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An Experimental Investigation into Effect of Reinforcement Material on Mechanical Properties of Linear Low Density Polyethylene (LLDPE)

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ABSTRACT

Through this paper an experimental investigation has been done. The composites of different reinforced material having significantly good strength and improved properties are prepared. A comparative study was performed among LLDPE with non-woven fabric, LLDPE and non-woven fabric reinforced with rice husk, LLDPE with non- woven fabric and ash of rice husk. Linear Low Density Polymer (LLDPE) is used as base material in this fabrication process. LLDPE is mixed with the non-woven fabric in different percentage composition by weight in addition to the other natural reinforcement material (rice husk). Further an experiment was performed to calculate the mechanical properties like tensile strength, Melt flow Index (MFI), flexural strength, hence a comparative study of composite with different types of reinforcement was done to investigate the effect of mixing of different reinforcement material. Results shows that LLDPE with non-woven fabric (15 %) have less strength as compared to LLDPE with non-woven fabric and rice husk (10 %) and LLDPE with non-woven fabric and ash of rice husk (5 %). Water absorption characteristics are studied following ASTMD 570, results shows that LLDPE absorbs 0.15 per cent water, followed by LLDPE with rice husk (0.03 %) and LLDPE with ash (0.038 %).

Key words: Linear low density polyethylene; Rice husk; Non-woven fabric

1. INTRODUCTION

For last few decades various engineering material has evolved that cater the need of manufacturing industry. Commercialization of the composites could be traced to early century when the cellulose fibers were used to reinforce phenolic, urea and melamine resins. Composites in the world of today have wide range of applications, wherever high strength-to-weight ratio remains an important consideration for use. The advent of the composites as a distinct classification of materials began during the mid-20th century with the manufacturing of deliberately designed and engineered multiphase composites such as fiberglass-reinforced polymers. Novel concept of combining together dissimilar materials during manufacture led to the identification of composites as a new class that was separate from the familiar metals, ceramics, and polymers[1]. To meet the critical demands of light weight and good mechanical strength Linear Low Density Polymers (LLDPE) is preferred over other polyolefin it is a simple ethylene based structure which is responsible for its easy processability, good heat preservation and resistance to chemical. Natural fibers have good longitudinal strength but the use of natural fiber as reinforcement in composite was a challenging job[2]. The fatigue strength can be enhanced by using hybrid fiber composites with a polypropylene hemp layer next to the bond interface which was expected to produce more uniform stress in temporary regions[3].

The processing of raw material (LLDPE) along with reinforcement can be achieved by compression molding. The various process parameters at the optimum values are set as shown in Figure 1. In this method, two matched metal molds are used to fabricate composite product. The material placed in between the molding plates flows due to application of pressure and heat and acquires the shape of the mold cavity with high dimensional accuracy into a disc, which is called a *preform*. Preheating of the preform reduces molding time and pressure, extends the die lifetime, and produces a more uniform finished piece.

In compression molder, base plate is stationary while upper plate is movable. Reinforcement and matrix are placed in the

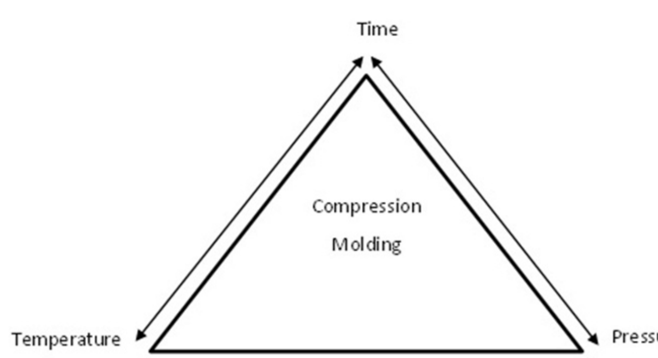

Figure 1. Critical process parameter of compression molding[4].

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metallic mold and the whole assembly is kept in between the compression molder as shown in Figure 2. Heat and pressure is applied as per the requirement of composite for a definite period of time.

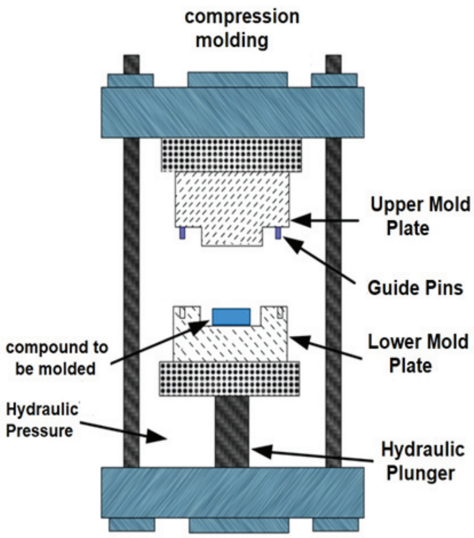

Figure 2. Method of compression molding.

