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Selection and Optimization of Structures of Double Screw Conveyors

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***Abstract*—The screw conveyor with no overlap between two screw blades and the screw conveyor with large overlap between two screw blades were simulated by discrete element method and the distribution of particle axial velocity, angular velocity, forces around the shell and forces around screw blades was carried out. The results show that: the screw conveyor with no overlap between two screw blades has better performance, because its average axial velocity of particles and conveying capacity are larger, its mean angular velocity of particles and forces around screw blades and the shell are smaller and its power consumption is also less; Particles around the bottom of the shell and the edge of screw blades are more prone to be worn-out and break up; Forces around the bottom of the shell and the edge of screw blades are larger, so double screw conveyors will most probable be destroyed in these two positions. The above results can provide references for structures selection and optimal design of double screw conveyors.**

***Keywords*—double screw conveyors; discrete element method; velocity distribution; forces distribution; structure optimization**

I. INTRODUCTION

Screw conveyors are widely used as a kind of continuous conveying equipments [1] and scholars at home and abroad have done many researches about the influence of different screw speed [2], filling ratio [3], particle viscosity [4] and feed inlets [5] on the performance of screw conveyors by discrete element method (DEM) which provides references for the selection of the working conditions of screw conveyors.

As a common type of screw conveyors, the double screw conveyor has simple structures, but the distribution of forces in it is complex and the motion of particles is unpredictable which make experiments almost impossible to obtain the movement of particles and the distribution of forces. But the discrete element method can be used to solve this problem. Therefore, in this part, DEM is used to study the velocity distribution of particles and the forces distribution around the shell and screw blades of two different types of horizontal double screw conveyors.

II. DISCRETE ELEMENT SIMULATION SETTING

A. Simulation Models of Double Screw Conveyors

The DEM simulation models of two horizontal double screw conveyors are shown in Figure I and Figure II. In Figure I, the diameter of each drive shaft is 59mm, the diameter of each screw blade is 165mm, the pitch t1 is 120mm, the offset S1 is 60mm, the distance between two drive shafts L1 is 165mm. The basic sizes of each component in Figure II are the same as those of Figure I, but the distance between two drive shafts L2 is 112mm. The structure in Figure I can represent the type of double screw conveyors which have no or small overlap between two screw blades, called as type 1. The structure in Figure II can represent the type of double screw conveyors which have large overlap between two screw blades, called as type 2. The simulation front views of two conveyors are the same, as shown in Figure III.

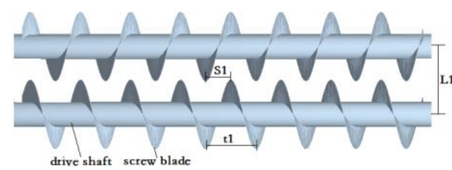

FIGURE I. THE STRUCTURE WITH NO OR SMALL OVERLAP BETWEEN TWO SCREW BLADES (TYPE 1)

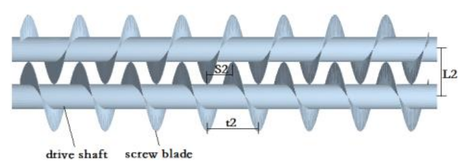

FIGURE II. THE STRUCTURE WITH LARGE OVERLAP BETWEEN TWO SCREW BLADES (TYPE 2)

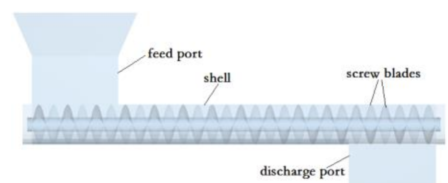

FIGURE III. THE SIMULATION FRONT VIEWS OF TWO DIFFERENT TYPES OF DOUBLE SCREW CONVEYORS

B. Simulation Parameters Setting

The simulated particles are approximately spherical peas, and the diameter of each particle is 8 mm, the poisson's ratio is 0.4, the shear modulus is $1.1x10^7$Pa, the density is 1053kg/m^3; The whole material of double screw conveyors is steel, and the poisson's ratio of the steel is 0.3, the shear modulus is $7x10^{10}$Pa, the density is 7800kg/m^3; The coefficient of static friction of pea-pea and pea-steel is 0.5 and 0.3 respectively.

