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Separation of Granule Non-Ferrous Metals in Shredded Cable Waste with Eddy Current Separator

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Abstract -1.5-2 mm diameter **w**iring or power cables are shredded with length4-5 mm for recycling. This is called granule cable waste which is mixed with pvc particles of insulations. This waste contains valuable non-ferrous metals. Separation is more difficult in conventional methods. Higher energy and longer time is needed. In this study, granule cable wastes were separated by eddy current separator (ECS) in a clear, low cost and efficient manner. Copper and aluminum granule wastes were separated via repellent force induced by eddy current. This force was analyzed using finite element method and separation experiments were carried out via prototype ECS. Average resultant force values of granule copper and aluminum were calculated as 57.92 μN and 50.04 μN respectively according to FEM analysis. Granule non-ferrous metal separation performance was determined by experiments. When belt speed is 0.2 m/s, drum speed is 3000 rpm separated granule copper amount is about 5 kg, aluminum is about 1.5 kg in 60 seconds. Accordance with experiments, separation performances are 94,7% for copper, 99.5% for aluminum and 97,8% for mixture.

Keywords: Eddy current separator, granule non-ferrous metal separation

1. Introduction

Valuable non-ferrous metals in cable waste are gained by recycling. First, wiring or communication cables are shredded in conventional methods and are processed as mixed granules. PVC wastes are aspired and taken out in the process using fans because it is lighter than metals. In actuality, little pvc particles may remain in the process as waste. Secondly, this remainder waste is immersed in the water tank. So granule non-ferrous metals are separated under water. But recycled metals have to dry since they are wet. Separation cost is higher due to energy consumption for drying. Small particles may be removed by fans. In this situation some valuable metals are not recovered.

In this study; ECS is proposed as an alternative to conventional cable separation process. Recently ECS design studies and high field neodymium magnets have made non-ferrous particle separation possible.

Eddy current is an effective method for the separation of non-ferrous valuable metals. An electric current is induced in the conducting metal in accordance with Faraday’s Law when it is cut off by changing magnetic flux. These currents make closed circuits in the material. They are called eddy currents. Magnetic field occurs in the material due to the effect of eddy currents in accordance with Ampere’s Law. This field interacts with rotating drum magnetic field. So separation force is induced in the material in accordance with the Biot-Savart Law. As a result of this force, the material is thrown out from waste flow. (Rem, et al. 1998, Lungu, 2005, Svoboda, 2004). Figure 1a) shows the principle diagram and figure 2 b) shows commercial product(BUNTING ®)of ECS(Web-1)

ECS is made up of a conveyor band system and a magnetic drum. This drum rotates at high speeds under the conveyor band independent of the driving gear of the band. Non-ferrous metals move towards the drum over the band and fall into the separated product container when they are on the drum with the effect of the force that occurs due to the eddy current. Thus, separation is completed.

Kang and Schoenung (2005) have carried out studies putting forth that the main criteria for an eddy current separator are the density of the material ρ, its electrical conductivity σ and the ratio of its density to electrical conductivity σ / ρ. Materials with higher conductivity per density can be separated more easily. It is observed that the separation ratio is higher for small particles in this separation process.

a) b)

Fig. 1. a) ECS principle diagram b) commercial product (BUNTING ®)

Magnetic drum is the most important part of ECS. Granule non-ferrous cable separation performance is determined according to variable drum speed. Granule copper and aluminum metals were separated from shredded cable wastes. Separation force is induced by magnetic drum on copper and aluminum granule metals was analyzed by finite element method (FEM) in order to correct design and to predict results. Separation experiments were carried out on prototype ECS.

2. Material and Method

The most significant variables are magnitude and frequency of eddy current to affect the separator efficiency. These variables directly influence separation efficiency since they also change the repellent force. The repellent force is generated by axial magnetic forces and depends on eddy current and its frequency. The factors that depend on material properties are type, density, resistivity, conductivity, shape and dimensions. Whereas parameters that depend on separator design and drum speed, number of poles, magnetic field intensity of the drum and the air gap distance between the drum and the material. The repellent force (F_r) on non-ferrous metal in the eddy current separator have expressed by Wang et.al.(2005) with Equations(1) and (2).Variables in Table 1 which are affected to repellent force depend on ECS design parameters.

$$F_r = H^2 f \times \frac{m\sigma}{\rho s} \tag{1}$$

$$f = \frac{np}{120} \tag{2}$$

Table. 1.Variables affect to repellent force

	ECS design parameters	Unit		Material properties	Unit
H	magnetic field	A/m	m	the material's mass	kg
f	eddy current frequency	Hz	ρ	density	g/cm^3
n	speed of the drum	rpm	σ	conductivity	S
p	number of drum poles		s	Shape coefficient	

The ratio of conductivity determines the magnitude of the force and the efficiency of separation. Under the same ECS operations aluminum material with the same size is separated more easily in comparison with copper due to high σ / ρ ratio is, even if induced force on the copper is higher (Kang and Schoenung, 2005). When the ECS design parameters are improved, granule metals which have low ratio can be separated easily. On the other hand, when drum speed, pole number, magnetic field intensity are increased, repellent force and separation efficiency increase.

Magnetic drum is covered 36 neodymium magnet poles which have N50 grade and size of 50x10x5 mm. It is driven by high speed servo motor. ECS magnetic drum is shown in Fig.2. Test materials are given in Fig. 3. as a mixed granule waste.

