International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Sustainability of Recycled PET Bottle

Shourya Agarwal

Abstract: ***The research explores to evaluate the suitability of recycled PET bottles through various industrial parameters.***

Keywords: Recycle

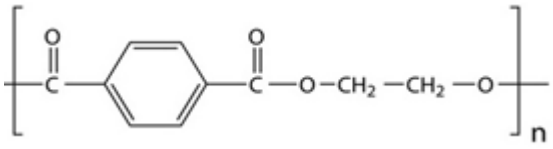
1. Objective

a) To understand the processing and chemical nature of PET resin.
b) To study how intrinsic viscosity is checked for PET resin
c) Compare the strength properties of the polyester film made from virgin polymer and also made from PCR up to 40%.

2. Introduction

PET (Polyethylene terephthalate) is used as a raw material for making Polyester fiber, PET bottles, and BOPET (Biaxially oriented polyester film). Polyester fiber is used for textile applications. PET bottles are used as containers for mineral water, soft drinks, alcoholic beverages, edible oils, and many other applications. Polyester films are used for packaging a wide range of food products and other consumer goods. PET is one of the most common consumer plastics used.

Chemical Structure of PET resin:



Where **n** stands for number of repeat units in the polyester molecule.

Post-Consumer Waste

The empty PET packaging is discarded by the consumer, after use and becomes PET waste. In the recycling industry, this is referred to as "post-consumer PET. Polyester Bottles are either discarded to Recycling bins, Reverse vending machines, or Garbage dumps. Polyester bottles are collected by rag pickers, many local governments, and waste collection agencies from other household waste. Besides that, there is container deposit legislation in some countries, which also applies to PET bottles.

Sorting & Processing

The collected post-consumer PET bottles are taken to recycling centers known as materials recovery facilities (MRF). Where it is sorted and separated from other materials such as other rigid plastics, metals, multi-layer laminate, metal scraps, polyethylene bags, etc. The separated PET waste is crushed, pressed into bales, and offered for sale to recycling companies. The picture of bales is given in Fig-1. These bales are purchased by Polyester flake manufacturers who separate, crush, wash and dry before supplying to BOPET film manufacturers.

Figure 1

3. Experiment

In order to find the suitability of Polyester bottle flake used in BOPET film manufacturing, the most crucial property is the Intrinsic Viscosity of PET resin; therefore, the following activities have been planned.

1) Analysis of Polyester bottle flake using the Intrinsic Viscosity method.
1.1 Definition of Intrinsic Viscosity(I.V)
1.2 Ubbelohde Viscometer
1.3 Measurement of I.V

2) Melt Mixing of Polyester bottle flakes
2.1 I.V measurement of melt mixed granules

3) Use of recycled granules in Polyester film manufacture
3.1 Manufacturing process of Polyester film
3.2 Testing of Polyester Film properties
3.2.1 Tensile Strength
3.2.2 Elongation
3.3 Comparison of Polyester Film using recycled granules and without recycled granules.

4. Analysis of Polyester bottle flake using the Intrinsic Viscosity method.

4.1 Definition of Intrinsic Viscosity (I.V)

Intrinsic viscosity is a measure of a solute's contribution to the ***viscosity*** of a solution. The I.V. of the material measured in dl/g (deciliters/gram) is dependent upon the length of its polymer chains. The longer the chains, stiffer the material, and the higher the Intrinsic Viscosity.

4.2 Ubbelohde Viscometer

Ubbelohde Viscometer is used to determine I.V. It is a measuring instrument that uses a capillary-based method of measuring viscosity. The advantage of this instrument is that the values obtained are independent of the total volume.

4.3 Measurement of I.V

Weigh accurately 0.2500 ±0.0002 gm (up to decimal's Fourth place) PET flakes/granules in a 25ml volumetric flask. Pour Approx. 10 ml of I.V. Mixture (60%phenol and 40% tetrachloroethane) into it. Keep it in Oven for at 90ºC to 95ºC for Complete dissolve. Take out the flask and cool it at room temperature. Make up the flask up to the mark with I.V.solution at room temp. Gently shake the volumetric flask now, fill the Ubblohde viscometer between the mark and keep it in the water bath at 25º±0.1ºC maintained temperature. Take the flow time of solution with the help of stopwatch, take three consecutive similar readings, and Calculate the average flow time. The IV bath with Ubbelohde viscometer is shown in fig-2.

Figure 2

Calculation: The I.V is calculated based on the following formulae.

$$R.V = \frac{\text{flow time of solution in seconds}}{\text{the flow time of solvent in seconds}}$$

$$I.V = \frac{\sqrt{1+\eta sp \times 1.48} - 1}{0.74} \quad \text{where, } \eta sp = R.V$$

4.4 MeltMixing of Polyester bottle flakes with BOPET film scrap

The recycling trial was conducted in the Erema machine. The Erema machine is typically used for recycling polyester film scrap. Typically, this machine is located adjacent to Biaxially oriented polyester film line and continuously converts the film scraps into polyester granules with specific shapes and sizes. Here, the polyester film scrap is shredded, compacted, and melted to make polyester granules, and these granules are conveyed to polyester film line feeding zone and mixed with virgin polyester raw material with specific proportions.

