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Analysis of Coal Transportation Efficiency of Horizontal Screw Conveyor Based on EDEM

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Abstract: *In order to analyze the coal conveying capacity of horizontal screw conveyor, the pitch, blade thickness and speed are combined in order, and the EDEM orthogonal test is carried out with the conveying time of a certain number of particles as the test index, and the simulation is carried out to explore the influence of test factors on the test index. The research shows that the larger the pitch, the shorter the time it takes to transport the same batch of materials, and the higher the transportation efficiency. Blade thickness has little effect on material transportation efficiency, and increasing the thickness of spiral blades can increase the strength of blades. In a certain range, the higher the rotating speed, the shorter the time it takes to transport the same batch of materials. However, after the rotating speed is too high, the particles will rebound and hit the wall due to the increase of centrifugal force. When the number of particles decreases gradually, the collision will be more obvious, which will lead to the unstable forward transportation of materials and even the backward movement of materials. Thereby reducing the transportation efficiency. This situation shows that when the speed is too high, its conveying capacity will decrease. The optimal combination is pitch 500mm, blade thickness 6mm and rotating speed 90r/min.*

Keywords: *Orthogonal experiment, horizontal screw conveyor, EDEM, conveying capacity*

1. Introduction

1971——Dr. Cundall proposed a numerical simulation method to study discontinuous media. Newton's second law under Lagrange solution system Kinetic simulation of each particle monomer in the system was carried out. 1986-The first national seminar on numerical calculation and simulation test of rock mechanics. 2002-The commercial discrete method simulation software EDEM was released, and the application of discrete element engineering began. 2006-EDEM was introduced to China by Haiji Technology Co., Ltd. 2017-Widely used in mineral processing, agricultural machinery, chemical industry, metallurgy, pharmacy, aerospace and other fields. EDEM is mainly used in the following industries:

(1) Mining machinery (shearer, bucket wheel machine, ball mill, crusher)

(2) Construction machinery (excavators, loaders, dumpers)

(3) Metallurgical industry (blast furnace distributor, feeding system)

(4) Agricultural machinery (seed selector, seeder, fertilizer spreader, vibrating screening equipment)

(5) Pharmaceutical industry (tablet coating, tablet packaging and processing)

(6) Chemical industry (optimized flow)

(7) Material processing and treatment (material conveying and grinding)

(8) Space exploration (electrostatic separation/dust removal, lunar soil)

The transportation of bulk materials plays an important role in industrial applications, such as minerals, agriculture, medicine and chemical industries [1]. According to its functions, the applications of screw conveyor mainly include: (1) As a bulk material conveying equipment, it can convey particles at a stable and controllable speed in agriculture and industry; (2) As a part of construction machinery and mining machinery, such as in underground tunnel drilling rig, it is used for uninterrupted discharge of soil or rock; (3) Used to calculate the storage bin [2].

Screw conveyor has the advantages of compact design, low maintenance cost, safe and continuous material transportation [3]. Ning Tingzhou [4] and others studied the influence of inclination angle, pitch and rotation speed on the conveying efficiency of screw conveyor by orthogonal experiment. Zheng

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Xinxin [5] used EDEM to simulate the conveying process of the screw conveyor, and summarized and analyzed the changing law of the conveying performance of the screw conveyor with time. Yang Weijie [6] and others calculated the pressure of granular particles on the spiral blades by the method of continuous medium hypothesis, established a model of vertical spiral conveyor and analyzed the influencing factors of blade wear. In this paper, the influence of the thickness, pitch and speed of the screw conveyor on the conveying capacity of the screw conveyor is studied by analyzing the previous research process and methods, using EDEM software, and the best parameter combination to improve the production efficiency is put forward. This study may provide theoretical reference for improving the conveying capacity of horizontal screw conveyor.

