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The research of simulation on eddy current separation process based on MATLAB and COMSOL

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Abstract

The separation process of eddy current separator is effected by the structure parameters of magnetic roller, the working parameters of the separator and some parameters of the scrap metal, such as the material, the shape, the size and so on .This is a complex process of electric field and magnetic field coupling. During this process, the sorting function of separator is powered by the existence of the eddy current power in waste particles, and the separation effect is directly determined by the flying distance of the scrap metal in the separation process. This paper armed for studying the eddy current power and the flying distance of the waste particles in separation to realize the simulation of the separation process. The eddy current force was obtained by the finite element analysis of the magnetic roller based on COMSOL, and the flying distance was got by the joint simulation of COMSOL and MATLAB.

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Keywords: Separator; The magnetic roller;The finite element analysis;Joint simulation

1. Introduction

Eddy current separator is an important equipment of recycling non-ferrous metal and its structure consists of mechanical and control cabinet. The main body of the mechanical is composed of magnetic roller, feeding system, separation system, the cover body, the frame and other institutions. As is shown in figure 1.Magnetic roller is the core component of eddy current separator composed of 10 pairs NdFeB permanent magnets around by the iron cylindrical magnetic drum. The permanent magnets were alternately configured by S-N-S direction, as shown in the figure 2.Eddy current would be produced inside the metal when the electrical conductivity of nonmagnetic metal goes through the alternating magnetic field produced by the rotation of the magnetic roller shown in figure 2. The direction of the magnetic field activated by the eddy current itself is opposite of the magnetic field produced by the magnetic roller, and eddy current force is obtained for the two magnetic fields interacting, namely the repelling force makes non-ferrous metals separated from the wastes, as a result, the purpose of separating and recycling non-ferrous metals can be achieved[1].Base on the separation principle, Rem etc.[2]described the trajectory of non-magnetic particles in the changing magnetic field by using the linear differential equation. On the basis of the model, the qualitative conclusion could be attained that the size, shape, conductivity of the particle affected the corresponding separation trajectory. Meanwhile, the calculation equation of magnetic field intensity about the eddy current separator in cylindrical coordinate could be obtained. Zhang and Forssberg[3] proposed the calculation model of the tangential force and radial force of particles by eddy current in separation process. The calculation model of the tangential force and radial force of particles by eddy current was put forward by Lungu and Schlett[4] when they separated copper and aluminum from fiber optic cable by using the developed eddy current separation equipment. For the problem of low efficiency of separation existing in the recycling process for abandoned drums, old refrigerator cabinet, the basic theory of the eddy current separation was studied through the method of combining the experiment and theory by RuanJuJun[5]. And the eddy current force model and the calculation model of flying distance for particles in separation process were

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established and verified. Due to the complicated separation process, some phenomenon of the separator can't be explained by the built mathematical model of eddy current force and flying distance by those scholars based on the premise of a number of assumptions, and there are some shortcomings. Based on the above research, the computer simulation technology was fully used in this paper in a different approach. The eddy current force was obtained by the finite element analysis of the magnetic roller based on COMSOL, and the flying distance was got by the joint simulation of COMSOL and MATLAB.

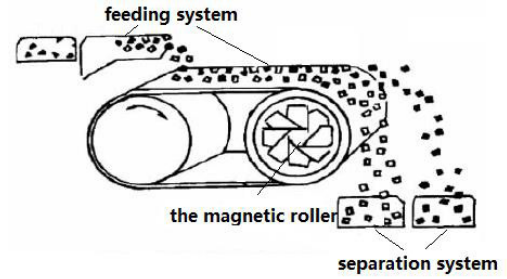

Fig.1.Main structure of eddy current separator

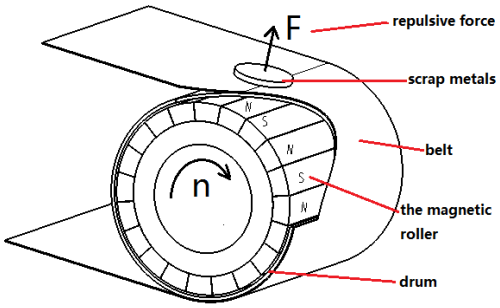

Fig.2. Main structure of eddy current separator

2. The calculation method of eddy current force

Due to the complexity of eddy current force calculation, the force of a particle in separation process was obtained based on the finite element analysis software COMSOL. And the process includes 9 steps, namely A-I.As is shown in figure 3.

