Influence of material shape on excavation resistance of bucket wheel stacker based on EDEM simulation

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Abstract

In order to better study the influencing factors of excavation resistance, the shape of the material is three-dimensionally quantified, and the discrete element simulation software EDEM is used to simulate the excavation resistance of the bucket wheel stacker when digging materials of different shapes. Through the research on the simulation data under different evaluation methods of material shape, it is concluded that the excavation resistance of bucket wheel stacker and reclaimer under different shapes is very different.

Keywords

EDEM;bucket wheel stacker ; excavation resistance; material shape.

1. Introduction

In recent years, many scholars at home and abroad are studying factors affecting the excavating resistance of bucket wheel stacker and reclaimer, such as material particle size, excavation speed, and excavation trajectory. However, there are few studies on the shape of materials. The reason is that the shape of material is complex in actual production and life. Many static and dynamic problems of particle system can not be explained by general hydrodynamics theory and solid mechanics theory. Moreover, the friction state between particles of different shapes is extremely complicated, and there is no formula to reflect the mechanism. In this paper, the relationship between the excavation resistance value and its shape is obtained by simulating and retrieving materials of different shapes.

2. Introduction to EDEM

EDEM is the world's first multi-purpose discrete element method modeling software, which can be used for particle processing in industrial production and simulation and analysis of equipment production process. Users can use EDEM to build the parametric model of particle solid system quickly and easily. They can import the CAD model of real particles and form the required particle model by adding mechanical, material and other physical properties.

The basic principle of this method is to divide the object into independent units. According to the interaction between the elements and Newton's law, the dynamic relaxation method and other iteration methods are used to calculate the cyclic iteration. The force and displacement of all elements are determined at each time step, and the positions of all elements are updated. By tracking and calculating the micro-motion of each unit, the Macro-motion law of the whole research object can be obtained. Fig.1

Another important principle of EDEM is contact model, which includes hard ball model and soft ball model. In the research process, according to the different simulation objects, it is necessary to select the corresponding contact model. In this paper, the speed of excavating materials in the bucket is general, and the iron ore particles in this paper are small in size and high in concentration, so the particle and its contact model are regarded as soft ball model. In the soft sphere model, the collision between particles is relatively slow, the contact points may overlap to a certain extent, and the size of overlap is much smaller than the movement displacement of colliding particles and particles. Therefore, in the calculation process, the surface deformation of particles is neglected, and the contact force is calculated according to the normal overlap and tangential displacement between particles. In order to ensure the accuracy of calculation, a smaller time step is needed[1].

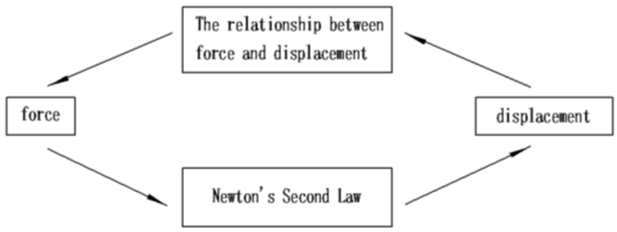

Fig.1 Computing cycle

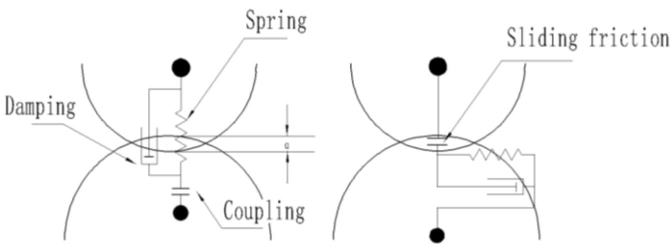

Fig.2 Softball model

3. 3-D Evaluation Method of Particle Shape

Barrett[2] believed that the morphological characteristics of particles should include three independent characteristics:the shape of particles (overall contour, such as roundness), the angularity (corner curvature and edge of particles) and the texture (roughness) of particles'surface. The three represent the spatial change of particle contour in different dimensions. The shape characteristics represent the macroscopic change rule of particles in large size ,the angular feature represents the change of particles in medium dimension, and the surface texture feature represents the change of particles based on small size. Scholars at home and abroad have long realized the importance of particle shape, and have carried out a series of studies and proposed a variety of quantitative methods.

