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Investigation on the Mechanical Behavior of Polyamide 66/Polypropylene Blends

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ABSTRACT
Polymer blending is widely used method for the modification of the polymeric materials. In this study, the mechanical behavior of polyamide 66/polypropylene (PA66/PP) blends was investigated. The different blends of PA66/PP with varying weight percentage of PP in PA66/PP were studied. The PA66/PP blends were prepared by melt mixing using twin screw extruder followed by injection molding. The mechanical properties of blends such as tensile strength, flexural strength, impact strength, and hardness were studied as per ASTM standards. It was observed that 95/5 wt.% of PA66/PP has good tensile strength (61.5 N mm^{-2}), flexural strength (94 N mm^{-2}), and impact strength (115 J m^{-2}). The same mechanical properties were observed in decreasing trend for the different proportions of PP in steps of 5 wt.% except the impact strength of the blend. The impact strength of the blend decreased to a value of 57 J m^{-2} for 85/15 wt.% of PA66/PP, after further progressive addition of PP, the strength increased. The hardness of the blends was tested as per ASTM D2240 standards. The hardness of the blend decreased by the addition of PP into PA66. However, the addition of PP into PA66 impaired the mechanical properties.

Key words: *Polyamide 66/polypropylene, Polymer blends, Mechanical behavior.*

1. INTRODUCTION

The use of polymer composites has become very popular in engineering applications. The polymer composites are used as alternative materials for the metal based ones. There has been an increasing interest in the development of polymer blends of polyamide and polypropylene (PA/PP) in the recent years [1-4]. The reason for the polymer blending is to bridge the property gap between two polymers. The PA possesses good mechanical properties, easy processibility, high crystalline melting point, corrosion resistance, very good resistant to solvents, and high wear resistance [5]. The PP is widely used because of its low cost, good resistant to moisture and processibility. The PA6/PP and PA66 based blends offers desirable characteristics such as good chemical resistance to organic solvents, low water absorption, and reduced cost [6-9]. Studies on the mechanical behavior of PA6 and high-density polyethylene blend with and without compatibilizer revealed the fact that the tensile strength of the blend increased when PA proportion was more than 20 wt.% and hardness increased with any PA proportion [10]. Investigation on the role of adding 7.5, 15, 22.5 and 30 wt.% of polytetrafluoroethylene (PTFE) into polyether ether ketone/PTFE (PEEK/PTFE) blend on the mechanical properties were studied [11]. PA66 is a semi-crystalline thermoplastic polymer that finds widespread applications that require strength and low toughness. It possesses good properties such as low density, easy processing, good strength, solvent resistance, self-lubricating, and good abrasion resistance. PP possesses good properties such as low density, high thermal stability, and resistance to chemical attack, easy processing and recyclability. The present research wok aims at the investigation on the role of PP in PA66/PP blend on the mechanical behavior and thereby selecting the best blend composition for mechanical aspects of future promising thermoplastic composites. In this study, the series of blends, 95/5, 90/10, 85/15, 80/20, 75/25, and 70/30 wt.% of PA66/PP were studied, and their mechanical behaviors along with hardness were presented systematically.

2. MATERIALS AND PROCESSING

Polyblends of PA66 and PP were prepared for this study. The sources and the characteristics of these materials are listed in Table 1. The material

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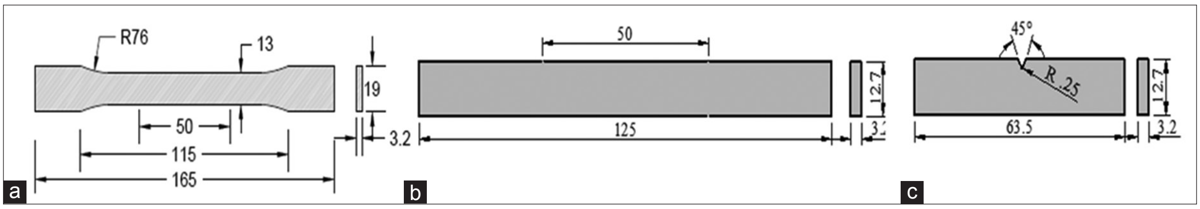

Figure 1: Specimen standards: (a) Tensile test, (b) flexural test, and (c) impact test.

Table 1: Details of the materials and their suppliers.

Material	Designation	Form	Trademark	Manufacturer	Density (g cm^{-3})	Melting point °C
PA66	PA66	Granules	Zytel 101L NC010	Dupont Co. Ltd.	1.14	262
PP	PP	Powder	Grade MP 1000	Dupont Co. Ltd.	0.9	166

