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Analysing the Mechanical behaviour of Natural fibre Composites

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ABSTRACT: Natural fiber reinforced composites with natural fiber bagasse sugar cane waste reinforcement and PP as matrix was fabricated using injection moulding process. The degree of recyclability and mechanical characterization of natural fiber reinforced composite was investigated and results were compared with neat polypropylene specimen. The mechanical properties Tensile Strength (TS), tensile modulus, Flexural Strength (FS), Flexural modulus and surface finish analysis were examined. It is observed that the tensile strength of pure PP is more as compared to reinforced PP. There is a reduction of 19.60 % in the tensile strength of the reinforced PP and even the effect of re-cycling the reinforced PP doesn't make any significant change in the value of tensile strength of reinforced PP. It is also observed that reinforced PP result in the increase in the value of tensile modulus to the extent of 19.94%. Subsequent recycling of reinforced PP further increases the tensile modulus up to 26.20%. When pure polypropylene was compared with reinforced PP, an increase of 5.08% in the flexural strength of reinforced PP was noticed. It is also observed an increase of 41.60% in flexural modulus of pure polypropylene, when it was reinforced, The surface roughness value of reinforced composites (1B) increased drastically by 191.05% when bagasse was reinforced in pure polypropylene.

KEYWORDS: Reinforced Composite Material, Microscope Analysis, Tensile test

I. INTRODUCTION

1.1 COMPOSITE MATERIALS

The composite materials are materials in which two or more than two materials are mixed together. These materials may be plastics or ceramics or metals. These materials are mixed with reinforced to increase the properties. These materials have better properties than individual property. The composite materials have high specific strength and high specific stiffness. The Fibers in composite materials have light in weight. The maximum percentage of fibers in composite materials is 65% [1].

The following are some of the reasons why composites are selected for certain applications:

- High strength to weight ratio (low density high tensile strength)
- High creep resistance
- High tensile strength at elevated temperatures
- High toughness

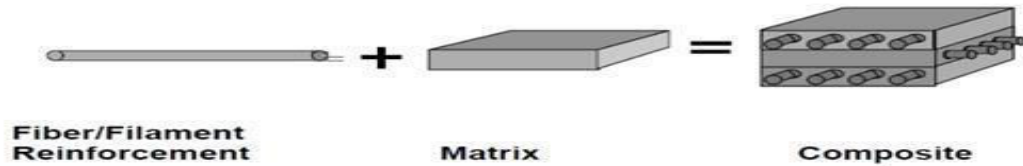


Fig. 1.1 Composite Material [2]

Where a lot of work and research has been done on the different properties of Polymer Matrix Composites, very little study has been done on the tensile and flexural strength of natural fiber PMCs.

1.2 CLASSIFICATION OF COMPOSITE MATERIALS

Broadly Composite materials can be classified under two categories as given below

1.2.1 According to the Type of Matrix Material

1.2.2 According to the Type of Reinforced Material

1.2.1 According To the Type of Matrix Material

Based on various combinations of matrix and fibers used, composites are classified on the basis on matrices is shown in figure 1.2 as under

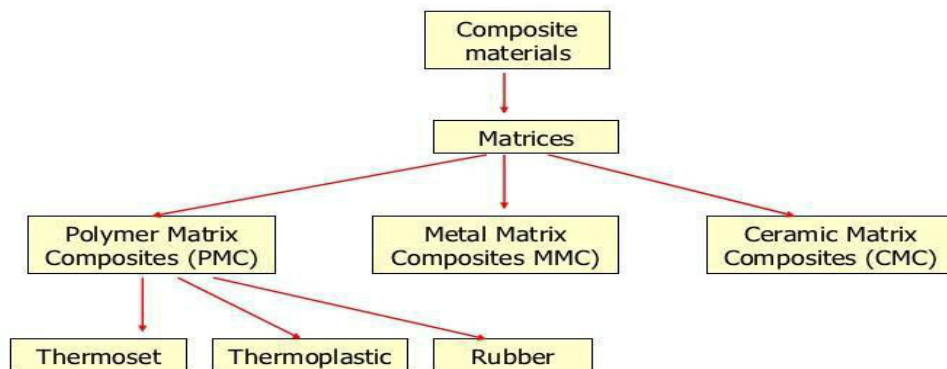


Fig. 1.2 Classification of Composite Material based on Matrix Material [3]

1.2.1.1 Metal Matrix

Metal Matrix has some properties such as higher strength, fracture toughness and stiffness. Metal matrix can withstand elevated temperature in corrosive environment than polymer composites. Titanium, aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications.

