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Research Article

STUDIES ON MECHANICAL PROPERTIES OF RECYCLED POLYPROPYLENE BLENDED WITH VIRGIN POLYPROPYLENE

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ABSTRACT

During the recycling process the material undergoes various operations that bring out several modifications in the molecular structure. As a matter of fact, the mechanical properties of the recycled products and their structural organization are quite different compared to those composed of virgin material [1]. Also, particular attention is attached to the relationship and several consequent changes in the mechanical properties. The aim of this work is to study the properties of recycled polypropylene in particular through the analysis of degradation by the mechanical properties from virgin and recycled material. These mixtures were analysed as a function both of blend composition and of the number of reprocessing of the recycled fraction. The results of virgin and the reprocessing polypropylene were correlated with the mechanical properties.

Keywords: recycled, polypropylene, virgin, extrusion, mechanical properties

INTRODUCTION

Population growth in large urban centres, social and technological developments and changes in consumers' habits have led to greatly increasing amounts of solid wastes. Thus, nowadays, waste management is one of the most significant issues that modern society deals with. The suitability of polymers for a large number of applications and uses is a consequent result of their important properties i.e polymers are lightweight, flexible and versatile, offering many practical benefits to various uses, easy to process in any desirable shape and available with various types of modified properties. They match optimum design with functional solutions; they are economic to produce in custom-made forms and are extremely durable [2, 3].

The use of plastics is growing steadily. Most industrialized have systems for the collection and recycling of plastic waste, either implemented on a full scale or on trial. An important aspect of plastic recycling is that the types of plastics used for most applications are inexpensive commodity materials. The price of corresponding virgin resins determines the ceiling for the price at which recycled materials can be sold for reprocessing. The processing of plastics often generates a considerable amount of production scrap. The mechanical recycling of such material, i.e. material that has not been converted to a useful product, is referred to as primary recycling. Examples of such plastic material that can be re-utilised are edge trims, start-up and change-over scrap, finished products or parts that fails to meet required standards, material solidified in mould runners, etc. Primary recycling can be done in-house if the necessary equipment is available. Machines used for primary recycling are shredders, grinders and extruders. The recycled material is often mixed with virgin resin and fed back into the same process that generated it, but it is also possible to produce other products. If a plastic processing industry does not recycle production scrap itself, the material can be sold to other companies for primary recycling. This solution may be attractive to processors who cannot afford to invest in the necessary recycling equipment. To sell production scrap on the open market can however be risky, since it may make it possible for competitors to acquire cheap raw-materials and thereby gain a competitive advantage. The primary recycling of production scrap has been practiced for a long time in order to save money [4-6].

Most thermoplastics are highly suitable for mechanical recycling. Numerous studies have shown that the important properties of the most common plastics are fairly well preserved throughout several cycles of processing and ageing. This means that any company that puts products on the market that are made of thermoplastics can claim that its products are recyclable. For it to become realistic that the material will be recovered and recycled, several other criteria must however be fulfilled. There has to be an infra-structure available for collecting, sorting and reprocessing the material and there have to be useful applications for the material in its second life. Recycling infrastructures are characterised by the requirement of economy of scale. This means that large amounts of material have to be recovered in order to sustain the system for recycling. A plastic product is consequently not in practice recyclable unless there is enough discarded material of the same kind to make recycling worthwhile. A possible strategy to overcome this dilemma is to recycle waste plastics as "commingled plastics", which means that the plastics are reprocessed without prior sorting according to plastic type. Park-benches, poles and fences are examples of products that are being made out of commingled plastics [7-8]. The value of materials made out of commingled waste plastics is very low compared to that of virgin plastics and this type of recycling is therefore sometimes referred to as "down-cycling". A critical factor is the depletion of antioxidants, but if the material is considered to have insufficient protection against oxidative degradation, it is possible to add more stabilizers during reprocessing. Antioxidant formulations are now commercially available that are designed specifically for the purpose of re-stabilising recycled plastics [9-10]. The present work is based on, to study the properties of recycled polypropylene and it is blended with virgin polypropylene in different proportion.

Sources of waste plastics:

Industrial waste (or primary waste) can often be obtained from the large plastics processing, manufacturing and packaging industries. Rejected or waste material usually has good characteristics for recycling and will be clean. Although the quantity of material available is sometimes small, the quantities tend to be growing as consumption, and therefore production, increases. Commercial waste is often available from workshops, craftsmen, shops, supermarkets and wholesalers. A lot of the plastics available from these sources will be polyolefin, often contaminated. Agricultural waste can be obtained from farms and nursery gardens outside the urban areas. This is usually in the form of packaging (plastic containers or sheets) or construction materials (irrigation or hosepipes). Municipal waste can be collected from residential areas (domestic or household waste), streets, parks, collection depots and waste dumps. In Asian cities this type of waste is common and can either be collected from the streets or can be collected from households by arrangement with the householders [11, 12].