PA66=Polyamide 66, PP=Polypropylene

composition in weight percentage are reported in the Table 2. The blends were produced in different weight percentage of 95/5, 90/10, 85/15, 80/20, 75/25 and 70/30 PA66/PP. All the materials were dried at 85°C for 48 h to avoid plasticization, hydrolyzing effects from humidity and to obtain the sufficient homogeneity. The materials were mixed and the mixture was extruded using Barbender co-rotating twin screw extruder (Make: CMEI, Model: 16CME, SPL, chamber size 70 cc). The temperature maintained in five zones of the extruder barrel were 220, 235, 240, 265 and 270°C, respectively, and the temperature at the die was set at 75°C. The extruder screw speed was set at 100 rpm which yielded a feed rate of 5 kg/h. The extruded material was obtained in the form of a cylindrical rod which was quenched in cold water and then palletized. The initial extruded material was discarded to flush impurities out of the system before getting the polyblend samples. Before compounding, all the pallets were dried at 100°C in vacuum oven for 24 h. The tensile test specimen (ASTM D 638 Type 1), flexural test specimen (ASTM D 790), and Izod impact test specimen (ASTM D 256) were injection molded from the pelletized polyblend material using a reciprocating screw injection molding machine equipped with standard test mold. The temperature maintained in the two zones of the barrel was 265 and 290°C and 27°C in the mold.

Table 2: Details of the material formulations in wt. %.

Composite	Material code	PA66	PP
Blend (PA66/PP)	1T	95	5
Blend (PA66/PP)	2T	90	10
Blend (PA66/PP)	3T	85	15
Blend (PA66/PP)	4T	80	20
Blend (PA66/PP)	5T	75	25
Blend (PA66/PP)	6T	70	30

PA66=Polyamide 66, PP=Polypropylene

3. MEASUREMENT OF MECHANICAL PROPERTIES

The mechanical properties such as tensile strength and tensile elongation at yield were measured using Universal Testing Machine (JJ Lloyd, London, United Kingdom, capacity 20 KN) in accordance with ASTM D 638. At least three tests were conducted in each material. Tests were performed at constant strain rate of 5 mm/min at room temperature. ASTM D638 Type 1 standard specimen is shown in Figure 1. Flexural strength or three-point bending was carried out on the same machine by changing the jaws of the set up and the specimen acts as simply supported beam subjected to point load at the center. The flexural strength and flexural modulus were determined at the rate of 2 mm/min as per ASTM D790. The standard specimen for the flexural strength was 100 × 13 × 3.2 mm specimen is shown in Figure 1. The density and the hardness (Shore D) of the blends were determined as per ASTM D792 (Archimedes principle) and ASTM D2240, respectively.

3.1. Tensile Strength

The tensile strength of PP filled PA66/PP blend (1T, 2T, 3T, 4T, 5T and 6T) composites was studied and percentage elongations at yield were observed. The tensile tests were performed at the crosshead speed of 5 mm/min.

The density and the tensile behavior of different weight percentage of PA66/PP blend is shown in the Figure 2a and b. The density of the 95 wt.% PA66/5 wt.% PP is 1.15 g/cc, with increase in the percentage of PP, the density of the blend increases. This is mainly due to the crystalline nature of PP in the blend. As the content of PP in the blend increases, the dense nature of the blend is increased due to the effect of compatibility between the two associates of the blend. There was an increase of 12% in density with the higher loading of PP into the blend against the low loading in the blend. The density of PEEK-PTFE blends increases by the addition of PTFE into the blend [12].

The effect PP on the tensile behavior of PA66/PP blend is shown in the Figure 2b. The tensile strength of 95/5 wt.% PA66/PP blend was 61.5 N/mm^2, addition of 10 wt. % of PP into the blend results in 47.5 N mm^{-2} which is 23% decrease. Similar observations were made after the inclusion of PP into the blend in steps of 5 wt.%. The decrease in tensile strength was in the order of 35.7, 44, 45.5, and 65% for 15, 20, 25, and 30 wt.% of PP in the blend. It was clear from the graph that the deteriorating trend starts after increase of PP in the blend. Initially at low loading of PP, there was a good tensile strength. But after the increase in the content of PP, the mechanical behavior decreases due to the non-compatibility between the associates of the blend. Even though maleic-grafted anhydride was used as the compatibilizer for the purpose of developing the bonds between these thermoplastics, due to the crystalline nature of PP, PA66 failed to develop the ductile phase of PA66/PP blend, this made the blend to deteriorate the strength of the composites. The strong phase separation between high crystalline PA66 and PP deteriorates the ductility of the blend [11]. The higher strength was obtained for 95/5 wt.% of PA66/PP and the least value for 70/30 wt.% of PA66/PP. The average strength was obtained for 80 wt.% PA66/20 wt.% of PP blend. Similarly, the ductility of the blend decreases as the content of the PP in the blend increases. This is mainly due to the brittle nature of the blend, addition of PP into the PA66/PP blend resulted in crystalline nature of the material, which made the material less ductile in nature.

