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Effect of Plastic Mixture in the Shredded E-waste Sample to the Performance of an Eddy-Current Separator

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ABSTRACT

Electronic waste, or e-waste, is generated significantly over time which contributes to the big problem of environmental pollution. The metal content in the e-waste is valuable and should be recycled. Therefore, the separation process needs to be carried out so that all valuable metals, including the non-ferrous metal can be recycled. This separation mechanism uses the eddy current principle, in which a rotated magnetic rotary drum exerts a repulsive Lorentz force to the non-ferrous metal in the scrap metal so that it will separate from other materials. One important case to consider is when the scrap metals still contain plastic. In this research, the objective is to investigate experimentally the effect of plastic mixture in the e-waste scrap. Several parameters are varied, such as the mass ratio of the plastic as well as the rotational speed of the magnetic rotary drum. The findings are hoped to contribute to the design improvement of eddy current separator in developing countries.

Keywords: e-waste, eddy current separator, magnets, non-ferrous metals

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INTRODUCTION

Electronic waste, or e-waste, accumulates significantly over time, contributing to the growing issue of environmental pollution [1-3]. E-waste from common electronic devices such as personal computers and cell phones contains valuable materials like aluminum, plastic, copper, and steel, which should be recycled [4-5]. Effective recycling requires a separation process to recover all valuable metals, with the separation of non-ferrous metals being a critical step.

Eddy current separation is one of the most effective methods for separating non-ferrous metals from e-waste in flake form [6-7]. Arvidson et al. demonstrated that this method effectively separates non-ferrous materials from various magnetic materials. However, in developing countries, the lack of beneficiation processes such as shredding due to cost barriers presents a significant challenge [8]. Without proper beneficiation, the resulting scrap metal is often irregular in size and shape and mixed with other materials, especially plastics.

Therefore, it is crucial to study how these factors affect the magnitude of the generated Lorentz force and optimize the separation process accordingly. The objective of this research is to experimentally investigate the impact of plastic mixtures in e-waste scrap on the generated Lorentz force, measured indirectly through deflection distance. The experiment will focus on non-ferrous materials, specifically copper and aluminum.

METHODOLOGY

Design of eddy current separator

The eddy current separator employed in this research is developed in-house in the Laboratory of Mechanical Design, Universitas Indonesia. The machine uses the most common commercial design, namely the rotary drum type, which achieves the time-varying magnetic field is achieved by rotating a cylindrical array of permanent magnets with alternating polarity [9]. The magnetic rotary drum used for this experiment was designed with the length of 42 mm as shown in Figure 1(a). The magnetic rotary drum was 3D-printed with a filament material of PLA. It contains eight permanent magnets made of neodymium with the size of 10 x 5 x 100 mm. The setup of the magnet is North-South-North and so on. One side of it was designed to fit with the motor and each side was carried by the bearing. The upper side of each permanent magnet slot was open to improve the eddy current effect towards the specimen. A pedestal to place the scrap metal specimen was designed to sport holes to improve the magnetic force [9]. The purpose of the bearing and motor fixtures, whose design is shown in Figure 1(b) are to aid with the assembly process of the experimental setup. These fixtures improve the connection between the electric motor and the magnetic rotary drum as well as to avoid its wear and tear. The fixtures also help to measure the deflection

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length. Finally, Figure 1(c) below shows the assembled machine in the experimental setup.

Figure 1. (a) design of the magnetic rotary drum, (b) design of the fixtures, and (c) the photo of the assembled eddy current separator used in this research.

Preparation of specimens

The specimens used for this experiment are copper and aluminum which are the most commonly found materials in e-waste. To prepare specimens which resemble the actual condition of the e-waste, copper and aluminum were mixed with Polylactic acid (PLA) with different mass ratio, i.e. 1:1 and 1:4. For control, specimens with pure copper and aluminum were also prepared with sizes of 10 x 10 mm and 20 x 20 mm. All different specimens prepared of copper and aluminum are shown in Figure 2(a) and Figure 2(b), respectively.

