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Simulation Analysis of One-time Shovel Method Based on EDEM

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Abstract: In view of the force problem in the process of the first shoveling method of the underground forklift, I used EDEM software to complete the numerical simulation calculation of the first shoveling method, used the software to generate ore stacks, imported the bucket model, set the bucket action, and completed the shovel simulation. Which pairs consider the distribution of ores. Summarize the force of the bucket to provide a certain reference for subsequent shoveling research.

Keywords: Shoveling, Ore, EDEM.

1. Introduction

Since the force situation in the underground shoveling process is not easy to obtain directly, in order to have a clearer understanding of the shovel force received by the bucket in the underground shoveling process, in today's data, the force of the shoveling process has always been the heat of research. This research has been carried out at home and abroad since 30 years ago, from the summary of empirical formulas from experiments, the theoretical calculation of bulk mechanics and earth pressure theory, to the current computer digital simulation calculation stage. This paper uses EDEM software to calculate the shovel resistance of the underground shoveling process.

2. Simulation Assumptions

In order to facilitate the establishment of the simulation model, this paper uses the following assumptions: the ore block is replaced by spherical particles, the radius of the ore block is characterized by the spherical radius, the friction coefficient is modified to compensate for the difference between spherical particles and lumpy particles, and there is no adhesion and extrusion between particles. Major issues during simulation.

The size problem of the ore; The size of the ore determines the size of the simulated particles, which in turn determines the reliability of the simulation.

The models of buckets; The model of the bucket determines the change in contact resistance during underground shoveling.

The trajectory of the bucket; EDEM only offers a limited range of movement, and different shoveling processes have a great influence on shoveling resistance.

2.1. Ore size distribution determination

Commonly used functions when describing the blocky distribution of ore after blasting are Gaussian distribution, lognormal distribution, Poisson distribution, gamma distribution, and · Rozin-Rammler distribution. Literature shows that for underground mine blasting, the Rozin-Rammler distribution and lognormal distribution are often used to collect ore distribution.

The Rozin-Rammler distribution function is

$$y = 100\left\{1 - exp\left[-\left(\frac{x}{x_0}\right)^n\right]\right\}\% \tag{1}$$

The lognormal distribution function is

$$\mathrm{y} = 100\left(\frac{x}{x_0}\right)^n \% \tag{2}$$

Where: y—the percentage of size through the sieve; x - ore size; x0—The characteristic size of the ore, which reflects the lumpiness or thickness of the ore.

Consulting the literature shows that for the distribution of ore block after a blast, the lognormal distribution is suitable for the distribution of fine grain parts, and the Rozin-Rammler distribution is suitable for the distribution of coarse grain parts, and a single distribution cannot fully describe the distribution of ore. The EDEM software provides four distribution methods: fixed, lognormal, random and normal. In order to fully describe the distribution of ore thickness after blasting, a normal distribution is selected in this paper[1][2]

According to the shoveling capacity, the maximum size of the ore block distribution l_{max} is calculated as follows:

$$\mathrm{l}_{max} = 0.23\sqrt[3]{\mathrm{E}}\sim 0.83\sqrt[3]{\mathrm{E}} = 0.332\text{-}1.197\mathrm{md} \tag{3}$$

Formula: E — Scraper bucket capacity.

Borrowing the block shape coefficient to describe the block shape of the ore, γ - the actual volume of the ore, ν- to the ratio of the volume of the sphere with the maximum size of the ore as the diameter

$$\gamma = \frac{6\ \mathrm{v}}{\pi \mathrm{l}^3{}_{\max}} \tag{4}$$

According to the above formula, the equivalent radius R of the ore can be obtained.

$$\mathrm{R} = \sqrt[3]{\frac{\mathrm{l}_{\max}^3 \gamma_{\mathrm{j}}}{8}} \tag{5}$$

Obtain the block shape coefficient of the blasted rock from the references, γj.

The above equation can be calculated to give the equivalent radius R=0.072-0.258

When the average distribution of ore particle radius

R=0.1725 is selected μ, the actual size of the ore at this time can be calculated as follows

$$l_{max}=\sqrt[3]{\frac{8R^3}{\gamma_J}}=0.801m, \quad (6)$$

According to the 6σ principle, the probability of 0.173-1.413m exceeds 70%. At this time, it is more in line with the general situation after blasting. The equivalent radius R is 0.037-0.304, so the normal distribution parameters are selected μ=0.17 and σ=0.04

The properties of the blasted ore after literature are shown in Table 1 below. The parameters in the table are obtained by consulting the literature, and the material pile particles in the literature are also blasted rocks, which have certain reference. The rock density is adjusted here to accommodate the blasting ore of the metal mine. The coefficient of friction in Table 1 is the coefficient of self-friction of the ore.