2. EXPERIMENT

2.1 Preparation of Sheet by Compression Molding

500gm LLDPE in the powder form is first conditioned at 70 °C for about 30 minutes in the circulating air oven to remove all moisture content. Pre-weighted granules are charged into the female part of heated compression mold at 160 °C, 7MPa pressure and maintained for 5 minutes the heaters are then switched off and material is cooled to 40 °C-50 °C at a uniform rate of 10 °C per minute under constant pressure after cooling the mold is removed from the press and sheet was taken out.

Three sheets are prepared of different composition of reinforcement material. First sheet of dimension 200 X 200mm was prepared containing only LLDPE. Second sheet containing 10% reinforcement of rice husk (by weight) was prepared of same dimension. Third sheet contains 5 % ash of rice husk as reinforcement material.

All the prepared samples of equal dimension are than tested in the laboratory.

3. TESTING OF SAMPLES

To check the mechanical properties of prepared samples tensile, flexural and MFI (Melt Flow Index) test are performed. Tensile and flexural tests are performed on Lloyd UTM (Lloyd LR 100 K), max load capacity of 100 kN, with force measuring accuracy better than 1 %. Crosshead Speed accuracy: ± 0.5 % of Set Speed (reviewer F) cross head speed of 2 mm per minute in this study. A water absorption test is also performed according to ASTMD – 570.

3.1 Tensile Test

Dumbbell shaped samples are prepared by contour cutter according to ASTM D638 as shown in Figure 3. All the samples were conditioned at 23 °C and 50 % RH for atleast 40 hours prior to test. Universal Testing Machine with tensile test fixture and different type of self-aligning grips are used for holding test specimen in machines. Machine was operated at constant speed of 1mm/min ±50 % until the material fails (yield or breaks). ASTM D638 standard procedures were followed for all samples.

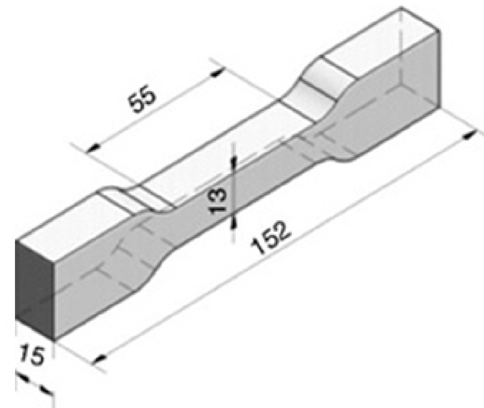

Figure 3. Dumbbell shaped sample for tensile test[5].

Five specimens are tested for each kind of sample. Width and thickness of each test specimens was measured accurately in the narrow parallel portion at several positions with an accuracy of 0.025 mm, gauge length were marked on the specimen. Initial position of grips was adjusted and the specimen was mounted between grips. An extensometer is attached with specimen for measuring extension. The load and extension are recorded at various points on curve till the material breaks.

3.2 Flexural Test

Flexural test are carried out to check material's resistance against bending these properties include flexural strength and modulus. Material under pure bending mode consists of combination of compression and tensile strength[6]. There are two methods for determination of flexural strength of material i.e. three point loading and four point loading system. Three points loading was used in this study. ASTM D790-07 (Standard test method for flexural properties of unreinforced and reinforced plastics and electrical insulating materials) method was followed to conduct test.

Specimen of size 127 mm x 12.7 mm x 6.4 mm. are prepared and conditioned at 23 ± 2 °C and 50 ± 5 % RH for atleast 40 hours prior to test. UTM having flexural test fixture such as specimen support and loading nose is used. Machine was connected to load cell and internal extensometer for recording the load and deflection of specimen. Length, width and thickness of specimens are measured by micrometer. Span length between two supports are adjusted equal to 16 times the thickness of specimen. Specimen is placed on support centrally with load axis perpendicular to the loading nose. The rate of straining for three point loading system is taken as 0.01mm/mm.min as per ASTM D790. The speed of cross-head for three point loading system is calculated by using formula[7].

$$R = ZL^2 / 6d \tag{1}$$

Where,

R = Rate of cross head motion (mm/min)
L = Support span (mm)
d = Depth of beam (mm)

Z = Rate of straining of entire fiber (mm/min)

Subsequently the flexural strength and modulus are calculated using formula as give below.

