DEVELOPMENT OF A CONTINUOUS THERMAL SEPARATION SYSTEM FOR THE REMOVAL OF PVC CONTAMINATION IN POST-CONSUMER PET FLAKE

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Abstract

Differences in thermal properties of plastics such as their softening and melting points can be exploited to separate mixed post-consumer plastic flake. This form of separation can be most effective if differences in melting or softening points of the two plastics are large. For example polyvinyl chloride (PVC) and polyethylene terepthalate (PET) differ in their softening points by ~ 60°C, (i.e. PVC becomes tacky at 200°C and PET at 260°C. This article examines the development of a rotary thermal separating system for the removal of PVC flake from a stream of post-consumer PET flake.

Introduction

Plastic bottles collected from the curbside in Victoria comprise of several different polymer types as well as numerous colors. The polymer types and colors are separated using bottle automated sorting systems to primarily produce post-consumer PET and HDPE flake streams. Although the PET flake is largely pure, residual PVC contamination still remains in the PET flake. The PVC needs to be removed in order to manufacture PET pellets that can be used in higher value applications such as sheet extrusion for thermoforming and in bottle to bottle recycling. From operating experience we had found that PVC levels of over 200 ppm can significantly degrade PET during the extrusion stage. The PET pellets will be significantly discoloured and the intrinsic viscosity (IV) of PET lowered due to the degradation by PVC. When the PET flake is being reprocessed even slight PVC contamination will lead to discolouration, black specs of charred PVC and evolve hydrochloric acid gas bubbles. The acidic by-products of PVC promote chain scission of PET and thus significantly reduce the IV of recycled PET resin [1]. It was decided that an inexpensive method was required to try to remove as much of the residual PVC from the PET flake stream. A continuous thermal separating system prototype was to be built and it's efficiency to be investigated.

Background

During the last decade there have been several thermal separating systems investigated, developed and commercialized. In Germany a patent was published in 1991 for a sorting plant that uses heated rolls or belts, with which a mixture of different plastics particles comes into contact. Sorting takes place by the selective thermoadhesion of the softened particles to the rolls or belts [2]. Another process developed and commercialized by Refakt (Germany) utilizes a hot belt separator where the PVC flake softens and sticks to the belts while the PET does not. The PET falls off at the end of the belt while the PVC is scraped off by a blade placed underneath the belt [3]. Resource Energy Ventures (Arizona, USA) had developed and patented a system that consists of heated PTFE belts that are heated with an increasing temperature gradient along the belt to sequentially remove the lower melting particles such as polyethylene (PE) followed by the higher melting plastics such as PVC. When the PE softens and becomes tacky it adheres to the belt and travels to the underside of the belt where it is separated using a blade and removed on a separate belt. Operational trials have indicated that the system has a separation efficiency of 99% [4]. TransTech Research & Development Corporation (USA) have also developed a thermal separating system that utilizes the differences in melting points for the separation of PET and HDPE [5].

Generally thermal separation systems have a number of advantages such as low capitol and operating costs while the disadvantages with these systems are that the flakes must form a monolayer to be effectively heated or with the use of pressing rollers be exposed to the heat source. Contamination from other plastics, glue, dirt, labels and paper can also create various problems such as sticking to the plastic that is being removed. In order for thermal separating systems to be accepted by material recycling facilities (MRF) the systems must prove themselves under the rigorous conditions in the MRF's.

Prototype Development & Design

A drum was acquired and modified for the purpose of heating up the PVC/PET flake mixture. The drum was horizontally mounted to allow for material to be fed from the opening using an auger feeding system. The inside of the drum was tapered so that as the drum was rotating the material from the back of the drum would slowly move to the outside opening where it was collected in several collection trays.

A hot plate was inserted into the drum with an initial angle of inclination of 45° which was later changed to 20° so that the flake mixture would have sufficient contact time with the heated surface of the hot plate. A vibrating motor was also fitted to the hot plate to assist in the formation of a monolayer of flake on the hot plate and to also move the flake down the plate. The optimum drum rotational speed was found to be 2.18 RPM, which allowed for a fully covered hot plate without flake build up on the plate or in the bottom of the drum. The contact time for the flake with the heated plate was measured to be around 10 seconds at an inclination of 20°.

Prototype Operation

The principle of operation for this prototype works on the basis of selective thermoadhesion of trace amounts of PVC contamination present in the PET flake stream. The plastic flake was conveyed into the back of the drum using an auger feeding system. The inside of the drum utilized a number of fins to continuously pick up the flake and carry it to the top of the drum. When the material got to the top of the drum it started to drop onto a vibrating hot plate creating a cascading 'rain-like effect' of the flake on the inclined hot plate. As the flake mixture of mainly PET flake cascades down the vibrating hot plate, the PET flake bounces off at the end of the hot plate while the PVC flake sticks to the hot plate.

The system was used for batch experiments and as such an automated scraping device was not used but it is envisaged that a commercial unit would use an automated scraping knife to remove the adhered PVC. The hot plate was angled and vibrating and as such this allows for a fairly consistent monolayer of the plastic flake to form on the hot plate and the individual flakes were exposed to the heat source. In this way the PVC, which was already slightly softened from the heated drum, further softened on the hot plate and adhered to the hot surface. The PET flake moved to the edges of the drum to be collected in collection trays.

Experimental

Material

A standard grade of recycled PET flake supplied by Visy Plastics. However the material used was off spec in terms of the PVC contamination content. The 500 kg bag contained high levels of PVC contamination (~800-1200 ppm) and as such was assumed to be ideal to test the separating efficiency of the developed prototype.

