

Impact Modification of Polytrimethylene Terephthalate (PTT) by Thermoplastic Polyester Elastomer (TPE)

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Abstract

The properties of any single polymer cannot meet the wide range of specifications. The chemical modification or synthesis of new polymers is not a practical solution on many occasions. PTT is an engineering thermoplastic which has the rigidity, strength, heat resistance and lower impact strength. In this study, the effect of impact modifier i.e. Thermo Plastic Elastomer (TPE) trade name as Hytel in varying weight % proportions in the batch sizes of 5%, 10%, 15% and 20% by weight of PTT were studied. Specimen samples were injection molded for characterization. Mechanical properties such as tensile strength, flexural strength observed decreased with the corresponding increase in TPE by weight % into PTT. Impact strength of the blend increased with increase in weight% of Hytel and it was optimum at 15 weight % of Hytel into PTT polymer. SEM of the blend was studied for finding structure of blend and compatibility.

Keywords: PTT, TPE, polymer blend, impact modifier, mechanical properties, SEM.

1. Introduction

In today's world polymer blends constitutes over 30 weight % of polymer consumption with annual growth rate of 9% over last 12 years [1]. Polytrimethylene terephthalate (PTT) is a thermoplastic of polyesters group that can be spun into both fibers & yarns. PTT belongs to a class of polymers called aromatic polyester. PTT polymer exhibits higher tensile strength, flexural modulus & heat deflection temperatures but with much lower impact strength than PBT. Due to its chemical structure, PTT may have more uniform shrinkage and better dimensional stability in some applications than competing semicrystalline materials. It has excellent resistance to a broad range of chemicals at room temperature, including aliphatic hydrocarbons, gasoline, carbon tetrachloride, oils, fats, alcohols, glycols, esters, ethers and dilute acids

and bases. Blending polymer has emerged to manufacturing new materials with specific properties. Most commercial polymer blends are designed to improvement of the parent components; including better processability, higher impact strength, better chemical resistance. PTT can join with the other polymer such as PBT, polycarbonate, poly (ethylene naphthalate) [2-4].

Polyester thermoplastic elastomer (Hytel[®]) is an important engineering thermoplastic elastomer combines the physical properties of elastomer with the excellent processing characteristics of thermoplastic. Polyester thermoplastic elastomer consisting of poly (butylene terephthalate) (PBT), as a hard segment and poly (tetramethylene ether glycol terephthalate) as soft segments. Typical structure of Thermoplastic Polyester Elastomer is shown in scheme 1. The x and y are integers chosen such that the resultant polyester elastomer has hardness varying from Shore D hardness 30 to 90 [5]. Polyester thermoplastic elastomer shows outstanding mechanical properties at temperatures up to 130 °C coupled with very good low temperature flexibility [6, 7].

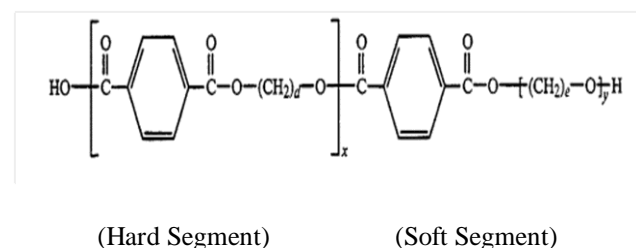


Fig.1 Typical structure of Thermoplastic Polyester Elastomer.

Xue et al. [8] investigated the miscibility and compatibilization of poly (trimethylene

