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Dry Separation of PVC Film from Plastic Film Mixture by Using Air Table

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ABSTRACT

This study was conducted in order to remove Poly vinyl chloride(PVC) from the waste plastic film mixture. The fittings of Air Table was modified to increase the separation efficiency of PVC and PE(poly ethylene). PE and PVC was successfully separated from PVC-PE film mixture with the yield of PE 90% or more and with his grade of 99% or more, using the improved Air Table. The details of the separation condition and results will be discussed in this paper.

Key words: Dry separation, Waste plastic film, PVC, Air Table

1. Introduction

In 1999, the total amount of waste plastics generated in Japan was 9.76 million tons, of which 4.52 million tons were recycled. Among them, 1.34 million tons were reused and 3.18 million tons were utilized as a heat energy source in the form of fuel for power generation facilities, solidified fuel, or reducing agent for blast furnace, etc.[1] Recycling of plastics for use as a source of heat energy has huge growth potential. The demand of reducing agent for blast furnace alone, for instance, is estimated to be around 20 million tons.[2] When using waste plastics as fuel or reducing agent for blast furnace, PE and PP are the most appropriate. The PVC contents in waste plastics are required to be 1% or less to prevent corrosion of facilities and other problems. Therefore, it can be said that the development of an efficient technique for removing PVC from waste plastics is very essential in their recycling.

On the other hand, plastic film is being produced with a share of about 20~25% in the total plastic production. However, the share of film in waste plastic is estimated to be 20~30% because of its short life cycle. According to a study[3] conducted in Japan, its share was about 36%. However, using a general separation method, it is very difficult to remove PVC from the waste plastic film mixture due to its wide area, high plasticizer contents and so on.

This study was conducted in order to remove PVC from the waste plastic film mixture, using Air Table. The motions of plastic film on the deck of Air Table were investigated in various operation conditions. The influences of height of riffle, frequency, air velocity, and end-slope affect on the separation efficiency of PE and PVC were also investigated.

2. Experiment

Samples were prepared by cutting PS, PP, PE and PVC films in 40~60 μm thickness to 5 mm under size, using a single roll shearing cutter. The mean sizes of prepared samples were 3.0± 0.3 mm. In investigating the motion, only particles 4~5 mm in size were used. The velocity and the direction of motion of a single film were measured in conjunction with changes in the angle of end-slope, air velocity, and frequency, using a riffle-less deck. The moving angle of particle is defined as shown in Fig. 1-B. The 0^{o} is taken when a particle moves horizontally toward left, and 90^{o} is taken when it moves vertically toward the discharging end of the deck. The numbers of measurement were set 50 times

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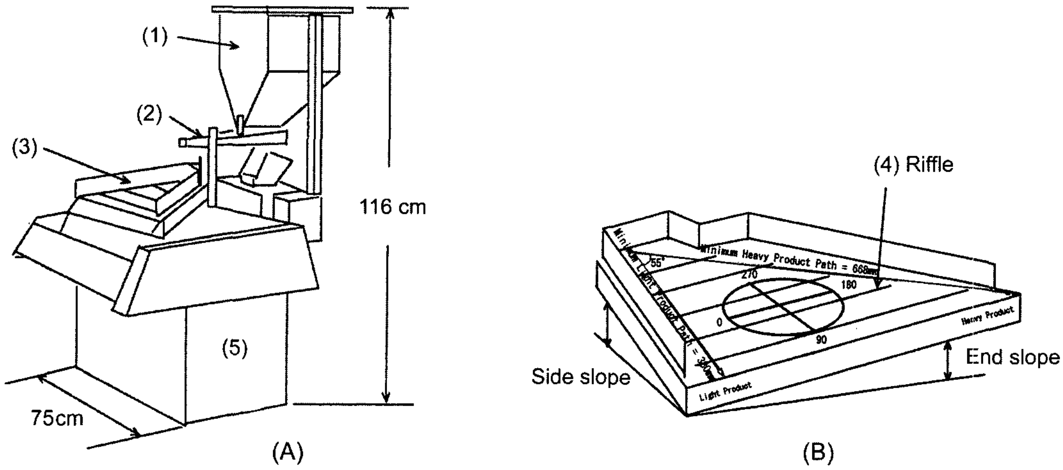