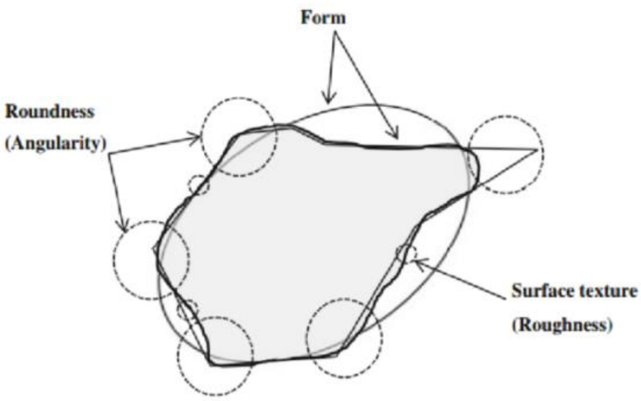

Fig.3 Schematic diagram of the overall shape, angularity and surface texture of the particles

Krumbein[3] considered that a particle can be approximated as a triaxial ellipsoid with three diameters, which is called long axis L, medium and long axis I, and short axis S. The following formula is used to describe the three-dimensional ellipsoid degree of particles:

$$\varphi = \sqrt[3]{\frac{(\pi/6)L \times I \times S}{(\pi/6)L^3}} = \sqrt[3]{\frac{I \times S}{L^2}}$$

Zou defined the ratio of long axis L to short axis S as the elongation degree of particles (α).

$$\alpha = \frac{L}{S}$$

Sneed[4] defined the ratio of short axis S to medium axis I as Flat Degree of particles (ε).

$$\varepsilon = \frac{S}{I}$$

Corey[5] combines two flat S/L and S/I into shape parameters and is called Corey's shape factor (CSF). CSF is also the square of the ratio of the maximum tangential spherical cross section to the maximum projection area. Therefore, CSF can be regarded as a spherical index.

$$\mathrm{CSF} = \sqrt{\frac{S}{L} \times \frac{S}{I}} = \frac{S}{\sqrt{L \times I}}$$

The true sphericity (γ) proposed by Wadell[6] describes the three-dimensional characteristic shape of material particles. It is specifically defined as the ratio of the surface area of the sphere equal to the volume of material particles to the actual surface area of material. According to this definition, the true sphericity calculation formula of particles can be obtained.

$$\gamma = \frac{4\pi}{S_P}\left(\frac{3V_P}{4\pi}\right)^{\frac{2}{3}}$$

Among them: sphericity of particles; surface area and volume of particles, respectively.

Many experts and scholars simplify the shape of material into spherical shape when they use EDEM for mining simulation. The bucket wheel stacker has two kinds of displacement movement in the process of reclaiming material, one is the translation movement relative to other particles, the other is the rotation movement of itself. However, the force of spherical materials in translation and rotation is obviously less than that of convex polyhedral materials, which greatly increases the simulation error and can not really reflect the actual excavation situation.

4. EDEM simulation

4.1 Setting of simulation parameters

In order to simulate the excavation situation of the bucket wheel stacker better, it is necessary to carefully set the solid models of particle, material stack and bucket in EDEM, and optimize their trajectory and simulation parameters in EDEM, so as to get ideal results. Of course, we can also simplify the unnecessary parts of the model to reduce the simulation calculation time and improve the efficiency of simulation.