terephthalate)/acrylonitrile–butadiene–styrene blends and found that the PTT/ABS blends exhibited typical pseudoplastic flow behaviour. Aravind et al. [9] investigated the compatibilizing effect of EPM-g-MA in EPDM/poly (trimethylene terephthalate) incompatible blends. Ravikumar et al. [10] investigated the thermal study of PTT/EPDM blends. XRD and DSC results show the decrease in crystallinity of the blend with the increase in EPDM concentration and this is in agreement with positron results. Jafari et al. [11] investigated the PTT/m-LLDPE system in the presence of compatibiliser has been carried out. Lee et al. [12] investigated the morphological changes and crystallization behaviours of PTT/PEI blends were examined. Echevarria et al. [13] investigated the influence of compatibilization on the mechanical behaviour of poly (trimethylene terephthalate)/poly (ethylene-octane) blends, In this case, compatibilization is attributed to chemical interactions between maleic modification and ester groups of PTT. Gaztelumedi and Nazabal [14] investigated phase behaviour and miscibility limits in PC/Hytrel blends over the full composition range. Ramirao et al. [15] investigated Synergistic mechanical and improved processability of poly (ether imide)/ poly (trimethylene terephthalate) blends. Liang et al. [16] reported miscibility and melting properties of poly (ethylene 2, 6-naphthalate)/poly (trimethylene terephthalate). Supaphol et al. [17] studied thermal, crystallization, mechanical and rheological characteristics of poly (trimethylene terephthalate)/poly (ether terephthalate) blends. Huang [18] investigated polymer blends of poly (trimethylene terephthalate) and polystyrene compatibilized by styrene glycidyl methacrylate copolymers. Impact modification of poly (trimethylene terephthalate)/polypropylene blend nanocomposites: fabrication and characterisation was studied by Upadhyay et al. [19].

In this investigation, we studied effect of impact modifier which is used as TPE (Hytrel) on the impact and other properties of PTT polymer.

2. Experimental

2.1 Materials

Polytrimethylene Terephthalate (PTT) were procured from Futura Polyesters Ltd, India. It has 1.20 intrinsic viscosity and melting temperature about 228°C. The Thermoplastic Polyester Elastomer (TPE) was obtained

from DuPont under the trademark name of Hytrel 6356. This is high performance grade with melt flow index of 11.12 g/min., shore hardness 63D and a melting temperature of 211°C. The virgin PTT samples were extruded and injection moulded in order to have the data regarding its properties prior to blending with Hytrel.

2.2 Preparation of PTT/Hytrel Blend

The batches of Hytrel were made as 0%, 5%, 10%, 15%, and 20% by the weight to that of PTT polymer. These batches were then kept in an air circulating oven at 110°C for 3 hrs prior to extrusion. Dry blended mixtures of these different weight proportions were melt compounded using single screw extruder (BRIMCO Plastic Machinery Pvt.Ltd, India) with a speed of 60 rpm and L/D ratio of 21. The temperature profile for the melt blending was kept as Zone 1-160 °C, Zone 2-180 °C, Zone 3-200 °C, Zone 4-220°C and Die-230°C. Blended material which was coming out of a die was then passed through water cooling tank where it is cooled and wound. This blended polymer was taken to the Boolani Pelletizer for palletizing. The speed of the pelletizer was maintained between the ranges of 60-80 rpm. These each batches were earmarked and packed in the labeled plastic packets.

2.3 Injection molding

After pelletization these granules were again predried at 110°C ± 5°C in an air circulating oven for 3 hours and then they were injection molded to produce the various samples for testing tensile strength, flexural strength and impact strength. Granules were injection molded using microprocessor-based injection molding machine (Patel Plast Industries Ltd., Goregaon, Mumbai.). The processing parameters for injection molding were kept as Zone 1-190°C, Zone 2-210°C, Zone 3-238°C, and Zone 4-245°C.

3. Characterization

3.1 Mechanical Properties

The dumbbell shape tensile strength specimens were injection molded as per ASTM standards. The tensile strength and elongation at break of the samples were

evaluated according to the ASTM D638 M-91, using Universal Tensile Tester LR50K [Lloyd Instrument Ltd., U. K.] The crosshead speed of 50 mm/min was maintained for testing and a load cell of 50 KN was used. The results reported are average values of at least 3 test specimens.

Rectangular bars of dimensions 125 x 13 x 6.5 (length x breadth x thickness (in mm) were prepared by injection molding. The flexural strength and flexural modulus was measured using universal testing machine [LR 50 K, LLOYD Instruments, and U.K.] according to ASTM D790 M-92. Jaw speed of 2.8 mm/min was maintained for 3-point flexural strength and the span was 200 mm. All the reported values are average of at least five samples. The rectangular bars for impact strength as per ASTM D-256 standards were injection molded. The impact strength was determined as per ASTM D 256 using Avery Denison's pendulum type, Impact Strength Tester, [model 6709] with 2.7J striker. The results reported are the average values of at least 5 specimens.