The flexural behavior of different weight percentage of PA66/PP blend is shown in Figure 3a and b. The effect PP on the flexural behavior of PA66/PP blend is shown in the Figure 3b. The flexural strength of 95/5 wt. % PA66/PP blend was 94 N/mm^2. The addition of 10 wt. % of PP into the blend results in 75 N mm^{-2} which is 25% decrease. Similar observations were made after the inclusion of PP into the blend in steps of 5 wt.%. The decrease in flexural strength was in the order of 31, 42, 49 and 38% for 15, 20, 25 and 30 wt.% of PP in the blend. It was clear from the graph that the deteriorating trend starts after increase of PP in the blend. Initially at low loading of PP, there was an appreciable flexural strength. But after the increase in content of PP, decrease in mechanical behavior is due to the non-compatibility between the associates of the blend. Even though maleic-grafted anhydride was used as the compatibilizer for the purpose of developing the bond between these thermoplastics, due to the crystalline nature of PP, PA66 failed to develop the ductile phase of PA66/PP blend, this made the blend to deteriorate the strength of the composites [11]. The higher strength was obtained for 95/5 wt.% of PA66/PP and the least value for 75/25 wt.% of PA66/PP. The average strength was obtained for 80 wt.% PA66/20 wt.% of PP blend. Similarly, the deflection due to bending of the blend decreases as the content of the PP in the blend increases. This is mainly due to the brittle nature of the blend.

Modification of flexural modulus due to the influence of PP in the blend is not appreciable as it tends the material to decrease in the flexural modulus. This modulus depends also on the method of conducting the test of the strength as per ASTM.

3.2. Impact Strength and Hardness

The impact behavior and the hardness of PA66/PP blend were shown in Figure 4. The impact strength

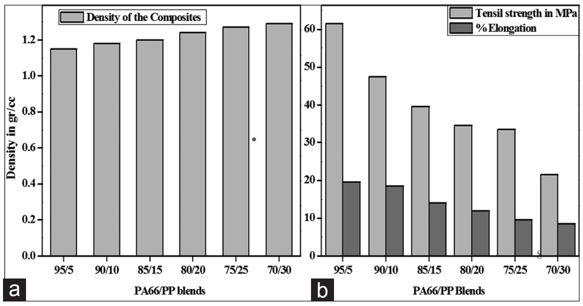

Figure 2: Variation of: (a) Density and (b) tensile strength of studied polyamide 66/polypropylene blends.

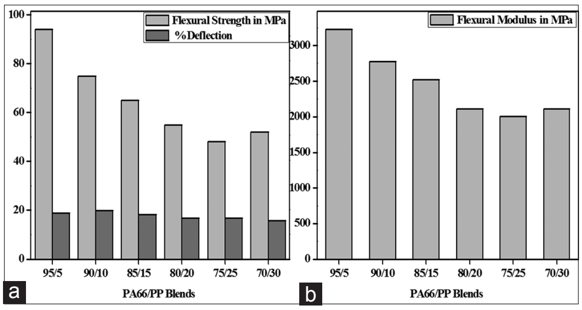

Figure 3: Variation of (a) Flexural strength and (b) flexural modulus of studied polyamide 66/polypropylene blends.

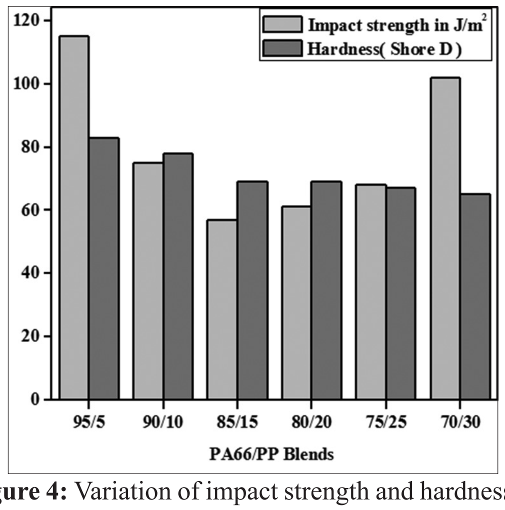

Figure 4: Variation of impact strength and hardness of studied polyamide 66/polypropylene blends.

of the blend with low loading of PP was 115 J m^{-2}. Further addition of PP into the blend decreased the impact strength of the blend. However, increase in impact strength starts when the content of PP in the blend was 20 wt.%. The least strength of 57 J m^{-2} was noticed for 85/15 wt.% of PA66/PP. The increase in impact strength of the blend is due to the brittle nature of the blend. The hardness of the blend decreases with increase in the percentage of PP in the blend. This is due to the transformation of the material from the ductile to the brittle nature. The hardness of the blend increases due to the hard nature of PP in PA66/PP blend.

4. CONCLUSIONS

- The polymer blend PA66 with PP was studied on the mechanical aspects
- 95/5 wt.% of PA66/PP blend has the good tensile strength and 70/30 wt.% of blend has poor tensile strength when compared with other studied polymer blend composites
- 95/5 wt.% of PA66/PP blend has the good flexural strength and 75/25 wt.% of blend has poor flexural strength when compared with other studied polymer blend composites
- The hardness of the composite was decreased as the PP content in PA66/PP blend was increased
- The impact strength of the blend decreased initially and then tremendously increased for 70/30 wt.% of PA66/PP blends
- The impair in mechanical properties can be attributed to immiscible blends, characterized by coarse, metastable morphology, and poor adhesion between the phases due to glass transition temperature difference of PA66 and PP.

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***Bibliographical Sketch**

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