III. ANALYSIS OF SIMULATION RESULTS

When the screw speed is 100rpm, filling ratio is 40%, the simulation of two types of double screw conveyors was carried out, and the distribution of particle axial velocity, particle angular velocity, forces around the shell and screw blades was obtained and analyzed.

A. *The Distribution of Particle Axial Velocity*

In the X-Y coordinate plane, the distribution of particle axial velocity is obtained at the same position of two screw conveyors, as shown in Figure IV. In the figure, particles are colored in different colors, the red represents the maximum velocity, and the blue represents the minimum velocity. The particle axial velocity in middle of two screw blades is larger than in two sides, as shown in Figure IV. And the average particle axial velocity of the type 1 double screw conveyor is larger than the type 2. In order to quantify the characteristic, the mesh of two screw conveyors is generated along the X axis, as shown in Figure V, and the axial average velocity of particles in each grid is counted and plotted in Figure VI.

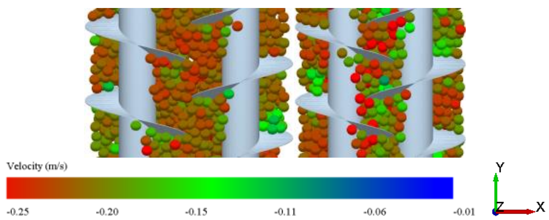

FIGURE IV. THE DISTRIBUTION OF PARTICLE AXIAL VELOCITY IN TWO SCREW CONVEYORS

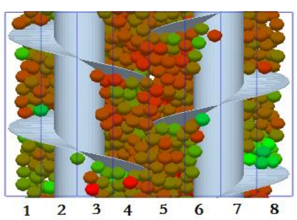

FIGURE V. THE MESH OF TWO SCREW CONVEYORS ALONG THE X AXIS

The average axial velocity of particles in the middle is larger than in other parts as shown in Figure VI which is similar to the conclusion in Figure IV, this is because both two screw blades will give energy to particles in the middle. What's more, the average axial velocity of particles in the type 1 double screw conveyor is larger than in the type 2, this is because the overlap between two screw blades of type 2 is larger, the space in the middle is narrower, so the collisions of particle-particle are more intense which leads to energy dissipation and the decrease of average axial velocity. And the average axial velocity of particles is a main factor affecting the conveying capacity [4], so the conveying capacity of the type 1 double screw conveyor will be greater than the type 2.

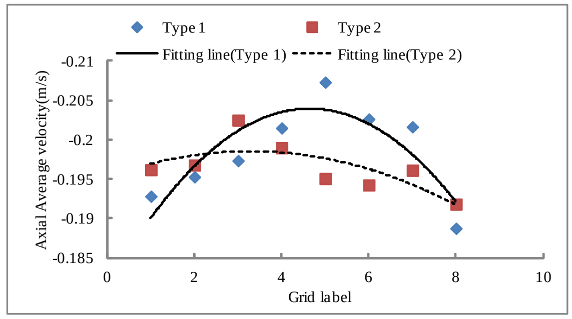

FIGURE VI. THE DISTRIBUTION OF AXIAL AVERAGE VELOCITY OF PARTICLES IN EACH GRID

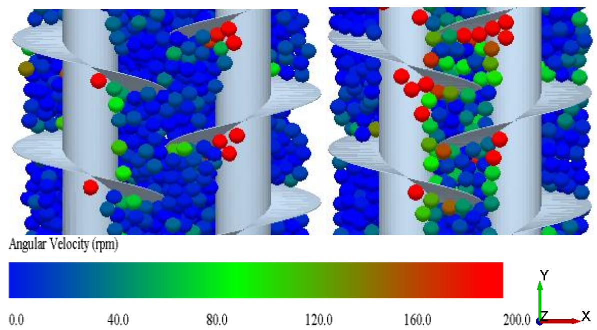

FIGURE VII. THE DISTRIBUTION OF PARTICLE ANGULAR VELOCITY IN TWO SCREW CONVEYORS

B. *The Distribution of Particle Angular Velocity*

In the X-Y coordinate plane, the distribution of particle angular velocity is obtained, as shown in Figure VII. Then two conveyors are meshed the same as Figure V, and the average angular velocity of particles in each grid is counted and plotted in Figure VIII.

The particle angular velocity is greater near drive shafts and screw blades as shown in Figure VII, this is because drive shafts and screw blades will do work on particles around them through the friction. In addition, the particle angular velocity in the middle of double screw conveyors is greater than in elsewhere as shown in Figure VII and Figure VIII, this is because both two screw blades will do work on particles in the middle through the friction. What's more, the average particle angular velocity of the type 2 double screw conveyor is greater than the type 1, this is because the space in the middle of the type 2 double screw conveyor is smaller, and the extrusion force acting on particles will be greater when going through narrower region which causes the instable movement of particles and the increase of particle average angular velocity.

If the particle angular velocity is greater, the movement between particles will be fiercer, the point contact among particles will be more, the probability of particle breakage will be greater, the power consumption of screw conveyors will also be greater. Thus, it can be concluded from Figure VIII that the power consumption and probability of particle breakage of the type 2 double screw conveyor are greater than the type 1.

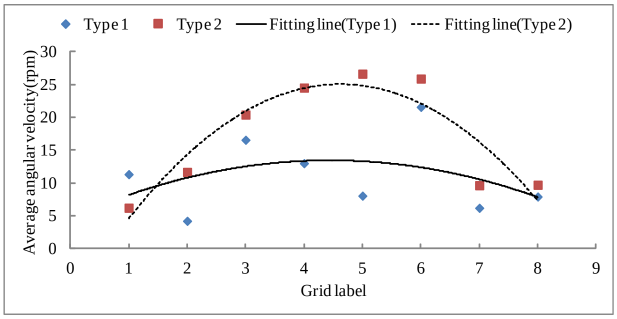

FIGURE VIII. THE DISTRIBUTION OF AVERAGE ANGULAR VELOCITY OF PARTICLES IN EACH GRID

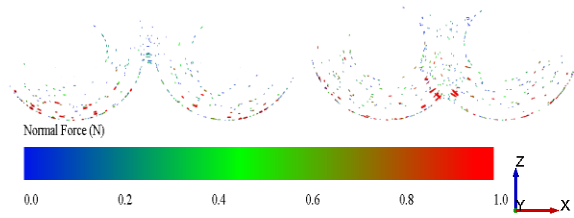

FIGURE IX. THE DISTRIBUTION OF NORMAL FORCE AROUND SCREW BLADES OF CONVEYORS

C. *The Distribution of Forces around Screw Blades and the Shell*

In the X-Z coordinate plane, the distribution of normal force and tangential force around screw blades is obtained, as shown in Figure IX and Figure X. It can be drawn from two figures that the farther it is away from the center of the screw blade, the greater the normal and tangential force around the blade will be. This phenomenon indicates that the impact and abrasion of the screw blade is greatest on the edge, so the edge is most probable to be worn-out and destroyed and particles are also most probable to break up around the edge of each screw blade. Therefore, during the design of double screw conveyors, it's useful to coat the edges of screw blades with a layer of wear-resistant and smooth material, so as to reduce forces on the edges, strengthen the ability to resist impact and abrasion and improve the life of screw blades.