Experimental Trials

The trials were conducted to primarily investigate the separation efficiency of the system but also to focus and investigate the effects of the following parameters:

- Drum temperature
- Temperature of the heated plate
- Contact time with the heated plate
- Angle of inclination of the heated plate
- Rotational speed of the drum
- Multi-stage separation

The infeed rate of the flake was set to 100kg/hr and batch test trials were initially run for 15-minute trials, followed by trials that lasted for 30 minutes and 60 minutes continuously. Each trial was performed at 220°C, 240°C and 260°C. Multi-pass batch trials using 5 kg of the RPET flake material were also performed to determine the effects of multi-stage separations on the end product purity and separation efficiency. The material was fed into the drum, exposed to the heated plate, collected and then immediately fed back in consecutively two more times to achieve a three-pass separation. The material was then collected in a collection tray placed under the drum to be analyzed.

Material from each trial was then tested in a laboratory oven. The material was placed into ovenable trays containing between 300-500 grams of the flake and aged for 1 hour at 230°C. The material is then visually inspected and the black degraded PVC is removed to determine the remaining parts per million (ppm) PVC contamination.

Results & Analysis

The results for the trials over 15, 30 and 60 minute trials are shown in Table 1. The results shown, indicate the final PVC contamination in the RPET flake after the thermal separation has taken place. The results are shown in a range as they did vary from sample to sample. This is considered fairly normal since PVC contamination in RPET flake can vary significantly from bag to bag as it usually depends upon the PVC contamination present in the infeed material as well as efficiency in bottle and flake sorting operations. The purpose of running the trials for 30 and 60 minutes was to see if the prototype system is capable of running continuously and to evaluate the operation of the system over a longer period of time. From the results obtained it can be seen that longer time trials did not have any particular effect on the end product purity or the separation efficiency.

The results from the trials showed that the most influential parameter, was the temperature of the hot plate. The PVC contamination after separation at 260°C was significantly lower to those at 220°C and 240°C respectively.

Observations and process investigations during the trials also showed that the system suffered from a number of operating limitations that effected the separation efficiency of the system. These included:

- Drum temperature only reached 100°C
- Uneven heat distribution on the hot plate
- Fluctuations in flake monolayer
- Possible fluctuations in contact time between the particles and the heated plate
- Agglomerations

From the trials it was discovered that the drum temperature only ever reached a maximum of ~ 100°C even after at least 1 hour of heating time. However it can be assumed that at 100°C the drum temperature would cause some degree of softening of the PVC particles and thus assist in the removal of the PVC contamination as the PVC should be in a softened state when falling onto the hot plate.

Observations from operational trials indicated that, flake contact time with the hot plate was dependent on the angle of inclination of the hot plate as well as the intensity of the vibrations from the vibrating motor attached to the hot plate.

Overall the effect of contact time on the purity of the final product in a single-stage pass seemed to be negligible in these trials. In a similar trial performed on a thermal separating conveyor in Germany the results indicated that the influence of residence time on the purity of the desirable fraction (PET) might be small since the heating required to melt the PVC particles takes place during the first moments of contact [6].

The hot plate suffered from poor heat distribution. Analysis showed that the temperature varied quite significantly from the center of the plate to the outer sections. Whilst the middle and central sections mostly remained at the set temperatures, the outer sections were often up to 40°C lower. It is assumed that this had significantly reduced the removal efficiency and decreased the purity of the PET flake, as large proportion of the flake would not have been exposed to the required temperatures to adhere the PVC particles. Constant hot plate temperature and even heat distribution was thus seen as the biggest limitation to efficient adhesion and removal of the PVC contamination.

At higher temperatures such as 260°C and especially during the 30and 60 minute trials agglomerations started to occur on the hot plate surface. The PET particles started to stick to the adjacent sticky PVC particles.

Table 2 shows the effects of multi-stage passes on the PET end product purity. The results presented are averages for 10 trials in a three-stage pass separation. The results clearly show that an increasing number of separation stages significantly increases purity and the removal of PVC without any notable material losses.

Conclusions & Recommendations

From the experimental findings, it can be concluded that, the thermal separation drum developed on the basis of the thermoadhesion principle has the potential to remove trace amounts of PVC in PET flake. The study found that the hot plate temperature was the most significant parameter to effect the separation efficiency. A further important parameter was the number of separation stages.

As a recommendation for further investigations it can be said that heated surfaces need to have high temperatures with even heat distribution over the entire surface and the incorporation of multi-stage systems would also help to compensate for fluctuations in temperature distributions, contact time and flake monolayer formation that are common in thermal separation systems.

Summary

While thermal separation systems do not incorporate state of the art technology and they cannot replace sophisticated bottle and flake sorting systems based upon optical and electrostatic techniques, they can be useful to separate particular plastic flake mixtures and assist in removal of trace amount of PVC from PET flake for example. Their main advantage is that capitol and operational costs are low and the systems are ideal for further downstream flake separating operations.

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Key Word Index

Plastic Recycling, Thermal Separation Systems, PVC/PET Separation,

Trial times (minutes)	**Hot-plate temp 220°C**	**Hot-plate temp. 240°C**	**Hot-plate temp 260°C**
15 minutes	40-460 ppm PVC	60-630 ppm PVC	40-180 ppm PVC
30 minutes	80-370 ppm PVC	70-400 ppm PVC	50-210 ppm PVC
60 minutes	130-520 ppm PVC	0-380 ppm PVC	0-230 ppm PVC

Table 1. Residual PVC contamination levels (ppm) in the PET flake after the thermal separation process. The infeed material contained (800-1200 ppm) of PVC.

Hot-plate Temperature (°C)	**PVC Contamination Levels (ppm)**
220	70-210
240	30-200
260	0-110

Table 2. Results of the three-stage separation using the thermal separation drum. The residual PVC contamination levels (ppm) are shown. The infeed material contained (800-1200 ppm) of PVC.