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Dry separation of PVC film from waste plastic film mixture using Air Table

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A study was conducted in order to remove PVC from the waste plastic film mixture. The fittings of Air Table was modified to increase the separation efficiency of PVC. By using the improved air table, the PE and PVC was successfully separated from PVC-PE film mixture with the yield of PE 90% or more and with the content of PVC in PE 1% or less. The detail of the separation condition and result will be discussed in this paper.

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, and the 3.18 million tons, excluding the 1.34 million tons that were reused, were utilized as heat energy 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 for reducing agent for blast furnace alone, for instance, is estimated to be around 20 million tons. 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 specified by 1% or less due to corrosion of facilities and equipment 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. Results were reported of a successful experiment whereby the structure of air table and conditions for separation were improved to obtain 99.9% grade PE with 98.9% yield. At the same time, PVC with a grade of 88.7% and a 99.6% yield form granular plastics mixture of PE85%+PVC15% under the separation speed of 658kg/m2 hr.

On the other hand, plastic film is being produced with a proportion of about 20~25% of the total plastic production. However, its life cycle is short which leads to the estimation that its share of the waste plastics is about 25 ~ 30%. According to a 1994 study[2] conducted in Japan, its share was about 36%. Using a general separation method, it is very difficult to remove PVC from plastics due to its wide area, high plasticizer contents, among others.

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

Experiment

Samples were prepared by cutting PE and PVC films in 40-60μm thickness to 5 mm under size, using a single roll shearing cutter. The sizes of prepared samples were 3.0 - 0.3 mm. The mixing ratio of mixed samples was fitted in PE90%+PVC10%, and to facilitate the analysis, blue PE and red PVC (painted) were used. Results of separation were measured by hand picking and weighing and then demonstrating the grade, yield, and overall separation efficiency[3]. The yield of PE and contents of PVC in light-products which are discharged from the left outlet of air table were also studied. SSS Dynamics V-135E type of air table (Fig.1) was used.

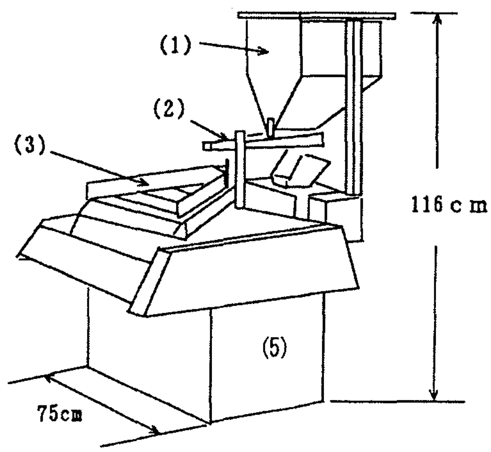

Fig.1. Schematic diagram of Air Table
(1)Hopper (2)Electromagnetic feeder (3)Deck (4)Riffle (5)Control box

Fig. 2 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. Assuming that deck is moving on an X-Y plane and particle is x-y plane, and deck makes sine motion of a $\sin\omega t$ for the β direction with a slope of α on the horizontal plane, the movement of the deck can be shown as follows:

$X = a\cos(\beta-\alpha)\sin\omega t$

$Y = a\sin(\beta-\alpha)\sin\omega t$

$\dot{X} = a\omega\cos(\beta-\alpha)\cos\omega t$

$\dot{Y} = a\omega\sin(\beta-\alpha)\cos\omega t$

$\ddot{X} = -a\omega^2\cos(\beta-\alpha)\sin\omega t$

$\ddot{Y} = -a\omega^2\sin(\beta-\alpha)\sin\omega t$

where a is amplitude of vibration and ω is angular velocity.

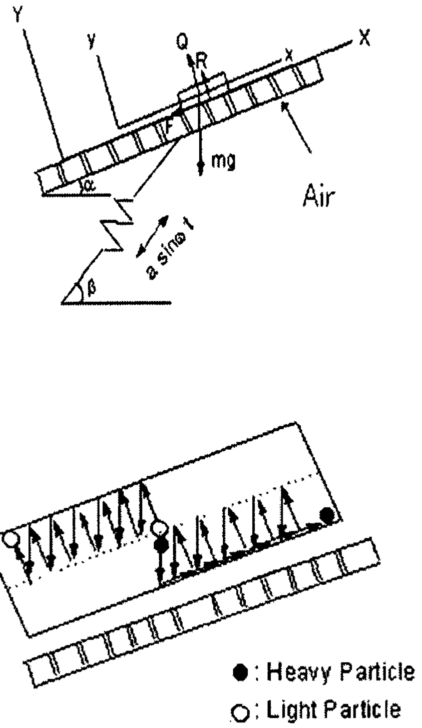

Fig.2. Force diagram and movement of the particles moving on a inclined shaking deck

Likewise, the equation of movement of the particle having mass m on the shaking deck can be shown as follows:

$m\ddot{x} = F - mg\sin\alpha$

$m\ddot{y} = Q - mg\cos\alpha$

where F is the frictional force, Q is the reaction force.