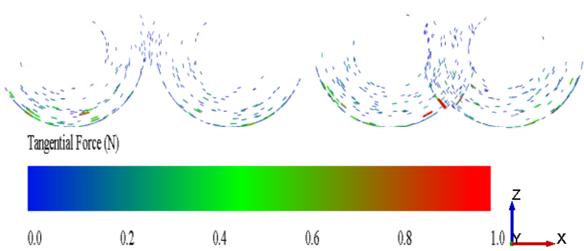

FIGURE X. THE DISTRIBUTION OF TANGENTIAL FORCE AROUND SCREW BLADES OF CONVEYORS

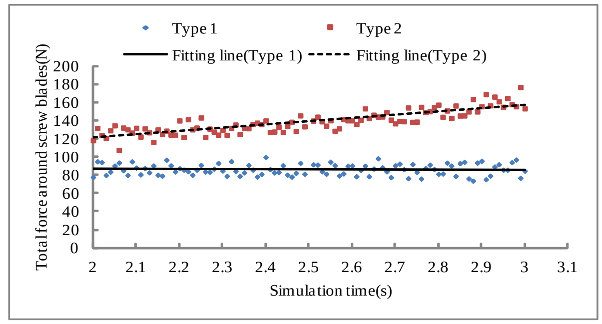

FIGURE XI. THE TOTAL FORCE AROUND SCREW BLADES VARIES WITH SIMULATION TIME

In order to explore the difference between screw blades of type 1 and type 2 double screw conveyors, the change of the total force around screw blades over time is obtained, as shown in Figure XI. The total force around screw blades of the type 1 double screw conveyor remains unchanged over time which indicates that the motion of particles in it is stable, but the total force around screw blades of the type 2 double screw conveyor increases a little over time which indicates that the movement of particles is unstable, so the impact and abrasion of screw blades will increase, and the power consumption will also increase. What more, the total force around screw blades of the type 1 double screw conveyor is greater than type 2 which indicates the screw blades of the type 2 double screw conveyor are more likely to be destroyed over time, but on the other way, it is more effective to break up particles.

It can also be concluded from Figure IX and Figure X that particles are mainly concentrated in the lower part of the shell of the double screw conveyor, which indicates that forces acting on the shell is mainly concentrated on the lower part of the shell. In order to explore the distribution of forces around the shell, the shell is meshed along the Z axis, as shown in Figure XII. The total normal force and tangential force in each grid are counted and plotted in Figure XIII.

FIGURE XII. THE MESH OF THE SHELL OF TWO SCREW CONVEYORS ALONG THE Z AXIS

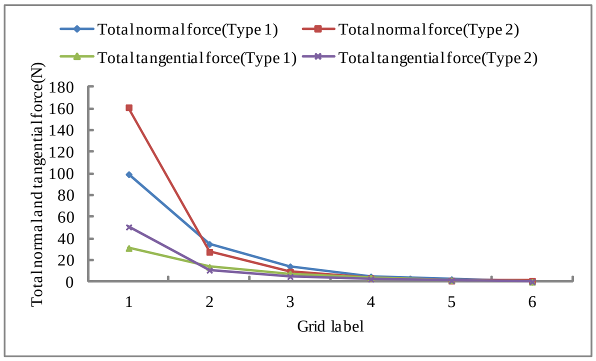

FIGURE XIII. THE DISTRIBUTION OF TOTAL NORMAL FORCE AND TANGENTIAL FORCE IN EACH GRID

The closer it is to the bottom of the shell, the greater the total normal and tangential force in the grid will be, as shown in Figure XIII. This phenomenon shows that the impact and abrasion caused by particles is greatest at the bottom of the shell, so the bottom is most probable to be destroyed, and the particles are also most probable to break up around this position. So it's useful to increase the shell's thickness at the bottom or coat the bottom of the shell with a layer of wear-resistant and smooth material, in order to strengthen its ability to resist impact and abrasion and improve the working life of the double screw conveyor. What's more, the total normal and tangential force in the grid of the type 2 double screw conveyor are greater than the type 1, as shown in Figure XIII, which indicates that the type 2 double screw conveyor is more probable to be damaged under the same conditions, but the performance of particle breakage will be better.

IV. CONCLUSIONS

The screw conveyor with no overlap between two screw blades and the screw conveyor with large overlap between two screw blades are simulated by DEM and the distribution of particle axial velocity, angular velocity, forces around the shell and forces around screw blades in two double screw conveyors which is impossible to be obtained by experiments was carried out and analyzed, and the following conclusions can be obtained:

(1) The screw conveyor with no overlap between two screw blades has greater particle average axial velocity and conveying capacity, lower particle average angular velocity, smaller forces around screw blades and the shell, less power consumption, better performance, but it is not good at the breakage of particles. So when design double screw conveyors, it's more suitable to adopt the structure with no overlap between two screw blades. But if there is a need for higher breakage rate of particles, the structure with large overlap between two screw blades can be adopted.

(2) The axial velocity and angular velocity of particles are greatest in the middle of double screw conveyors, forces acting on particles are greatest in the bottom of the shell and in the edge of screw blades. In these parts, the particles are most probable to be worn-out and break up.

(3) The forces are greatest around the bottom of the shell and the edge of each screw blade, so double screw conveyors are most probable to be destroyed in these two parts. It's reasonable to coat wear-resistant and smooth material in the two parts, so that the mechanical properties in the two parts can be improved and the life of double screw conveyors will be longer.

ACKNOWLEDGEMENTS

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