3.2 Thermal Properties

DSC was used to study the thermal properties of the composites. DSC measurements were performed using TA Q100 analyzer (TA Instruments, U.S.). The weight of sample was between 6 to 9 mg in a standard aluminium pan.

3.3 Rheological properties

The melt Rheology of the PTT/Hytrel blend were studied using rotational rheometer (Physica MCR 101, Anton Paar, Germany), employing a parallel plate assembly, diameter 35 mm, at 260°C. The samples were predried before analysis. The shear rate range was varied from 1-100 s⁻¹. Melt viscosity, η (pa-s) as a function of shear rate; $\dot{\gamma}$ (s⁻¹) was recorded.

3.4 Morphological Properties

SEM was used to study morphology of the PTT/Hytrel blend. SEM studies of liquid nitrogen fractured samples were carried out using JSM 6380 LA Analytical Scanning Microscope of JOEL make, Japan. The digitized images of the samples were recorded and studied.

4. Results and Discussion

4.1 Tensile Properties

Fig.2 shows the variation of tensile strength as a function of Thermoplastic Elastomer (Hytrel) in weight %. Tensile strength of the blend was found decreased with increase in the weight % of Hytrel. This can be attributed to the fact that there was a decrement in stress transfer as the bond between the Hytrel and PTT was weak and may be termed as non compatible blend. The percentage elongation at break increased on addition of higher weight % of Hytrel into the polymer matrix as shown in Fig.3. This is mainly because of elastomeric nature of Hytrel. Fig.4 represents the variation in tensile modulus with the weight % loading of Hytrel into the PTT matrix. Tensile modulus of the blend decreases steadily with increase in weight% loading of Hytrel into the matrix.

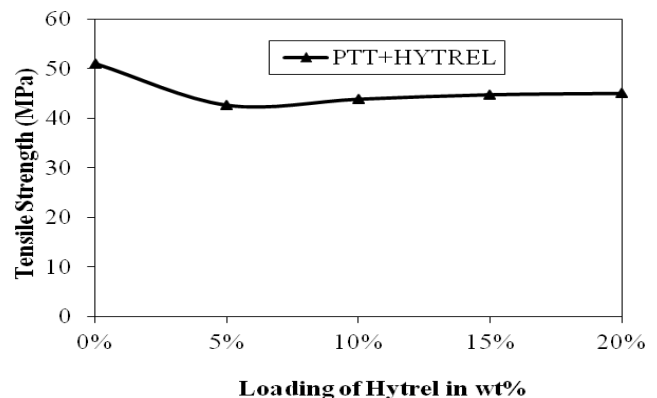


Fig.2 Variation in tensile strength with Hytrel loading by weight %.

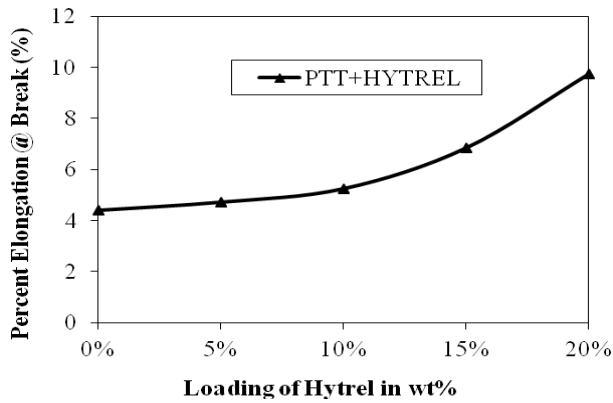


Fig.3 Variation in percent elongation @ break with Hytrel loading by weight %.

