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風力 및 濕式比重 選別에 의한 混合폐플라스틱 終末品으로부터 PVC 除去에 관한 研究†

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Removal of PVC from Mixed Plastic Waste by Combination of Air Classification and Centrifugal Process†

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요 약

가정에서 분리 배출된 폐플라스틱은 일반적으로 수선별 등 분리선별 공정을 거친 후 종말품으로 회수되어, 현재 대부분이 매립이나 소각되고 있다. 혼합폐플라스틱 종말품의 경우 2006년 약 175만톤 발생된 것 으로 예측되고 있으나, EPR실시 이후로 발생량은 2000년에 비해 2배 이상 크게 증가한 실정이다. 특히, 혼합폐플 라스틱 종말품의 경우 PVC 함량(4 wt.% 이하)이 매우 높아 이들의 재활용에 커다란 제약이 되고 있다. 본 연구에서는 혼합폐플라스틱 종말품으로부터 풍력 및 습식 비중선별장치를 이용하여 폴리올리핀계 (PE, PP, PS) 플라스틱을 경량물로 회수하는 선별시스템을 개발하였다. 본 선별시스템은 풍력선별, 자력선별, 1단계 파쇄, 정량공급 및 습식 비중선별 공정으로 구성되어 있으며, 습식 비중선별 공정은 원심분리를 기본으로 혼합-세척-선별 및 탈수가 단일장치내에 집약된 특징이 있다. 또한, 본 연구에서는 연질 플라스틱의 분쇄 효율을 크게 개선한 파쇄기를 개발하였다. 개발된 습식 비중선별장치의 용량은 시간당 0.5 톤으로, 이를 이 용하여 회수된 경량물의 PVC 함량은 0.3 wt.% 이하이며, 경량 및 중량 회수물의 수분 함량도 각각 10% 이하를 달성하였다.

주제어 : 혼합폐플라스틱, 재활용, PVC제거, 풍력선별, 습식 비중선별

Abstract

The mixed plastic waste generated from households after hand-picking and/or mechanical sorting processes amounts to 1,750,000 ton in 2006, and most of these waste are finally end up with landfill and/or incineration due to the lacks of separation technologies and economical reasons. The mixed plastic wastes can not be used as raw materials for chemical and/or thermal recycling processes because of their high content of PVC(upto 4.0 wt.%). In the present research, gravity separation system has been developed to remove PVC from the mixed plastic waste and to recover the PO-type plastics. This system mainly consists of air classification, magnetic separation, one-step crushing, feeding system at fixed rate and wet-type gravity separation system. The gravity system based on centrifugal separation has been developed at capacity of 0.5 ton/h and it consists of mixing, pre-cleaning, separation, dewatering, recovery system and wastewater treatment system, etc. The main objective of this process is to achieve high separation efficiency of polyolefins with less than 0.3 wt.% PVC content and less than 10% moisture content in the final products. In addition, a crushing unit of with 8 rotor system is also developed to improve the crushing efficiency of soft-type plastics. The system with a capacity of 1.0 ton/h is developed and operational results are presented.

Key words : mixed plastic waste, recycling, PVC removal, air classification, centrifugal process

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1. General Introduction

Plastic wastes generated from the households are generally hand-sorted into different types, i.e., PET, HDPE, LDPE, PVC, PP, PS, etc. The separated plastics are baled and shipped to reclaimers. The hand-sorting, however, is labor-intensive and costly. Therefore, many different types of automatic sorting machines have been developed recently. Some of the automatic sorters are based on using optical sensors, while others use infrared or X-ray fluorescence (XRF) sensors. The automatic sorters available today are capable of separating bottles by resin type at high throughputs.

Gravity separation technique is also used for separating plastics from heavier materials such as copper, aluminum and ferrous metals. Because of the large differences in specific gravities (S.Gs) between plastic and metals, the separation can be very efficient. It is more difficult to separate various plastics from each other using gravity separation techniques. Nevertheless, they are being used to separate heavier plastics from lighter ones. Table 1 shows the S.G values of some of the plastics. A series of dense-medium baths (or float-sink separators) are also used to separate different types of plastics from one another [1]. The dense media of different S.Gs are prepared by mixing water, alcohol and/or salt.

CENSOR based on the screw type centrifuge was developed by KHD Humboldt Wedag AG in Germany for plastics recycling process, particularly to recycle either of films, bottles and containers, or the cups fraction. By employing two-step processes, high selectivity can be achieved by using CENSOR system. In separation results, a purity of polyolefins(PO) 99.9% could be achieved from a plastic mixture but with a loss of valuable material of 0.5% [2].