3. Simulation of separation process

The eddy current force of particles could be attained in separation process based on COMSOL, but the motion state of waste metals affected by the force couldn't be got, such as velocity, displacement, less likely the trajectory. Due to the simulation of separation process, the flying trajectory of a particle was obtained by the joint simulation of COMSOL and MATLAB. Namely writing the front program in MATLAB to calculate the corresponding motion state, then calculating the eddy current force of particles in corresponding location in COMSOL, and returning the front program to get the motion state based on the force, as shown in figure 4.The script program in MATLAB was transformed by the established analysis model of previous section. The separation process was

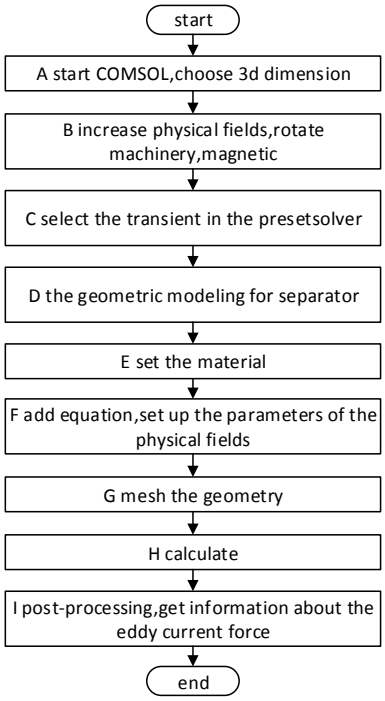

Fig.3. Flow chart of eddy current force calculation

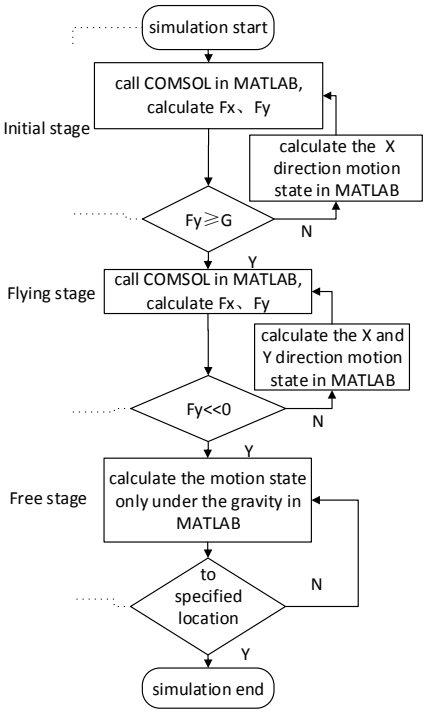

Fig.4.Simulation of separation process

divided into three stages, namely initial stage, flying stage and free stage. The eddy current force of a particle is insufficient to make it fly off the belt in beginning phase, and the particle flies away from the belt in flying stage, and the trajectory of wastes

in free stage is only decided by its own state and gravity. As is shown in figure 5.

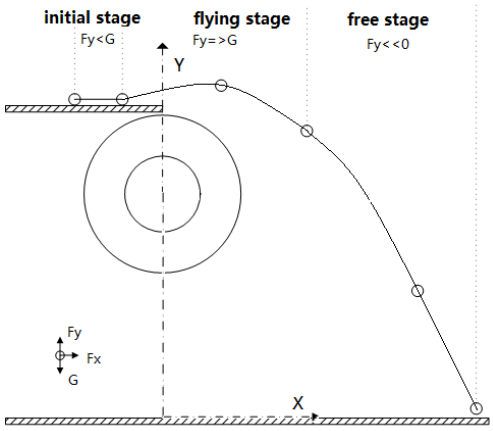

Fig.5.The schematic diagram of separation process

Initial stage (F_y<G).In this phase, the waste and the belt are always in a state of relative rest. The state of the waste was described in three parameters, namely the horizontal position(x),the vertical position(y),the horizontal velocity(v_x) and the vertical velocity(v_y).Taking general state to calculate, namely the nT moment(T is the operation cycle).Formulas are shown from(1)to(4).The state of waste is initial value when nT is 0.

$$v_x[(n+1)T] = v_x(nT) + a_xT \quad (1)$$

$$v_y[(n+1)T] = v_y(nT) + a_yT \quad (2)$$

$$x[(n+1)T] = x(nT) + v_x(nT)T + \frac{1}{2}a_xT^2 \quad (3)$$

$$y[(n+1)T] = y(nT) + v_y(nT)T + \frac{1}{2}a_yT^2 \quad (4)$$

Here, $a_x = 0$， $a_y = 0$.

Flying stage (Fy≥G).The waste leaves the belt and moves under the effect of eddy current force and gravity in the phase. The motion formula of the waste is shown from (1) to (4).Here,

$$a_x = \frac{F_{x1}+F_{x2}+F_{x3}+F_{x4}+F_{x5}}{5m} \quad (5)$$

$$a_y = \frac{F_{y1}+F_{y2}+F_{y3}+F_{y4}+F_{y5}}{5m} \quad (6)$$

Due to the periodical changing of the eddy current force, the acceleration of two directions can be solved using formula(5)and(6).The eddy current force F_x and F_y are shown in(7)and(8).In the formula,F_{x1},F_{x2},F_{x3},F_{x4} and F_{x5} are five equal parts in one cycle which makes the velocity of calculation same with the actual and the displacement of calculation different with the actual. Consequently, it's necessary to make compensation for the displacement of calculation and the value Δx is shown in(9).Here, t is one of the five equal parts of T shown in (11).The actual location is shown in (10)and a_{x1} in(9)is calculated by (12). a_{x2}, a_{x3}, a_{x4} and a_{x5} are same as a_{x1}.

