadheader. The large diameter suction duct cannot be directly set up for the limited space up roadheader. Therefore, \(\Phi\) 800mm air duct is changed into 8 skeleton small air duct of \(\Phi\) 300mm, then extending them to the front of the roadheader as shown in Figure 6.
Industrial Applications and Conclusions

The field application has been carried out at the 52501 driving face of Daliuta coal mine. According to the layout of the system, five dust concentration measurement points were selected and compared with the 52307 driving face before the adjustment. When the face is driven 4000m, the dust concentration data are shown in table 3.

Table 3. Comprehensive tunneling face dust concentration measurement data tables.

<table>
<thead>
<tr>
<th>Dust location</th>
<th>52307 Fully mechanized face</th>
<th>52501 Fully mechanized face</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full dust (mg/m³) lowest~highest</td>
<td>Respirable dust (mg/m³) lowest~highest</td>
</tr>
<tr>
<td>Top left side of anchor rod machine</td>
<td>5.25~27.31</td>
<td>0.46~5.71</td>
</tr>
<tr>
<td>Upper work place of anchor rod machine</td>
<td>2.60~19.95</td>
<td>0.56~6.97</td>
</tr>
<tr>
<td>Press in and dust off air duct overlap section</td>
<td>0.42~23.56</td>
<td>0.18~4.93</td>
</tr>
<tr>
<td>Dust removal fan outlet tunnel (from the air outlet of the blower is 15m)</td>
<td>1.56~16.35</td>
<td>0.00~4.21</td>
</tr>
<tr>
<td>heading roadway (return air)</td>
<td>0.58~11.69</td>
<td>0.00~6.68</td>
</tr>
</tbody>
</table>

According to table 3, in the 52501 driving face, the total dust concentration of these points was about 0.00~9.34 mg/m³ , excepting the point of top left side of anchor rod machine which reached 12.98 mg/m³ beyond the "Regulations" provisions [13]. The respirable dust concentration of these points was 0.00~3.2 mg/m³. Compared with 52307 fully mechanized excavation face, the total dust and the respirable dust concentrations were significantly decreased by more than 50%. The dust removal effect achieved the best level of heading face in Shendong Coal Group. At present, the research results have been applied in Shendong mining area.

Acknowledgement

This research was financially supported by the National Science Foundation (51504088), Harbin city science and technology innovation talent research special fund project (2017RAQXJ118), Shenhua science and technology innovation project (201491548076) and the open fund of National Central Laboratory of Hydrocarbon Gas Transportation Pipeline Safety (HKDGH-20140008, 20140003).
References


Reference to a book:


Reference to a book: