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Study on Wear form of Split Cone of Vertical Shaft Impact Crusher

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Authors' contributions

This work was carried out in collaboration among all authors. Author FF designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors JS and JY managed the analyses of the study. Author JM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The three-dimensional model rotor of vertical shaft impact crusher was established by using the three-dimensional software Solidworks and it was imported into the discrete element software EDEM for dynamic simulation. The force of the split cone, the motion trajectory and force of the particles were analyzed in rotor by using the post-processing function of EDEM. The results show that the split cone was mainly affected by the normal action of particles. According to the definition of impact wear, it was finally determined that the wear form of the split cone is impact wear.

Keywords: Vertical shaft impact crusher; split cone; wear form, dynamic simulation; EDEM.

1. INTRODUCTION

With the construction of infrastructure such as construction industry and road traffic, the demand for sands is increasing annually in recent years. The vertical shaft impact crusher had the characteristics of simple structure, light weight, smooth operation and low energy consumption, so it was widely used in sand making [1].

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The vertical shaft impact crusher is mainly composed of spindle, motor, rotor, crushing cavity, feed hopper and control system. The material is fed by the feed hopper and falls into the rotor through the feed port. The vertical Shaft impact crusher adopts internal air circulation system. The air flow generated during the high-speed rotation of the rotor forms self-circulation in the crusher to drive the flow of materials. Under the action of the internal air circulation system of the crusher, the material is broken by the collision between the material and the material or the impact between the material and the crushing chamber [2,3].

When the parts are impacted by external materials, they will be worn to different degrees. The special structure inside the rotor can make the material form material cushion in the rotor, which is used to prevent the large area wear of the rotor caused by the acceleration of the material in the rotor, reduce the replacement times of the rotor and prolong the service life of the rotor [4]. The split cone, guide plate and hammer of the rotor are all vulnerable parts. Frequent replacement will not only increase the production cost of the enterprise, but also affect the production efficiency of the enterprise [5].

EDEM is the world's first multi-purpose discrete element method modeling software, which can be used to simulate and analyze the production process of particle processing and its manufacturing equipment in industrial production.

In this paper, the motion process of the rotor was simulated by discrete element software EDEM. The force of the split cone, the motion trajectory and force of the particles were analyzed in order to explore the main wear forms of the split cone.

2. ROTOR MODEL

Rotor is an important part of vertical shaft impact crusher, which can be divided into two categories: open-loop rotor and closed-loop rotor. The rotor is mainly composed of feeding ring, split cone, guide plate, hammer, upper and lower wear-resistant plate. The split cone is located in the center of the rotor and is usually made of hard metal such as medium and low carbon multiple alloy steel [6]. The material fall into the rotor could be equally distributed to both sides of the guide plate by split cone. Then the material accelerates, collides, grinds in the guide plate and leaves the rotor under the action of centrifugal force. It collides with the lining plate or material layer to achieve the crushing of the materia [7]. The three-dimensional model of the rotor was established by using the three-dimensional software Solidworks and imported into EDEM for dynamic simulation. In order to save the time of modeling and simulation and ensure that the simulation can be completed smoothly, the rotor model is simplified. The three-dimensional model of the rotor is shown in Fig. 1. Because the hammer has no effect on the on the simulation results, it is not drawn in the rotor model.

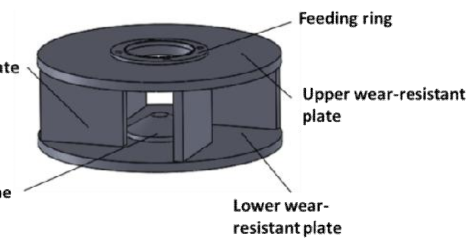


Fig. 1. Three-dimensional model of rotor

3. SETTING OF SIMULATION PARAMETERS

In the simulation software EDEM, the material of the particles was defined as limestone and the material of the rotor was defined as steel. The material properties of particle and rotor are shown in Table 1. The contact parameters between particle and rotor are shown in Table 2.