Fig. 1. Schematic diagram of air table: (1) Hopper, (2) Electromagnetic feeder, (3) Deck, (4) Riffle, (5) Control box

under the same conditions, and the results were calculated in arithmetical mean. The mixing ratio of mixed samples used in separation experiment was fitted in PE90% and PVC10%, and for the facility of analysis, blue PE and red PVC were used. The products of separation were separated into each plastic by hand-picking, and the grade, yield and overall separation efficiency (From now on, it will be called 'separation efficiency')[4] were calculated from the weight of each plastic. To avoid complications, in this paper, the yield of PE and contents of PVC in light-products which are discharged from the left outlet of Air Table will be mainly discussed. The SSS Dynamics' V-135E type of Air Table (see Fig. 1) was used as a main experimental instrument. This Air Table has a deck designed to have a longer migration path and larger moving angle on heavy particle than light particle. That is, the light particle's path has a minimum length of 380 mm and the heavy particle's path has a minimum length of 668 mm, and the difference between this paths' direction is 55 degrees. Also, it is needed to have a difference of 0.1 cm/sec or more between the moving speeds of light particle and heavy particle, for the effective separation with a feeding speed of 50 g/min. Fig. 2-A shows a force diagram for the particle moving on an inclined shaking deck of Air Table. In this figure, it is explained how a particle is subjected to the action of shaking and how it moves on the shaking deck. The details of it had reported in another report.[5]

Fig. 2-B demonstrates the movements of heavy and light particles within the fluidized bed that formed on the deck due to the influence exerted by air and vibra-

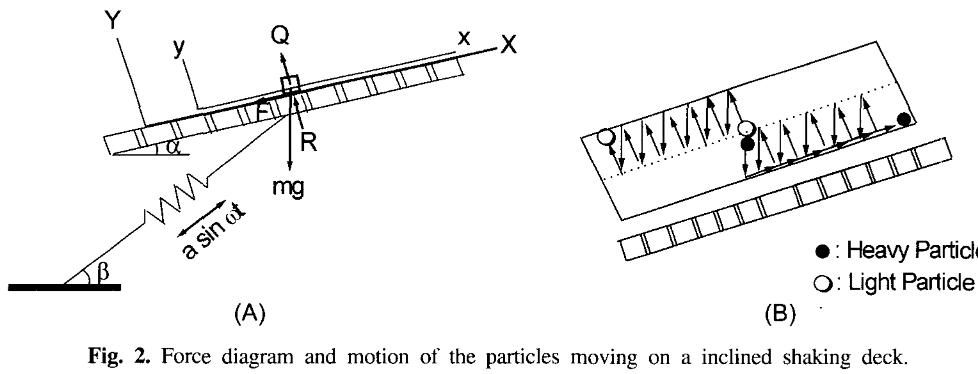

Fig. 2. Force diagram and motion of the particles moving on a inclined shaking deck.

tion. The particles, lighter or having larger projected area move towards the upper part of fluidized bed whereas the heavy or having smaller projected area particles move towards the bottom and eventually two layers are made. Particles at the bottom layer move towards the right direction, driven by the vibrating force and those on the top layer move to the left of deck affected by the air movement. Thus, these two types of particles are separated.

3. Results and Discussion

For the consistency of data, frequency of 7Hz, air velocity of 45 cm/sec, and side-slope of 5^{o} were set as standard condition. Fig. 3 shows the influence of end-slope which varies in the range of $5{\sim}9^{o}$ on the motion of plastic films. In this figure, PE shows a consistent speed regardless of end-slope. The speed of PVC, PP and PS also show the consistent value of 4.3~5.3 cm/sec within the $5{\sim}8^{o}$ range, However, when they reach 9^{o}, their speed increase rapidly to the 5.4~6.7 cm/sec. In addition, as the end-slope increases, the movement direction of the particles shows a tendency of leaning towards the left (toward the direction that moving angles become smaller). The difference in the moving angles of PVC from other plastics becomes further pronounced and reaches up to 10^{o} when the end-slope ranged $5{\sim}6^{o}$. These results can be explained as follows: particles tend to move toward the right side of the deck due to vibration, but the end-slope and air flow provide the resistance against this motion. When the end-slope is within the range of $5{\sim}8^{o}$, the reciprocal opponent

