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Research on Fin Wear of Combined Drum Slag Cooler based on DEM Discrete Element Method

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Abstract

In order to study the abrasion of the fins and the drum caused by the movement of the particulate material in the drum with a six-prism cold slag tube drum slag cooler, a fine model of the six-prism cold slag tube was established, which was divided by a hexahedral grid. Under the particle concentration of Q=30000, calculated V1=6m/s, V2=8m/s, V3=10m/s under three drum speed working conditions, the wear rule and wear distribution of the wall and fins, the results show that Under the normal operating conditions of the slag cooler, the bottom slag particles are carried by the fins from the bottom to roll down along with the rotation of the slag cooler. In one cycle, the velocity of the bottom particles is lower at the beginning. Movement, the speed of the bottom layer particles gradually increases, reaching the maximum value at 0.5s, and then as the rolling of the higher particles is completed, the speed of the bottom layer particles gradually decreases. At the same particle concentration and drum speed, the wall wear is mainly concentrated on the top of the fin and the contact surface between the fin and the particle, and the wall between the fins. The wear on the top of the fin is relatively large. The amount of wall wear between the walls is evenly distributed. Under the same particle concentration, the faster the rotation speed of the drum, the greater the wear on the top of the fin and the contact surface between the fin and the particles at the same time. The wear is mainly concentrated on the top of the fin and the contact surface between the fin and the particle, and the wear on the top of the fin is the largest.

Keywords

Drum Cold Slag Machine; Fin Wear; Discrete Element Method; EDEM.

1. Introduction

The combined drum slag cooler is widely used in the heat exchange supporting system of fluidized bed (CFB) boilers due to its simple structure and stable operation [1]. In order to enhance the heat transfer effect of the slag particles in the pipe of the slag cooler, the tube wall of the drum slag cooler will be designed with a special fin structure, so that the bottom slag particles will be lifted to a certain height through the fins during the rotation of the drum and thrown down. , Let the slag particles fully dissipate heat and achieve excellent heat transfer effect. During the operation of the slag cooler, due to the impact of the slag particles, the contact surface between the fins and the slag particles will wear tangentially and normally. The wear and wear of the fins reduces the heat exchange capacity of the slag cooler and deteriorates its reliability. Therefore, studying the movement law of internal slag particles and fin wear during the operation of the slag cooler is very important for optimizing the fin structure of the slag cooler and reducing the fin wear during operation [2-8].

The phenomenon of fin wear caused by slag particles in the drum is more complicated, and the energy accumulation of slag particle slip and impact on the fin surface is one of the key factors for fin wear. During the operation of the slag cooler, the slag particles are in a discontinuous medium state, and it

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is difficult to obtain the slag particles and the movement parameters inside the slag cooler. In order to clarify the fin wear mechanism of the slag cooler, this paper uses the discrete element method (DEM) to study the slip and collision law of slag particles and fins during the operation of the slag cooler, and simulates the operation process of the slag cooler based on EDEM discrete element software. Obtain the movement state of the slag particles and the wear rule of the fins. Based on the simulation results, a fin optimization scheme is proposed. Provide support for the improvement of the structure of the combined drum slag cooler [9-22].

2. Physical model

Compared with the traditional drum type slag cooler, the combined drum slag cooler adopts a tandem heat exchange tube and a multi-tube structure that are easier to disassemble and assemble. At the same time, it realizes the series connection of the cold slag pipe body and the adjustment of the hot water exchange volume. Greatly improve the heat exchange efficiency of the slag cooler. In addition, the slag is completely in the closed tube cavity during operation, avoiding dust pollution. The combined drum slag colder selected this time adopts a double-layer cold slag tube structure, with 4 cold slag tubes in the inner layer and 8 cold slag tubes in the outer layer evenly arranged around the center of the circle.