Table 1. Ore Attribute Parameters

Property	Numeric value
Elastic modulus E	1.5×108N/m2
Density	1.9×103kg/m3
Friction angle	32.5°
Poisson's ratio	0.35
Drag coefficient	0.20
Static friction coefficient	0.90
Rolling friction coefficient	0.66

2.2. Properties of the bucket

Import the bucket model from SolidWorks and select the bucket properties, using the bucket attribute parameters as shown in Table 2. The coefficient of friction is the coefficient of friction between steel and ore.

Table 2. Bucket Properties Parameters

Property	Numeric value
Modulus of elasticity E	7×1010N/m2
Density	7.8×103kg/m3
Poisson's ratio	0.3
Recovery factor	0.3
Static friction coefficient	0.84
Rolling friction coefficient	0.5

Then, select the contact model for the model. EDEM software offers four contact models. Hertz-Mindlin (no-slip) contact model, which is the software default model. Hertz-Mindlin models, commonly used in simulation studies suitable for rock structures and concrete. Hertz-Mindlin heat transfer model, commonly used in the simulation of dense phase particle flow. Linear contact model is divided into linear bond contact model and linear spring contact model. For most granular materials, the use of nonlinear contact models can more realistically reflect the relationship between the forces between particles, deformation, and collision speeds. After comprehensive consideration, in order to improve the computational efficiency, this paper adopts the EDEM default contact model Hertz-Mindlin (no-slip). [3-7]

3. Simulation Process

After the preparation work is completed, the first step is to form an ore pile, where the ore particles can be further generated by the factory in EDEM to further become the ore pile, first establish a geometry, as a mining space, geometry selection box model. Set the corresponding size, select the material attribute as ore, cancel the front and side of the top surface, build another virtual plane at a 45-degree angle to the bottom surface, add factory to the virtual plane to generate ore, and fall freely at a set speed to form a 45-degree inclination ore pile.

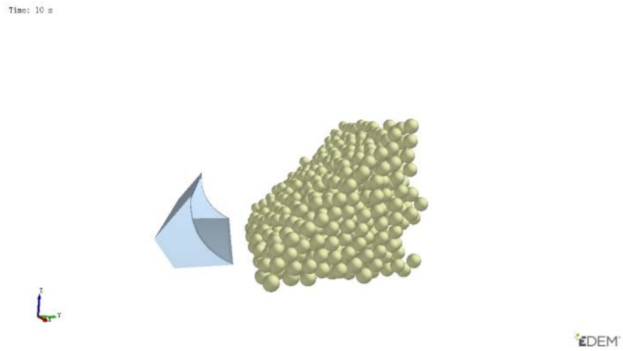

Figure 1. Mine pile

After reviewing the relevant literature, it can be known that the current shoveling is divided into three shoveling methods, namely the one-time shoveling method, with the shoveling method and the segmented shoveling method, this paper uses the simplest one-shoveling method, that is, the bottom of the bucket is parallel to the ground, the forklift moves forward, pushes the bucket into the pile until the back wall of the bucket is in contact with the ore, the forklift stops moving forward, and then flips the bucket or lifts the bucket to complete the shoveling. [8] In EDEM, we put the bucket in the appropriate position, complete the forward action by directly giving the bucket a linear movement of speed, direction, and time, and then add an angular speed, direction, and time to the bucket that rotates around the axis, and complete the shovel after giving an exit speed, direction, and time.