Because the discrete element method has not been introduced to China for a long time, the analysis of screw conveyor with discrete element method has just started in China and belongs to a new industry. Moreover, screw conveyors are often associated with large-scale environmental protection equipment. China's environmental protection industry started late, with only a few decades of history and relatively backward technology. These factors restrict the development of screw conveying equipment in China, which leads to the defects of screw conveying equipment in China and the performance needs to be improved urgently. The materials used in the transportation experiment of the screw conveyor have high performance and cost a lot, so it may not develop rapidly in a short time. However, with the improvement of China's industrial level, the development of the national economy and the support of national policies, this large-scale screw conveyor equipment will surely develop. However, in the long run, there is still a long way to go for the screw conveyor in China because the requirements for materials are generally high and it cannot be widely used for the time being.

There is still a certain gap between domestic screw conveyor and foreign level. The development of science and technology is the trend of industrial development, and it is this gap that exists. Therefore, we should pay attention to the strategic industry of screw conveyor development. As the pillar of national industry and the vanguard of economic growth, screw conveyor will surely grow sturdily with the development of emerging industries and reflect the overall trend and times of intelligence, networking, precision, energy saving and global development characteristics.

2. Theoretical analysis

2.1. Calculation theory of conveying capacity of screw conveyor

The formula for calculating the conveying capacity of the screw conveyor is Formula (1):

$$Q = 47 D^2 sn\psi\gamma C \tag{1}$$

In formula (1), D is the diameter (m) of the spiral blade; S is the pitch (m) of the spiral blade; N is the rotational speed of the screw shaft (r/min); ψ is the filling factor; γ is the bulk density of materials (t/m^3); C is the correction factor.

2.2. Basic parameter calibration

2.2.1. Spiral blade diameter

Spiral diameter can be preliminarily calculated by the following formula:

$$D \geq K \sqrt[2.5]{\frac{Q}{\psi\rho C}}(m) \tag{2}$$

(2) In the formula, q represents the conveying capacity t/h, k represents the material characteristic coefficient, ψ represents the filling coefficient, and c represents the inclination coefficient. Look-up table shows that K=0.0415 ψ=0.35 C=1.0 When the transportation output is Q=15t/h, and the bulk density of materials is $\rho=0.85t/m^3$, the diameter of the spiral is D = 20mm. The final sentence of a caption must end with a period.

2.3. Selection of variable parameters

2.3.1. Selection of rotational speed

When the screw conveyor is conveying materials, the cross section occupied by the diameter [7] of the screw shaft has certain influence on the conveying capacity of materials. Therefore, the size of the crosssectional area of the shaft cannot be ignored in the calculation. When conveying materials, the rotation speed plays a decisive role in the transportation of materials, but excessive rotation speed will reduce the transportation efficiency of materials. When the rotating speed of the blades of the screw conveyor increases, the time it takes for the screw conveyor to convey the same batch of materials is shorter, but when the rotating speed exceeds a certain limit, a larger centrifugal force is generated, which leads to an increase in the collision between material particles or the collision between material particles and the inner wall of the conveyor, which leads to a decrease in the conveying capacity, so the rotating speed needs to be limited to some extent. When the conveying capacity is satisfied, the speed should not be too high or exceed the maximum allowable speed [8]. The formula for calculating the speed of the spiral blade is formula (3)

$$n \le n_{max} = A/D^{1/2} \tag{3}$$

In formula (3), the spiral diameter d is 200mm, and the material comprehensive characteristic coefficient A = 50mm. The limit speed n1=110(r/min) can be obtained by calculation. The rotating speed of the screw shaft can be reduced by one grade to prolong its service life. Therefore, the rotational speed can be selected as 80r/min, 90r/min and 100r/min.

2.3.2. Selection of pitch

The pitch not only determines the starting angle and transportation efficiency of the spiral blade, but also determines the movement process of the material particles and the contact with the spiral blade, so the pitch directly affects the material transportation process [9].