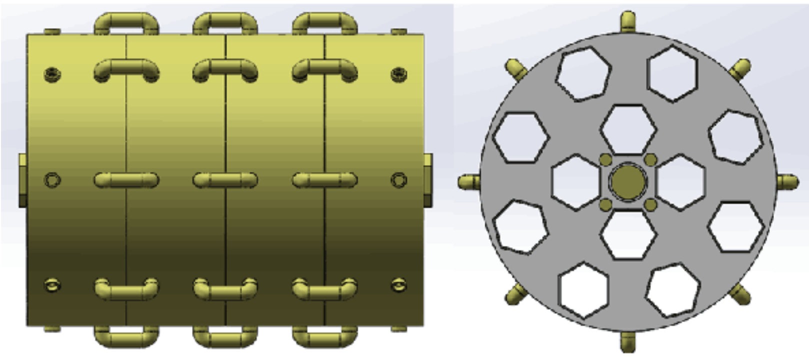
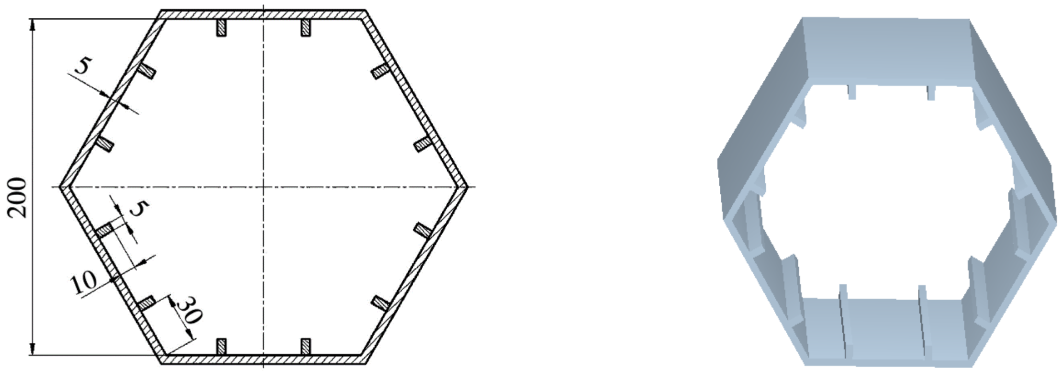


Fig. 1 Combined drum slag cooler structure

Based on the structural characteristics of the existing drum slag cooler, the simulation calculation uses a single slag cooler center rotation method. The drum is symmetrical. The inscribed circle of the six-prism cold slag tube is 200 mm in diameter and 1000 mm in length. The entire roller device is driven by a frequency conversion motor, and the speed adjustment range is 2-10 r/min. The inclination angle of the drum is controlled by two hydraulic jacks under one end of the support, and the inclination angle ranges from 1° to 5°. The three-dimensional model diagram of a single cold slag tube is shown in Figure 2



(a) Two-dimensional drawing (b) 3D model diagram

Fig.2 Cold slag tube structure

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3. Theoretical model

3.1 Hertz contact theory model

Hertz contact theory assumes that the pressure distribution on the contact surface is a semi-ellipsoid, the contact surface of the point contact object is elliptical after force, and the contact surface of the line contact object is rectangular after force. The elastic deformation of the material conforms to Hooke's law, so the stress change law on the contact surface and the strain of the contact body become a linear relationship. When two spherical particles collide with each other, the contact surface is a circle with radius a. Under the action of pressure P, the compressive stress distribution formula of the contact surface is:

$$p(r) = \frac{3P\left[1 - {r^2}/{a^2}\right]^{1/2}}{2\pi a^2} \tag{1}$$

In the formula: p(r) is the pressure stress of the contact surface; P is the pressure; a is the radius of the contact circle; r is the variable of the contact circle radius, and its value range is 0~a.

The calculation formula of contact circle radius and total deformation is:

$$a^3 = \frac{3}{4}R\left(\frac{1-{\mu_1}^2}{E_1} + \frac{1-{\mu_2}^2}{E_2}\right)P \tag{2}$$

$$\delta^3 = \frac{9}{16}R\left(\frac{1-{\mu_1}^2}{E_1} + \frac{1-{\mu_2}^2}{E_2}\right)^2 P^2$$

$$R^{-1} = {R_1}^{-1} + {R_2}^{-1} \tag{3}$$

In the formula: δ is the total deformation; R is the equivalent radius; R_1 and R_2 are the radii of the two contact spheres; μ_1 and μ_2 are the Poisson ratios of the two contact spheres respectively; E_1 and E_2 are the two contact spheres respectively Elastic Modulus.