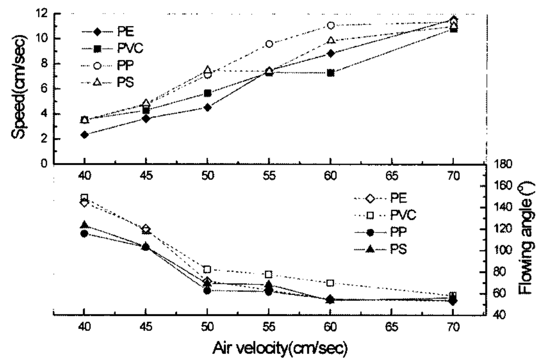

Fig. 4. Influence of air velocity on the speed and direction of plastic film moving on the deck of Air Table.

forces (those leaning towards the left and the right) are balanced each other and as a result, particles move in a zigzag manner with relatively slow speed. However, when the side slope reaches 9^{o}, the balance is broken and particles tend to drift rapidly toward the left.

Fig. 4 shows the influence of air velocity which varies in the range of 40~70 cm/sec on the motion of plastic films. Along with the increase in air velocity, the moving speed of films increases while their moving angles decreases. The differences of moving angles between PVC and other plastics, the one which greatly affects the separation efficiency, shows the maximum value, in the air velocity of 50~60 cm/sec.

Fig. 5 shows the influence of frequency varying in the range of 6~11 Hz. As shown, the speed tends to slow down with increasing frequency from 6 Hz to 7Hz, which can be attributed to the particles' zigzag motion caused by balancing of the reciprocal forces.

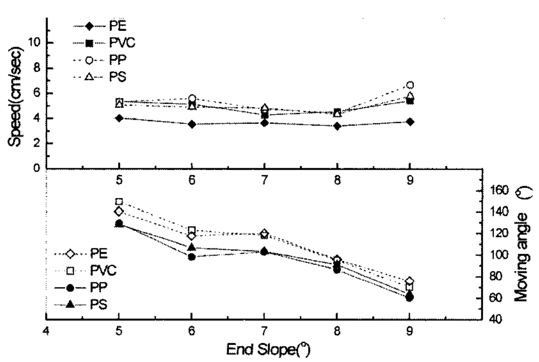

Fig. 3. Influence of end-slope on the speed and direction of plastic film moving on the deck of Air Table.

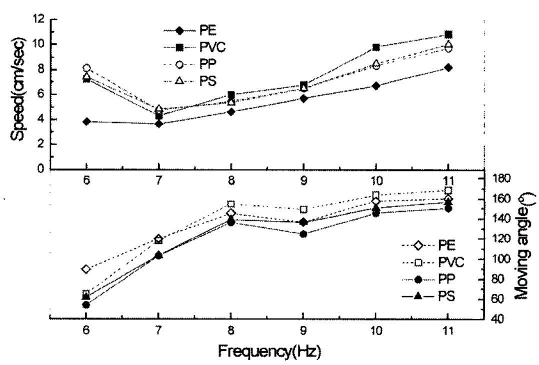

Fig. 5. Influence of frequency on the speed and direction of plastic film moving on the deck of Air Table.

The moving speed of PVC becomes fastest and the moving angle becomes largest at a frequency of 8 Hz or more. Taking into considering the fact that the structure of Air Table is designed to have a longer migration path and larger migration angle on heavy particle than light particle, it can be said that 8 Hz or more frequency are needed to remove PVC film from plastic film mixture.

From the results of the above mentioned investigation on the movement of plastic film on the deck that has no riffle, It can be seen that the difference on moving angle of 10~30° and difference on speed of 1~4 cm/sec can be generated by control the factors. This difference on moving angle is insufficient, comparing with the needed difference of 55° for separating the two particles. However the difference on speed is about 10 times as big as the needed difference of 0.1 cm/sec. Consequently, it can be expected that the separation of plastic film by Air Table become possible through improving the riffle and equipping the deck with it, by which the difference on moving angle of particles will be increased.

In the separation experiment of PE and PVC from their mixture, the following condition was chosen as a standard condition, i.e. riffle's height of 25 mm, air velocity of 50 cm/sec, side-slope of 5°, end-slope of 8°, frequency of 9 Hz, feeding speed of 50 g/min.

Among these parameters, only one parameter was varied in a predetermined range, while the rest of them were fixed to standard values, and the influence of the parameter was investigated.