Flexural strength = $3PL/2bd^2$, flexural modulus = $FL^3/4bd^3Y$ where F is load in newton, Y is deflection caused by load in mm corresponding to force F.

Figure 4. UTM Machine for flexural test (llyod LR 100K).

3.3 Melt Flow Index (MFI)

MFI of the test samples were calculated. This test is based on extrusion property of thermoplastic material. Material is extruded through a small die under a weight of 2.16 kg by a piston rod for 10 minutes at the temperature of 190 °C ±±2 °C. The mass of the sample in grams are recorded. MFI is as assessment of average molecular mass and is an inverse measure of the melt viscosity, i.e., high melt flow rate corresponds to low molecular weight. ASTM D1238 method was followed to carry out test. This test signifies the uniformity of flow, differentiation in polymer grades, determination of extent of degradation, rheological properties of composite etc. In present study MFI is performed on CEAST MF20.

Figure 5. MFI apparatus.

3.4 Water Absorption Test

To investigate water absorption characteristics water absorption test was carried out according to ASTMD-570. In this test the samples are prepared (60 x 60 x 1mm) the samples are pre weighted after drying them at 100 °C and 24 hours duration, later samples are dipped in water for 24 hours. After 24 hours the samples are taken out wiped with cloth and then weighted with 4 digit digital machine[8]. Moisture content percentage were calculated using Eqn. (1)

$$\Delta M(t) = \frac{M_t - M_o}{M_o} X100 \quad (2)$$

M_t is weight of sample before immersion and M_o is weight of sample after immersion.

The results obtained are tabulated below.

Table 1. Water absorption characteristics received from Testing

Sample	Percentage water absorption
A	.015
B	.030
C	.038

4. RESULT AND DISCUSSION

After conducting various experiments it has been revealed that the reinforcement type in composite material plays a significant role in improving the mechanical and rheological properties of composite.

4.1 Mechanical Properties

Mechanical properties such as tensile strength, flexural strength increases when reinforcement of LLDPE and non-woven fabric was done with rice husk (distributed randomly throughout composite). There will also a significant increase in the tensile strength when ash alone was used as reinforcement with non-woven fabric as LLDPE.

Table 2. Result showing mechanical properties of LLDPE and non-woven fabric composite

Sample No.	Tensile Strength (Mpa)	Elongation (%)
1	7.89	28.16
2	8.28	20.18
3	7.92	28.98
4	8.74	19.44
5	9.12	18.28
Sample No.	**Flexural Strength (Mpa)**	**Flexural Modulus (Mpa)**
1	7.12	356.49
2	7.63	371.70
3	7.55	363.67
4	*8.02*	*373.86*
5	*7.93*	*372.12*
Sample No.	**MFI (190^{o}C/2.16Kg)**	
1	22.53	
2	22.10	
3	22.32	
4	21.97	
5	22.18	

Table 3. Result showing the mechanical properties of sample made up of LLDPE, non-woven fabric & rice husk (distributed randomly throughout composite)

Sample No.	Tensile Strength (Mpa)	Elongation (%)
1	14.28	16.02
2	15.26	14.82
3	13.12	16.71
4	15.73	14.13
5	12.98	16.53
Sample No.	**Flexural Strength (Mpa)**	**Flexural Modulus (Mpa)**
1	13.25	410.22
2	14.12	411.84
3	13.56	410.45
4	13.07	410.01
5	14.86	412.25
Sample No.	**MFI (190 °C/2.16 Kg)**	
1	20.92	
2	20.09	
3	20.23	
4	20.57	
5	20.72	

Table 4. Result showing mechanical properties of sample made up of LLDPE, non-woven fabric and rice husk ash

Sample No.	Tensile Strength (Mpa)	Elongation (%)
1	10.46	18.01
2	10.73	18.02
3	13.44	16.53
4	11.38	17.88
5	12.32	16.98
Sample No.	**Flexural Strength (Mpa)**	**Flexural Modulus (Mpa)**
1	9.77	396.54
2	10.13	398.11
3	12.15	409.13
4	11.56	407.32
5	10.45	398.62
Sample No.	**MFI (190°C/2.16Kg)**	
1	21.26	
2	21.19	
3	21.13	
4	21.58	
5	21.24	

5. CONCLUSION

From the result obtained by the experiment it has been concluded that, LLDPE, non-woven fabric and rice husk composite has high tensile strength, high flexural modulus & strength but low MFI (poor rheological properties) of 20.54 °C/2.16kg (table 3) on the other side it was found that LLDPE with non-woven fabric have good MFI of 22.22 °C/2.16kg (average of observations) but less tensile and flexural strength as compared to LLDPE with rice husk & non-woven fabric (Table 2). The tensile and flexural strength of composite made up of LLDPE non-woven fabric & rice husk ash is intermediate of the above two with MFI of 20.56 °C/2.16kg (average of observations).