EXPERIMENTAL

Polypropylene waste was collected from municipal collection centre and virgin moulding grade polypropylene was used is purchased from Reliance Industries Ltd.

Recycling of Polypropylene:

Initial upgrading: Once the plastic has been collected, it will have to be cleaned and sorted. The techniques used will depend on the scale of the operation and the type of waste collected, but at the simplest level will involve hand washing and sorting of the plastic into the required groups. More sophisticated mechanical washers and solar drying can be used for larger operations. Sorting of plastics can be by polymer type (thermoset or thermoplastic for example), by product (bottles, plastic sheeting, etc.), by colour, etc.

Size reduction techniques: Size reduction is required for several reasons; to reduce larger plastic waste to a size manageable for small machines, to make the material denser for storage and transportation, or to produce a product which is suitable for further processing. There are several techniques commonly used for size reduction of plastics. Cutting is usually carried out for initial size reduction of large objects and followed with scissors, shears, saw, etc.

Shredding: Shredding is suitable for smaller pieces. A typical shredder has a series of rotating blades driven by an electric motor, some form of grid for size grading and a collection bin. Materials are fed into the shredder via a hopper which is sited above the blade rotor. The product of shredding is a pile of coarse irregularly shaped plastic flakes which can then be further processed.

Agglomeration: Agglomeration is the process of pre-plasticising soft plastic by heating, rapid cooling to solidify the material and finally cutting into small pieces. This is usually carried out in a single machine. The product is coarse, irregular grain, often called crumbs.

Extrusion and pelletizing: The process of extrusion is employed to homogenise the reclaimed polymer and produce a material that it subsequently easy to work. The reclaimed polymer pieces are fed into the extruder, are heated to induce plastic behavior and then forced through a die (see the following section on manufacturing techniques) to form a plastic spaghetti which can then be cooled in a water bath before being palletised. The palletisation process is used to reduce the 'spaghetti' to pellets which can then be used for the manufacture of new products. The detailed of preparation of various batches is given in Table No. 1to3

Proportion	Weight of Ist time Recycled (gms)	Weight of Virgin PP (gms)	Total Batch Size (gms)
90:10	25	225	250
80:20	50	200	250
70:30	75	175	250
60:40	100	150	250

Table 1: First time Recycled Polypropylene with Virgin Polypropylene

Proportion	Weight of IInd time Recycled (gms)	Weight of virgin PP (gms)	Total Batch Size (gms)
90:10	25	225	250
80:20	50	200	250
70:30	75	175	250
60:40	100	150	250

Table 2: Second time Recycled Polypropylene with Virgin Polypropylene

Proportion	Weight of IIIrd time recycled (gm.)	Weight of virgin Polypropylene (gm.)	Total Batch Size (gm.)
90:10	25	225	250
80:20	50	200	250
70:30	75	175	250
60:40	100	150	250

Table 3: Third time Recycled Polypropylene with Virgin Polypropylene

Preparation of test specimen:

Injection moulding machine is used for the preparation of test specimen. The first stage of this manufacturing process is identical to that of extrusion, but then the plastic polymer emerges through a nozzle into a split mould. The quantity of polymer being forced out is carefully controlled, usually by moving the screw forward in the heated barrel. A series of moulds would be used to allow continual production while cooling takes place.

Measurements:

The important parameters for the end users are obviously determined by the application, but the most important requirement is for the material to be mouldable. To establish this, it is necessary to know the melt flow index (MFI) of the material, which determines the melt strength and indicates whether the material is likely to be suitable or not. The melt flow index of the material produced was measured to determine suitability for use. The recovery rate for the material was also recorded.

Melt Flow Index (MFI) (ASTM D 1238 I): The MFI was established using test method with a 2.16 kg weight and test temperature of 230^{0}C.

Tensile Strength (ASTM D 638): Tensile test gives a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking.

Flexural Strength (ASTM D 790): Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The stresses induced by to the flexural load are a combination of compressive and tensile stresses.

Izod Impact Strength (ASTM D 265): Izod Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Izod impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness.

RESULT AND DISCUSSION

The data obtained from results of tensile properties shows that the IIIrd time re-processed material is showing lower tensile properties compared to the Ist and IInd time re-processed. The decrees in the tensile properties are comparable with the tensile properties of virgin polypropylene. So, on the basis of these data these data we can see that if the Ist time re-processed material is used with virgin PP, then it will show maximum tensile strength when blended in 60:40 ratio and for IInd and IIIrd time the 90:10 ratio is best to use. The results are given in Table No. 4 to 5.

