Triboelectric separation of binary plastic mixture

M. Saeki

Abstract**—** This paper presents the results of an experimental study on the performance of a triboelectric separator of plastic mixtures used for recycling. The separator consists of four cylindrical electrodes. The principle behind the separation technique is based on the difference in the Coulomb force acting on the plastic particles after triboelectric charging. The separation of mixtures of acrylonitrile butadiene styrene (ABS) and polystyrene (PS) using this method was studied. The effects of the triboelectric charging time and applied voltage on the separation efficiency were investigated. The experimental results confirm that it is possible to obtain a high purity and recovery rate for the initial compositions considered in this study.

Keywords**—**Coulomb force, Recycling, Triboelectric separator, Waste plastics.

I. Introduction

PLASICS are light and easily mass-produced and thus they are widely used in various fields. Most products usually contain several types of plastic. When they are discarded, it is necessary to separate each plastic for recycling [1]. During recycling, the following separation process is carried out. First, waste products are dismantled manually. Waste products that cannot be dismantled are broken into pieces by crushers. Then, iron and aluminum pieces are separated using a magnetic separator and an eddy current separator, respectively. The remaining materials are sorted using a specific gravity separator. Since there is, however, little difference among the specific gravities of most plastics, it is very difficult to separate a mixture of plastics with high separation efficiency.

For the separation of a mixture of plastics, triboelectric separation has been studied[2]–[12]. Triboelectric separation involves the electrostatic charging of waste in a charging device which can then be separated in an electrostatic field owing to the difference in the electrostatic force acting on different plastics. Although free-fall triboelectric separators are typically used and have many advantages such as a simple structure and dry separation, it is expected that the method is improved to obtain higher separation efficiency.

This paper presents the results of an experimental study on the performance of a free-fall triboelectric separator consisting of four cylindrical electrodes. This approach makes it possible to avoid the collision of charged particles with the electrodes. Separation tests were performed on a sample containing acrylonitrile butadiene styrene (ABS) and polystyrene (PS). The effects of operating parameters such as applied voltage and triboelectric charging time on the separation efficiency were examined.

II. Triboelectric Separation

Figure 1 shows a model of the triboelectric separator used in this study. In this figure, the X-Y plane is parallel to the horizontal plane. The separator consists of four cylindrical electrodes and a feeder. The four electrodes are aligned vertically. A high positive voltage and a high negative voltage are applied to the two left electrodes and two right electrodes, respectively, using a high-voltage generator. Prior to the separation, the particles are charged in a tribocharging device, which will be discussed in detail later. Then, the charged particles are fed to the center of the space between the four electrodes through the feeder. The positively charged particles are attracted toward the space between the negative electrodes by electrostatic force, whereas the negatively charged particles are attracted toward the space between the positive electrodes. In this way, the positively charged particles are separated from the negatively charged particles owing to the difference in their trajectories. This approach makes it possible to avoid the collision of charged particles with the electrodes.

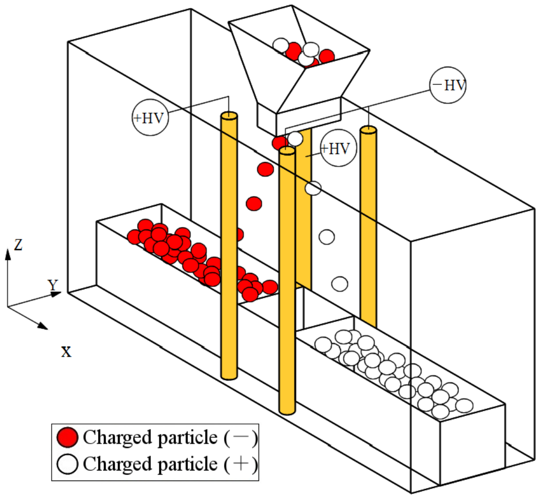

Fig. 1 Model of triboelectric separator

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III. Electric-field Strength

The separation efficiency depends on the electric-field strength.

Figure 2 shows the electric-field vector map of the region surrounding the electrodes obtained by the finite element method. The radius of each electrode is 0.04m. The distance between the electrodes subjected to voltages with different polarities is 0.18m, and the distance between the electrodes subjected to voltages with the same polarity is 0.24m. The two left and two right electrodes are subjected to voltages of 30 and -30kV, respectively. Since the electric field is directed from left to right at the center of the space between the four electrodes in Fig. 2, it is expected that the positively charged particles in the center will move towards the space between the two right electrodes owing to the Coulomb force acting on the particles.