The graphical values are shown in Figure 6,7,8. The difference in the values of different mechanical properties can be observed. In the below given results blue color will indicate LLDPE, non-woven mixed composite, green color will indicate LLDPE, non-woven & rice husk and red color will indicate LLDPE, non-woven, rice husk ash mixed composite.

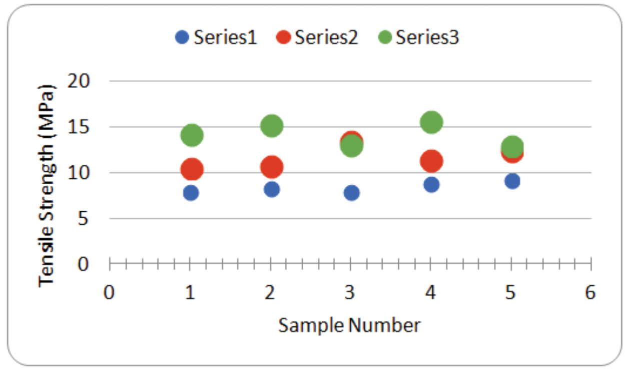

Figure 6. Comparison chart showing tensile strength of composite.

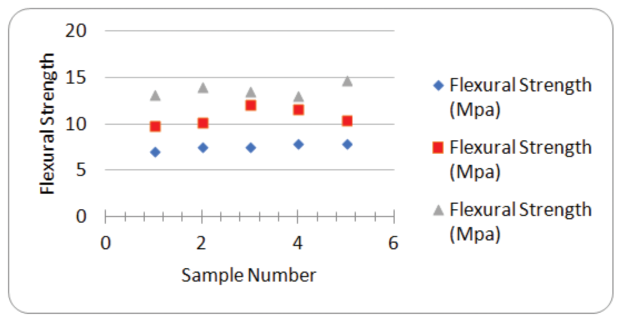

Figure 7. Result showing flexural strength of different samples.

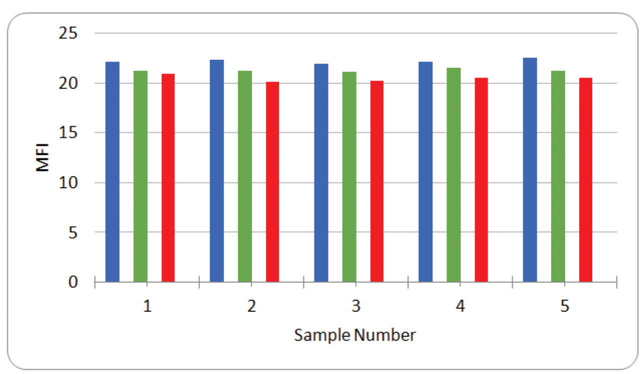

Figure 8. Result showing MFI property of different samples.

6. DISCUSSION

In the present study it is observed that after mixing rice husk with LLDPE with non-woven fabric the interfacial addition becomes very strong, so it gives higher tensile strength as compared to other two, at the same time the restriction to the flow also increases hence less MFI is observed as compared to other two. In extrusion process rice husk may be degraded hence LLDPE with non-woven fabric and rice husk ash have larger MFI than LLDPE and non-woven fabric with rice husk. In water absorption test (ASTMD-570) it is observed that LLDPE with non-woven fabric have least water absorption capacity (0.015%), LLDPE with ash have highest water absorption capacity. Due to agglomeration pores are generated so water absorption increases as compared to rice husk. This result is also corelated with MFI test.

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Dr Tameshwer Nath is working as an Assistant Professor in Mechatronics Engineering Department at Indian Institute of Information Technology, Bhagalpur since 2020. Before Joining to IIIT Bhagalpur, he completed his PhD in Mechanical Engineering from IIT Indore. His area of interest includes smart materials, shape memory alloy and polymer, surface engineering, opto-mechatronics and fabrication of micro devices for practical applications.
He has edited the paper very carefully and included some more references for its proper validation.