4.1.1 Establishment of material particle model

In this paper, the hematite heap of the iron ore wharf yard is selected as the research object. According to the above three-dimensional evaluation method of material shape, the material shape is described by three orthogonal long axis L, middle axis I and short axis S. In order to better study the influence of material shape on excavation resistance, six materials with different shapes are set up in this paper. As shown in Table 1. In EDEM software, it is impossible to directly build different shape particle models. It is necessary to superimpose spheres of different particle sizes into materials approximating different shapes through the method of sphere superposition.Table 1,Fig.4

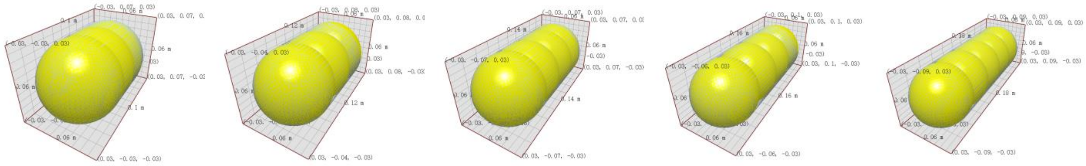

Fig.4 Material drawings of different shapes in EDEM

Table 1 Dimensions of materials with different shapes and their three-dimensional descriptions

Material Shape Number	long axis/mm	middle axis/mm	short axis/mm	elongation degree	Flat degree	ellipsoid degree	Corey's shape factor	true sphericity
1	60	60	60	1.00	1.00	1.00	1.00	1.00
2	100	60	60	1.67	1.00	0.71	0.77	0.95
3	120	60	60	2.00	1.00	0.63	0.71	0.95
4	140	60	60	2.33	1.00	0.57	0.65	0.89
5	160	60	60	2.67	1.00	0.52	0.61	0.86
6	180	60	60	3.00	1.00	0.48	0.58	0.84

4.1.2 Setting simulation parameters

The physical properties of iron ore and the contact coefficients between iron ore itself and between iron ore and steel are set as shown in Tables 2 and 3, respectively.

Table 2 Physical properties of iron ore[7]

Material	Poisson's ratio	shear modulus/Pa	densityKg/m3
Iron ore	0.27	2.46×10^7	3380
steel	0.30	1×10^{10}	7850

Table 3 Contact coefficient of iron ore

contact function	static friction coefficient	rolling friction coefficient	recovery coefficient	contact model
Iron ore-Iron ore	0.6	0.01	0.5	Hertz-Mindlin(no slip)
Iron ore-steel	1.2	0.01	0.42	

4.1.3 Motion parameters of bucket wheel mechanism

The reclaimer of bucket wheel mechanism rotates around the revolving center of bucket wheel machine at the same time. Because of the short simulation time, the revolving motion can be simplified to translation motion. The rotational speed and translation speed of bucket wheel are 0.73 rad/s and 0.5 m/s respectively.

4.2 Simulation process analysis

In the first 2 seconds of the simulation, the material is generated by the particle factory and falls naturally under the influence of gravity. After all the particles are generated, they go through a second of static state. Then the three-dimensional model of bucket wheel is imported, and two kinds of motion, rotation and translation, are applied. Under the condition of collapse, the collapsed material heap is released in 5 seconds to simulate the actual condition of collapse. Fig.5 is the EDEM simulation bucket wheel excavation drawing.

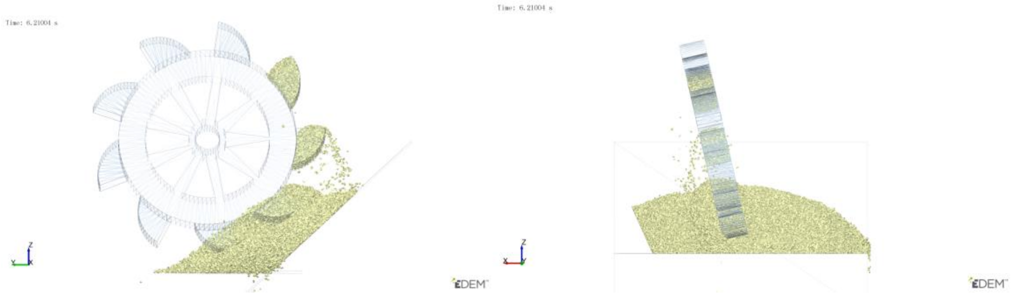

Fig.5 diagram of bucket reclaiming

5. Analysis of simulation results

Through EDEM post-processing, the time history data of mining resistance for different shapes of materials are derived, and the origin curve is fitted to obtain a large number of simulation data.