Table 1. Material property sheet

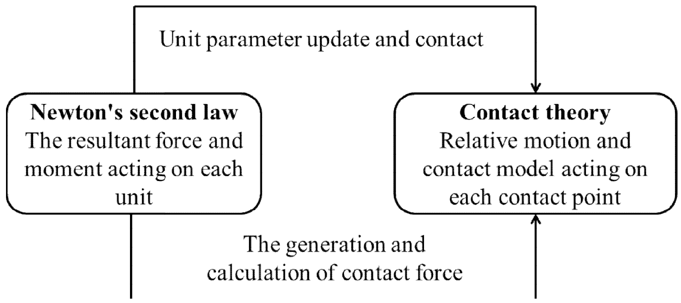
Materials	Poissonby	Density (kg/m^3)	Cut mod (*pa*)
Limestone	0.25	2640	2.09×10^8
Steel	0.30	7800	7×10^8

The generation plants and generation methods of particles were defined in Particle Factory. The particle factory was cylindrical in shape and it was the same as the entrance radius of the rotor shaft. The contact model was set up in the discrete element software EDEM and the Hertz-mindlin (no slip) contact model was used between particles and between particles and rotor [8,9].

The calculation cycle of EDEM is shown in the Fig. 2. In the course of its cycle, the force of the split cone, the motion trajectory and force of the particles are obtained.

Table 2. Contact parameter table

Contact materials	Recovery factor	Static coefficient of friction	Scroll the coefficient of friction
Limestone and limestone	0.207	0.77	0.1
Limestone and steel	0.557	0.61	0.07

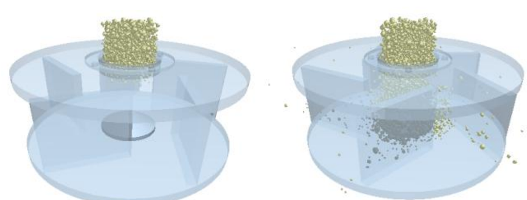


4. SIMULATION RESULTS AND ANALYSIS

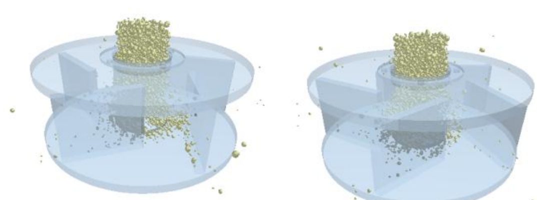
The production parameters of the rotor are selected: the feed quantity was 10 t/h and the rotational speed of the rotor was 2400 r/min. In order to make the particles leave the particle factory quickly, added an initial velocity to the particles. The simulation time was set to 10s and the simulation process of the rotor was shown in Fig.3.

It can be seen from Fig. 3 that a large number of particles have been generated in the particle factory when the simulation time was about 0.1s. When the simulation time was about 0.5s, the particles were uniformly distributed to both sides of the guide plate by the spit cone and then they left the rotor after being accelerated by the guide plate. In the subsequent simulation time, a large number of particles left the rotor under the action of centrifugal force.

As shown in Fig. 4 with the continuous progress of the simulation process, the number of particles inside the rotor gradually increased. When the simulation time was about 0.3s, the number of particles inside the rotor reached its peak. In the subsequent simulation time, the total number of particles inside the rotor has stabilized.



