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**PSO Algorithm Based Shredding Parameter Optimizing for the Body of ELV**

**Abstract:** In order to improve the utilization ratio of scrap iron and steel in the shredding material of the body of End of life vehicle after disassembly, it is necessary to determine the optimized parameter in order to reduce the energy consumption of the crushing equipment. With the software of EDEM, the crushing material accumulation process is simulated. The porosity of the broken material pile is also obtained, and the optimal fracture radius model of waste steel is established. In the end, the Particle swarm algorithm for optimization is used to solve the optimal shredding material size.

**Keywords:** ELV; EDEM; PSO Algorithm; Shredding parameter

## 1 Introduction

With the development of the automobile industry, China has become the world’s third largest automobile manufacturer. According to the relevant agencies predicted, China’s annual number of ELV (end of life vehicle) will reach 6 million until 2020. The rapid increase in the number of scrapped vehicles is accompanied by the waste of land due to the accumulation of scrapped cars and the threat to the surrounding environment, and the scrapped cars themselves contain large amounts of metallic and non-metallic resources. If the resources are discarded without effective recycling, they will cause serious waste of resources, so the dismantling of scrap cars,
broken and sorting on environmental protection, resource recovery, energy saving is of great significance. In the process of crushing scrap cars, if scrap metal is too large to be fully melted in the furnace. When undissolved iron accumulates in the bottom of the furnace, the long run, the bottom of the furnace need to be regularly cleaned up, which not only reduces the utilization of scrap steel but also consumes a lot of manpower and material resources in the process of cleaning up the bottom of the accumulation; although the scrap iron that is too small can be fully melted, it still consumes too much energy in the crushing process. Thus, the optimal size of the crushed material in reducing energy consumption and improving the utilization of scrap has an important significance. At present, there is no literature on the shredding materials optimization of the study.

2 Porosity of Shredding Materials for The Body of ELV

ELV are packed, broken and sorted to form shredding materials, the shredding material is output and piled up by the belt conveyor. Porosity, which is the ratio of pore volume to bulk volume, is an important particle accumulation parameter. However, in the study of particle accumulation, due to the porosity is irregular and computationally cumbersome, EDEM is used to simulate the shredding material to obtain the porosity.

Simply speaking, particle accumulation is place particles in a finite space, and cannot occur deformation in the process of accumulation. Because of the simplicity of the sphere itself and the application background in the scientific research, engineering practice and daily life, the spherical particle are the most studied objects in the study of particle accumulation. We will simplify the simulation, select the cone limited space to create a sphere of normal distribution random accumulation simulation.

The sphere model established by the simulation is different from the shape of the steel detritus in the engineering practice. So the density of the sphere can’t be simply considered equal to the density of steel, there is a transition relationship between the density of the sphere density and the density of steel. Through the continuous measurement and calculation of scrap iron, the average conversion ratio between sphere and scrap iron density is obtained $\rho_{sphere} = \eta \rho_{Fe}$, where $\eta = 0.25$.

Since the particles are randomly stacked, the sphere size is set to a normal distribution; the mathematical expectation is the sphere radius $r$, sphere drops at 3 m/s, until the volume is filled with 1 m$^3$ cone. In the process of material crushing and sorting, as the diameter of more than 85 mm of shredding material is a large
material, which need to be crushed manually, and those less than 20 mm in diameter non-metallic materials need to be buried, so the best crushing size is between 20 mm–85 mm. The spherical particles with radius \( r = 15, 20, 25, \ldots, 50 \text{ mm} \) were selected for particle packing simulation, and the pore volume was obtained under the corresponding sphere radius. Figure 1 shows the random packing of particles with radius of 15 mm and 50 mm, respectively. Table 1 shows the pore volume under different particle radius.

![Random accumulation of spheres](image)

**Fig. 1:** Random accumulation of spheres

**Tab. 1:** Sphere radius and the total volume of the particles

<table>
<thead>
<tr>
<th>Radius ( r/(\text{m}) )</th>
<th>Volume/(\text{m}^3)</th>
<th>Sphere volume ( V )</th>
<th>Pore volume ((1-V))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.015</td>
<td>0.617108</td>
<td>0.382892</td>
<td></td>
</tr>
<tr>
<td>0.020</td>
<td>0.603545</td>
<td>0.396455</td>
<td></td>
</tr>
<tr>
<td>0.025</td>
<td>0.601792</td>
<td>0.398208</td>
<td></td>
</tr>
<tr>
<td>0.030</td>
<td>0.579737</td>
<td>0.420263</td>
<td></td>
</tr>
<tr>
<td>0.035</td>
<td>0.56673</td>
<td>0.43327</td>
<td></td>
</tr>
<tr>
<td>0.040</td>
<td>0.551526</td>
<td>0.448476</td>
<td></td>
</tr>
<tr>
<td>0.045</td>
<td>0.542735</td>
<td>0.457269</td>
<td></td>
</tr>
<tr>
<td>0.050</td>
<td>0.539019</td>
<td>0.460981</td>
<td></td>
</tr>
</tbody>
</table>

We use MATLAB to fit the curve of discrete points in Table 1 to get the mathematical relationship between the porosity and the sphere radius \( r \). The porosity is

\[
\phi = 1 - V = e^{-1.08817 + 9.21369 - 55.90788r^2}
\]
3 Model for Optimal Shredding Parameter

In order to maximize the degree of melting of scrap iron and steel, we establish the optimal radius calculating model of iron and steel scrap, showing as follows:

3.1 Objective Function

\[ A = \text{Max} (r) \]

Where: \( r \) is the radius of the crushed material.