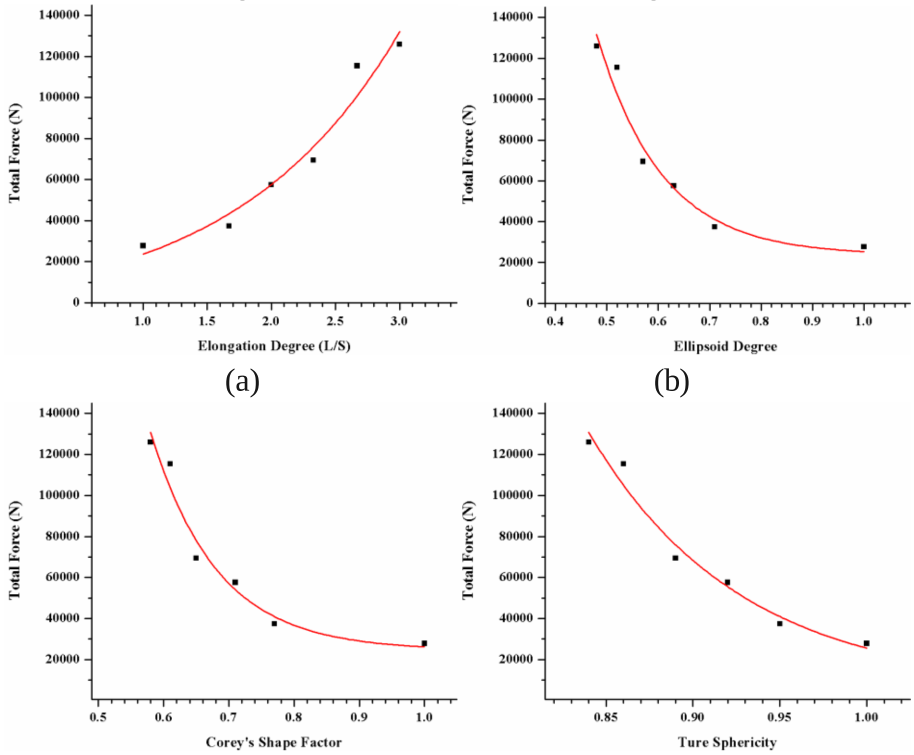

Fig.6 The relationship between different shape evaluation methods and excavation resistance

Fig.6 (a) shows that the excavation resistance increases exponentially with the increase of material shape elongation degree. It shows that the longer the material is, the closer the meshing between the materials will be, resulting in greater resistance when the material moves in translation and rotation.

Fig.6 (b) shows that the excavation resistance decreases exponentially with the increase of ellipsoid degree. It shows that the closer the three dimensions of material shape are, the bigger the sphericity is, and the smaller the contact force between materials is.

Fig.6 (c) shows that the excavation resistance decreases exponentially with the increase of Corey's shape factor. The greater the ratio of the maximum tangential circle to the maximum projection area, the closer the material is to the sphere, the smaller the occlusion force between the materials.

Fig.6 (d) shows that the bigger true sphericity is, the lower the excavation resistance is exponentially. Because when the surface area of the equal volume sphere is larger than that of the actual material, the outline of the material tends to be more spherical and easier to be excavated.

6. Conclusion

1) When the flatness of material shape is constant, the excavation resistance increases exponentially with the increase of elongation degree, and decreases with the increase of ellipsoid degree, Corey's shape factor and true sphericity.

2) Through three-dimensional quantitative evaluation and analysis of different materials, it is concluded that when the shape of materials tends to be spherical, the resistance of particles moving in the material pile is smaller.

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