Table 1. Specific gravities of plastics

Plastics	S.G
PP	0.90-0.92
LDPE	0.91-0.93
HDPE	0.94-0.96
PET	1.35-1.38
PVC	1.32-1.42
PS	1.03-1.06

In the present paper, gravity separation system based on the combination of air classification and centrifugal process is developed to recover valuable plastics and a purity of recovered PO type plastics has over 99.65% (PVC content < 0.3 wt.%) and less than 10% moisture content in the final products can be obtained.

2. Process Description

Fig. 1 shows a flowsheet of gravity system for separating PO-type plastics from the mixed plastic waste. This system consists of the following steps [3-6].

Plastic wastes are hand-sorted into different types, and the separated plastics are baled and shipped to reclaimers. The remaining mixed plastic wastes are subjected to air classification to remove heavy fractions, i.e., metals, ceramics, glasses and products such as telephones, toys, video tapes, etc.

The air classification system with a capacity of 1 ton per hour is developed, and vibration, blowing and suction mechanisms are applied in this system to obtain 4 different products as shown in Fig. 1. Film-type plastics can also be separated with suction mechanism from the waste and their volume can be reduced by using an extruder, which is attached to the air classification system.

Magnetic separator is also applied to remove ferrous metals from the light fraction (i.e., mainly plastics) obtained from the air classification stage. The drum-type magnetic separator is located on the belt conveyor

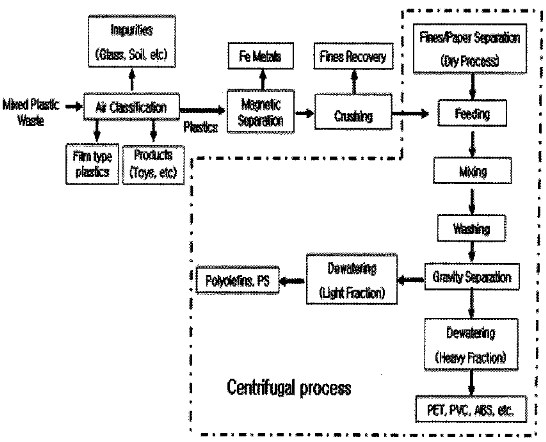

Fig. 1. Flowsheet of the gravity separation system.

before feeding the plastic waste into the crushing unit. The magnetic separator has a capacity of 0.5 tons per hour.

The material obtained after magnetic separation is crushed down to a particle size of minus 15 mm by using a specially designed crusher. The crusher is designed with one-shaft shredder with 8 rotors, and a compression feeding unit and a forced discharge unit to improve crushing efficiency of the sift-type plastics. The crusher is designed for a throughput rate of 0.6 tons per hour and capable of crushing the film-type plastics. A bag filter is also installed in the crushing unit for removal of fines during the crushing stage. The crushed fractions are fed into the gravity separation system at a fixed rate. The gravity separation system is designed to a capacity of 0.5 ton/h of the crushed plastic fractions. In feeding system, fine size fractions such as paper, glass, ceramics, etc. could be removed from the crushed materials before feeding into the gravity separation system to improve the separation and dewatering efficienies of the final products. The wet-type gravity separation system is based on centrifugal process with high-speed agitation mechanism, which could achieve the mixing and precleaning at the same time for the granulated materials.

Inside of the centrifuge, the material is separated by specific gravity value of the plastics as described above, i.e. lighter fractions (polyolefins, i.e. LDPE, HDPE, PP and PS) are separated out of other heavier ones (PET, PVC, ABS and other plastics). In this system, PS fraction (S.G.=1.03~1.06) could be recovered either as lighter or heavier fractions. Both fractions are discharged from the centrifuge at opposite conical ends to send the dewatering units. In particular, lighter fractions are freely discharged to the flow direction due to high fluidity of water medium. In dewatering process, vibration and centrifugal/vortex methos are adopted to achieve lower moisture contents, i.e below 10wt.% in the final separation products. In the present work, water is only used as separating medium and then recycled to the mixing tank after SS removal by filtration.

One of the major advantages for this system is that thermal drying is not applied to the final products after dewatering. As mentioned above, the heart of the CENSOR process is a combination of an effective prewashing and a two-step centrifugal separation. However, the gravity system we developed is one-step process and thermal drying process is not necessary.

Fig. 2 shows gravity system based on cenfrifugal process with a capacity of 0.5t/h.

3. Experimental

The sample used for separation tests is shown in Table 2. The mixed plastic waste contain about 63% plastics and 37% others including products such as toys, video tapes, etc. The plastics mainly consist of packaging materials, i.e., containers, trays, film sheets, etc. Fig. 3 shows the mixed plastic wastes obtained from the households after mechanical and/or hand-sorting processes. As shown in Fig 3, the mixed plastic waste contains various items, such as cans, vessel, glass bottle, paper-based materials, etc.