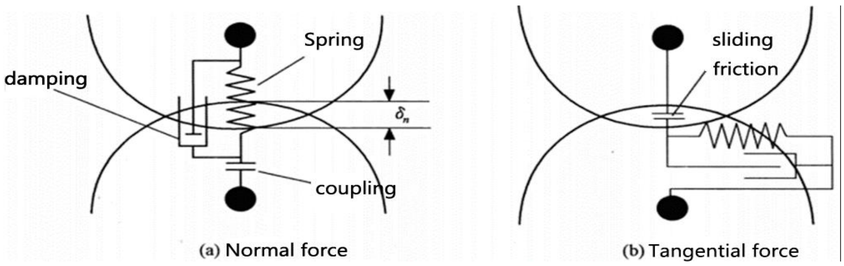

Fig. 3 Soft ball model

3.2 Archard Wear model

The Archard Wear model built in EDEM is used to calculate the amount of wear. The Archard Wear model believes that the wear depth W is related to the contact pressure P, the wear coefficient K, the relative slip length L, and the hardness H. The expression is:

$$W = \frac{KPL}{H} \tag{1}$$

In the formula: K is the wear coefficient; L is the sliding formation (m); Fn is the normal phase load (N); H is the surface hardness of the material. In EDEM, the wear volume is expressed as the wear amount h per unit area:

$$h = \frac{W}{A} \tag{2}$$

In the formula, A is the contact area between the solid particles and each part (m^2).

In order to show the wear relationship of each part more intuitively, the relative wear amount W^* of dimension 1 is introduced:

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$$W^* = \frac{W_i}{\sum W_i} \tag{3}$$

3.3 Calculation parameter settings

According to the actual working conditions, the particle shape is set to a single spherical shape, and the number of particles is set to 30,000. The properties of the particles and the mutual force parameter settings are shown in Table (1) (2).

Table 1. Material properties

	Particles	Wall
Poisson's ratio μ	0.15	0.3
Density ρ [kg·m^3]	2500	7800
Particle size$r$ [mm]	1.0	-
Shear modulus G [MPa]	18	35

Table 2. Material interaction

	Particle-particle	Particle-wall
Coefficient of static friction K_s	0.01	0.01
Rolling friction coefficient K_r	0.27	0.15
Material recovery coefficient e	0.5	0.45

4. Results and analysis

4.1 Particle movement

The slag particles in the drum show different motion states over time, and may appear slipping, sliding, rolling, throwing, centrifugal and other motion states. Under normal circumstances, the longer the slag stays in the drum, the better the cooling effect. Therefore, the drum speed is generally set to be less than 10r/min, and the main movement state of the slag particles at this time is rolling off. The movement of the first 0.6s cold slag tube is intercepted at a speed of 5r/min. As can be seen in Figure 4, with the rotation of the cold slag tube, the movement of slag particles appears periodic. Initially, the bottom slag particles are carried by the fins. High places, roll down after reaching high places.

