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Calculation of Required Air Volume and Verification of Ventilation Capacity for Mines

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Abstract: The ventilation system is an important component of the mine safety production system, which directly affects the mine production capacity and on-site safe and efficient production. Taking the air demand and ventilation capacity of the Xinyuan coal mine as the research object, the air demand of the coal mining face, excavation face, backup face, chamber, and other air consumption tunnels were analyzed and calculated. The ventilation capacity of the mine ventilation system was verified, and the actual total air demand of the Xinyuan coal mine was determined to be 15943.6m^3/min. After verification, its ventilation capacity can meet the daily safety production needs of the mine.

Keywords: Mine Ventilation; Ventilation System; Air Volume Required; Ventilation Capacity; Verification.

1. Introduction

Xinyuan Coal Mine of Shanxi Qinxin Coal Industry Co., Ltd. is located in the west of Qinyuan County, Shanxi Province [1-2]. The plane shape of the mine field is nearly rectangular, with a length of 5400m from north to south, a width of 3800m from east to west, an area of 18.9988km^2, and an approved production capacity of 1.2 million t/a. The coal bearing strata in the mine field are mainly the Taiyuan Formation of the Upper Carboniferous System and the Shanxi Formation of the Lower Permian System. The thickness of the Shanxi Formation is 39.59~58.86m, with an average thickness of 46.46m. The thickness of the Taiyuan Formation is 97.5~127.00m, with an average thickness of 108.53m. The minable coal seams in the mine field are No.2, No.10, and No.11, with No.2 coal seam belonging to the Shanxi Formation and No.10 and No.11 coal seams belonging to the Taiyuan Formation. The current layout of working faces in Xinyuan Coal Mine includes 2 fully mechanized working faces, 3 backup working faces, 1 withdrawal working face, and 7 excavation working faces. The coal mining method of this mine adopts a fully mechanized mining process, which adopts a long wall layout with a strike direction. The entire height is mined at once, and the coal is cut by the shearer. The working face is in a backward mining mode, and the roof is managed by the full collapse method. The excavation face adopts machine excavation technology. Xinyuan Coal Mine adopts a zoning mechanical extraction ventilation method. There are currently 7 shafts, including the main inclined shaft, auxiliary inclined shaft, pedestrian inclined shaft, inclined ditch vertical air shaft, Liyuan auxiliary vertical shaft inlet air, Mugou vertical air shaft, and Nanshan vertical air shaft return air. According to the measurement results of gas emission in 2021, the absolute gas emission of the mine is 53.73m^3/min, the relative gas emission is 38.16m^3/t, the absolute carbon dioxide emission is 7.36m^3/min, and the relative carbon dioxide emission is 5.23m^3/t, indicating a high gas mine.

The mine ventilation system is an important guarantee for safe production in mines, and is the foundation for coal mines to do a good job in the "one ventilation and three prevention" work [3-6]. Especially in high gas mines, the ventilation system is particularly important. Once it is misaligned, it is easy to cause various safety accidents such as gas exceeding limits and outburst, which has a great negative impact on mine safety production [7-9]. From this, it can be seen that Xinyuan Coal Mine belongs to a high gas mine, and it is urgent to calculate the required air volume of its mine and verify its ventilation capacity to ensure that it can meet daily safety production needs.

2. Calculation of Required Air Volume for the Mine

The required air volume for the mine is calculated based on the air consumption locations of each mining face, chamber, and other air consumption tunnels, including the required air volume for backup working faces equipped according to regulations. The existing ventilation system should ensure stable and reliable air supply at each air consumption location [10]. The specific calculation formula is as follows:

$$Q_{ra} \geq (Q_{cf}+Q_{hf}+Q_{ur}+Q_{sc}+Q_{rl}) \cdot k_{aq} \quad (1)$$

In the equation: Q_{ra} is the required air volume for the mine, m^3/min; Q_{cf} is the actual required air volume for the coal mining face, m^3/min; Q_{hf} is the actual air volume required for the excavation face, m^3/min; Q_{ur} is the actual required air volume for the chamber, m^3/min; Q_{sc} is the actual required air volume for the backup working face, m^3/min; Q_{rl} is the actual required air volume for other air tunnels, m^3/min; k_{aq} is the ventilation demand coefficient of the mine (1.15~1.2 for the extraction type and 1.25~1.3 for the compression type).