(a) The simulation time is from 0.1s to 0.5s



(b) The simulation time is from 1s to 10s

Fig. 3. The dynamic simulation process of the rotor

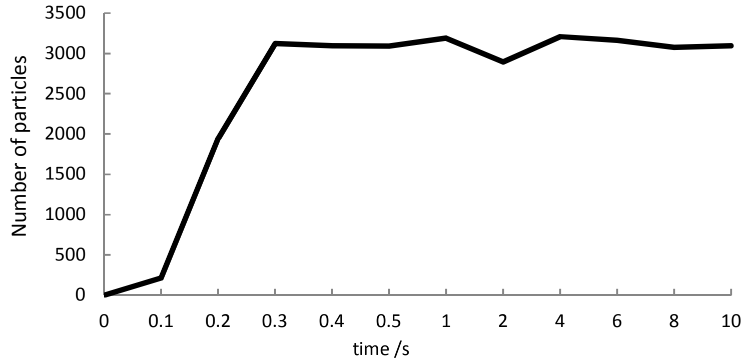


Fig. 4. The total number of particles in the rotor

4.1 Analysis of Split Cone Force

The post-processing function of EDEM was used to obtain the impact force of the particle on the surface of the split cone in each time step in the crushing process.

As shown in Fig. 5, it was the analysis of the split cone force per unit time. It can be seen from Fig. 5 that at about 0.17s, the particles begin to contact the surface of the split cone. After 0.17s to 0.2s, the total collision average normal force and the total collision average tangential force began to increase gradually.

As can be seen from Fig. 5, the total collision average force on the split cone was not stable in each time step and the total collision average normal force and the total collision average normal force reach the first maximum at about 0.3 s.

In the following time, as the particles were continuously accelerated by the rotor, although the total collision average force fluctuated up and down, the rotor system tended to be stable.

It can be clearly seen from the figure that, when the rotor system tends to be stable, the total average collision normal force on the feeding cone is greater than the total collision average tangential force at any time.It is obvious from the figure that, when the rotor system tends to be stable, the total collision average normal force of the split cone was larger than the total collision average tangential force at any time. So it can be seen that the split cone was mainly affected by the normal action of particles.

Does the change of the inclination angle of the split cone affects the relationship between the total collision average normal force and the total collision average tangential force?

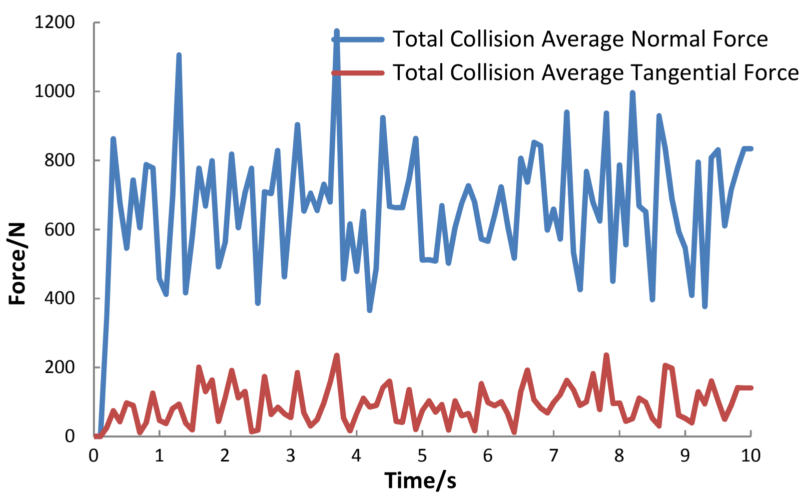


Fig. 5. Analysis of the split cone force

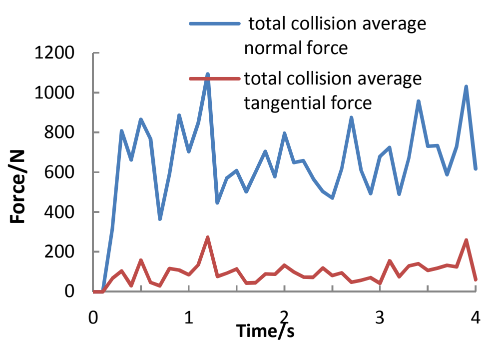
Therefore, in order to solve this problem, all other things being equal, the inclination angle of the split cone was selected as 35^0, 40^0, 45^0, 50^0. As can be seen from Fig. 5, when the simulation time was 4s, the rotor system was already stable. In order to save the simulation time, the total simulation time was set to 4s to observe whether the different inclination angle of the split cone would affect the relationship between the total collision average normal force and the total collision average tangential force.