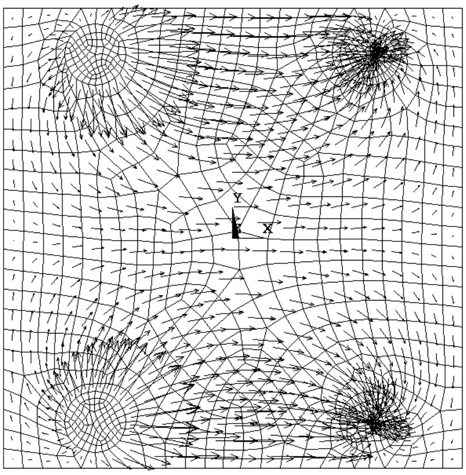


Fig. 2 Electric-field vector map

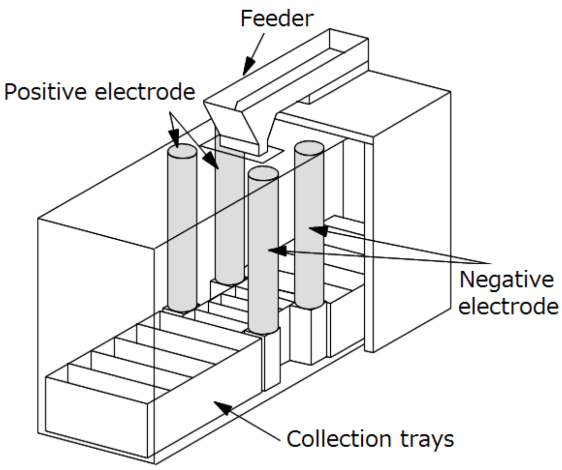


Fig. 3 Electric-field vector map

IV. Experiment

An experiment was performed to verify the validity of the separation method.

Figure 3 shows the experimental apparatus used for separating the plastic particles. The separator consists of four aluminum pipe electrodes. The collection system consists of 13 collection trays.

Figure 4 shows the rotating cylinder used for triboelectric charging the particles. The rotating cylinder, which is made of ABS, has an interior diameter of 90mm and a length of 65mm. Four ABS plates, which have a length of 65mm, a width of 10mm, and a thickness of 5mm, are situated on the inside surface of the cylinder.

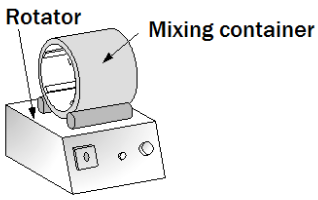


Fig. 4 Triboelectric charger

Figure 5 shows the PS and ABS particles used in this study. All particles were obtained from crushed plastic plates. As there is little difference between the densities of PS and ABS, these plastics were selected. Prior to each experiment, the plastics were dried for 30 min to ensure equilibrium conditions.

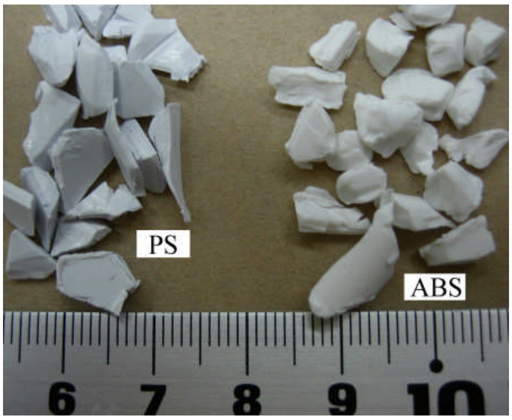
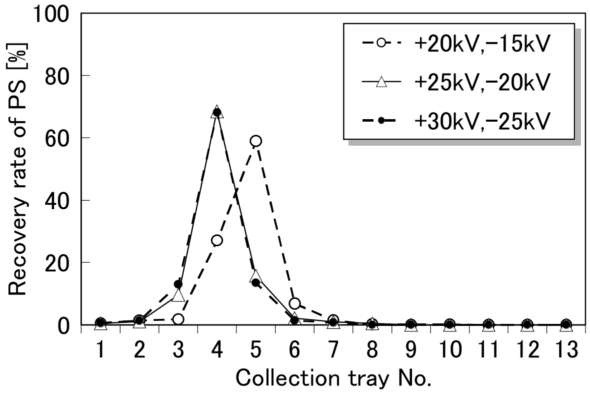
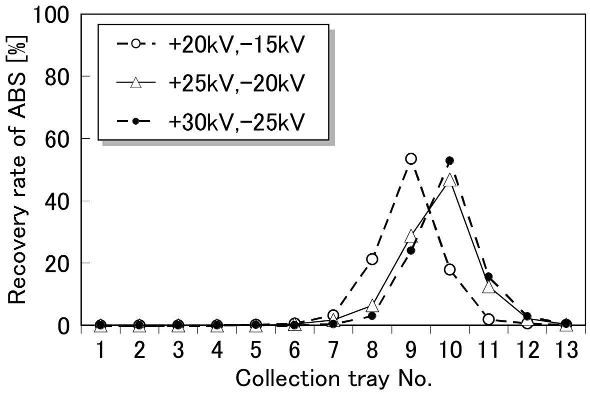