The mixed plastic waste shows high PVC level

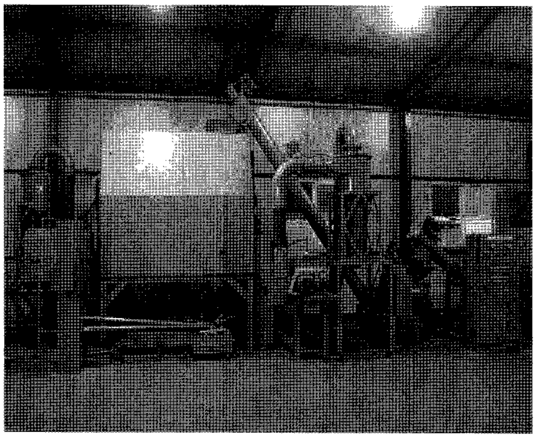

Fig. 2. Gravity separation system with a capacity of 0.5 t/h.

Fig. 3. Mixed plastic wastes containing cans, vessel, paper, etc.

because of stationery, toys, packaging materials for tools, cosmetics, medical supplies, etc.

Air classification tests were conducted at feed rate of 1ton/h. The result of the tests showed that the separation efficiency was about 98% and plastic recovery was 90~95% range. Fig. 4 shows sideview of the air classification unit used in the present work.

In the air classification tests, about 2.4% of film-type plastics was also recovered and could be compressed by using an extruder, which was attached to the air classification unit. Only plastic-based materials after magnetic separation were fed into the crushing stage.

The material was crushed down to a particle size of minus 15 mm and the capacity of crushing unit was varied depending on the types of plastic as shown in Table 3. It can be noted from the Table 3 that film-type plastic showed high crushing efficiency compared to the PET and household waste. Fig. 5 shows the crushing unit that we developed for crushing of soft-type plastic wastes.

For the gravity separation tests, mixed plastic waste samples were collected from four different cities. The amounts of the plastics in the waste were analyzed by using a total 1,357kg sample and the plastic ratios in

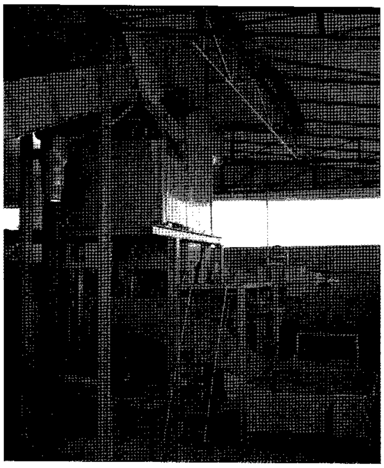

Fig. 4. Sideview of the air classification unit.

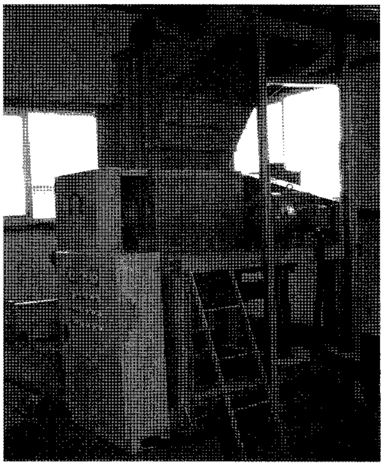

Fig. 5. Crushing unit for plastic wastes.

Table 2. Physical composition of mixed plastic wastes obtained from the households

Items	Plastics						Paper	Products	Soil, Glass, Metals	Total
	PS	PO	PET	PVC	Film	Total				
Amount (g)	7,300	11,370	4,140	6,550	1,230	30,590	2,610	12,650	2,560	48,410
Ratio (%)	15.1	23.5	8.6	13.5	2.5	63.2	5.4	26.1	5.3	100.0

Table 3. Results of crushing tests on the different plastics

Items	Film-type	PET	PE · PP	Household waste	Remark
Amounts (kg/h)	640	522	623	421	Plastics must be compressed before crushing.

Table 4. Major components in plastic-based materials obtained from mixed plastic waste prepared by hand sorting

Items	Paper, Dust	PO(PE, PP)	PS	PET, PVC, ect	Glass, Sand	Total
Mass(g)	1,620	8,747	1,833	3,958	622	16,820
Ratio(%)	9.63	52.0	10.9	23.53	3.94	100

Table 5. Results for gravity separation tests

Section	Paper Dust, etc.	Light Fraction					Heavy Fraction			Total
		PO (PE, PP)	PS	PET	PVC	Fiber, etc.	PET, PVC	PS	PO	
Mass (g)	10,000	66,800	2443	456	18	448	26,000	20,000	N.D	126, 165
Ratio (%)	7.93	52.95	1.94	0.36	0.01	0.35	20.61	15.85	-	100.0
Total		63.54%					36.46%			
Moisture (%)		10.7~12.6%					2.5~4.5%			

the samples were varied 39~57%. In addition, major components in the plastic-based materials after hand sorting of the waste were also analyzed using the representative sample. The result is shown in Table 4. As shown in Table 4, the total ratio of PO and PS in the samples was around 63%, and the sample also showed high amounts of paper/dust, glass/soil, etc.