2.1. Air Volume Required for Coal Mining Face

According to regulations, when calculating the air volume required for a coal mining face in a mine, it should be calculated separately according to the meteorological conditions of the face, gas emission, carbon dioxide emission, personnel and harmful gas production, and then the maximum value should be taken. At present, Xinyuan Coal Mine has two coal mining faces for production, namely 11228 fully mechanized working face and 12214 fully mechanized working face. The specific calculation results are shown in Table 1.

Table 1. Calculation Results of Air Demand for 11228 and 12214 Fully Mechanized Mining Faces

Calculation basis	11228 fully mechanized mining face	12214 fully mechanized mining face	Total/ (m^3/min)
Meteorological condition	615.7 m^3/min	887.2 m^3/min	-
Gas emission	822.0 m^3/min	1462.5 m^3/min	-
Carbon dioxide emission	44.22 m^3/min	44.22 m^3/min	-
Number of staff	196 m^3/min	196 m^3/min	-
Wind speed verification	103.11~1347.36 m^3/min	116.865~1735.44 m^3/min	-
Maximum value	822.0 m^3/min	1462.5 m^3/min	2284.5

According to Table 1, the required air volume for the 11228 fully mechanized working face of Xinyuan Coal Mine is 822.0m^3/min, and the required air volume for the 12214 fully mechanized working face is 1462.5m^3/min. Therefore, the total required air volume of the coal mining working face is Q_{cf}=822.0+1462.5=2284.5 (m^3/min).

2.2. Air Volume Required for Excavation Face

The actual air volume required for each excavation working face should be calculated separately according to regulations such as gas emission, carbon dioxide emission, and the actual suction air volume of personnel and local ventilation fans, and then the maximum value should be taken. The excavation working faces in Xinyuan Coal Mine that require air volume calculation include the southern section of 11211 air tunnel, 11211 air tunnel, 21903 machine tunnel small system, 21903 machine tunnel small system, 12210 machine tunnel, 12213 air tunnel, and 12213 machine tunnels, all of which are semi coal rock tunnels. The specific calculation results of the required air volume are shown in Table 2. From Table 2, it can be seen that the total required air volume of the excavation face Q_{hf}=743.9+615.3 +389+ 665.2 +804.6+766.6+837.3=4821.9 (m^3/min).

Table 2. Calculation results of required air volume for excavation working face (Unit: m^3/min)

Calculation basis	11211Wind lane south section	11211 Wind alley	21903 Machine Lane small system	21903 Air Lane small system	12210 Machine Lane	12213 Wind tunnel	12213 Machine Lane	Total
Gas emission	122.4	82.8	19.2	28.8	64.8	128.4	129.6	576
Carbon dioxide emission	4.02	4.02	4.02	4.02	4.02	4.02	4.02	28.14
Actual suction volume of local ventilation fan	743.9	615.3	389	665.2	804.6	766.6	837.3	4821.9
Number of staff	120	120	120	120	120	120	120	840
Wind speed verification	237.9~3806.4	234.3~3748.8	262.4~4197.6	262.4~4197.6	267.6~4281.6	234.6~3753.6	237.3~3796.8	-
Maximum value	743.9	615.3	389	665.2	804.6	766.6	837.3	4821.9

2.3. Air Volume Required for Backup Working Face

According to regulations, the air volume required for calculating the backup working face in the mine should meet the air volume calculated according to regulations such as gas and carbon dioxide, and should not be less than 50% of the actual air volume required for the mining working face. At present, Xinyuan Coal Mine has three backup working faces and one withdrawal working face, namely 11230 backup face, 21901 backup face, 12205 withdrawal working face, and 12212 pre-extraction face. The air volume is calculated based on the coal mining working face, and the specific required air volume calculation results are shown in Table 3. From Table 3, it can be seen that the total required air volume of the backup working face Q_{sc} =411+731.3+731.3+731.3=2604.9 (m^3/min).