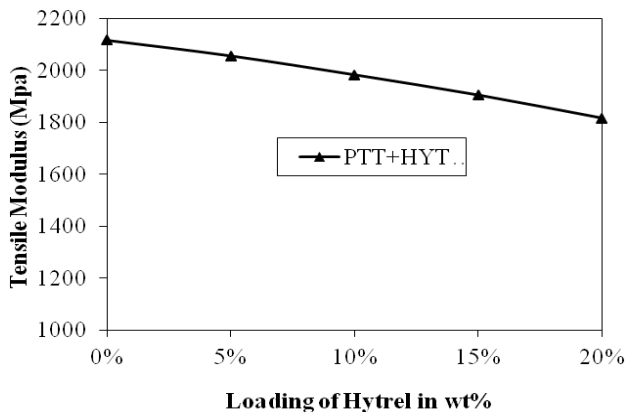


Fig.4 Variation in tensile modulus with Hytrel loading by weight %.

4.2 Flexural Properties

The Flexural strength of PTT decreased with the increase in weight % loading of Hytrel. This is due to the improper bonding of two phases in each other. The variation of the flexural strength with Hytrel loading by weight % is shown in Fig.5. The flexural modulus of the PTT/Hytrel blend decreased with increase in the concentration loading of Hytrel into the polymer. The variation of flexural modulus is shown in Fig.6.

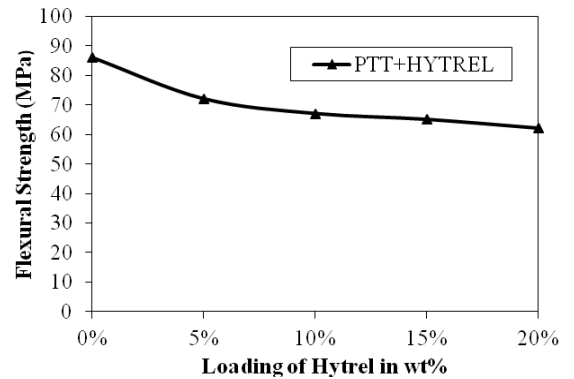


Fig.5 Variation in flexural strength with Hytrel loading by weight %.

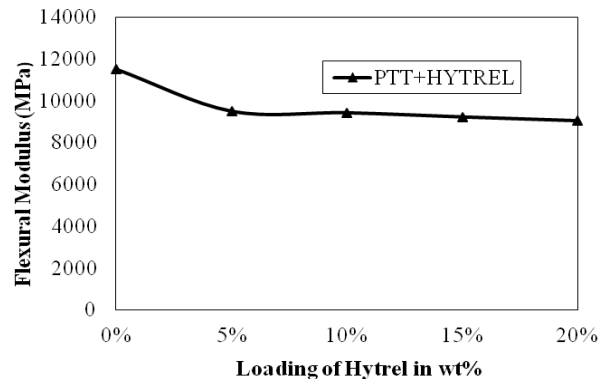


Fig.6 Variation in flexural modulus with Hytrel loading by weight %.

4.3 Impact Strength

The Izod impact tests were conducted at room temperature. The notched specimens were tested. It was found that as the % loading of Hytrel in the PTT polymer increases, there was an increase in the impact properties of polymer matrix. This is mainly due to the compatibility of Hytrel with the PTT and Hytrel being thermoplastic polyester elastomer the properties of which lie between plastic and rubber therefore able to absorb more energy. But it was observed by the experimental results that when we increase the % loading of Hytrel beyond 15% say at 20% the impact strength of PTT starts decreasing. This may be because of orientation and improper phase formation. The variation of the impact strength with Hytrel loading by weight % was shown in Fig.7.

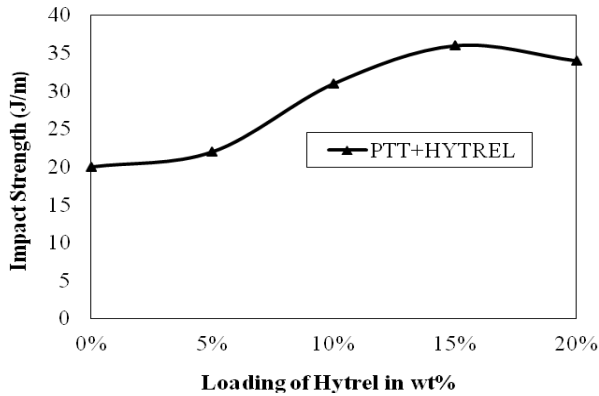


Fig.7 Variation in impact strength with Hytrel loading by weight %.