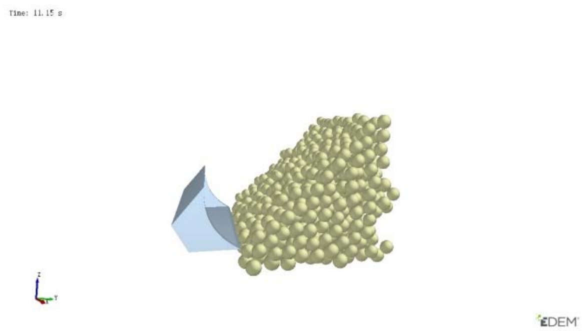

Figure 2. Start shoveling

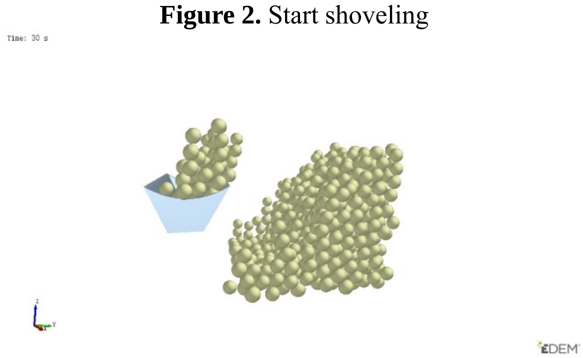

Figure 3. Completing the Shovel

4. Simulation Results

The figure below shows the simulation result, which shows the relationship between the force received by the bucket in the three directions of X, Y, and Z in the three directions of X, Y, and Z, where the abscissa starting point is 10, indicating the start of the shoveling, 20 means the end, and the bucket moves backward in units of s; The ordinate represents the magnitude of the forward and tangential forces in each direction, and is measured in N.

