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Experimental Study of the Characteristics of Thermoplastic Polymer Blend

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Abstract: **Today, Polymer blends may contribute to make variety of polymeric materials for different applications especially where none of the available polymer can meet the desired property individually for a particular application. When applied to the physical testing, thermoplastic polymer blends yield mechanical properties depending on their composition ratio and the degree of mixing. The physical property also depends on processing conditions, such as processing temperature, pressure, and the degree of homogeneity between components. The aim of this work was to make polymer blend of two different thermoplastics to study and analyze the blend and its properties. The test specimen prepared by directly feeding the polymer granular mixture into the injection molding machine. Universal Testing Machine (UTM) is used for study of properties. The present work is, therefore, carried out to follow a new approach for preparing the test specimen in three stages. In this research two widely used polymer materials were used for preparation of polymer blend. The polymer materials are low density polyethylene (PE) and polypropylene (PP).**

Keywords: **Polymer, Polymerization, Injection Molding Machine, Universal Testing Machine (UTM), Polyethylene (PE) and Polypropylene (PP).**

1. INTRODUCTION

Polymers are extremely class of materials without which the present life style seems very difficult. They are all around us in everyday use, in various forms such as rubber, plastic, resins, adhesives and foams etc. The linking together of a large number of small molecules termed as monomers with each other to form a macromolecule polymer molecule through chemical reaction is termed as polymerization.

In 2014, Muhab & Seedahmed observed that the addition of LLDPE to PP in most cases increased the flexural modulus to 5.8 to 39.8%, impact resistance to 23.5 to 50%. PP provides the best HDT is 30 wt %. The addition of LLDPE to PP decreased the MFI.

In 2013, Sheila et al. made the samples of copolymer of poly-ethylene and Polypropylene, with different PP: PE content and studied the failure in mining wire ropes.

In 2014, Nurul-Akidah et al. studied and proved that addition of PP in PE/PP blends affected the mechanical properties of the product in a way that PP improved the blends' tensile strength before exposure to weathering.

In 2005, Strapasson et al. observed that the widespread presence of polypropylene and low density polyethylene in municipal wastes and their common combined use by the recycling industry makes the study of the mechanical behavior of these blends valuable for practical every-day use.

In 2009, Dikobe et al. prepared PP/EVA/WP polymer blend composites and investigated their morphology as well as thermal and mechanical properties. The PP/EVA blend shows immiscibility due to a lack of interaction between PP and EVA.

In 2010, Buthaina & Karrer introduces a new study of blends of polystyrene (PS) and Acrylonitrile-Butadiene-Styrene (ABS) that are prepared in different ratios by melt blending technique which was carried out using a single screw extruder.

2. METHODOLOGY

2.1 Materials and Equipments

In this research two widely used polymer materials were used for preparation of polymer blend. The polymer materials are low density polyethylene and polypropylene. The density of the polypropylene is 0.905 g/cm^3 and that of the low density polyethylene is 0.912 g/cm^3. Polypropylene and low density polyethylene were mixed in various PP/LDPE weight contents in the ratios 100/0, 80/20, 60/40, 40/60, 20/80, and 0/100 and subsequent melt processed in a single screw extruder machine with extrusion speed of 30 rpm.

The equipments used in carrying out the present work include, a single screw extruder to prepare the uniform mixtures (blends) of polypropylene and low density polyethylene in required proportions. A granulator to make granules from the extruded lumps of polymer blends. Specification of injection moulding machine are manual hand operated, temperature range (0-300^{0}C) and thermostat temperature control.

The injection moulding machine used the mould with cavity of tensile test specimen according to the ASTM D638 test method to mould the required tensile test specimen. The universal testing machine (DUTT 101) used to test the tensile strength of the test specimen have load capacity of 500 kg. The injection moulding machine was hand operated type and the extruder was having a 20cm screw length.

Fig 1: - Injection Moulding Machine

Fig. 2. Photograph of the Extruder

Fig. 3. Plastic Granulator

Fig. 4. Photograph of the machine after injection of plastic melt in the closed mould mould posion

Fig. 5. Photograph after ejection of the tensile specimen in the open mould posion.

3.2 Mould of Test Specimen

The dimensional specifications of the test specimen as per ASTM D638-Type IV, is given in the figure 3.6, according to which the mould was fabricated.

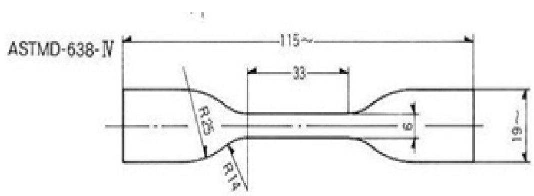


Fig. 6. Design of the Test specimen as per ASTM D638 IV.