The influence of riffle`s height is shown in Fig. 6. Increasing the height within the 5~25 mm range, both the yield of PE discharged as light-product from the deck's left outlet and the content of PVC within PE decrease (for instance, at 5 mm; yield of PE 89.3%, and PVC content of 0.68% → at 25 mm; yield of PE 86.2%, and PVC content of 0.34%). In this case, the separation efficiency scarcely changes because the decrease of yield is compensated by the increase of grade (decrease of PVC content). However, when the height of the riffle becomes higher than 35 mm, the yield decreases remarkably. At the same time, PVC content shows steep increase. During this experiment, it was also observed that the thickness of stable fluidized bed always exceeds the height of riffle by 5~15 mm, that is, for the riffle's height of 5~25 mm, stable fluidized bed with a thickness of 10~35 mm is formed. In this height range, the higher the riffle is the lower PVC content, which can be attributed to the longer separation zone provided by the thicker fluidized bed. However, riffle not only acts as the agent that maintained the height of fluidized bed, but also acts as an impediment to longitudinal flow of fluidized bed. The higher riffle leads the flow direction to lean towards the right side and causes the decrease in the yield of PE. When the riffle's heights exceeds 35 mm, the fluidized bed can no longer maintain the state of homogeneous fluidization due to the formation of fixed bed at the upper side, which resulting from the increased pressure loss caused by increased length of air path. Consequently, the state of homogeneous fluidization transformed into a bubbling or slugging state and the separation efficiency decreases remarkably.

On the test of air velocity (see Fig. 7), minimum fluidization manifested at 35 cm/sec and homogeneous

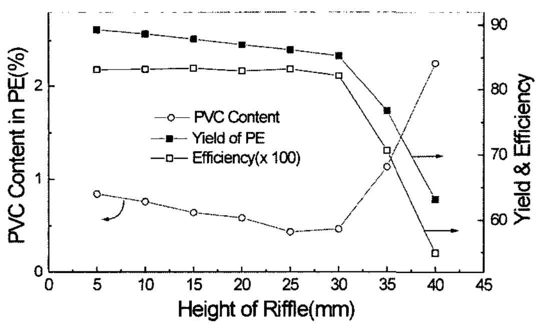

Fig. 6. Influence of the height of riffle on the separation of PVC and PE from PVC-PE film mixture.

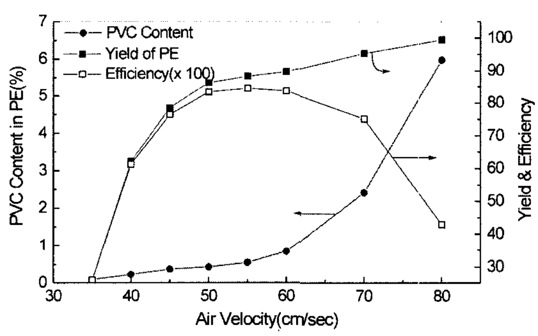

Fig. 7. Influence of the air velocity on the separation of PVC and PE from PVC-PE film mixture.

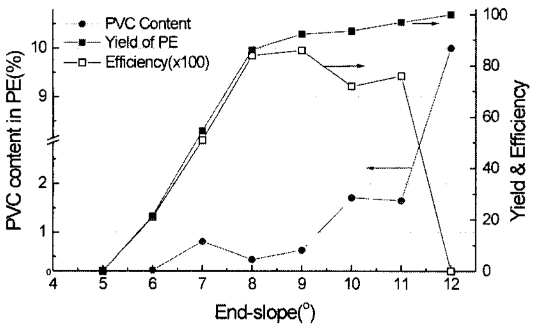

Fig. 8. Influence of end-slope on the separation of PVC and PE from PVC-PE film mixture

fluidization state was maintained in the range of 35~60 cm/sec.

The separation efficiency is the best at the air velocity of 55 cm/sec, when the yield of PE is 88.3% and the content of PVC in PE is 0.55%. When the air velocity was 70 cm/sec, a fluidized bed started to show turbulent fluidization while separation efficiency started to decrease remarkably with the increase of PVC content in PE.

The influence of end-slope is shown on Fig. 8. When the end-slope is less then 5^{o}, the force caused by shaking of the deck, which acting on a particle to move toward the right side of deck, becomes exceedingly greater than resisting force generated by air flow and slope of the deck. In result, both PE and PVC are discharged from the right outlet, and separation does not occur. In the $5\sim9^{o}$ range, the yield of PE shows linear increase with increasing end-slope, and the overall separation efficiency reaches 0.85, the best, at 9^{o}. At the end-slope of 10^{o}, content of PVC in PE product starts to increase due to the increase of resisting force which prevents PVC film to climb up the deck. At 12^{o}, separation does not occur since all products were discharged from left side of the deck in a mixed state.