When the friction coefficient is μ, then the relationship between F and Q is as follows:

$F = \mu Q \quad (\dot{X} > \dot{x})$

$F = -\mu Q \quad (\dot{X} < \dot{x})$

In addition, the mean velocity of the particle on the deck, Vav ,can be shown as follows.

$Vav = 2\mu\omega a\cos\alpha$

where ω is frequency (Hz), a is amplitude (cm), α is end-slop, and μ is friction coefficient.

The resistance R of the air-flows acting onto the particle can be shown as follows.

$R = C \cdot A \cdot \rho \cdot u^2/2$

where C is the resistance coefficient, A is the projected area of the particle, ρ is the density of air, and u is the relative velocity of particle and air. From this relation, it can be seen that the resistance is mainly influenced by the shape of particle and air velocity.

Fig.2's schema 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 vibration. The light particles with large projected area move towards the upper part of fluidized bed whereas the heavy particles with smaller projected area move towards the bottom and eventually two layers are made. Particles at the bottom layer move towards the right direction, driven by the vibrating forces and those on the top layers are affected by the air movement which means that they move to the left of deck. Thus, these two types of particles are separated.

Results and Discussion

Conditions, such as riffle height of 25 mm, air velocity of 50cm/sec, side-slop of 5°, end-slop of 8°, frequency of 9 Hz, feeding speed of 50g/min, were considered standard and only the respective factors were changed in predefined scope to study the influence of riffle height, air velocity, end-slop, and frequency on the separation of mixed samples (see Figs.3, 4, 5, and 6 for results).

On the study regarding the influence of riffle's height (Fig.3), it was found that by increasing the height within the 5~25 mm range, the yield of PE and the content of PVC in PE which discharged as light-product from the deck's left outlet decreased (5 mm; yield of PE 89.3%, and PVC content of 0.68% → 25 mm; yield of PE 86.2%, and PVC content of 0.34%).

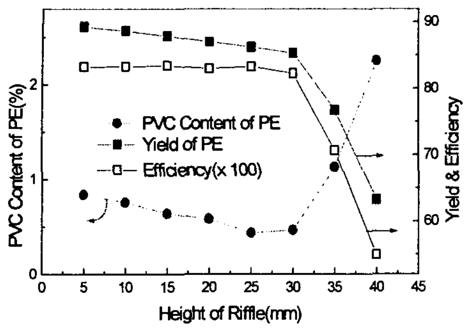

Fig.3. The effect of height of riffle on the separation of PVC-PE film mixture by Air Table

In this case, the separation efficiency was scarcely changed to offset the decrease of yield by the increase of grade (decrease of PVC content). However, when the height of the riffle became higher than 35 mm, the yield decreased rapidly. At the same time, PVC content showed explosive growth. In addition, the height of fluidized bed level tended to form about 5~15 mm higher than the riffle, that is, when the riffle height was less than 25 mm, stable fluidized bed with a thickness of 10 ~ 35mm was formed. In this height range, the higher the riffle was, the longer the separation zone was formed, and PVC and PE were relatively well separated. However, riffle not only acted as the agent that maintained the height of fluidized bed, but was also an impediment to longitudinal flow of fluidized bed. The higher riffle lead the flow direction to lean towards the right side, and the yield of PE to decrease. When the riffle heights were over 35 mm, the fluid level could no longer maintain the state of homogeneous fluidization due to the formation of fixed bed at the upper side, a result of increased pressure loss due to an increase in the path of air. Consequently, the state of homogeneous fluidization transformed into a bubbling or slugging state and the separation efficiency decreased remarkably.

On the test of air velocity (Fig.4), minimum fluidization manifested at 35cm/sec and the homogeneous fluidization state was maintained in the range of 35 ~ 60cm/sec. And the separation efficiency was best at the air velocity of 55cm/sec, when the yield of PE was 88.3% and the content of PVC within PE was 0.55%. When the air velocity was 70cm/sec, a fluidized bed started to show turbulent fluidization while separation efficiency started to decrease remarkably with an increase of PVC content mixed in PE.

When the end-slop was less than 5°, the force that moving the particle to the right side of the deck mobilized by frequency become exceedingly greater than that of the resistance of air velocity and slope (Fig. 5). Thus, since both PE and PVC were discharged from the outlet located on the right, separation did not occur.