(b)

Fig. 7. (a) Front-view of the cavity side Mould Half, (b) Front-view of the second Mould Half

Fig. 8.. Universal Testing Machine (DUTT 101)

3.3 Method of Sample Preparation

The individual polymers taken under study can be blended together by heating to them above their crystalline melting temperatures. Before we charge the hopper of injection moulding machine, a uniform mixture of the solid polymeric granules are made in a simple drum type mixer without providing any kind of heating system therein. The purpose of this mixing is to prepare a premixed granular system with desired materials ratio. This also helps in early achievement of the uniform blend when the component polymers. get mixed inside the barrel of injection moulding machine. A better uniformity in the polymer blend ensures better result of the final material when tested.

When the screw of extruder rotates, materials move simultaneously in forward direction through the heated inner wall of the extruder's barrel and melted therein. Due to the rigorous mixing specially in the metering zone of the barrel, a uniform polymer blend is prepared and found in forms of long lumps. The lumps obtained from the extruder were crushed in a granulator to make granules for easy feeding in the injection moulding machine. And finally the test specimens were prepared using injection moulding technique.

Fig. 9. Photograph of the Tensile Test Specimen

3.4 Test Methods

For the evaluation of the mechanical properties of molded specimen of the polymer blends, tensile tests were performed on universal testing machine according to the ASTM D638 test method and data for yield strength, elastic modulus and elongation at break were obtained. Tensile tests resulted many properties of materials, such as modulus of elasticity, yield stress, maximum yield point, elongation at break, percentage elongation etc. The results obtained by this study were analyzed to know the effect of blending polymers and polymer blend properties which was the aim of this study.

3. RESULTS AND DISCUSSION

3.1 Tensile Data of the Different Polymer Blends

The dimensions of the tensile test specimen used are as below:
Gauge length: 30 mm
Thickness: 3.5 mm
Cross sectional area: 3.5x6.0 mm^2

The results of tensile tests (Yield force Vs Elongation and Break Force Vs Elongation) for the blends of LDPE and PP are presented below. The results show pure polypropylene can withstand higher load than the other PP/LDPE polymer blends, whereas LDPE show elastic behavior (soft and weak) so they have higher elongation as compared to pure PP.

TABLE 1: Tensile test results for the blend sample of PP Composition 0%

Yield Force	19.07 Kgf
Yield Elongation	6.0 mm
Breaking Force	16.76 Kgf
Elongation at Breaking point	8.7 mm

TABLE 2: Tensile test results for the blend sample of PP Composition 20%

Yield Force	30.01 Kgf
Yield Elongation	3.6 mm
Breaking Force	21.43 Kgf
Elongation at Breaking point	mm

TABLE 3: The tensile test results for the blend sample of PP Composition 40%

Yield Force	40.71 Kgf
Yield Elongation	3.6 mm
Breaking Force	27.86 Kgf
Elongation at Breaking point	7.8 mm

TABLE 4: Tensile test results for the blend sample of PP Composition 60%

Yield Force	49.28 Kgf
Yield Elongation	3.3 mm
Breaking Force	38.57 Kg f
Elongation at Breaking point	mm

TABLE 5: Tensile test results for the blend sample PP Composition 80%

Yield Force	62.14 Kg f
Yield Elongation	2.7 mm
Breaking Force	60.03 Kg f
Elongation at Breaking point	3.1 mm

TABLE 6: Tensile test results for the blend sample of PP Composition 100%

Yield Force	70.71 Kg f
Yield Elongation	3.0 mm
Breaking Force	62.14 Kg f
Elongation at Breaking point	3.3 mm

4.2 Yield Point Calculations:

By using the above results the yield stress, strain and young's modulus for different blends were calculated by using the formulae given below, and the results are given in table 8.

$$\text{Yield Force (N)} = \text{Yield Force (Kgf)} \times 9.8$$

$$\text{Yield Strain} = \frac{\text{Change in gauge lentgh at yield point}}{\text{Original gauge lentgh}}$$

$$\text{Yield Stress} = \frac{\text{Yield Force (N)}}{\text{Cross sectional area (mm}^2\text{)}}$$

$$\text{Young's Modulus} = \frac{\text{Yield Stress (MPa)}}{\text{Yield Strain}}$$