Table 3. Calculation results of air demand for standby working face (Unit: m^3/min)

Calculation basis	11230 spare surfaces	21901 spare surfaces	12205 Retract Working Face	12212 pre-drawn surfaces	Total
Gas emission	159.6	112.1	91.0	401.7	764.4
Carbon dioxide emission	3.2	3.2	3.2	3.2	12.8
Number of staff	80	80	80	80	320
Working face air volume 50%	411	731.3	731.3	731.3	2604.9
Wind speed verification	198.0~3168.0	198.0~3168.0	198.0~3168.0	198.0~3168.0	-
Maximum value	411	731.3	731.3	731.3	2604.9

2.4. Air Volume Required for the Chamber

The required air volume for each independent ventilation chamber should be calculated separately based on different types of chambers. Therefore, the central substation of Xinyuan Coal Mine needs 80m^3/min, the 1 # Electrical substation of Level 1 mining area needs 90m^3/min, the 2 # Electrical substation of Level 1 mining area needs 130m^3/min, the distribution point of Level 2 centralized belt lane needs 200m^3/min, the water pump room of Level 1 mining area, the 1 # distribution point of Level 1 mining area, the 15 # parallel channel water pump room of Level 1 mining area, the 2 # distribution point of Level 1 mining area, the substation room of Level 1 mining area 100m^3/min is required for 6 locations including water pump rooms in the first level and second mining area. Therefore, the total air volume of the chamber is Q_{ur}=1100 m^3/min.

2.5. Air Volume Required for Other Air Tunnels

The air volume required for other air tunnels should be calculated separately based on the amount of gas emitted and the wind speed, using their maximum values. The required air volume for other tunnels in Xinyuan Coal Mine is shown in Table 4. According to Table 4, the required air volume for other tunnels in Xinyuan Coal Mine is Q_{rl}=2475 m^3/min.

Table 4. Calculation results of air demand for other air tunnels

Location	Section /m^2	Minimum wind speed/ (m/s)	Required airflow /(m^3/min)
West section of Donghuifeng Lane	11	0.15	100
End of East Transportation Lane	13.1	0.25	200
End of East Auxiliary Transportation Lane	11.3	0.25	200
End of North Wing Transportation Lane	12	0.25	200
Donggou Vertical Air Shaft 2 # Matou Gate	15	0.15	150
End of second level centralized belt roadway	15.7	0.15	150
At the end of the second level south return air roadway	14.85	0.25	250
Two level concentrated return inclined roadway	15	0.25	250
End of East Transportation Lane in Mining Area 2	12.21	0.25	200
Track inclined shaft	15	0.25	300
End of Zhengnan Auxiliary Transportation Lane	14.2	0.25	250
12208 Machine Lane Small System	15	0.25	225
Total	-	-	2475

2.6. Total Mine Air Demand

According to equation (1), it can be seen that the Xinyuan Coal Mine adopts the zoning mechanical extraction ventilation method, with a k_{aq} value range of 1.15~1.2. Therefore, this article takes its maximum value of 1.2. In summary, $Q_{ra} \geq (Q_{cf} + Q_{hf} + Q_{ur} + Q_{sc} + Q_{rl}) \cdot k_{aq}$= (2284.5+2604.9+4821.9+1100+2475) × 1.20=15943.6 (m^3/min).

3. Mine Ventilation Capacity Verification

Table 5. Characteristics of coal mining face

Working face	Average length of working face /m	Average mining height /m	Apparent density of raw coal /t.m^{-3}	Recovery rate/%	Annual working days /d	Daily push progress /m. d^{-1}	Production capacity /ten thousand t.a^{-1}
First mining area and second level coal mining face	182	1.65	1.375	96	330	3.5	38.92
Second mining area coal mining face	201	1.8	1.35	96	330	5	65.76

Table 6. Characteristics of the excavation face

Working face	Pure coal area of the roadway /m^2	Apparent density of raw coal /t.m^{-3}	Annual working days /d	Daily push progress /m.d^{-1}	Production capacity /ten thousand t.a^{-1}
Excavation in the first mining area	6.5	1.35	330	7.6	2.20
Excavation in the second mining area	9.0	1.35	330	7.6	3.05
Lower group coal excavation	10	1.4	330	11.2	5.17

At present, the actual air intake of Xinyuan Coal Mine is 16935m^3/min, which is greater than the calculated actual air demand of the mine of 15943.6m^3/min. Based on the actual production situation of Xinyuan Coal Mine, the production capacity of the mining face is determined, and 3 coal mining faces and 6 excavation faces are allocated. The characteristic parameters of the coal mining and excavation faces in Xinyuan Coal Mine are shown in Tables 5 and 6.