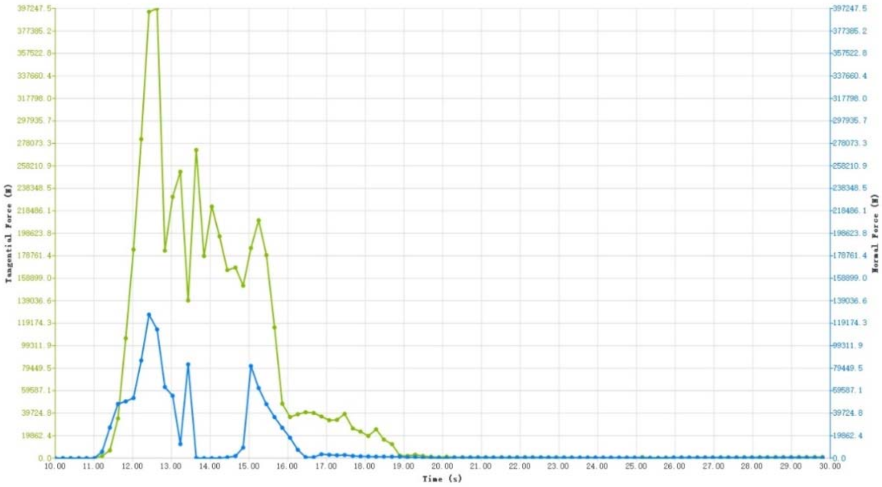

Figure 4. Normal and tangential forces in the X-axis

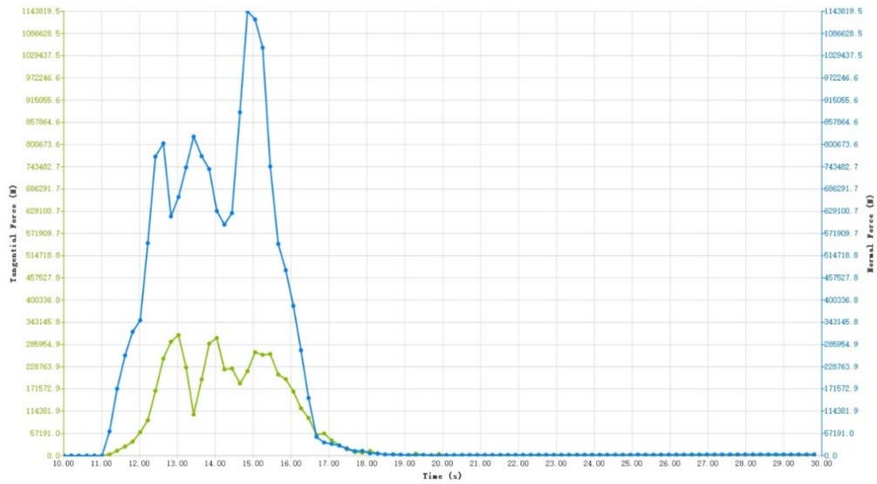

Figure 5. Normal and tangential forces in the Y axis

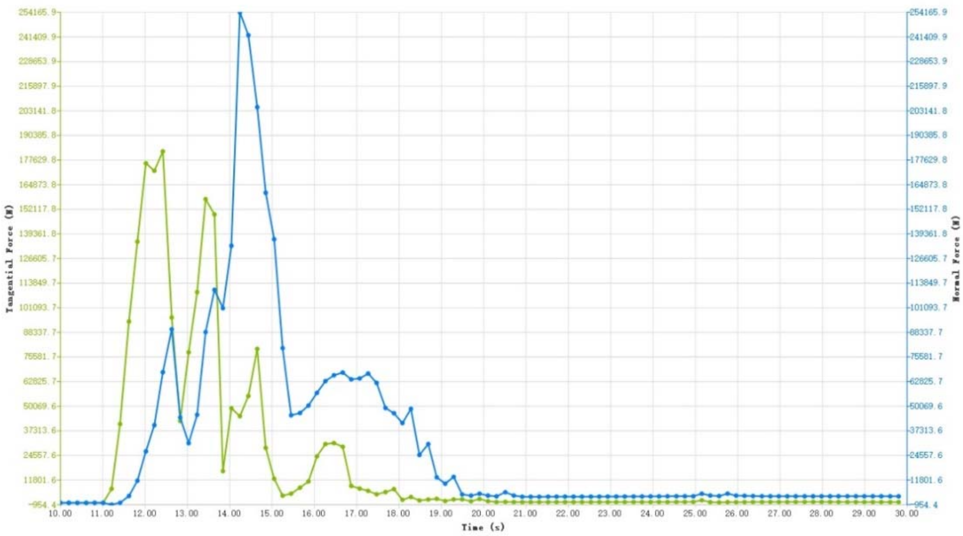

Figure 6. Normal and tangential forces in the Z axis

The figure below shows the total tangential and normal force changes during the shoveling process.

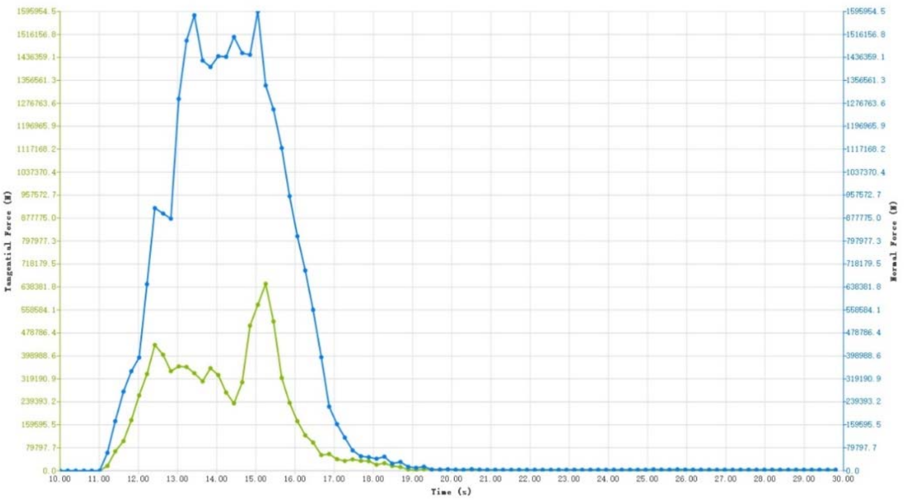

Figure 7. Total positive and tangential forces

The above figure can be the x-axis, y-axis, z-axis, and total maximum force and recorded into the table below.

Table 3. Size and time of force

Attribute	x	y	z	total
Maximum normal force (KN)	130	1143	254	1596
Maximum tangential force (KN)	397	314	184	639
Occurrence time n(s)	12.5	14.8	14.2	15
Occurrence time t(s)	12.5	13	12.5	15.2

From the above table, it can be seen that the maximum stress time of the x-axis is about 12.5s, the y-axis is 14.8s and 13s, the z-axis is 14.2s and 12.5s, and the total maximum force appears in 15s, because the bucket only touches the ore pile in about 12 seconds, so the forward force is the largest, and the maximum total force that appears in 15 seconds is caused by the bucket being ready to flip at the end of loading.

5. Conclusion

This paper uses EDEM discrete science software to simulate and analyze a shoveling method in the underground shoveling process, a shoveling method, brought to the force curve, in the shoveling stage the force is proportional to the time, that is, proportional to the depth of the shovel, to the last moment, the total force is as high as 1596kn and 639kn, indicating that the maximum force of the first shoveling method is very large, and the full bucket rate is not high, and it is not suitable for the shoveling process.

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