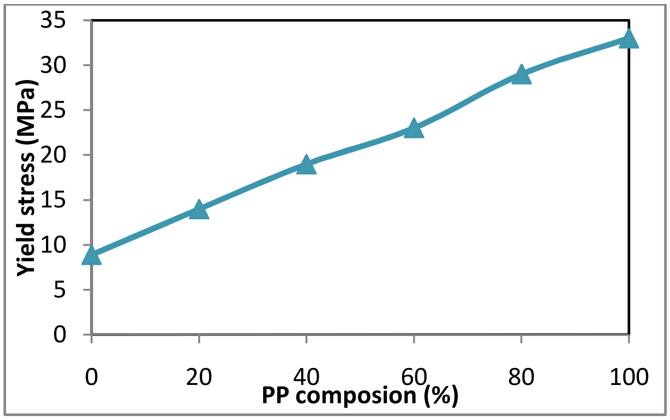
TABLE 7: Yield Force and Yield Elongation for Different Blends

PP Composition (in %)	Yield Force (Kgf)	Yield Force (N)	Yield Elongation (mm)
0	19.07	186.89	6.0
20	30.01	294.10	3.6
40	40.71	398.96	3.6
60	49.28	482.94	3.3
80	62.14	608.97	2.7
100	70.71	692.96	3.0

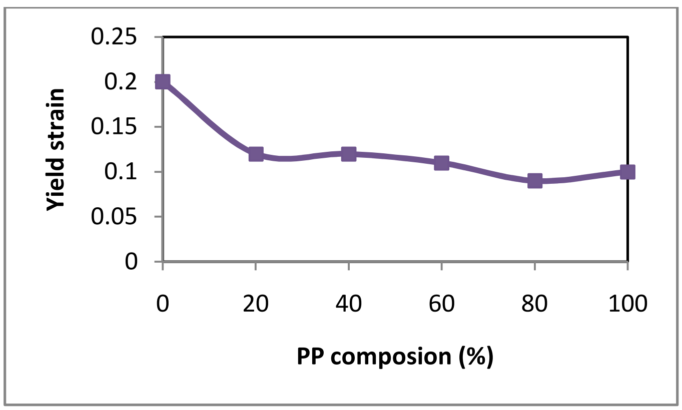
TABLE 8: Yield Stress, Strain and Young's Modulus for Different Blends

PP Composition (in %)	**Yield Strain**	**Yield Stress (MPa)**	**Young's Modules (MPa)**
0	0.20	8.90	44.49
20	0.12	14.00	116.70
40	0.12	18.99	158.32
60	0.11	23.00	209.07
80	0.09	28.99	322.21
100	0.10	32.98	329.98

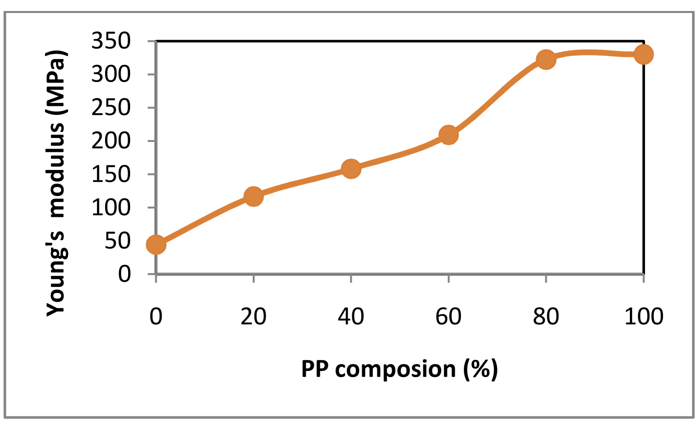
The results of yield stresses of the polymer blends having different PP/LDPE ratio are compared in Graph 1, the results of yield strains are shown in Graph 2, and the results of Young's modulus are shown in Graph 3.



Graph 1: - Comparision of Yield Stress of PP/LDPE Blends at Different composition



Graph 2: - Comparision of Yield Strain of Blends having Different PP/LDPE Ratio



Graph 3: Comparision of Young's Modulus of Blends having Different PP/LDPE Ratio

The increase in the PP composition in the blend increases the yield stress almost uniformly with a constant slope as a straight line function. However, at the later stage of increasing the PP composition from 40% to 60% shows a slight reduction in the yield stress in comparison to the PP content up to 40%. The increase in the yield stress value after 60% PP composition is due to the role of PP as continuous phase at higher proportion and its better yield property in comparison to that of LDPE. The comparison of yield strain at different PP composition, presented in Graph 2 shows a fast reduction in the yield strain of the blend as the PP is added to the LDPE even in a low proportion. This indicates the reduction in elongation of blend with respect to the pure LDPE. However, if the PP content is increased beyond 20% the yield strain is not much affected and the yield strain almost remains the same.

The Young's modulus of blend are plotted and compared in Graph 3. This graph shows that at up to 60% of PP composition the blend property changes linearly, however when PP composition is increased in the blend beyond 60% the value of Young's modulus shows much better improvement leading to a maximum at 80% of PP composition. When the PP content is increased further, there is no significant change in the Young's modulus.