The gravity separation test was carried out by using a system with a capacity of 0.5 ton/h. The test result is shown in Table 5. The 126 kg of representative sample after separation was used to determine the product quality, i.e. the amount of PET, PVC, ABC, etc. in the lighter fraction.

As shown in the Table 5, about 63.5% of recovered lighter fractions (i.e., film type and PO) could be used for recycling. The PVC content in the PO after gravity separation showed less than 0.01 wt.%, on the other hand, the PVC content in the feed was about 0.89%.

Based on the separation result, it was possible to achieve high separation efficiency(over 99.65%) with PVC content of less than 0.3wt.%. In the case of PO fraction after separation, the recovery rate of 99.9% is assumed to be achieved. The achievement of a high selectivity means that the separation parameters, purity and recovery of valuable plastics are optimized simultaneously. The obtained lighter fraction after gravity separation could be used as a raw materials for plastic recycling, thermal and/or chemical recycling. Fig. 6 shows the crushed sample before feeding into the gravy separation system, and recovered light and

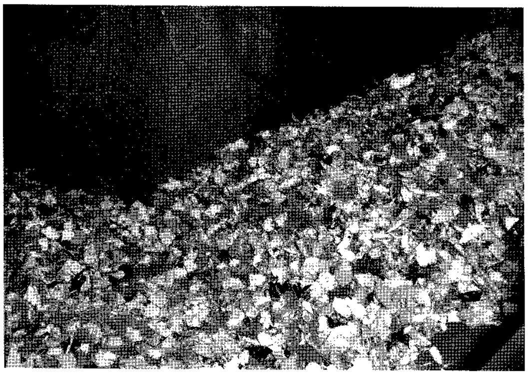

Fig. 6. Plastic-based materials after one-step crushing (<15mm).

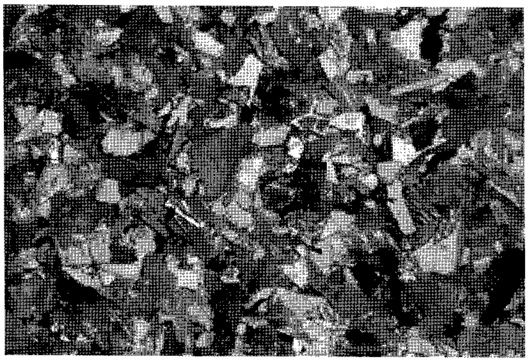

Fig. 7. Light fractions PO(PE, PP, PS, EPS, PSP) after gravity separation.

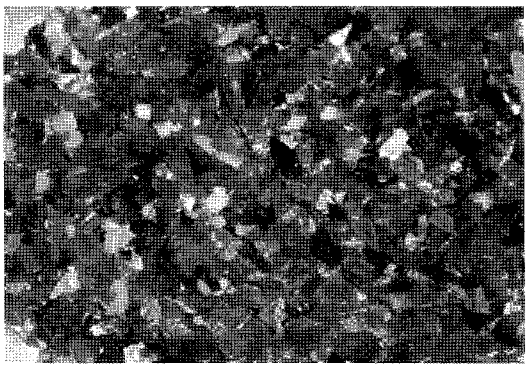

Fig. 8. Heavy fractions (PET, PVC, ABS, PS, paper fines) after gravity separation.

heavier fractions after gravity separation are shown in Fig. 7 and 8, respectively.

The gravity separation system we developed has high efficiency with low water(880 liter) and electricity consumption. The gravity system is one-step process, on the other hand, CENSOR process is two-step process, and thermal drying process is not necessary. In addition, the system could be applied to the mixed plastic wastes with high contamination, such as plastic waste from landfill sites and/or waste agricultural film.

4. Conclusions

Plastic recycling has become an established national industry in Korea. However, it is still in its infant stage and experiences growing pains. In the present work, the gravity separation system with a capacity of 1 ton/h is developed to enhance the recycling of mixed plastic waste. The process consists of air classification, magnetic separation, one-step crushing, paper and fines separation, gravity separation with a centrifuge, dewatering, and light and heavy fraction recovery. In the present study, crushing unit is also developed with 8 rotor system to improve crushing efficiency of the soft-type plastics. The heart of the gravity separation system we developed is a combination of an effective mixing/washing and one-step centrifugal separation. In addition, fines and/or paper fractions are removed before feeding into the system to improve the separation and dewatering efficiencies. Based on the gravity separation tests with a capacity of 0.5 t/h, the result shows that a purity of PO(polyolefins) 99.65% could be achieved with PVC content of less than 0.3% in the final product. Further development of this system will be continued, and contribute to improving efficiencies and growth of the recycling industry in the near future.

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