Design of Improving Coal Chute in Thermal Power Plant Based on DEM Simulation Technology

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Abstract. Aiming at the coal dust pollution at the transfer point under the screening and coal crushing equipment in our power plant, the discrete element method (DEM) was used to simulate the transfer process of coal under different chute profiles and cross-sectional shapes to analyze the movement state and movement law of the material during the transfer process. The results show that using the improved chute can effectively reduce the coal flow vertical impact velocity, reduce the impact wear of coal flow on the coal received belt, and help to solve the problems of reducing dust pollution at the transfer point.

1. Introduction
Coal transportation is an important part of the normal operation of coal-fired power plants. However, at present, most of the transfer points of the coal transportation system have adopted the conventional straight chute design, and the falling coal which impacted the belt has produced a large amount of dust, which not only pollutes the environment but also causes the loss of coal. In the design of the transfer point, the chute mainly plays the role of diversion and direction change. At the same time, its structure will directly determine the movement state of the coal flow during the transfer process, thereby affecting the dust scattering and the degree of environmental pollution.

This paper aimed to deal with the problems of coal blockage in the chute, liner wear, conveyor belt deviation and dust pollution of the transfer point under the screening and crushing equipment in our power plant. Thus, the discrete element method (DEM) was used to simulate the coal transfer process under different chute profiles and cross-section shapes, and the movement state of materials in the transfer process was studied, so as to provide reference for the structural optimization of coal transfer chute.

2. Current status of in-use conveying chute
The screening and crushing equipment are the throat part of the coal conveying system in thermal power plants. At present, the coal chute at the tail of the coal crusher building #14AB belt conveyor in our plant is a traditional 900mm×900mm square straight-through coal drop chute (see Figure 1), which does not match with the coal flow trajectory. The irregular scattering track of the bulk coal impacts the coal drop chute, and results in a large number of dust particles and induced wind. In this case, the dust concentration of the #14AB belt conveyor tail and the entire belt conveyor trestle becomes too large, the coal falling chute is easy to block coal, the coal chute and the air lock are worn, and the penetration is frequent. The eccentric load and deviation of the downstream belt conveyor are serious,
the transfer point is too much to scattered coal as well as escaped dust, so as to the cleaning and maintenance workload is large.

![Design of the original linear square chute at the original transfer point](image)

1. upstream belt conveyor 2. roller screen 3. Hopper under screen 4. chute under screen 5. guide trough 6. downstream belt conveyor 7. coal crusher 8. chute under crusher 9. return air duct

Figure 1. Design of the original linear square chute at the original transfer point

3. Discrete Element Method

3.1. Discrete element method

Discrete Element Method (DEM) is an analysis method for studying the movement state of bulk materials. Its basic principle is to separate discrete particles into discrete element sets that move independently based on dynamic principles. By establishing the mathematical model and motion equation of each element, the contact and separation states of each element are analyzed, so as to reflect the movement of the entire system with the movement of the unit body. Among them, the contact and collision behaviour between the elements are described by an appropriate contact mechanics model, the motion equation of each element is established according to Newton's second law, and the dynamic relaxation is used to solve it iteratively, so as to obtain the overall motion behaviour of the loose body. When the average unbalanced force between each unit tends to zero, the bulk presents a stable accumulation state. For the $i$ th particle in the bulk, its motion satisfies the following formula:

$$m_i \frac{d^2 x_i}{dt^2} = m_i g + \sum_{j=1}^{ci} F_{ij}$$

(1)

$$I_i \frac{d}{dt} \omega_i = \sum_{j=1}^{ci} T_{ij}$$

(2)
Wherein $m_i$ represents the mass of particle $i$, $x_i$ represents the particle $i$’s position vector; $F_{ij}$ represents the force of particle $j$ acting on particle $i$; $g$ denotes gravitational acceleration; $\omega_i$ is the angular velocity vector; $c_i$ means the number of contacts for particle $i$; $T_{ij}$ refers to the torque vector of particle $j$ acting on particle $i$.

3.2. **Software of discrete element**

At present, the mainstream discrete element software includes Rocky and EDEM. The Rocky software used in this paper is used for the simulation analysis of the discrete element. Rocky software can establish a parametric model for the solid particle system, accurately describe the shape of the particle by importing the CAD model of the real particle, establish a particle model by adding mechanical properties, material properties and other physical properties, and simulate the movement of the material through the discrete element method. Data information that is not easy to be measured in the test can be obtained, which can greatly save test costs and better solve practical engineering problems.

4. **Establishment of coal system discrete element model**

The models used in this simulation include the interaction model between particles and the interaction model between particles and geometry, involving the traditional Hertz-Mindlin dynamics model and the moving plane model of the conveyor belt. According to the particle size distribution listed in Table 1, the material particles are automatically generated through the particle factory built in Rocky software. In order to ensure the accuracy of the calculation results, it is necessary to confirm whether the simulation process parameters are consistent with the reality before the simulation, and accurately test the material rest angle, belt conveying capacity and belt speed.

