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RECYCLING OF POST USE PET PRODUCTS

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A***bstract:*** Recycling of polymers is an attractive option which responds to restriction for waste disposal in a lot of countries. Different processes are investigated such as degradation of plastics to monomers, pyrolisis into monomers and oil, gasification into syngas, etc. In this paper some problems concerning manufacturing and recycling of the PET in the case of drink bottles are presented, including material characteristic, processing techniques, recycling methods and constrains as well as an recycled R-PET application and upgrading.
Key words: *terephthalate, polyester, recycling, drink bottle*

1. INTRODUCTION

Plastics recycling has been successfully implemented with primary processed materials resulting in economic benefits. From environmental concerns the recycling of wasted or plastics is nowadays highly encouraged to reduce the increasing amounts of pollutant.

Polyethylene terephthalate (PET), polyester, has been known for many years only as fiber. Now PET is considered as one of the most important engineering polymers in the past two decades due to rapid growth in use [3, 5]. It is regarded as an excellent material for many applications and is widely used for making liquid containers. It has excellent tensile and impact strength, chemical resistance, clarity, processability, colour ability and reasonable thermal stability. Commercial pet has a melting temperature of above 265 ^{0}C and the glass transmission temperature of virgin pet varies between 67 ^{0}C and 140 ^{0}C. The rate of crystallisation of virgin pet depends on temperature and reaches its maximum at the temperature of 150÷180 ^{0}C. Virgin pet manufactures have tended in recent years to produce pet co-polymers; such as isophthalic modified pet rather homopolymer pet [4]. Pet is used broadly in products such as: bottle, electrical and electronic instruments (e.g. X-rays sheets, recording tapes, insulator), material holding equipment, sporting goods.

In recent years PET is widely used in manufacturing of soft drink bottle. The injection stretch blow moulding (ISBM) process is the most widely used for bottle manufacturing. Biaxial orientation during the ISBM process gives PET bottles produced by this technique toughness and low gas permeability. There are two basic techniques used in making ISBM bottles. The first technique is a two-stage process; in the first stage a preform is produced by injection moulding them later it is re-heated to the temperature for stretching and blowing. The second technique involves one stage in which the injection moulding, stretching and blowing of preform are combined in single operation. In two-step moulding, two separate machines are used, one for injection moulding the preform, the second for stretch-blow moulding it into the final container shape. In one-step machines, the entire process from raw material to finished container is conducted within one machine, making it especially suitable for moulding non-standard shapes (custom moulding), including jars, flat oval, flask shapes etc. Its greatest merit is the reduction in space, product handling and energy, and far higher visual quality than can be achieved by the two-step system.

The PET soft drink bottle is available either as at two-piece container with a base cup made of different plastics or as a base-free one-piece container [4]. Another characteristic of the PET soft drink bottle that has to be considered in designing a recycling line is the nature of the bottle closure (turn button and liner), as well as labels. Historically, the PET bottle only come with an aluminium roll-on closure and paper labels. Today these materials are generally not acceptable and other materials are recommended: polyolefin for turn button, ethylene vinyl acetate (EVA) copolymer for liner, plastic labels fastened using glues solvable in water.

2. RECYCLING TECHNOLOGIES

Recycling of PET soft drink bottle began soon after their introduction because of waste disposal is a growing worldwide problem. One possible objective for polymer recycling would be any process which diverts polymer waste to any place, other than landfill. Three main groups of polymers recycling methods exist in production practice [2, 4, 5, 7]: mechanical (material) recycling, chemical recycling and incineration (Fig. 1). Material recycling is a term used to describe process in which the macromolecular structure is kept basically intact, and the material is reformed into a new product. Chemical recycling refers to the decomposition of the macromolecular structure to generate low molecular weight compounds. Incineration is a third category of polymer waste utilization; here the product is heat, which is used in the production of electricity. Mixed polymer waste could be added as blast furnace and coke oven raw material [7].

The PET recycling industry started as a result of environmental pressure to improve waste management. The other aspect that acts as driving force fo PET recycling industry is that PET products have slow rate of natural decomposition. A major concern during the reprocessing of PET is to remove all contaminants that can catalyze the hydrolysis of PET. As the post use PET bottle recycling industry begins to recover PET bottles from curbside collection, the industry is facing the greater challenge of hand sorting plastic bottles not only by color but by polymer type. The removal of contaminants from post PET is still vital step in recycling process. The sorting process is basically separating PET bottles from PVC, PE and other plastic containers. PVC van be removed manually from PET bottle scrap before the grinding process; however, no more than 90% of the total PVC is manually removed. Efficient separation of PVC from mixed PET/PVC bottles scrap can be achieved using methods based on the difference between physical or chemical properties [6].