3.2 Bulk Density Constraint

According to the national standard GB4223–004, which is stipulated that the vehicle shredding material bulk density should be no less than 1100 kg/m\(^3\), which is:

\[ \rho_{\text{pile}} = \frac{\sum_{i=1}^{n} m_i}{V} = \frac{\eta \rho_{\text{c}} \sum_{i=1}^{n} V_i}{V} \geq 1100 \]

Where:
\( \rho_{\text{pik}} \) — bulk density;
\( V \) — volume of scrap iron and steel shredding material pile, assume \( V = 1 \text{m}^3 \);
\( V_i = \frac{4}{3} \pi r_i^3 \);
\( r_i \sim (r, 0.1) \).

3.3 Volume Constraint

The sum of the volume of the shredding material (scrap iron and steel) and the volume of the material gap is equal to the total volume of the material, which is:

\[ \sum_{i=1}^{n} V_i + \phi \cdot V = V \]
3.4 Decision Variable Constraint

In the process of material crushing and sorting, as the diameter of more than 85mm of shredding material is a large material, which need to be crushed manually. Therefore, the upper limit of not more than 80mm, and those less than 20mm in diameter non-metallic materials need to be buried, so the range of shredding material radius is:

\[10mm \leq r \leq 40mm\]

4 PSO Algorithm Based Solving Approach for Optimal Shredding Parameter

PSO is a group search algorithm. We assume in such a target search space \(D\), the position of the \(i\)-th \((i=0,1, ..., N)\) particle in the population can be represented as a \(D\) dimensional vector \(\mathbf{x}_i = (x_{i1}, x_{i2}, ..., x_{iD})^T\), meanwhile, using \(\mathbf{v}_i = (v_{i1}, v_{i2}, ..., v_{iD})^T\) \((i=0,1, ..., N)\) indicates the flight speed of the \(i\)-th particle to update the location of the particle. Using \(\mathbf{p}_i = (p_{i1}, p_{i2}, ..., p_{iD})^T\) represents the best point of the \(i\)-th particle itself, which is optimal location of individual history. Mark \(\mathbf{p}_g = (p_{g1}, p_{g2}, ..., p_{gD})^T\) is the best point to search for the current population, which is global optimal location of population.

Updating the velocity and position of every particle according to the following formula:

\[
\begin{align*}
\mathbf{v}_i^{k+1} &= \lambda \mathbf{v}_i^k + c_1 r_1 \left( \mathbf{p}_i^k - \mathbf{x}_i^k \right) + c_2 r_2 \left( \mathbf{p}_g^k - \mathbf{x}_i^k \right) \\
\mathbf{x}_i^{k+1} &= \mathbf{x}_i^k + \mathbf{v}_i^k
\end{align*}
\]

Where \(i = 0, 1, ..., N\), \(j\) represents the \(j\)-th dimension of the particle, \(k\) represents the number of iterations. \(\lambda\) is the inertia coefficient, assigning in \((0,1)\). \(c_1, c_2\) are acceleration constant, which take values generally between \((0,2)\). \(c_1\) is used to adjust the flying step of the optimal position of their own particles, \(c_2\) is used to adjust the step of the particle flying to the global best position. \(r_1, r_2\) is the random number between \((0,1)\).

In the solution space, particle will keep track of the individual extremum and global extremum to search until it reaches the specified maximum number of iterations or minimum error standard position. Figure 2 shows the flow chart of PSO algorithm.
In this paper, the random number is used to represent the radius of the shredding material particle. The basic process of the algorithm is as follows:

Step 1: Produces a random number of particles between (0.015, 0.05) to calculate the current total particle volume;

Step 2: Determine whether to meet the volume constraint, if meet, and then determine whether to meet the bulk density constraints, if meet, then record the particle location;

Step 3: If not meet the volume constraint, go to step 1.

The results of the calculation are shown in Figure 3, the optimal size radius is 0.036m, or 36mm.
5 Conclusion

In order to improve the utilization rate of scrap iron and steel, we have researched the optimization method of crushing material parameters based on PSO. EDEM software is used to simulate the accumulation process of shredding material, and calculate the porosity of material pile. This paper establishes a solving model of the optimum crushing size of scrap iron and steel, and use PSO algorithm to solve the problem. The solution of optimal crushing size can greatly improve the utilization rate of scrap iron and steel, which is of great significance for saving resources and environmental protection.

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References