According to Tables 5 and 6, it can be calculated that the production capacity that the ventilation capacity of Xinyuan Coal Mine can meet is: A_{pc} =38.92 × 2+65.76 + (2.20+ 3.05+ 5.17) × 2=164.44 (10000 t/a).

4. Ventilation Capacity Verification

4.1. Verification of Mine Ventilation Power

At present, Xinyuan Coal Mine has two air shafts, namely the Mugou vertical air shaft and the Nanshan vertical air shaft. The Mugou return air shaft is currently equipped with two FBCDZ № 26 explosion-proof axial flow fans for mining, with a supporting motor power of 2 × 355kW, 1 working and 1 standby, with the main fan operating in two stages at 0 ° C, generating an air volume of 8400~8500m^3/min and an air pressure of 1900Pa. The Nanshan return air shaft is equipped with two FBCDZ № 28 explosion-proof axial flow fans for mining, with a matching motor power of 2 × 500kW, 1 working and 1 standby, with the main fan operating at 0 ° in two stages, producing an air volume of 8600~8700m^3/min and a air pressure of 2230Pa. The actual operating conditions of the ventilation fan in the mine return air shaft are all within a safe, stable, reliable, and reasonable range. According to the rated ventilation capacity of the main ventilation fans in the mine and the ventilation capacity of the mine ventilation network, the maximum ventilation capacity of the mine is 17200m^3/min, which is greater than the approved required air volume of 15943.6m^3/min.

4.2. Verification of Mine Ventilation Network Capability

The total intake air volume of Xinyuan Coal Mine is 16935m^3/min, the total return air volume is 17024m^3/min, the air pressure of the Mugou return air shaft is 1900Pa, the air pressure of the Nanshan vertical air shaft is 2230Pa, and the mine's equivalent pore volume is 5.69m^2. This indicates that the mine ventilation system is in a period of low resistance and difficulty in ventilation. The air volume and ventilation resistance of the mine ventilation system meet the requirements, and the mine ventilation system complies with the provisions of the "Coal Mine Safety Regulations". The ventilation system of the mining face is complete and reasonable, and the ventilation facilities are reliable. There are no locations that violate regulations such as series ventilation, diffusion ventilation, and goaf ventilation.

4.3. Verification of Effective Air Volume at Mine Air Consumption Sites

The effective air volume of each air consumption location in Xinyuan Coal Mine is mainly verified based on the air volume, as shown in Table 7. From Table 7, it can be seen that the actual air volume at the current location of the Xinyuan Coal Mine meets the relevant regulations of the Coal Mine Safety Regulations (2022).

Table 7. Validation of effective air volume at mine air consumption sites

Name	Air volume required /(m^3/min)	Measured air volume /(m^3/min)
Coal face	2284.5	2782
Development end	4821.9	6135
Backup working face	2604.9	2792
Chamber	1100	2146

4.4. Verification of Mine Dilution Gas Capability

According to the measurement results of gas emission in 2021, the absolute gas emission of Xinyuan Coal Mine is 53.73m^3/min, and the relative gas emission is 38.16m^3/t. The gas concentration at various points complies with the Coal Mine Safety Regulations (2022). Under normal ventilation conditions, there was no frequent gas exceeding limit phenomenon at each air consumption location in the mine, which verified that the effective air volume at each air consumption location in the mine can meet the air volume requirements.

5. Conclusion

This article takes the air demand and ventilation capacity of Xinyuan Coal Mine as the research object, analyzes and calculates the air demand of coal mining faces, excavation faces, backup working faces, chambers, and other air consumption tunnels in the mine. The ventilation capacity of the mine ventilation system is verified, and the following main results are obtained:

(1) According to the calculation of the mine ventilation capacity, the actual air volume required for the Xinyuan Coal Mine is 15943.6m^3/min.

(2) The ventilation capacity of Xinyuan Coal Mine was verified based on the mine ventilation power, mine ventilation network capacity, effective air volume at the mine air consumption location, and mine dilution gas capacity. It was found that the ventilation system of Xinyuan Coal Mine is reliable and meets the needs of daily safety production.

(3) Through verification, the ventilation capacity of Xinyuan Coal Mine can meet the production demand of 1.6444 million tons/a.

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