Chemical recycling (chemolysis) of post PET is achieved by total depolymerisation into monomers or partial depolymerisation into oligomers. This is typically carried out under high temperature and in the presence of various types of catalysts. This approach consumes large amounts of energy, and in many cases results in rather low value products. The chemicals used for the depolymerisation of PET include water (hydrolysis), methanol (methanolysis) and EG (glycolysis). Another chemical recycling approach is high-temperature gasification using a non-stoichiometric amount of oxygen, to generate “synthesis gas”, which is of use in the chemical industry.

The mechanical recycling of PET waste normally consists of contamination removal by sorting, washing, drying and melt processing (Fig. 1). The sorting of post use PET bottles is an important and critical step. High levels of contamination by other materials causes great detoriation of R-PET during processing. Water reduces recycling efficiency through a hydrolysis reaction. Fragments of coloured bottles and printed ink labels cause undesirable colours during processing. Acetaldehyde is present in PET as a by-product of PET degradation reactions. The high volatility of acetaldehyde means that it can be minimized by processing under vacuum or by drying. The public use of PET bottles for storing other substances such as detergents, fuel, pesticides, etc. The remains of these substances could be a health hazard if traces of these substances remain after PET recycling.

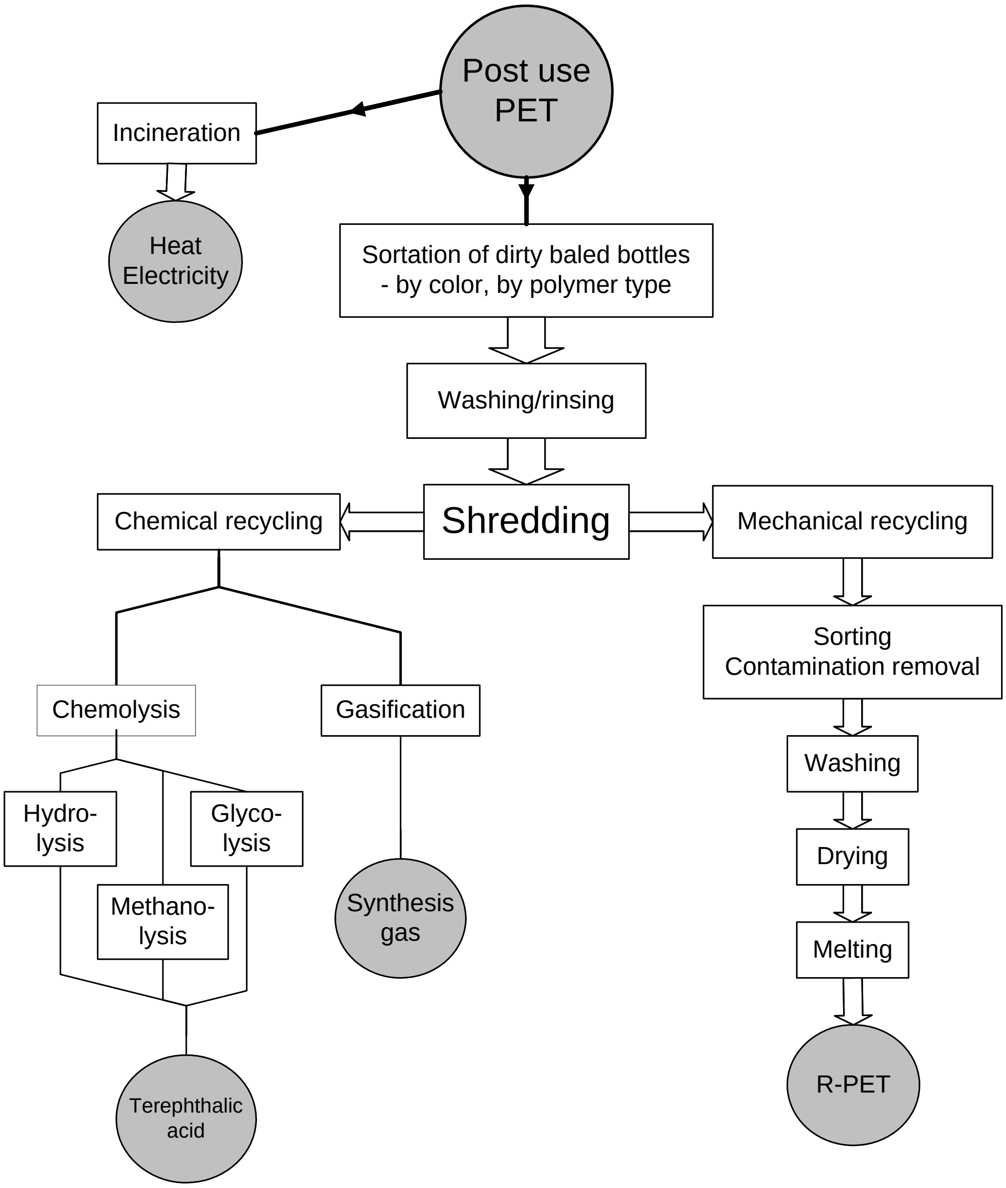

Fig. 1. PET recycling process variants and products

After sorting PET waste is ground into flaces in order to be easily reprocessed. PET flaces are washed following grinding [5]:

- aqueous hot washing at 80 ^{0}C with 2 % NaOH and a detergent followed by a cold wash with water only,
- solvent washing for which tetrachloroetylene has been reporeted to be suitable for washing PET flaces.

Drying is regarded as an essential step in PET recycling, minimises the moisture content of PET flakes reduces the hydrolytic degradation effect and leads to higher R-PET melt strength. In typical operating conditions, no more than 50 ppm water is allowed to be present in the PET flakes and this is normally achieved by drying at 170 ^{0}C for 6 h. R-PET flakes can be processed in a normal extrusion system into useful granules. However, due to the contaminants that are present in R-PET flakes, the produced granules have a low molecular weight.

The main advantage of mechanical recycling of end of use PET products is the fact that the process is relatively simply, environmentally friendly and requires low investment. The main disadvantage of mechanical recycling is reduction of molecular weight during processing. Overcoming the reduction of R-PET's molecular weight and the loose of mechanical properties has been the objective of many research works [1, 2, 3, 5]. Different methods and processes have been reported to restore or maintain R-PET properties, such as:

- Reprocessing under vacuum.
- Stabilization.
- Solid state polymerisation.
- Chain extension.
- Radiation.
- Electron-beam processing.
- Addition of PC to PET.

The transformers use recycled PET to manufacture various products. R-PET flakes can be directly used for the production of polyester fibres (with the extrusion phase becoming unnecessary). These fibres are then used in the production of varied textile articles: clothing, pillow and duvet filling, blankets, automobile linings, etc. Another application for recycled PET is the production of new packaging. In this case the flakes (from colourless packaging) must go trough the extrusion process. Recycled PET is also increasingly used to manufacture new bottles for non-food products. PET flakes can be used in the manufacture of alkaline resin used in the production of paints and unsaturated resins, and in adhesive and polyester resin. The most recent applications are in the extrusion of tubes for residential sewerage and in injection for the manufacture of taps. It has been established that recycled bottle grade PET has suitable processing and physical properties to be used in melt spun non woven geotextiles. Coloured PET bottles can also be successfully made into geotextile fibre. The physical properties that have been achieved have been lower than those achieved using clear recycled PET, but a blend of clear and coloured should have improved properties over coloured alone and whilst still achieving a material cost reduction through the use of coloured PET. The evolutions of the market and technological advances have stimulated new applications for recycled PET. With the recovered raw material new PET polymer is made.

3. CONCLUSION

Although PET has an excellent balance of performance properties, there are some shortcomings that have prevented large scale use of recycled PET in injection-molded, durable products. The primary drawbacks are PET‘s low glass transition temperature, the slow crystallization rate of copolymer grades of PET, and relatively low impact strength. The properties of recycled PET must be modified for use in durable products, such as appliances, electronics, furniture, transportation, and building and construction. Compounding of recycled PET can correct these shortcomings, enhance other properties, and tailor performance properties to meet specifications. In the past years, essential technological progress has been made in the area of decontamination of post-consumer plastics, in particular from the PET soft drink bottle market. The development of modern recycling procedures increasingly allows cleaning and reconditioning of R-PET for being reused in direct food contact applications. Today consumers can buy soda drinks in PET bottles produced with a variable percentage of recycled material. This use could grow with advances in the chemical recycling process in which post-consumption PET is depolymerised, thereby recovering the basic raw materials used in PET.

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