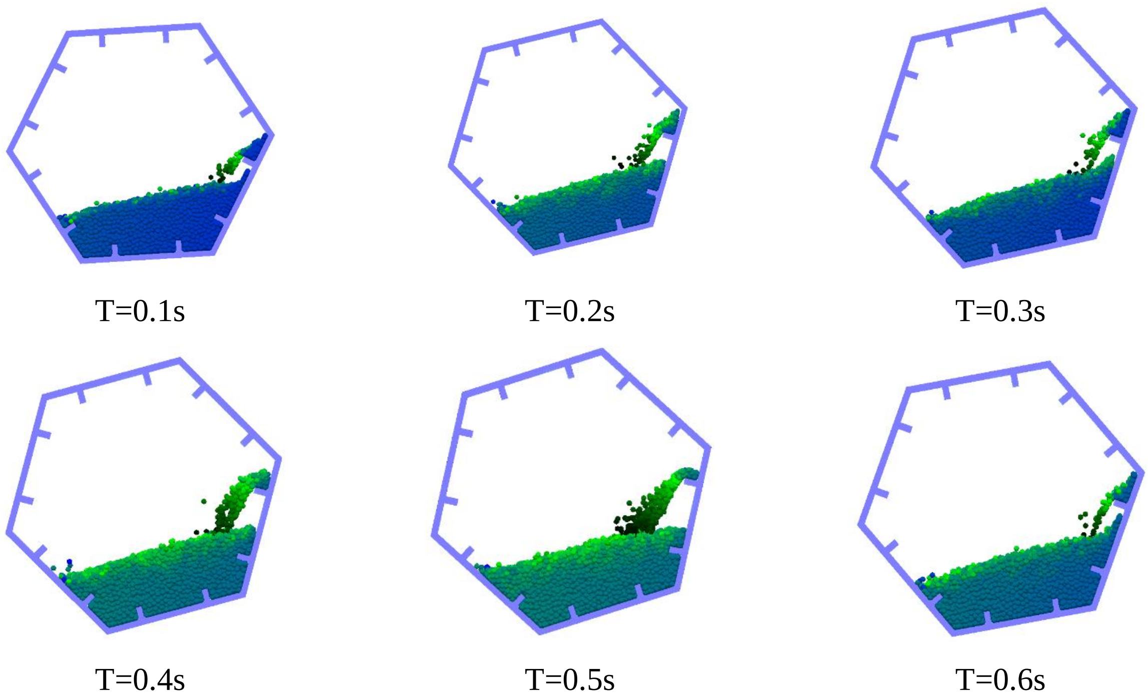

Fig. 4 Particle movement

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4.2 Wear distribution

Figure 4 is a cloud diagram of fin wear at each time node. It can be seen from the figure that the wear of the cold slag tube is mainly concentrated on the top of the fin, the edge line and the wall between the two fins. With the increase of time, the amount of wear at the top of the fin, the edge line and the wall surface between the two fins increases in a positive correlation.