4.3 Failure Point Calculations

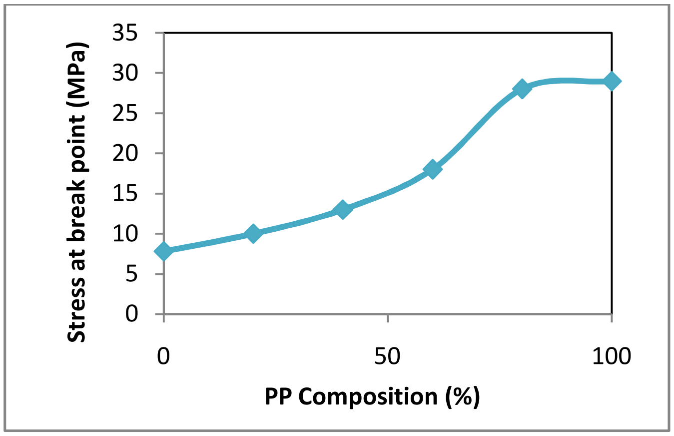
By using the data of tensile test results the stress and strain at breaking point for different blends were calculated, which are given in table 10.

TABLE 9: Break force and Elongation at break for Different Blends

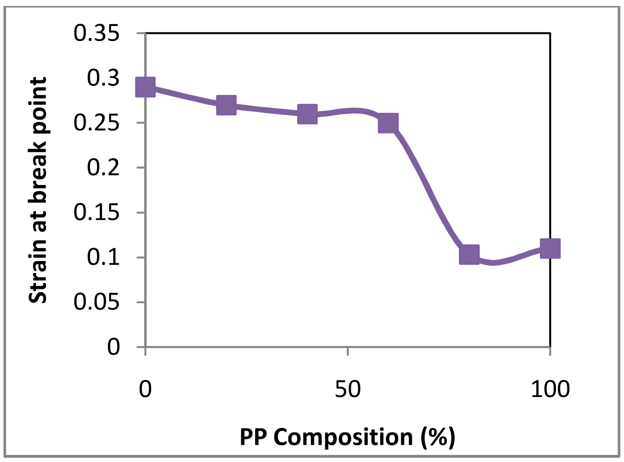
PP Composition (in %)	Break force (Kgf)	Break force (N)	Elongation at break (mm)
0	16.76	164.24	8.7
20	21.43	210.01	8.1
40	27.86	273.03	7.8
60	38.57	377.99	7.5
80	60.03	588.30	3.1
100	62.14	608.97	3.3

TABLE 10: Stress and Strain at Failure Point for Different Blends

PP Composition (in %)	Strain at Failure point	Stress at Failure point (MPa)
0	0.29	7.82
20	0.27	10.00
40	0.26	13.00
60	0.25	17.99
80	0.10	28.01
100	0.11	28.99



Graph 4: Comparision of Failure Stress of Blends having Different PP/LDPE Ratio



Graph 5: - Comparision of Failure Strain of Blends having Different PP/LDPE Ratio

This Graph indicates that the properties of blends are intermediate of their pure component polymers; however at 80% PP content of the blend, break stress is almost same as that of pure PP. The rate of increase in the failure stress of has been noted maximum at 50% of PP content in the blend.

The stresses at break point for the different polymer blends compared in the Graph 5 indicate that the strain at break point is almost the same with slight reduction till 60% of PP content. The minimum strain is obtained for blend with PP content from 80% to 100%.

4. CONCLUSION

Following conclusions are derived:

1. The yield stress value increases after 60% PP composition is due to the role of PP as continuous phase at higher proportion and its better yield property in comparison to that of LDPE.
2. At very low PP composition, the value of yield strain reduces very fast as a result of reduction in elongation of blend with respect to the pure LDPE. However, if the PP content is increased beyond 20% the yield strain is not much affected and the yield strain almost remains the same.
3. If the PP content is increased beyond 20%, the yield strain is not much affected and the yield strain almost remains the same.
4. Up to 60% of PP composition, Young's modulus changes linearly, however when PP composition is increased in the blend beyond 60%, the Young's modulus increases leading to a maximum at 80% of PP composition. When the PP content is increased further, there is no significant change in the Young's modulus.
5. The properties of blends are intermediate of their pure component polymers; however at 80% PP content of the blend, break stress is almost same as that of pure PP. The rate of increase in the failure stress of has been noted maximum at 50% of PP content in the blend.
6. Strain at break point is almost the same with slight reduction till 60% of PP content (figure 4.5). The minimum strain is obtained for blend with PP content from 80% to 100%.

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