Fig. 5 PS and ABS particles

Next, the experimental procedure is described. Known quantities of the feed materials (30g of each material) were placed into the rotating cylinder for triboelectric charging, as shown in Fig. 4. The charged particles were then fed into the separation unit, as shown in Fig. 3. After collecting the plastic particles that fell into each collection tray, the plastic in each collection tray was weighed. All the experiments were carried out at room temperature and at a relative humidity of less than

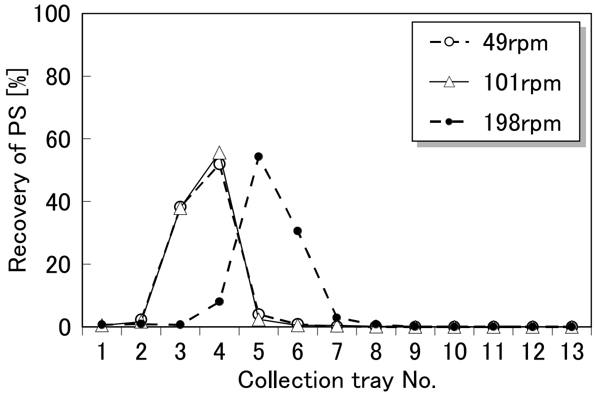


(a) Recovery rate of PS

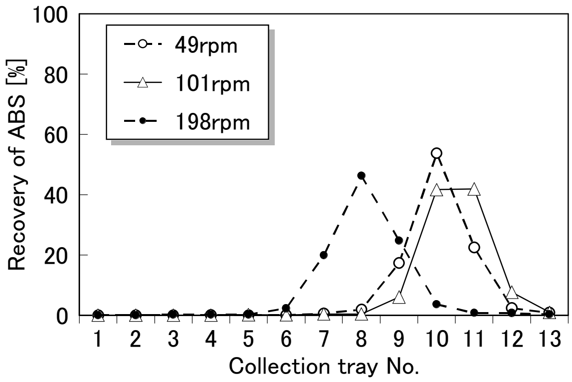


(b) Recovery rate of ABS

Fig. 6 Effect of applied voltage on recovery rate



(a) Recovery rate of PS



(b) Recovery rate of ABS

Fig. 7 Effect of applied rotation speed of triboelectric charger on recovery rate (charging time =3min.)

45%.

Figure 6 shows the effect of the voltage applied to the electrodes on the recovery rate. The recovery rate for plastic A in tray B is defined as the mass of plastic A collected in tray B divided by the mass of plastic A in the feed materials. The position at which the largest amount of PS or ABS is collected becomes further from the center tray 7 as the applied voltage is increased. The reason for this is that the Coulomb force acting on the plastic particles increases with the applied voltage.

Figures 7 and 8 show the effect of the rotation speed on the recovery rate. for tribocharging times of 3 and 7min, respectively. It was observed that the position at which the largest quantity of PS or ABS was collected is strongly affected by the rotation speed. The position at which the largest amount of PS or ABS is collected in Fig. 8 is further from the center tray 7 than that in Fig. 7. As shown in these figures, the charge of the plastic particles increases as the tribocharging time is increased.