On frequency test (Fig. 9), the minimum fluidization started at 6.17 Hz. And the separation efficiency increases with increasing frequency. The best separation efficiency is obtained in the range of 8.5~9.0 Hz. When frequency increased to over 10 Hz, the yield of PE decreases according to an increase of PE discharged from the right side with PVC.

Fig. 10. Relationship among frequency, end-slope, and overall separation efficiency in the separation of

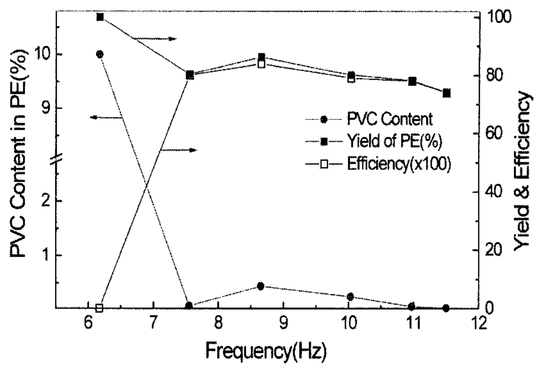

Fig. 9. Influence of frequency on the separation of PVC and PE from PVC-PE film mixture.

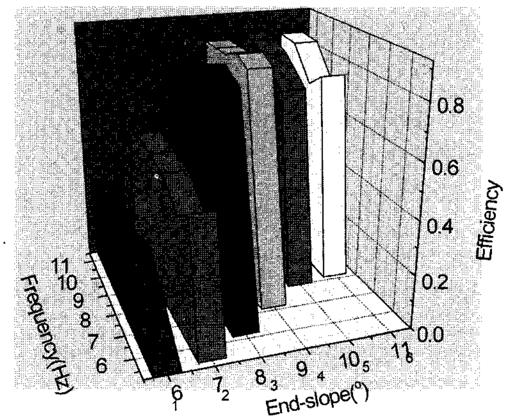

Fig. 10. Relationship among frequency, end-slope, and overall separation efficiency in the separation of PVC-PE film mixture.

PVC-PE film mixture

From the results of experiments mentioned above, it might be concluded that the optimal conditions to operate the Air Table for the separation of PE and PVC film are riffle's height of 25 mm, air velocity of 55 cm/sec, end-slope of 9^{o} and 9 Hz frequency. However, these factors tend to interlink with each other and thus, it is recommended that the optimum condition is determined from the results of an interlinked condition test. The results of such a test on frequency/end-slope with conditions of riffle's height of 25 mm, 55 cm/sec of air velocity, 5^{o} side-slope, and feeding speed of 50 g/min, are shown on Fig. 10. The separation efficiency is more than 0.84 or more, in the interlinked conditions of 8.65 Hz-8^{o}, 8.95 Hz-9^{o}, 10.83 Hz-10^{o}, and 11.45 Hz-11^{o}. Of these results, overall separation efficiency at 8.95 Hz-9° shows a maximum value of 0.86 and at this point, yield of PE is 92.48% and content of PVC in PE is 0.63%.

4. Conclusion

From the investigation on the motion of plastic films on the deck that has no riffle, it was found that the difference of films on moving angle of 10~30° and difference on speed of 1~4 cm/sec can be generated by controlling the operation factors of Air Table. Consequently, it can be expected that the separation of plastic film by Air Table become possible through improving the riffle and equipping the deck with it, by which the difference on moving angle of particles will be increased.

The obtained optimum condition for separating PE and PVC from PE90%-PVC10% film mixture were riffle's height of 25 mm, air velocity of 55 cm/sec, end-slope of 9°, and frequency of 9 Hz. In this condition, the PE and PVC were able to be separated with an overall separation efficiency of 0.86, yield of PE 92.48% and content of PVC in PE of 0.63% by using Air Table.

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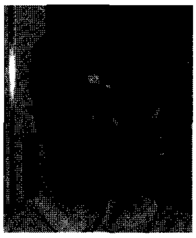

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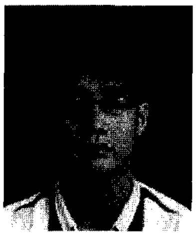

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