Study on prevention and control technology of mineral dust discharged from high and deep chute

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Abstract. Based on the production process characteristics of the deep pass in Xiadian Gold Mine, a pass unloading model was established, and the dust return characteristics of pass unloading operations were simulated and studied. The dust production law of pass unloading was tested and analyzed, and it was concluded that the transient conditions of deep pass unloading are different. According to the distribution of the concentration of each section at the moment, according to the flow field distribution law of the discharge port, a blow-suction airtight dust extraction and purification treatment measure is proposed, which realizes the effective dust control of the discharge surface of the chute and improves the dust extraction efficiency of the dust collector. After the on-site supporting research and treatment, the total dust concentration of the chute unloading operation was reduced from 378.3 mg/m$^3$ to 5 mg/m$^3$, the dust reduction efficiency reached 98.7%, and the respirable dust concentration was reduced from 133.3 mg/m$^3$ to 3 mg/m$^3$. The efficiency is 97.7%, and the dust reduction effect is good. It solves the problem of the pollution of mineral dust unloading in the deep pass, and provides a basic basis for the treatment of metal mines.

1. Introduction
Orepass operation is one of the most common production technology of metal mine underground mining, with the increase of depth of underground mining, short chute gradually to the deep development of chute, part of the profound depth of the chute of a few hundred meters, through multiple middle, take mine operating strength, mineral dust discharge concentration also increased dramatically, mine dust and shock producing dust diffusion distance, duration long, causing serious pollution of roadway, harm to workers' health [1-4]. In recent years, more and more attention has been paid to the control of dust production in the chute, but the law of dust production in the ore unloading operation in the chute is complex. The dust changes with time in space accompanied by the impact air flow and dust return air flow in the process of dust production, making it difficult to control and difficult to solve the common dust control measures [5-7]. Therefore, in view of deep chute unloading operation, through simulation research and test analysis, after mastering the rules of deep chute unloading mineral dust, targeted treatment measures can be taken to effectively solve the problem of ore chute unloading mineral dust.
2. The profile of deep chute
The deep chute is arranged at the -780m level of Xiadian gold mine, which is directly connected to the -1020m level. The depth of the chute is up to 240m, and there is no other branch in the middle, so it is the main ore unloading port. The ore pass is cylindrical, with a diameter of 3m, and the ore pass adopts grizzly screen to filter large ore. The grizzly screen size is 4m×4m. The ore pass is placed at the end of the roadway with a width of 7m and a height of 5m. During ore unloading operation, the mine car will transport the ore to the -780m level chute head along the transport main roadway, and the ore will fall into the ore bin at the bottom of the -1020m level along the high and deep straight chute. The air pressure balance between -780m level and -1020m level mainly depends on the deep chute and skip shaft for lifting ore. When unloading, the air current at -780m level is sucked into the chute to move at -1020m level, while the air current at -1020m level blows along the skip well to -780m level, forming a cycle, and the instantaneous wind speed can reach 10m/s. When the ore falls into the bottom ore bin, the airflow slowly moves upward along the chute, forming another circulation, and the velocity of the airflow back from the chute head reaches 1m/s. With the reciprocating of mine car unloading, stopping and unloading, the airflow is also constantly circulating. Under the action of circulating airflow, the dust produced by ore unloading operation causes great pollution to both -780m and -1020m levels. The site orientation of pass mouth is shown in Fig. 1.

3. Law of mineral dust discharged by chute
3.1. Simulation analysis of ore chute unloading
Based on the actual size of -780m level slip wellhead roadway, set up the alleys of 45 m long,7 m wide, 5 m high, the right end face for the head, the left end face a long 10 m, 5 m, 4 m wide lane, sneak wellhead of side length 4 m square, to help the distance of 0.5 m, 2.5 m, respectively to the lane distance of 1 m, Gambit software is adopted to establish the model as shown in figure 2.

Assuming that the dust is a regular sphere and the discharge port is taken as the reference frame, the dust concentration equation at the spatial position at time t is established as follows:
\[
c = \left( \sum_j \int \int \int \frac{1}{6} \rho \pi d^3 n_j x d y d z \right) / V \quad (1)
\]

**Type:**
- \(c\) — is the mass concentration, mg/m\(^3\);
- \(\rho\) — is dust density, kg/m\(^3\);
- \(d\) — is dust diameter, m;
- \(n_j\) — is the amount of dust of a certain particle size;
- \(V\) — is the volume of the domain, m\(^3\).

Since the velocity of dust is not invariable, the changing process of dust in space with time can be better reflected under transient conditions [8-9]. Therefore, the dust return process is calculated in the transient way, and the concentration distribution of each section at different moments under the transient condition is simulated, as shown in Fig. 3.