As shown in Fig. 6, it was the total collision average normal force and total collision average tangential force under the split cone with different inclination angles in the simulation process. It can be seen that no matter how the inclination angle of the split cone changed, the total collision average normal force was always larger than the total collision average tangential force. It meant that the inclination angle of the split cone had no influence on the relationship between the total collision average normal force and the total collision average tangential force. The split cone was still mainly affected by the normal action of the particles.

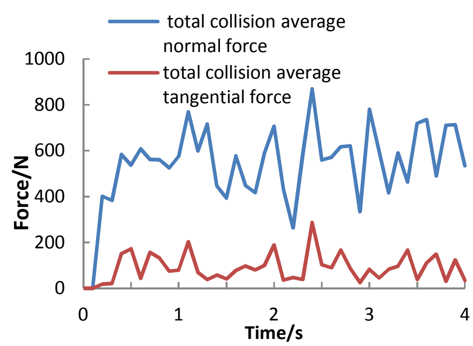
4.2 Trajectory Analysis of Particles

It can be seen from Fig. 6 that no matter how the inclination angle of the split cone changed, the total collision average normal force on the split cone was larger than the total collision average tangential force. In order to explore the cause of this phenomenon, the motion trajectory of particles inside the rotor was analyzed. In order to ensure the reliability of the results, a particle ejected by the rotor was randomly selected in this paper. And the other particles were hidden, the motion form of the particle in the rotor was observed separately.

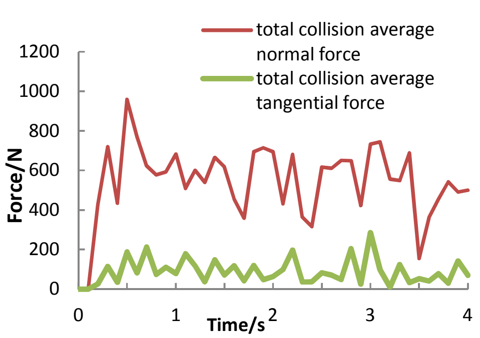
As shown in Fig. 7, it was the trajectory of particles inside the rotor. It can be found that after the particles were generated by the particle factory, they fall into the rotor under the action of gravity and were accelerated by the guide plate before leaving the rotor under the action of centrifugal force. By using the post-processing function of EDEM, the collision times between the particle and the split cone were got. It was found that the particle does not collide with the split cone only once.



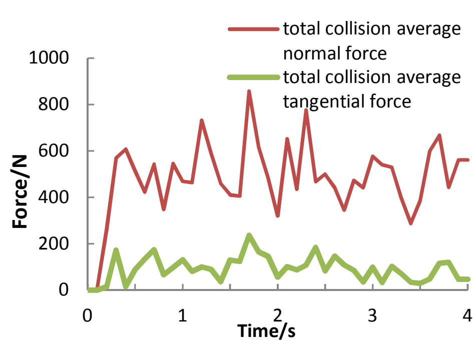
(a) The installation angle is 35^0



(b) The installation angle is 40^0

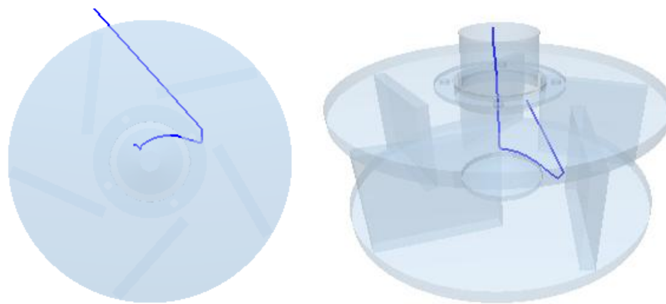


(c) The installation angle is 45^0



(d) The installation angle is50^0

Fig. 6. Force analysis of the split cone with different inclination angles



(a) Top view **(b) Isoaxonometric map**

Fig. 7. Particle motion trajectory

In Fig. 7 (b), it was found that the particle is almost close to the surface of the split cone. This was because the particle would immediately interact with other particles when they were in contact with the distribution cone, so that the particle collided with the surface of the split cone again and so on. Finally, the particle was dispersed on the guide plate.