4.1. **Materials simulation parameters**

According to the sampling analysis of the sampler, the basic parameters of coal are as follows. Bulk density is 0.86 t/m$^3$, the particle size under screen is 0-30 mm, the particle size after crushing is <=25mm, rated output of coal loading system is 1000t/h, belt conveyor belt width is 1.2 m, and the belt speed is 2.5m/s. According to on-site statistical tests, the particle size distribution of coal coming from the upstream of the screening system is shown in Table 1.

| Serial number | Particle Size (mm) | Proportion (%) |
|---------------|-------------------|---------------|
| 1             | >80               | 0             |
| 2             | 50–80             | 1             |
| 3             | 25–50             | 44            |
| 4             | 13–25             | 30            |
| 5             | 6–13              | 20            |
| 6             | 0–6               | 5             |

According to the roller screening efficiency of 70%, the output on screen $Q_1=1000t/h$, it can be estimated that the flow rate under screen $Q_1=1000* (1-44%)*70%=392t/h$, the flow rate under the crusher $Q_2=1000-392=608t/h$.

4.2. **The model of in-service coal transit point**

Firstly, three-dimensional geometric models of receiving hopper, chute, guide trough and receiving belt conveyor are established, and then they are imported into the discrete element analysis software Rocky.
4.3. The improved model of the transfer point

The original cross section of the chute was 900 mm×900 mm. Considering the bond effect on the scattered material flow, the following improvement measures were taken:

(1) The square cross-section chute is improved to a U-shaped cross section. Figure 3 shows the structural diagram of linear square section chute and curved U-section chute.

(2) In order to reduce the vertical impact force of the material flow, the linear chute is changed to a space curved chute, and the angle between the slide line of the curved chute and horizontal line is no less than 62.5°. Figure 4 shows the improved curved chute.

(3) In order to prevent dust from scattering, the expansion -type fully enclosed guide trough design is adopted. The improved transfer point design is shown in Figure 5.

Figure 2. 3D model of the in-service coal chute

Figure 3. The cross-sectional shape of the chute before and after improved

Figure 4. The improved curved chute
4.4. Discrete element analysis of coal flow in the chute

After completing the modelling, import the model into the software to perform discrete element analysis on the coal chute. The specific analysis steps are as follows:

(1) Simplify the main structure of the coal chute, extract the wall surface that comes into contact with the coal during the fall of the material to form the outer wall of the material flow, and convert it to a neutral geometry file (.STL format), including guide trough, chute and downstream receiving conveyor, etc.

(2) Set the coefficient of friction, Poisson's ratio and shear modulus according to the material properties of the chute. The discrete element program is used to generate particles. The particle size, physical property parameters and distribution rules of the particles need to be set according to the characteristics of the actual coal conveyed, as shown in Table 1. The contact model between particles usually adopts the Hertz-Mindlin non-sliding contact model.

(3) According to the material particle size distribution table in Table 1, after completing the particle generation in the model, use the discrete element calculation tool to solve the material flow model. The calculated time step shall meet 20-30% of Rayleigh time step [2]. The total number of grid cells should not exceed 100000. After the calculation is completed, the results are imported into the post-processing software for data analysis.

5. The simulation and experimental results analysis

Figure 6 shows the comparison chart of logistics analysis before and after the chute improved. From the graph analysis, we can see:

(1) The cross-sectional area of the coal flow in the chute is reduced dramatically. The reason is that the bond effect of the cross section of the U-shaped chute changes the large area of material scattered state in the original chute.
(2) After the guidance of the improved curve chute, the vertical component of the end velocity of the material flow decreases and the speed division component along the conveyor belt direction increases. The zero velocity accumulation effect of material flow at blanking point is reduced.

(3) The impact force of the bottom of the material flow on the receiving belt is reduced. The reason is that the vertical velocity of coal flow is reduced, and at the same time due to the friction among coal particles in coal flow, friction between coal particles and liner of chute when guided and bonded by the improved curved coal chute.

![Figure 6. Material flow analysis of the chute before and after improvement](image)

6. Conclusion
In this paper, the coal transfer point of thermal power plant was modelled, and the material flow in it was simulated by using discrete element method. According to the simulation results, the movement state of coal flow in the chute was known, and according to the simulation results, the improvement scheme for the existing chute structure was put forward. Through the comparison of the simulation data before and after the improvement, it shows that the improved design of curve chute can effectively reduce the impact of coal flow on the downstream belt, reduce the phenomenon of zero speed stopping of materials, and help to solve the problems of eccentric load and deviation of conveyor belt, material spreading along the conveyor, excessive wear of equipment and reducing dust pollution in engineering practice. The relevant discussion in this paper can provide a reference for the improvement of the chute at the transfer point of a similar coal-fired transportation system.

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