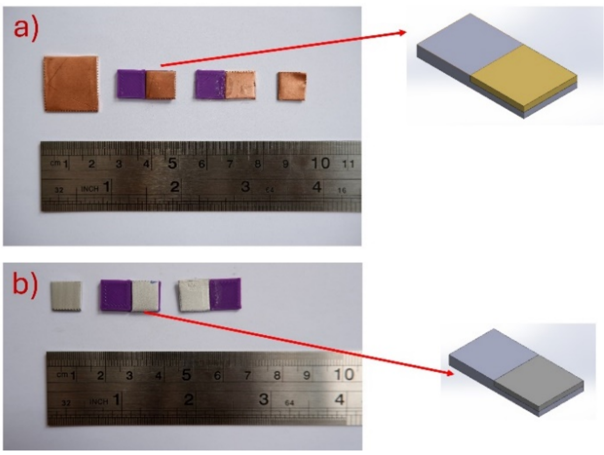

Figure 2. (a) various copper specimens, i.e. pure, 1:1 with plastic mixture, and 1:4 with plastic mixture, and (b) various aluminum specimens, i.e. pure, 1:1 with plastic mixture, and 1:4 with plastic mixture

Experimental setup

The experimental setup used an electric motor which is supplied a voltage of 12 – 18 VDC by a power adapter. The top view of the setup is shown Figure 3(a). Three variations of rotational speed were applied, i.e. 1300, 1800, and 2300 RPM. As the first step, a measurement using a tachometer was conducted to ensure that the value of rotational speeds was at the intended value. Subsequently, the specimen was placed on the pedestal and was deflected instantaneously due to the generated Lorentz force. Subsequently, the deflection was recorded and the final distance was measured. The experiment was conducted for each variation of rotational speed and each specimen, three times each. Figure 3(b) and Figure 3(c) show the snapshot of the typical deflected specimen, seen from the side. A red guide line was added to the photo to show the trajectory of the deflected specimen which shows a typical projectile motion.

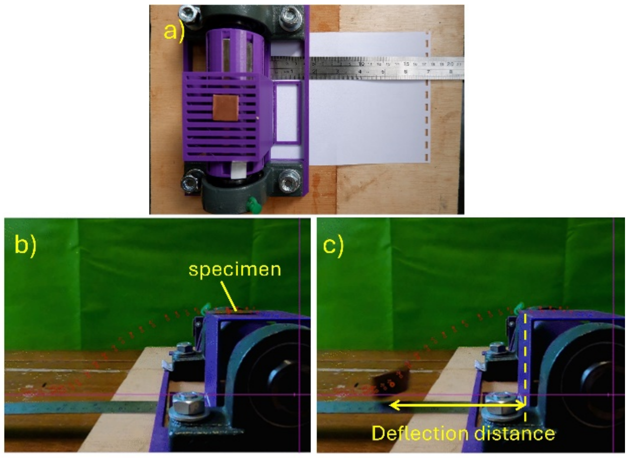

Figure 3. (a) Top view of the experimental setup, (b) the specimen is prepared at the pedestal, and (c) is deflected by the eddy current separator, making a projectile motion trajectory

RESULTS AND DISCUSSION

The results of the experiments for all specimens are shown in Figure 4(a-c). The experiments were conducted three times for each of the variations and the data shown in Figure 4 were the average of them.

For both aluminum and copper, the deflection distance is generally proportional to the rotational speed of the magnetic rotary drum. Also, generally aluminum was found to deflect further than copper, which is well validated by other researchers (see for example Smith et al. [9]). Furthermore, it could also be observed that the mass ratio between the metal and PLA greatly affects the deflection distance as well, as shown by comparing the maximum distances shown in Figure 4(a-c). For example, when pure aluminum was deflected with 2300 RPM, the distance recorded was 58 cm, and it drops by about 37% when the rotational speed was reduced to 1300 RPM. When the fraction of the metals in the specimen is much smaller than the PLA, i.e. at the 1:4 mass ratio, there are cases in which the deflection distance cannot be determined due to a

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very minimum amount of the Lorentz force generated which results in a negligible deflection.