To determine the most reasonable pitch size, it is necessary to comprehensively consider the friction relationship between spiral surface and material and the appropriate distribution relationship between velocity components [10]. The calculation formula is formula (4)

$$s = kD \tag{4}$$

In formula (4), d is the screw diameter, and the screw diameter calculated by formula (2) is 400 mm. For standard screw conveyor, the value of k is 0.8 to 1. When the inclined screw conveyor is studied, the k value is less than 0.8; Because the object of this experiment is the standard screw conveyor, the k value can be 0.8, 0.9 and 1. By calculating the available pitch. Therefore, the pitch S can be selected as 400mm, 450mm and 500 mm.

2.3.3. Selection of thickness of spiral blade

The thickness of the spiral blade affects its service life, but it doesn't mean that the thickness determines everything. From the design of the spiral conveyor, the pitch, the relationship between the diameter of the spiral blade and the clearance of the shell, and finally the rotation speed of the spiral shaft will have certain influence in many aspects. The greater the blade pressure during the rotation of the screw conveyor, the faster the damage. Therefore, the thickness of spiral blades can be selected as 4mm, 5mm and 6 mm. The relationship between the thickness of spiral blade and its transportation capacity and service life is comprehensively analyzed.

2.4. Research Method

Selecting three experimental factors, i.e. rotational speed, pitch and blade thickness, an orthogonal experiment table $L_9(3^4)$ was used to carry out a three-factor three-level experiment [11]. Firstly, according to the orthogonal experimental table, nine kinds of experimental models of horizontal screw conveyor are established by SoildWorks, and then they are imported into EDEM to simulate the transportation of pulverized coal system. In the process of material transportation simulation of screw conveyor, it is necessary to set the same number of particles, and record the time spent transporting these particles by these nine groups of screw conveyors respectively, and analyze and get a set of three experimental factors with the smallest collision and the shortest transportation time, and get the optimal parameter combination. The orthogonal table of three factors and three levels is shown in Table 1, and the parameters and interaction of materials are shown in Table 2.

Table 1: Three-factor and three-level orthogonal table.

Factor	screw pitch /mm	Blade thickness /mm	rotation speed (r/min)
1	400	4	80
2	450	5	90
3	500	6	100

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Table 2: Three-factor and three-level orthogonal table.

Materials	Attribute
	Poisson ratio of coal =0.3
	Coal shear modulus =1.3×10^9Pa
	Coal density =1300kg/m^3
	Coal-coal recovery coefficient =0.5
Coal	Coal-coal static friction coefficient =0.6
	Coal-coal rolling friction coefficient =0.05
	Coal-steel recovery coefficient =0.5
	Coal-steel static friction coefficient =0.4
	Coal-steel rolling friction coefficient =0.05.
	Poisson's ratio of steel =0.3
	Shear modulus of steel =7×10^{10}Pa
Steel	Density of steel =7800kg/m^3.
	Steel-steel recovery coefficient =0.7
	Steel-steel static friction coefficient =0.2
	Steel-steel rolling friction coefficient =0.01

3. Simulation analysis

3.1. Establishment of horizontal screw conveyor model

Draw by using Soildworks:

1) Three spiral blades with pitches of 400mm, 450mm and 500mm, each with three thicknesses: 4mm, 5mm and 6mm.

2) A spiral shaft with a diameter of 200mm and a length of 4000mm.

3) The shell with a thickness of 10mm has a clearance of 2mm between the inside of the shell and the spiral blade.

4) Assemble in turn according to the requirements of orthogonal experiment. The assembly drawing is as follows Figure 1:

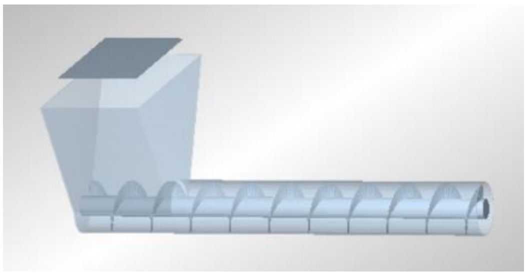

Figure 1: This is the assembly drawing of the screw conveyor.