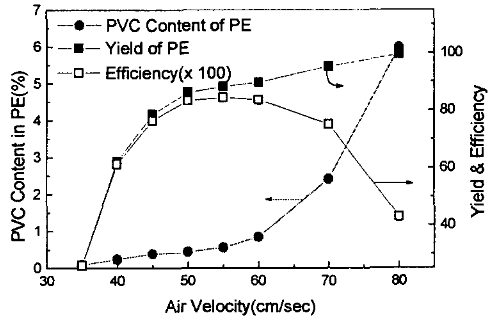

Fig.4. The effect of air velocity on the separation of PVC-PE film mixture by Air Table

In the 5° ~ 9° range, the yield of PE showed linear increase with end-slop, and the overall separation efficiency reached 0.85, with the best, at 9°. At the end-slop of 10°, content of PVC in PE product started to increase because of the excessive increase of resistance to frequency. At 12° , Separation did not occur since all products were discharged from left side of the deck in a mixed state.

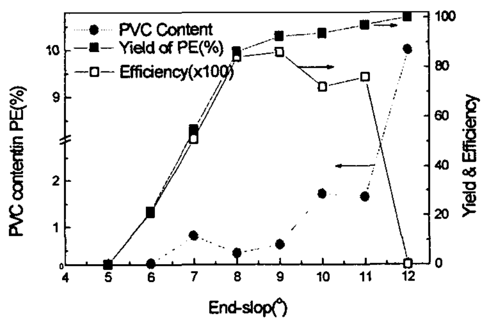

Fig.5. The effect of End-slop on the separation of PVC-PE film mixture by Air Table

On frequency test (Fig.6), the minimum fluidization started at 6.17Hz. Afterwards, separation efficiency increased along with an increase of frequency, and the best separation efficiency showed in the range of 8.5 ~ 9.0Hz. When frequency increased to over 10Hz, the yield of PE decreased with an increase of PE discharged from the right side with PVC.

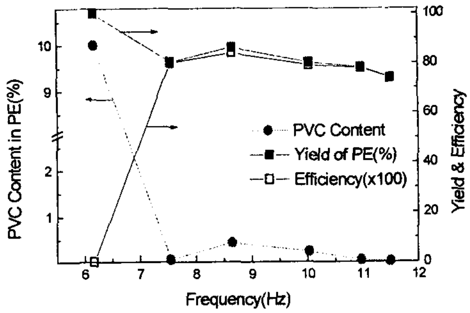

Fig.6. The effect of Frequency on the separation of PVC-PE film mixture by Air Table

When the results of the above-mentioned four experiments are summarized, we can say that the optimal conditions to operate the air table to separate PE and PVC film are: riffle height of 25 mm, air velocity of 55cm/sec, end-slop of 9°, and 9Hz 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 slop with conditions of riffle height of 25 mm, 55cm/sec of air velocity, 5° side-slop, and feeding speed of 50g/min, are shown on Fig.11. The separation efficiency was high, 0.84 or more, in the interlinked conditions of 8.65Hz-8°, 8.95Hz-9°, 10.83Hz-10°, and 11.45Hz-11°. Of these results, overall separation efficiency at 8.95Hz-9° showed a maximum value of 0.86 and at this point, yield of PE was 92.48% and content of PVC in PE was 0.63%.

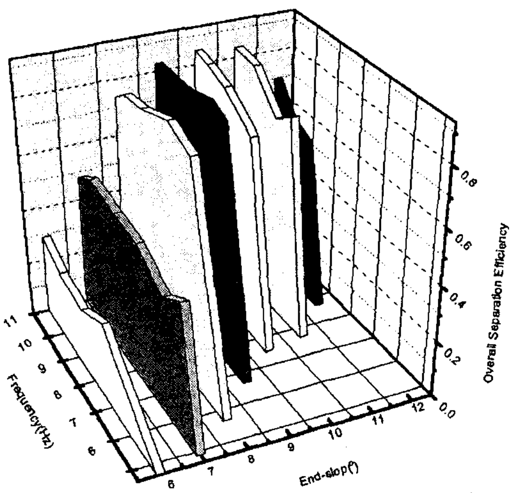

Fig.7. Relationship among Frequency, Endslop and Overall separation efficiency in the separation of PVC-PE film mixture by Air Table

Conclusion

The obtained optimum conditions for separate PE and PVC from PE90%-PVC10% film mixture are: riffle height of 25 mm, air velocity of 55cm/sec, end-slop of 9°, and frequency of 9Hz. With the other conditions of side-slop of 5° and feeding speed of 50g/min, we could separate the PE and PVC with an overall separation efficiency of 0.86. The yield of PE 92.48% and content of PVC in PE of 0.63%could be separated from the PE90%-PVC10% film mixture using air table.

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