From the obtained data, it could be deduced that the greatest deflection distance is contributed mainly by the rotational speed of the magnetic rotary drum. Additionally, the fraction of the metal in a specimen also plays an important role. On another note, the deflection characteristic of copper is not much different from that of aluminum and they are generally reproducible. Therefore, such an experiment to determine the deflection distance from a given scrap metal with random plastic mixture is deemed feasible and beneficial for the operational aspects of a recycling center.

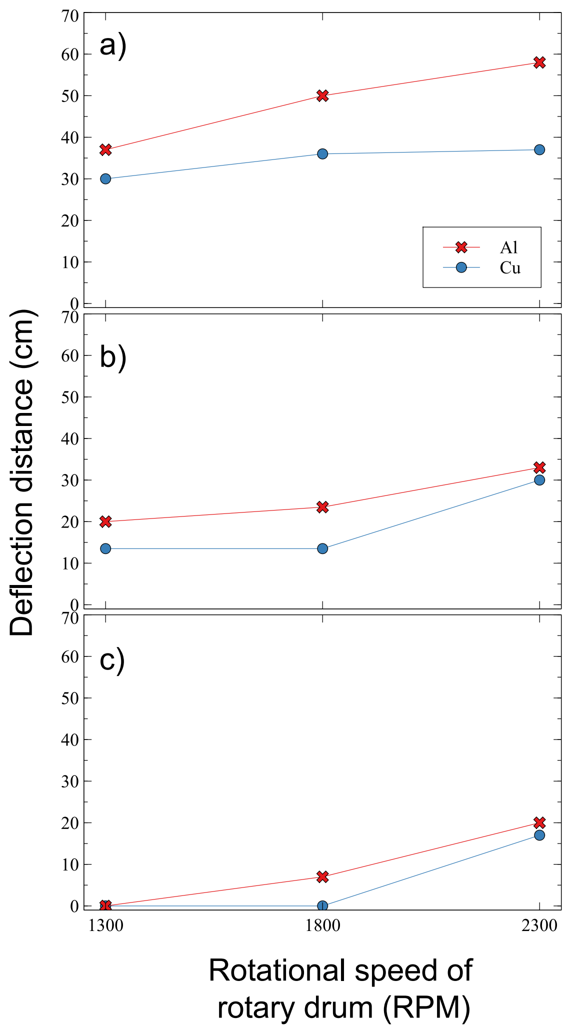

Figure 4. Comparison of deflection distances between various Aluminum and copper samples, i.e. (a) pure without plastic/PLA mixture, (b) 1:1 mass ratio, and (c) 4:1 mass ratio

CONCLUSION

The experimental setup This study explored the effects of plastic mixtures within shredded e-waste samples on the performance of an eddy-current separator. The results revealed that both the rotational speed of the magnetic rotary drum and the mass ratio of plastic to metal significantly influenced the separation efficiency, as measured by the deflection distance of non-ferrous metals like aluminum and copper. Higher rotational speeds consistently resulted in greater deflection distances, while a higher proportion of plastic in the samples reduced the effectiveness of the separation process. The findings suggest that optimizing the eddy-current separation process, particularly in environments where e-waste contains significant plastic contamination, requires careful consideration of both operational parameters and material composition. The insights gained from this research could inform design improvements for eddy-current separators, particularly in recycling facilities in developing countries where e-waste processing is crucial for resource recovery and environmental protection.

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AUTHOR'S CONTRIBUTION

DMS was mainly in charge of the experiments, data collection, and analysis. MYQ contributed to the analysis and writing of the manuscript. RD contributed to analysis and writing the manuscript. All authors read and approved the final manuscript.

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