3.2. EDEM simulation experiment

Nine models were introduced into EDEM respectively, and the parameters and rotating speed were set according to the orthogonal experimental combination, and the time of all particles passing through was recorded in turn. The transportation process is as follows Figure 2.

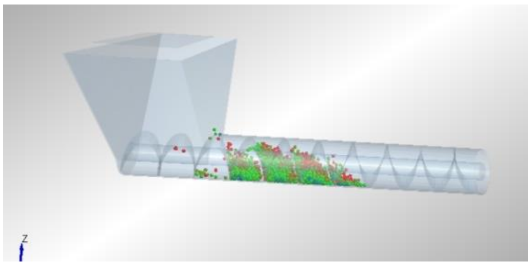

Figure 2: This is the transportation process diagram.

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3.3. Simulation results

Through simulation, the time required for each group of simulation is obtained, as shown in Table 3. The effect curve can be obtained from Table 3, as shown in Figure 3.

Table 3: Simulation results

Factor	screw pitch /mm	Blade thickness /mm	rotation speed (r/min)	Time (s)
1	1	1	1	10.9100
2	1	2	2	9.40001
3	1	3	3	9.55021
4	2	1	2	8.44406
5	2	2	3	8.83002
6	2	3	1	8.95101
7	3	1	3	7.13021
8	3	2	1	8.54753
9	3	3	2	7.67080
Mean value 1	9.9534	8.8281	9.4695	
Mean value 2	8.7417	8.9258	8.5050	
Mean value 3	7.7828	8.7240	8.5035	
Extreme range	2.1706	0.2081	0.966	

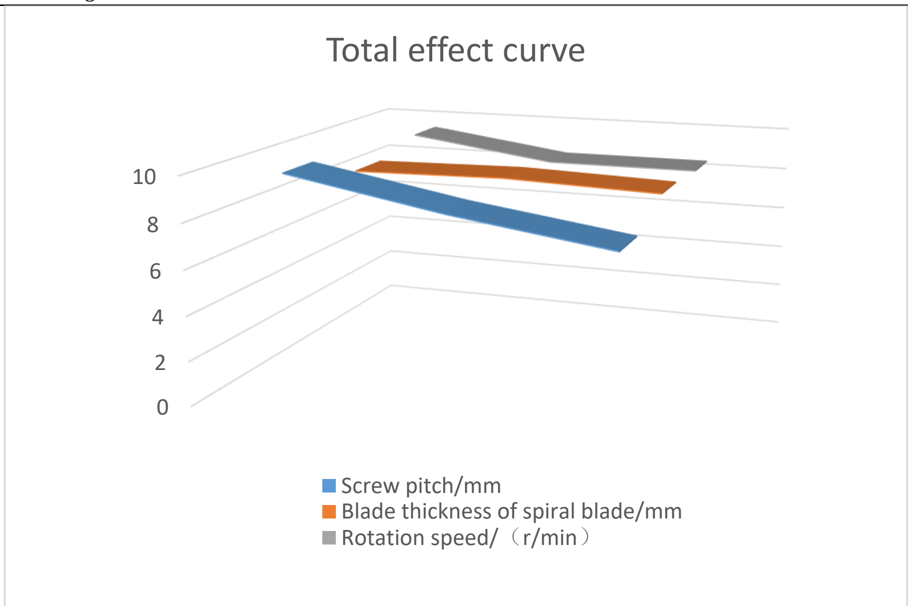
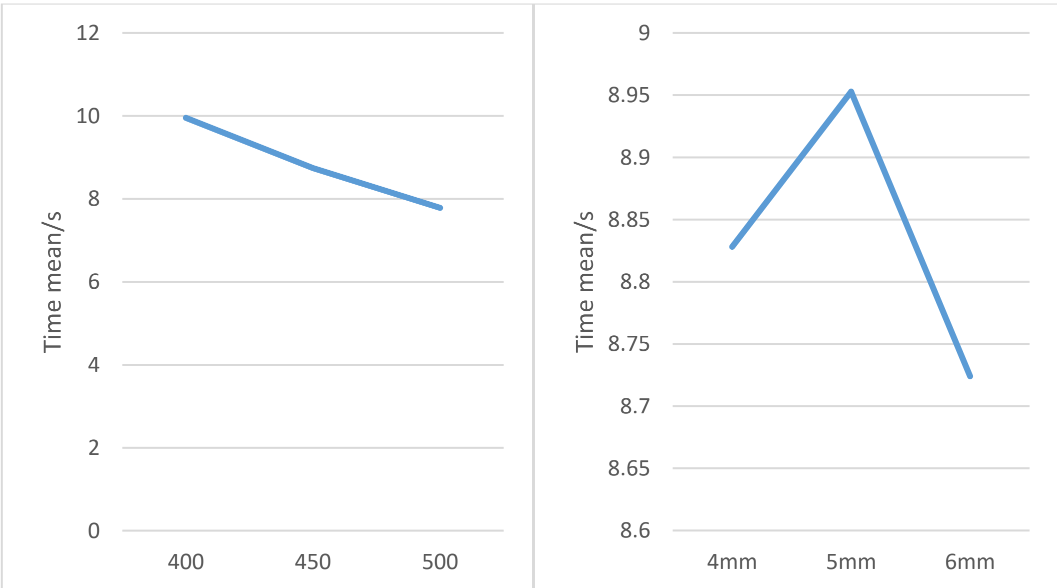