Sample	Tensile strength KgF/cm^2	Elongation at break KgF/cm^2	Young's Modulus KgF/cm^2
Virgin PP	347.82	20	1739.10
Ist time Recycled	340.57	32	1064.28
IInd time Recycled	340.57	46	740.36
IIIrd time Recycled	335.65	20	1678.25

Table 4: Tensile Properties of Virgin Polypropylene and Recycled Polypropylene

Sr. No.	Ratio Virgin PP : Recycled	Tensile strength KgF/cm²			Elongation at break KgF/cm²			Young's Modulus KgF/cm²		
		Batch I	Batch II	Batch III	Batch I	Batch II	Batch III	Batch I	Batch II	Batch III
1	90:10	313.07	317.24	306.84	18	26	26	1739.32	1220.15	1180.15
2	80:20	315.06	304.71	284.24	26	24	18	1211.76	1159.05	1134.25
3	70:30	308.49	301.69	277.96	22	22	16	1402.13	1105.15	1100.00
4	60:40	319.44	305.55	250.00	26	20	14	1228.61	1005.63	961.53

Table 5: Tensile Properties of Virgin Polypropylene and Recycled Polypropylene

Here, a very opposite trend can be seen i.e. the values of the flexural for the re-processed ones is higher than the virgin PP. This behavior could be a result of using re-processed material because when a polymeric material is processed its molecular weight decreases as a result of deterioration of chains and these results in the brittleness in material. The flexural strength according to the data is increasing continuously and is highest in case of IIIrd time re-processed at 90:10 ratios. The obtained results are given in Table No. 6 and 7.

Sample	Flexural Strength KgF/cm²	Flexural Modulus KgF/cm²
Vergin PP	568.42	3339.52
Ist time Recycled	593.50	3232.03
IInd time Recycled	593.50	3456.00
IIIrd time Recycled	586.56	3243.52

Table 6: Flexural Properties of Virgin Polypropylene and Recycled Polypropylene

Sr. No.	Ratio Virgin PP : Recycled	Flexural Strength KgF/cm^2			Flexural Modulus KgF/cm^2		
		Batch I	Batch II	Batch III	Batch I	Batch II	Batch III
1	90:10	627.94	549.75	500.00	4490.34	3525.25	3300.52
2	80:20	502.94	505.50	475.25	4434.91	3450.00	3350.25
3	70:30	470.58	475.00	460.65	3855.95	3400.00	3300.00
4	60:40	450.60	450.00	425.25	3760.80	3350.25	3250.80

Table 7: Flexural Properties of Virgin Polypropylene and Recycled Polypropylene

The data is for the impact strength of material and from the shown peaks we can evaluate that when the Ist time re-processed PP is used then the optimum ratio of blending should be 80:20 and for IInd and IIIrd time re-processed material the ratios preferred are 70:30 and 90:10 respectively if optimum imact strength is required.

We can clearly observe from the above given data that the Ist and IInd time re-processed materials are having a higher value for MFI compared to the virgin polypropylene. This increase in the flow value is as a result of reduction in molecular weight due to the processing. The results of MFI and Izod impact strength is given in Table No. 8 and 9.

Sample	Izood Impact Strength Joule/cm	MFI gm./10min.
Vergin PP	568.42	2.16
Ist time Recycled	593.50	2.18
IInd time Recycled	593.50	2.20
IIIrd time Recycled	586.56	2.23

Table 8: Izod Impact Strength & Melt Flow Index (MFI) of Virgin Polypropylene and Recycled Polypropylene

Sr. No.	Ratio Virgin PP : Recycled	Izod Impact Strength Joule/cm			Melt Flow Index (MFI) gm./10 min.		
		Batch I	Batch II	Batch III	Batch I	Batch II	Batch III
1	90:10	0.538	0.520	0.510	2.17	2.18	2.18
2	80:20	0.524	0.485	0.460	2.19	2.20	2.22
3	70:30	0.490	0.460	0.410	2.21	2.21	2.23
4	60:40	0.461	0.416	0.390	2.23	2.25	2.26

Table 9: Izod Impact Strength & Melt Flow Index (MFI) of Virgin Polypropylene and Recycled Polypropylene

Recycling is of prime importance nowadays as its favours cost-cutting and is a greener route to save premium resources. Recycled products are used widely in the secondary preferred places i.e. where the demands of strength and resistive properties are not very critical.

CONCLUSION

From the above data and all the interpretation we conclude that for optimum tensile strength requirement the ratio of neat to the recycled proportions is best shown when blended in 90:10 ratios. Good flexural strength, is obtained at the best proportion is 60:40. Optimum impact strength is observed ratio taken should be 90:10. It is also concluded that this best way to utilize polypropylene waste without compromising any properties.

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