$$F_x = \frac{F_{x1}+F_{x2}+F_{x3}+F_{x4}+F_{x5}}{5} \quad (7)$$

$$F_y = \frac{F_{y1}+F_{y2}+F_{y3}+F_{y4}+F_{y5}}{5} \quad (8)$$

$$\Delta x = \frac{9}{2}a_{x1}t^2 + \frac{7}{2}a_{x2}t^2 + \frac{5}{2}a_{x3}t^2 + \frac{3}{2}a_{x4}t^2 + \frac{1}{2}a_{x5}t^2 - \frac{25}{2}a_xt^2 \quad (9)$$

$$x[(n+1)T]_{actual} = x[(n+1)T] + \Delta x \quad (10)$$

$$t = \frac{T}{5} \quad (11)$$

$$a_{x1} = \frac{F_{x1}}{m} \quad (12)$$

Free stage. The waste flies away from the effective range of the magnetic field and the waste is only under the gravity. The dynamic calculation formula of the metal are shown from(1)to(4).Here,

$$a_x = 0 \quad (13)$$

$$a_y = -g \quad (14)$$

4. Simulation of separation process for square aluminum scrap

The finite element analysis model was established in COMSOL based on the size, material and shape of the waste and the parameters about structure and working for separator, as shown in figure 6.Completing A-I9 steps successively shown in figure 3 and saved the file as M type. Then the script program in MATLAB was obtained, as shown in figure 7. The complicated process wouldn't be described in detail in the section.

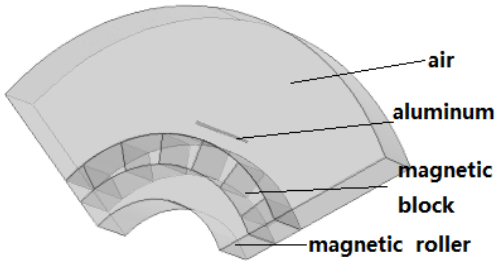

Fig.6.The finite element analysis model

Writing the font program after getting the callback script program in MATLAB. Considering the facility of modifying model parameters and the interaction with the customers, GUI was designed combined with the last simulation algorithm to realize the simulation of separation process. The eddy current force of X and Y direction for aluminum particles in separation are shown in figure 8.And the separation trajectory of aluminum particles is shown in figure 9.

```
function[out,Fy,Fz]=cigun3D_jubu_biaozhun_qiujie(Px,
Py,Pz,a,b,c,Nx)
A=num2str(a);
B=num2str(b);
C=num2str(c);
importcom.comsol.model.*
importcom.comsol.model.util.*
model=ModelUtil.create('Model');
model.modelPath('G:\wodianliu\study');
model.modelNode.create('comp1');
```

Fig.7.Part of script program

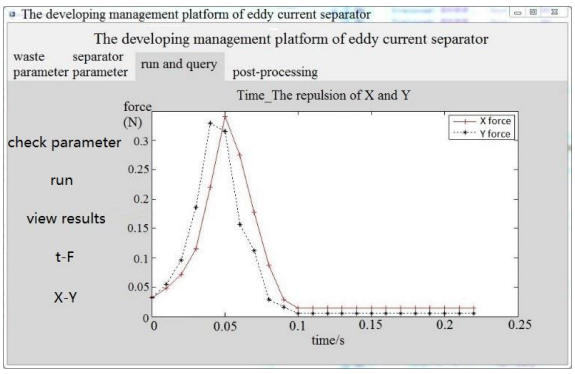

Fig.8.The eddy current force of aluminum particle

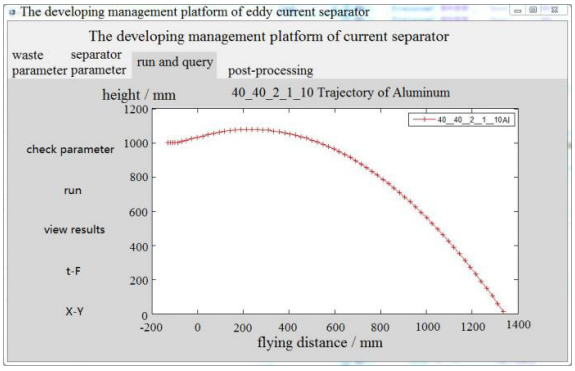

Fig.9.The separation trajectory of aluminum particle

5. Conclusions

In view of the complex problem that the separation process of separator is difficult to describe using model, the method of joint simulation of COMSOL and MATLAB was proposed in this paper. Writing the font program in MATLAB, calling COMSOL in the background and running the script program of the finite element analysis in COMSOL. Then, calculating the analysis results of the background in font program. Again and again, the simulation of separation process about eddy current separator could be realized. Compared with other methods, the paper utilized MATLAB and COMSOL synthetically considering many factors, such as the size, shape and material of the waste, the parameters of structure and working about the separator. The problem of simulation of separation process was solved which lays the foundation for the design and optimization of the separator. What's more, the method in the paper is easy to operate and which is with high efficiency and reliable results. Therefore, the method has important reference value for finite element analysis and virtual prototype, etc.

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