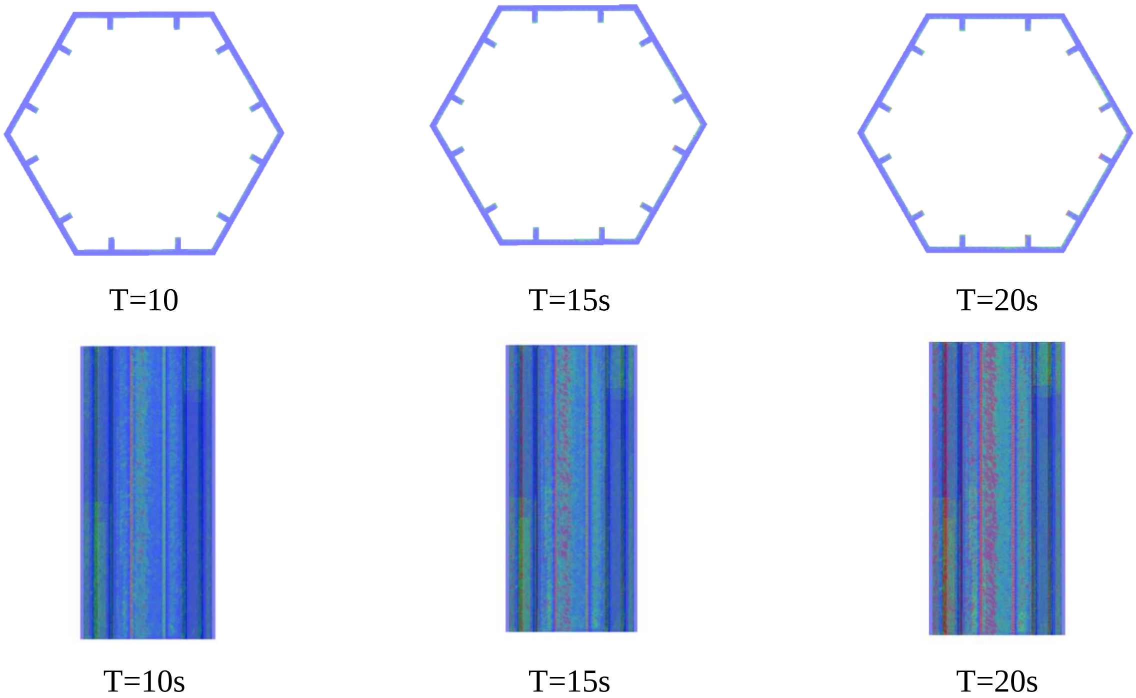

Fig. 5 Contours of wall surface wear at different times

In order to explore the influence of the drum speed on the wear of the fins and the wall surface, the wear amount is simulated and calculated under the three drum speeds of V1=6m/s, V1=8m/s, and V1=10m/s. The results are shown in Figure 6, the maximum wear of each part is concentrated on the top of the fin and the contact surface between the fin and the particle, and the wear on the wall between the fins is evenly distributed. As the roller speed increases, the wear on the top of the fin and the contact surface between the fin and the particle increases linearly at the same time. When V1=10m/s, the wear on the top of the fin is the largest, reaching 3×10- 5mm.

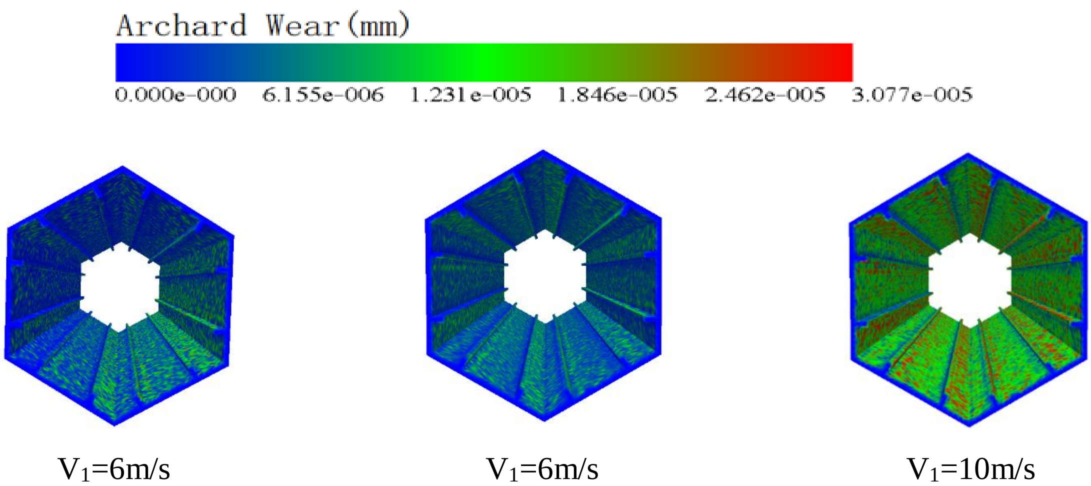

Fig. 6 Contour of wear in the pipe wall

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5. Conclusion

(1) Under the normal operating conditions of the slag cooler, the bottom slag particles are carried by the fins from the bottom to roll down along with the rotation of the cold slag tube. In one cycle, the velocity of the bottom slag particles is lower at the beginning. The velocity of the bottom layer particles gradually increases, reaching the maximum value at 0.5s, and then as the rolling of the higher particles is completed, the bottom layer particle speed gradually decreases.

(2) At the same particle concentration and roller speed, the wall surface wear is mainly concentrated on the top of the fin and the contact surface between the fin and the particle, as well as the wall between the fins. The wear on the top of the fin is relatively large. The amount of wall wear between the walls is evenly distributed.

(3) Under the same particle concentration, the faster the rotation speed of the drum, the greater the wear on the top of the fin and the contact surface between the fin and the particles at the same time. The wear is mainly concentrated on the top of the fin and the contact surface between the fin and the particle, and the wear on the top of the fin is the largest.

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