4.4 Thermal Properties

The melting and the crystallisation temperature of the PTT/Hytrel blend were studied by using DSC. Fig.8 shows the variation of melting temperature with weight % content of Hytrel into the PTT polymer. The polymer matrix showed a melting temperature around 228.25°C. Fig.9 shows the variation of crystallization temperature with weight % content of Hytrel into the PTT polymer. The matrix polymer shows the crystallization temperature around 193.75°C. The melting temperature (T_m) showed a significant shift due to the addition of thermoplastic polyester elastomer compare to virgin PTT polymer. The T_m of blends decreases by addition of thermoplastic polyester elastomer (Hytrel). The T_m decreases due to melting of Hytrel at low temperature. The crystallisation temperature (T_c) showed a significant shift due to the addition of thermoplastic polyester elastomer. The crystallisation temperature is shifted right to around 5°C with the addition of Hytrel at 15 weight %. This increment is mainly due to proper bonding of Hytrel with PTT.

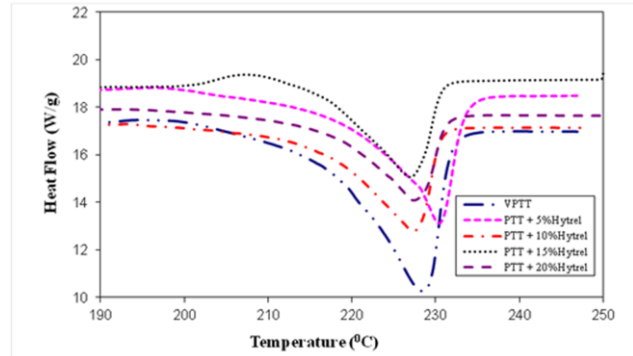


Fig.8 Variation of Melting temperature of PTT with Hytrel concentration (weight %).

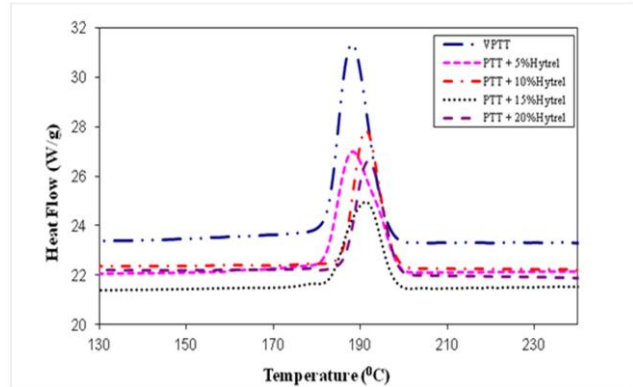


Fig.9 Variation of crystallization temperature of PTT with Hytrel concentration (weight %).

4.5 Rheological properties

Fig.10 illustrates the variation of shear viscosities (in Pascal sec) with weight % loading of Hytrel into PTT polymer at 260 °C. Curve from the figure shows the shear viscosity of PTT/Hytrel blend is higher than virgin PTT at low shear rates. Very high viscosity at low shear rates and relatively lower viscosity at high shear rates clearly indicates that onset of non-Newtonian flow behaviour for blend system is much earlier as compared to that for base polymer. The decrease in the shear viscosity at higher shear rate indicates good processability of the blend.