Fig. 2. Magnetic drum of ECS

a) b)

Fig. 3. Granule cable waste a) mixture cable waste with pvcb) granule cable

Granule cable waste was experimentally separated via prototype ECS. Test wastes were prepared in the experiments after which separation tests were completed. Magnetic drum position, drum and belt speed were adjusted for optimal performance. Belt speed was kept constant as 0.2 m/s and drum speed was kept constant as 3000 rpm.

3. Results

The repellent force on granule aluminum and copper material was analyzed via Ansys-Maxwell software using finite element method for solutions. Simulation model for magnetic flux line is shown in Fig.4.

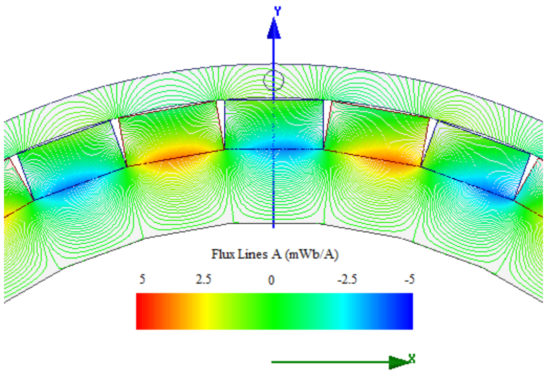

Fig. 4. Magnetic flux lines

Forces have been examined only for copper and aluminum during the analyses keeping all other parameters constant. The resultant force is vector sum of axial forces (F_x, F_y). The resultant force generates repellent force which separates materials. Axial and resultant forces have been given in Fig. 5.for same sized copper and aluminum. Resultant force is analyzed by FEM according to experiment conditions. Granule copper and aluminum diameter is 2 mm, length is 5 mm, drum speed is 3000 rpm, and rotational displacement is $\pi/18$ radian or one magnet pole step. Average resultant force values for copper and aluminum are 57.92μN and 50.04 μN respectively according to FEM solutions

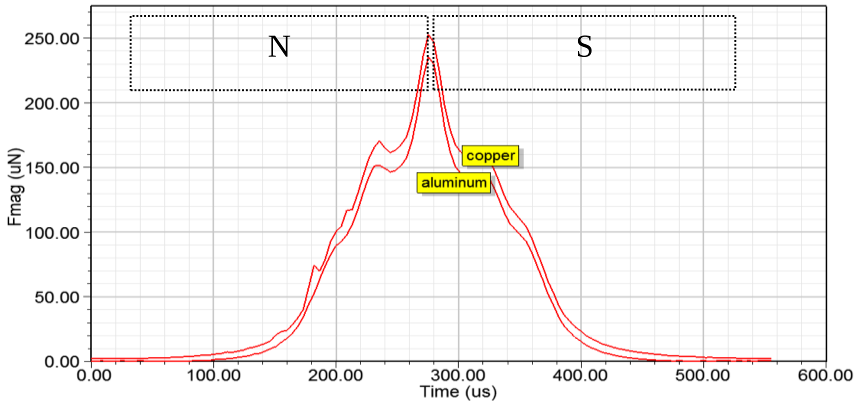

Fig. 5. Axial and resultant forces

According to FEM solutions, force induced on the copper is higher than that on aluminum due to high conductivity. However, copper separation performance is lower than that of aluminum due to higher density. In literature, density per conductivity determines separation performance. If σ / ρ ratio is bigger than force ratio, performance and efficiency is higher.

In separation experiments granule cable materials and pvc particles were weighed before separation. Copper, aluminum and mixed wastes were separated respectively. When belt speed is 0.2 m/s, drum speed is 3000 rpm granule copper separation is about 5 kg; aluminum separation is about 1.5 kg in 60 seconds. Separated granule materials are weighed after separation. In this measurements separation performances are 94.7% for copper, 99.5% for aluminum and 97.8% for mixture. Separation result is demonstrated in Figure 6 for mixture waste.

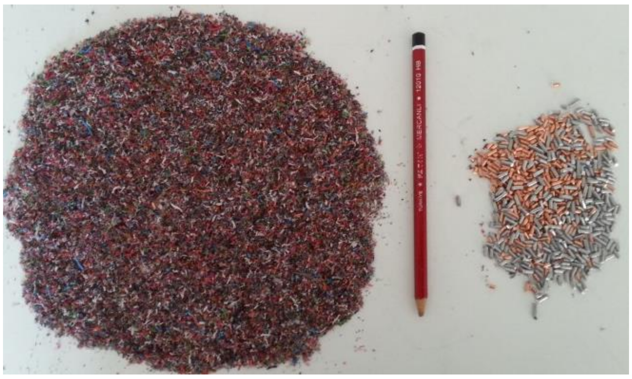
Fig. 6. Granule cable waste separation results

4. Conclusions

ECS systems are machines that are designed to separate non-ferrous metals from the waste. But conventional ECS doesn't separate granule material. In this study prototype ECS is designed for granule non-ferrous metal separation. Proposed design properties will be presented in a new publication after Intellectual Property Rights procedures are completed.

Average resultant force values for granule copper and aluminum are 57.92µN and 50.04µN respectively according to FEM solutions. Thus separation performance is predicted and operation parameters are corrected before experiments.

Granule shredded cable waste with size of 1.5-2 mm diameter and length of 4-5 mm are separated successfully. When band belt speed is 0.2 m/s, 36 magnets poled magnetic drum speed is 3000 rpm, granule copper separation amount is about 5 kg, aluminum separation amount is about 1.5 kg in 60 seconds. In measurements separation performances were determined as 94.7% for copper, 99.5% for aluminum and 97.8% for mixture.

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