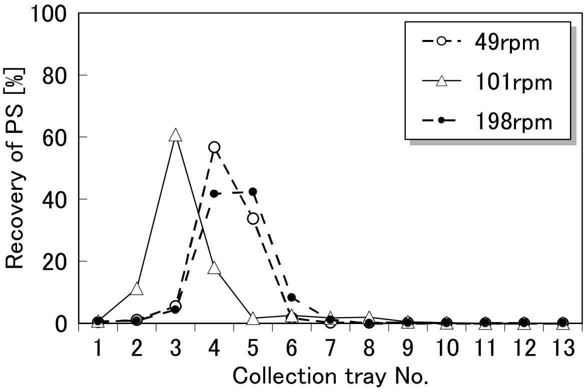
Figure 9 shows the effect of the initial composition of the plastic mixture on the amounts of ABS and PS recovered from each collection tray. For each composition, ABS is collected at a different position from PS. It is expected, therefore, that for the initial compositions considered in this study, the separation method has high separation efficiency. The position at which the largest amount of PS is collected for the composition ratio of PS: ABS=7:3 is different from that when the composition ratio is PS: ABS=1:1. The reason for this is that the ABS particles are more highly charged for the composition ratio of 7:3 than for the composition ratio of 1:1.

After considering numerous experimental results, trays 1-5 and 9-13 were designated for the collection of PS and ABS, respectively, and the particles collected in trays 6-8 are required a second stage of separation.

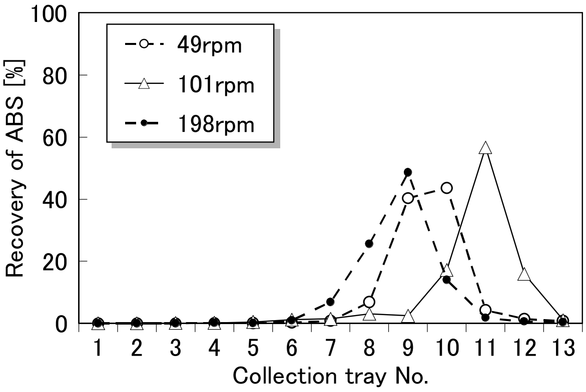
Table 1 shows the best experimental results obtained. In this table, purity is defined as the mass of a specific plastic divided by the total mass of plastics collected in a specific tray. Since all these results exceed 97%, this separator has higher separation efficiency than other currently obtainable separators.

V. CONCLUSION

The triboelectric separation of binary plastic mixtures was investigated experimentally. Separation tests were performed using a free-fall triboelectric separator with cylindrical electrodes. It was possible to obtain a high purity and recovery rate for the initial compositions considered. It was also found that the separation efficiency depends on the applied voltage and tribocharging time.



(a) Recovery rate of PS



(b) Recovery rate of ABS

Fig.8 Effect of applied rotation speed of triboelectric charger on recovery rate (charging time =7min.)

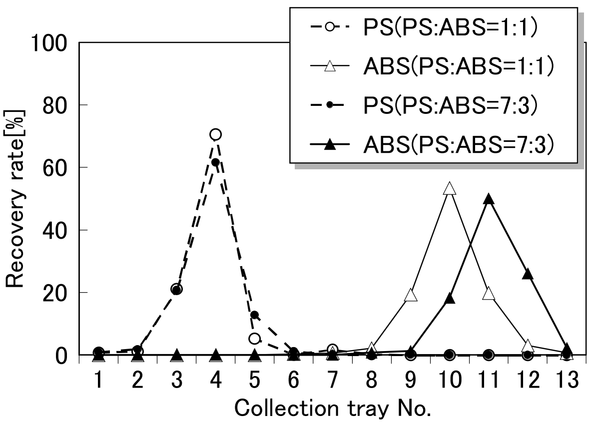


Fig. 9 Effect of the initial composition of the plastic mixtures on the amounts of ABS and PS recovered

TABLE I
BEST EXPERIMENTAL RESULTS

Type	Plastics	Initial composition %	Purity%	Recovery rate %
A	PS	50	99.8	97.8
	ABS	50	100	97.7
B	PS	70	100	97.9
	ABS	30	99.7	98.0

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