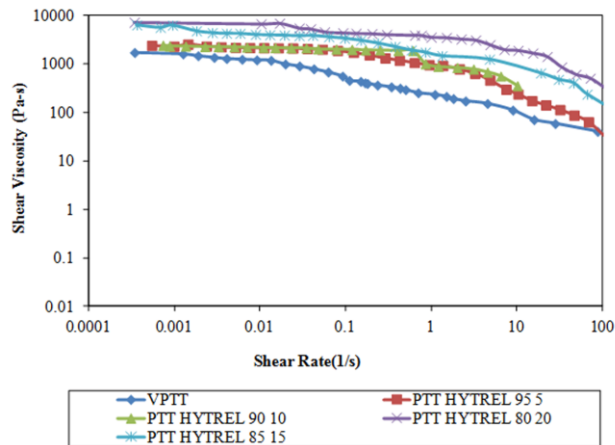


Fig.10 Variation in shear viscosities of PTT/Hytrel blend with wt% loading at 260°C.

4.6 Morphological Properties

Mechanical properties of the blends are well explained on the basis of fracture morphology. Liquid Nitrogen fractured of the PTT/Hytrel blend for 5%, and 15% weight proportions were shown accordingly in Fig. 11 and Fig.12. At 15% loading as Fig.12 shows proper miscibility of two phases which gives the improved result of impact strength. Fig.13 depicts PTT/Hytrel blend for 20% Hytrel loading by weight into the polymer matrix in which some oriented structures are formed and seen which may increase impact strength as compared to virgin PTT but due to non uniform structure impact value achieved at 20% is less than as achieved with 15% of Hytrel. Also other mechanical properties are observed decreased.

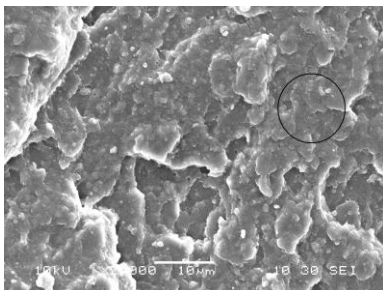


Fig.11 SEM Morphology of 5%Hytrel/PTT blend composition without at 2000 x magnification.

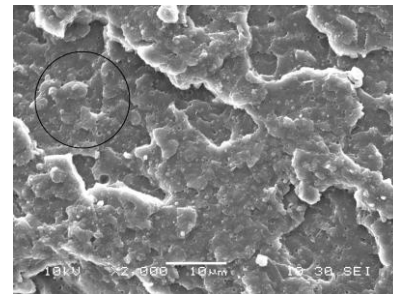


Fig.12 SEM Morphology of 15%Hytrel/PTT blend composition at 2000 x magnification.

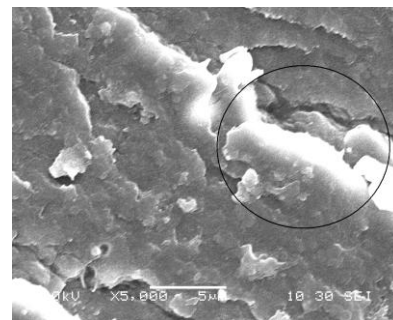


Fig.13 Morphology of 20%Hytrel/PTT blends composition at 5000 x magnification.

5. Conclusions

The principle conclusions obtained from the experimental results of PTT/TPE blend with different weight % loading of TPE are summarized as follows:

- ❖ There was an increase in impact strength when thermoplastic polyester elastomer (Hytrel) was used as an impact modifier in PTT polymer. This is mainly due to the elastomeric nature of Hytrel into PTT. It can be also concluded that at 20% loading of Hytrel impact strength decreased marginally which can be attributed to the fact that there might be improper interaction between both the phases.
- ❖ Tensile strength of the blend system found decreased significantly with increased in weight % concentration of Hytrel as compared to virgin PTT polymer. The

decrease in tensile strength may be due to the increase in strain in one of the phase.

- ❖ There was a decrease in flexural strength and flexural modulus with increased in weight % loading of Hytrel in the PTT. This is mainly due to the increased softening of the blend because of the elastomeric phase.
- ❖ The addition of Hytrel in PTT showed increasing viscosity in rheological properties which was also suggested an increase in impact strength. Therefore an increase in impact strength values was to be expected.
- ❖ SEM morphology shows platelet oriented structure for the 20 weight % loading of Hytrel into the PTT polymer which suggests decrement in tensile properties and increment in % elongation and impact strength.

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