**Figure 3.** The diagram of concentration distribution at different moments under transient conditions.
The figure 3 shows that the discharging mouth side there was a small dust concentration area is about 500 mg/m³, the main source for the slip wellhead back up dust, dust the return air flow is not in the direction of a single radiation movement, but rises to a certain height, first and then spread from high concentration to low concentration area, in the discharge outlet side show counterclockwise pollution trend, with the increase of time, the low concentration area decreases. From the perspective of time, when the dusty airflow moves towards the main roadway, the area at the top of the roadway is polluted first, and part of the dusty airflow continues to move forward, while the other part diffuses towards the middle of the roadway, resulting in a phenomenon similar to the superposition of waves. For example, the distribution at the position of 5m at 10s is similar to that at the position of 10m at 15s. From the position point of view, at a certain moment, the degree of pollution increases with the increase of the distance. In the simulation process, the distance between the underground mouth of the chute and the upper mouth of the chute is 15m. After the dust returns from the chute, it will move to the upper mouth of the chute in about 30s, which is basically consistent with the actual situation.

Through simulation analysis, the level of -780m ore discharge chute mouth flow field distribution rule as shown in figure 4, the wind flow along the slip wellhead back up, in the space, overall dust-containing air flow to the Z direction, the overall direction for space motion slip wellhead to top part of the airflow directed negative X direction deviation trend, namely the airflow spread along the cross section, height at about 1.5 m above the position. Therefore, in the three-dimensional space, the dust-bearing airflow moves along the chute head to the top of the roadway. At a position 1.5m away from the chute head, the dust-bearing airflow gradually diffuses along the transverse section of the roadway.

Through simulation analysis, the dust in the chute returns upward along the chute after ore unloading, and the dust concentration at the chute head changes with time, as shown in Fig. 5. About 3min after ore unloading, the dust in the high depth straight pass began to return upward, and the dust concentration gradually increased. About 5min, the dust concentration reached the peak value, and the maximum dust concentration at the pass head was about 450mg/m³, among which respirable dust accounted for a large proportion.

Figure 4. The movement diagram of upper space flow field of pass mouth.

Through simulation analysis, the dust in the chute returns upward along the chute after ore unloading, and the dust concentration at the chute head changes with time, as shown in Fig. 5. About 3min after ore unloading, the dust in the high depth straight pass began to return upward, and the dust concentration gradually increased. About 5min, the dust concentration reached the peak value, and the maximum dust concentration at the pass head was about 450mg/m³, among which respirable dust accounted for a large proportion.
3.2. Test and analysis of ore dust discharged from chute

The filter membrane mass method was used to test the dust concentration at the ore unloading mouth of the deep chute. The measuring points were arranged at the ore unloading mouth, the height of the breathing belt was 1.5m, and the flow rate was 20L/min. Through field observation and field measurement, dust production rules at the chute head are shown in Fig. 6. At the moment of mine car unloading, the air flow in the roadway is sucked into the chute, and the dust concentration in the roadway is relatively low, which is 8–10mg/m². About 3-5min after unloading, the dust return concentration from the chute head increases gradually, and 5min later, the dust return flow from the chute head is clearly visible. In 5-10min, the dust-bearing air flow gradually accumulates, and the maximum dust concentration reaches 421mg /m³. When the next mine car unloads ore into the chute, the dust-bearing airflow is sucked into the chute again, and the dust concentration at the chute head decreases to less than 10mg/m³. After ore unloading, the dust concentration gradually increases. With ore unloading, the dust concentration increases and decreases in a cyclic manner.
4. Study on chute control dust removal technology

Based on the dust production law of the -780m horizontal chute head, the dust pollution diffusion of the chute head is disordered and repeated, which is difficult to be solved only by a single dust control measure. It is necessary to guide the dust-containing air flow to move to one side, and then collect and control it. Due to the large depth of the chute and the high mud content of the ore, it is not suitable to adopt spray dust removal measures [10]. Therefore, an efficient dust extraction and purification system is designed to treat the dust returned from high depth straight chute. Because of the large space of the chute head, the fast dust return speed and the frequent unloading operation of the mine car, the chute head is not easy to be closed, and the dust control efficiency in the open space is extremely low. Therefore, the key technology of dust control at the chute is to control the dust disorderly diffusing in a certain area, and carry out dust extraction and purification on the basis of dust control.

According to the characters of harvesters ore unloading process, unloading mining operations, harvesters in mine chute side only, the other side no homework, therefore, slip wellhead in space, other than the car unloading surface can be completely sealed with airtight cover, and form a u-shaped closed form, arrangement and filter in the U shield tail, dust purification U enclosure of dust extractor. The unloading surface of the mine car has frequent unloading operations, and the transparent sealing of the unloading surface is realized by using the way of dust control with air curtain, which isolates the inside and outside of the chute mouth through the air curtain, and the dust-containing airflow in the chute cannot diffuse outward through the gas curtain wall. The air curtain sealing wall and U-shaped sealing cover realize the full sealing of the chute head [11-15]. In addition, when a vertical air curtain isolation wall is formed on the discharge surface, a positive air flow is formed to the suction outlet of the dust remover, which changes the direction of the dust-bearing air flow at the pass mouth and promotes the dust-bearing air flow to the suction outlet. Combined with the suction outlet of the dust remover, a blowing-suction dust purification technology is formed to improve the efficiency of dust extraction and purification. The blowing-suction dust purification system is shown in Fig. 7, and the blowing-suction air flow movement path is shown in Fig. 8.