Figure 3: This is the total effect graph.



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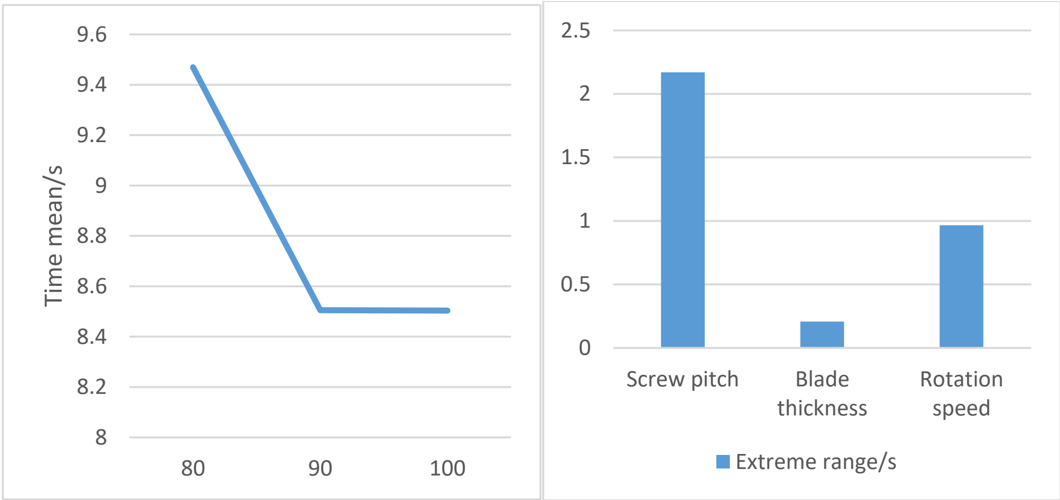

Figure 4: This is the effect curve and range diagram of pitch, blade thickness and speed.

3.4. Result analysis

The research results show that

(1) Within the allowable range of pitch, the larger the pitch, the shorter the time it takes to transport the same batch of materials, and the higher the transportation efficiency. Among the three factors, pitch has the greatest influence on transportation.

(2) The blade thickness has little effect on the material transportation efficiency, and it takes the shortest time when the thickness of the spiral blade is 6mm. In order to improve the strength of the spiral blade and shorten the transportation time, the blade with 6mm thickness can be adopted.