The bottle flakes cannot be used in a Polyester film line directly because of its irregular shape and size. It is, therefore, processed in Erema to convert into polyester granules with specific shapes and sizes. Polyester bottle flakes were dried in Oven at 130oC for 2 hrs and then extruded in the Erema machine. The processing temperature is 260-270oC, with a production output of 800 Kg/hr.

5. Use of recycled granules in Polyester film manufacture

5.1 Polyester Film manufacturing process

Polyester film manufacturing process involves drying, crystallization, extrusion, MDO stretching, TDO stretching, Annealing, corona treatment if required, followed by wind. The polyester film is manufactured by either a sequential stretching method or a simultaneously stretching method. The dried and crystallized polyester granules are melted and cast onto a chill roll, which quenches it into the amorphous state. The casting is done under a very high voltage pinning process; the cast film is MDO stretched using heated rollers and subsequently drawn in the transverse direction through the tenter clamps, which grabs the film edge in a heated oven and spreads towards the transverse direction. i.e., TDO stretching, Draw ratios are typically around 3 to 4 in each direction.

Once the drawing is completed, the film is "heat set" under tension in the oven at temperatures typically above 200 °C (392 °F). The heat setting is required for stabilized the film dimensionally. The heat setting freezes the polyester molecules and stops them from shrinking. The orientation of the polymer chains is responsible for the high strength and stiffness of biaxially oriented PET film

Additives are added in the polyester film to prevent the blocking of rolls. If it were produced without any additives, the surface of the film would be so smooth that layers would adhere firmly to one another when the film is wound up. Usually, synthetic silica is used as an additive in Polyester film to prevent blocking.

100% polyester bottle flakes were chosen to conduct a trial in the BOPET film line to produce a Polyester film. In the polyester feeding zone, 40% of recycled granules are added to 60% virgin polyester granules and melted at 265-275oC for a line speed of 450m/min. The film specification was chosen as 12-micron Polyester film.

5.2 Testing of Polyester Film Properties.

5.2.1 Tensile Strength

Tensile Strength is the maximum force of Resistance divided by the film's initial cross-section area. The values are expressed in terms of Kg/cm2. The tensile strength is measured in LLOYD Instrument. The tensile test and %elongation is measured as per ASTM standard ASTM D-882.
In order to measure Tensile Strength, A film strip of 15 mm width is cut and appropriately fixed and vertically in the grips. The sample is stretched at 100 mm / Min speed. The displayed value of tensile strength and elongation are noted down for few samples, and the average of all is reported

5.2.2 Elongation

Elongation is the percent change in length of the material under stress from start to break. The units are %.

Table 1: Experimental Results

Item Description	I.V (dl/g)
Bottle Flake I.V before processing in Erema	0.71
Bottle Flake I.V after processing in Erema	0.60

Following is the comparison of film tested with polyester bottle flake and without any polyester flake

Film Properties	Unit		Experimental Results			Test Method
			Film with Virgin polymer	Film with Polyester bottle flakes		
Thickness (+/- 2.5%)	Micron		12.0	12.0		INTERNAL
				Results obtained	Average Values	
Tensile Strength	Kg/cm^2	MD	1950	i).1920 ii) 1900 iii) 1940	1920	ASTM D 882
		TD	2030	i)2025 ii)2015 iii)2030	2023	
Elongation	%	MD	100	i)105 ii)101 iii)103	103	ASTM D-882
		TD	90	i)91 ii)93 iii)94	93	

6. Conclusion

***Trial Results*:**
Up to 100% polyester bottle flakes were recycled, and the recycled granules I.V was found to decrease during processing in Erema, During the processing of polymer, degradation of the polymer takes place, resulting into lowering of I.V, In the final film, the concentration of bottle flake was approx. 40%. There was no problem with processing either in Erema and BOPET film Line. If we compare the film properties, we find that there is no change in the properties of the polyester film due to the addition of polyester flakes. The addition of Polyester bottle flakes into polyester film reduces the impact on the Environment to a great extent.

Recycling PET reduces greenhouse gas
PET recycling reduces CO2 emissions. If 1,000 kg of PET flakes are recycled along with virgin Polyester, it is expected to reduce the production of up to 3,000 kg of greenhouse gases.

Recycling PET saves Energy
Re-using recycled PET reduces energy consumption. If 100% polyester flakes are recycled to produce a product, the total energy consumption can be reduced by a maximum of approximately 50%.

Recycling PET is sustainable
Since the natural reserve of oil and natural gas is finite, Recycling PET means sustaining the natural reserve for a more extended period of time. Furthermore, during **100% recycling, there is no harmful emission, and polyester is able to preserve its** characteristics in a substantial way and can thus be repeatedly re-processed to make high value-added products.

References

[1] An Article on " Post Consumer Recycled Polyester Yarn" by Radici Group
[2] Picture of PET bales has been taken from Wikipedia "Polyester bottle recycling."