![Figure 7. Blow-suction dust extraction and purification system.](image_url)

![Figure 8. Blow-suction dust extraction and purification system.](image_url)
5. Treatment effect of dust return in chute

Based on the size of the slip wellhead Xia Dian gold dust and return wind speed, calculated cover mouth area of 1.25 m², the smoke dust system for rigid enclosed on three sides, one side adopts closed in the form of air curtain, air curtain closed surface of inlet, and the dust collector to form a wind blow into a suction, but due to the large chute discharging mouth closed space, discharging surface dust hood 4 m distance is far, to ensure unloading the dust can be effective to inhale dust hood, cover mouth design is 4 m/s wind speed, air leakage coefficient and the system resistance and field use KCS-550-D- type I mine wet filter dust collector. The dust concentration at the chute head was measured on site by the membrane mass method, and the dust concentration before and after the blowing-suction dust purification measures was compared to investigate the dust removal efficiency. In the testing process, the two working areas of the chute head and the tail of the dust collector were taken as the sampling points, and the test height was the height of the breathing belt. The test results were shown in Table 1.

| Type of dust          | Sampling location         | Original dust concentration (mg/m³) | Dust concentration after high-pressure spray dust control (mg/m³) | Dust reduction efficiency (%) |
|-----------------------|---------------------------|------------------------------------|---------------------------------------------------------------|------------------------------|
| Total dust            | Slip the well's mouth     | 378.3                              | 5                                                             | 98.7%                        |
| Breathable dust       |                           | 133.3                              | 3                                                             | 97.7%                        |
| Total dust            | Dust collector tail       | 336.5                              | 4                                                             | 98.8%                        |
| Breathable dust       |                           | 98.6                               | 2                                                             | 98.0%                        |

Field test data shows that the blowing dust suction airtight smoke purification measures, implements the chute on the surface of the discharge dust control effectively, and improve the efficiency of the smoke dust filters, chute ore unloading work of total dust concentration is 378.3 mg/m³ reduced to 5 mg/m³, the dust efficiency is 98.7%, respiratory dust concentration reduced from 133.3 mg/m³ to 3 mg/m³, the dust efficiency is 97.7%, the dust effect is remarkable. At the tail of the dust remover, the total dust concentration decreases from 336.5 mg/m³ to 4mg/m³, and the respirable dust decreases from 98.6 mg/m³ to 2mg/m³. The dust collection efficiency and treatment efficiency of the dust remover are both high. Can be seen from the deep ore discharge chute work observation, governance, mine roadway homework, dust chute in return airflow by chute introverted sneak wellhead movement, reached after sneaking wellhead moment to filter dust mouth, reach the central dust collection mouth after all into the suction mouth, achieve the desired effect, to solve the problems of deep discharge chute mineral dust pollution, for metal mine deep of mineral dust discharge chute governance provides the basis.

6. Conclusion

Based on deep chute production process characteristics, ore discharge chute model and simulation studies the chute ore discharging work return to dust characteristics, test and analysis the rule of mineral dust discharge chute, the deep discharge chute ore transient conditions is obtained under different time the concentration distribution of each section according to the mine mouth flow field distribution, this paper proposes a blowing dust suction airtight smoke purification measures, and at the scene of the Xia Dian gold mine was tested, the actual control effect is remarkable, summed up the following conclusions:

1) The air flow back from the chute does not radiate in a single direction in space, but first rises and then spreads laterally from the high concentration area to the low concentration area, showing a counterclockwise pollution trend at the chute head; In terms of time, the area at the top of the roadway was polluted first, then diffused to the middle of the roadway, and superimposed with time in the roadway.

2) The measurement of dust return in the chute shows that the air flow is sucked into the chute at the moment of ore unloading, and the roadway concentration is reduced to 8-10mg /m³. About 3-5min
after ore unloading, the dust return concentration from the chute head gradually increases and accumulates, and the maximum dust concentration reaches 421mg/m³.

(3) According to the characteristics of ore chute unloading operation, air curtain is used to control the dust on the unloading surface of the cart, which realizes the isolation of the unloading surface and forms a positive air flow flowing to the dust suction port. Combined with the dust suction port of the dust remover, a kind of blowing-suction dust purification technology is formed.

(4) The effective dust control on the discharge surface of the chute is realized after the treatment measures of blowing-suction closed dust extraction and purification. The total dust concentration in the chute operation is reduced from 378.3mg/m³ to 5mg/m³, and the dust removal efficiency is 98.7%. The respirable dust concentration is reduced from 133.3mg/m³ to 3mg/m³, and the dust removal efficiency is 97.7%, and the dust removal effect is significant.

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