(3) Within a certain range, the higher the rotating speed, the shorter the time required to transport the same batch of materials. However, after the rotation speed is too high, the particles will be subjected to the increased centrifugal force, so that the particles will rebound and hit the inner wall. When the number of particles is gradually reduced, this collision will be more obvious and more. The larger centrifugal force makes the material move forward smoothly, even the material moves backward. Thereby reducing the transportation efficiency. This situation shows that when the speed is too high, its conveying capacity will be reduced [12]. In order to increase the conveying efficiency, reduce the conveying time and reduce the power loss of the screw conveyor, the rotating speed of 90r/min can be selected.

(4) By analyzing the data in Table 3, it can be concluded that when the pitch of the screw conveyor is 500mm, the thickness of the screw blade is 6mm, and the rotating speed is 90r / min, a set of experimental data with the shortest time and the least collision can be obtained, and the optimal parameter combination can be obtained.

4. Conclusion

(1) Pitch, blade thickness and rotating speed all affect the conveying capacity of screw conveyor. By analyzing the extreme difference of the three, it can be concluded that the influence of pitch on the conveying capacity of screw conveyor is relatively greater. Through the curve of pitch effect, it is concluded that the larger the pitch, the shorter the time it takes to transport the same batch of materials and the higher the transportation efficiency. It can be clearly seen from the rotation speed effect curve in Figure 4 that the higher the rotation speed of the spiral blade, the better the conveying capacity of the spiral conveyor. However, by observing the experimental process and analyzing the simulation results, it is concluded that with the increase of the rotation speed of the spiral blade, the collision between particles or the collision between particles and the inner wall of the conveyor becomes more obvious, which leads to the decrease of the conveying capacity. By analyzing Figure 4 and Figure 4, it can be concluded that the influence of blade thickness on transportation capacity is not obvious, but thicker blade thickness can slightly shorten transportation time and improve blade strength. This conclusion may provide reference for the theoretical design of horizontal screw conveyor.

(2) To sum up, the optimal combination is pitch 500mm, blade thickness 6mm and rotating speed

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90r/min.

References

[1] Mondal D, NabenduGhosh. Study on filling factor of short length screw conveyor with flood-feeding condition [J]. Materials Today Proceedings, 2018, 5(1):1286-1291.
[2] Hu Guoming. Discrete element analysis and simulation of particle system [M]. Wuhan: Wuhan University of Technology Press, July 2010
[3] Wang Guoqiang. Discrete Element Method and Its Practice on EDEM [M]. Xi'an: Northwest University of Technology Press, May 2010
[4] Ning Tingzhou, Li Nuo, Gou Yanan. Research on the conveying capacity of inclined screw conveyor based on EDEM [J]. Journal of Mudanjiang Normal University (Natural Science Edition), 2019 (04): 38-41
[5] Zheng Xinxin. Finite Element Simulation Research on the Conveying Performance and Spiral Body of Inclined Screw Conveyor [D]. Harbin University of Technology, 2020
[6] Yang Weijie, Meng Wenjun, Li Wenjun, Dai Xiaobing, Yin Zhenxiao. Wear model analysis of vertical screw conveyor spiral blade [J]. Coal Mining Machinery, 2021, 42 (04): 109-111
[7] Wang Sen. Optimization and design of new screw extrusion biomass molding machine [D]. Henan Agricultural University, 2008
[8] Tan Chunlin. Design and research of cow feeding device [D]. Shihezi University, 2007
[9] Hu Weibo. Localization design and research of pneumatic conveying system in artificial vegetation production line [D]. Institute of Mechanical Sciences, 2004
[10] Liu Hongjie. Research on forming mechanism and equipment of biomass seedling nutrition bowl [D]. Hebei Agricultural University, 2015
[11] Yang Laixia, Gong Lin. Study on the forming accuracy of selective laser sintering polystyrene/glass fiber parts [J]. Plastic Science and Technology, 2016, 44 (07): 38-41
[12] Guo Chuang, Pu Xianglan. Numerical simulation analysis of screw conveyor based on EDEM [J]. Journal of Yanbian University (Natural Science Edition), 2018, 44 (02): 179-182