4.3 Force Analysis of Particles

In order to better understand the interaction between the particle and the split cone, the contact force between the particle and the split cone during this period of time was selected as the research object. The contact force between the particle and the split cone was derived by using the post-processing function of EDEM.

As can be seen from Fig. 8, during the period from the generation of the particle factory to the time when the particle leaves the rotor under the action of centrifugal force, the particle comes into contact with the split cone twice. At 3.213222s, the particle contacted with the split cone for the first time. Then the normal contact force and tangential contact force between the particle and the split cone increased at the same time. The normal contact force and tangential contact force reached the maximum at about 3.413235s. At 3.413259s, the particles were separated from the split cone. At 3.532657s, the particle contacts the feed cone for the second time. And then the normal contact force and tangential contact force increased at the same time. At 3.5326675s, the normal contact force and tangential contact force reached the maximum. At 3.532681s, the particle was separated from the dividing cone again and the particle was shunted to the guide plate by the split cone in the following time.

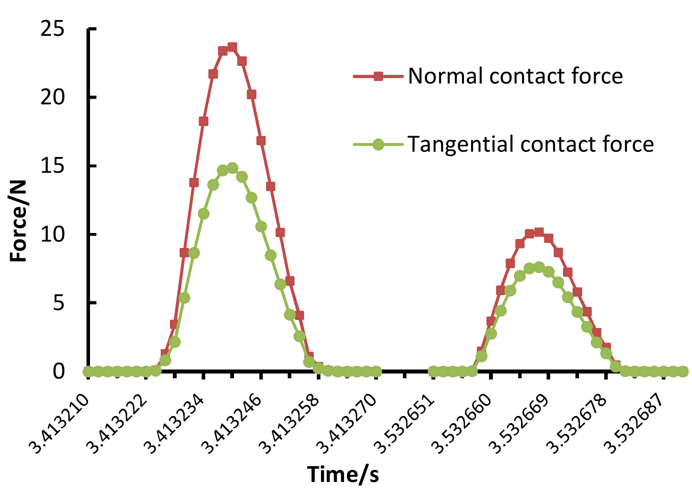


Fig. 8. Contact force between particles and split cone

Throughout the whole process of contact between the particle and the parting cone, the normal contact force between them was always larger than the tangential contact force no matter it was the first contact or the second contact. It can be seen that the split cone was mainly affected by the normal impact of particles.

5. DETERMINATION OF WEAR FORM OF SPLIT CONE

Under the continuous impact of particles on the material surface, the progressive wear of the material surface is called impact wear. In reality, impact and slide are always inseparable when the contact surfaces are close to each other, there will be both normal and tangential components of the impact [10].

The split cone was subjected to the normal and tangential action of the particles, but the normal action was the main one. So it can be seen that the wear form of the split cone was impact wear.

6. CONCLUSION

In the process of simulation, the total collision average normal force between the particle and the split cone was always larger than the total collision average tangential force. It can be seen that the split cone was mainly affected by the normal action of the particles, but also by the tangential action of the particles.

By observing the force of the split cone with different inclination angles, it was known that the split cone was mainly affected by the normal action of the particles and the inclination angle of the split cone had no effect on it.

During the period of collision between the particle and the split cone, the force analysis of the particle was carried out. It can be known that the particle had two times of contact with the split cone and the normal contact force between the particle and the split cone was always larger than the tangential contact force, which also proves that the action between the particle and the split cone was mainly in the normal direction.

According to the definition of impact wear, the wear form of the split cone is impact wear.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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