1.2.1.2 Polymer Matrix

Polymer Matrix is very popular due to their low cost and simple fabrication methods. Most commonly used matrix materials are polymer. In general the mechanical Properties of polymers are inadequate for

many structural purposes. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers.

1.2.2 According to the Type of Reinforcing Material

Further Composites are classified based on the type of reinforcing material as under

1.2.2.1 Fiber Reinforced Composites

1.2.2.2 Particle Reinforced Composites

1.2.2.1 Fiber Reinforced Composites

A fibre is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibers are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices

II. EXPERIMENTAL PROCEDURE

1. INTRODUCTION

Based on earlier research and literature review, it is found that natural fiber reinforced composites are widely used in various industries and they have a huge potential for future work.

1.1 SELECTION OF REINFORCING FIBER

There are dissimilar types of fiber present in the market. The foremost objective was to select between natural and synthetic fiber. To make it more rational, a comparison has been made which can be seen in the table 1.1 below.

Table 1.1. Natural Fiber Vs. Synthetic Fibers

ASPECT	PROPERTIES	NATURAL FIBER	SYNTHETIC FIBER
Technical	Mechanical	Moderate	High
	Moisture Sensitivity	High	Low
	Temperature Sensitivity	Moderate	Low
Environmental	Resources	Unlimited	Limited
	Production	Low	High
	Recyclability	Moderate	Good
	Pollution	Low	High
Economical	Cost	Low	Moderate

In India, mainly bamboo, nettle, jute, banana, sisal, cotton, coir, bagasse and cotton fibers are cultivated and these species can be used for fiber productions. It can be observed from table 1.2 that major species, which are produced in India is sugarcane.

1.2 SELECTION OF POLYMER MATRIX

After carrying out market survey, it was concluded that there are varieties of polymer matrix materials, available for different uses, manufactured by different companies but only few of them have market potential based on their cost availability and use.

1.3 MATERIAL PROCUREMENT AND PROCESSING

From the market survey, it has been concluded that polypropylene (PP) is available in wide variety for use in different processes, by various companies (Indian Oil Corporation, Reliance Industries, Cairn India, Plus polymers etc.), PP was procured from Indian Oil Corporation Ltd. (IOCL) for experimentation as it has higher Melt Flow Index (MFI) value (=11), low cost (Rs.110.00 per kg) easily availability and wide use

Table 1.2. Production & Use of Various Natural Fibers Species

S.No.	Species	Average Annual Production		Use in Industry
		India	World wide	
1	Bamboo	4.6 MMT	14 MMT	Construction, paper, textile
2	Jute	1.5 MMT	2.5 MMT	Packing, textile, construction
3	Coir	0.15 MMT	0.25 MMT	Mattress, mats, ropes
4	Cotton	5.5 MMT	25 MMT	Textile
5	Banana	23 MMT	70 MMT	Food
6	Sisal	0.01 MMT	0.3 MMT	Ropes
7	Kenaf	0.18 MMT	0.45 MMT	Packaging, ropes
8	Sugarcane	357 MMT	1.83 MMT	Sugar, paper, chemical

Table 1.3. Properties of PP 1110 MAS (Source IOCL)

S.No.	Tested Properties	Test Method	Unit	Values
1	Melt flow index (163 ⁰ C)	ASTM D 1238	g/min	11
2	Density @ 23 ⁰ C	ASTM D 1505-10	g/cm ³	0.91
3	Tensile strength	ASTM D 3039	M Pa	30.004
4	Elongation	ASTM D 3039	%	10.15
5	Flexural Modulus	ASTM D 7264	M Pa	1567
6	Hardness	ASTM 2240	Shore D	50
7	Melting Point	TGA	0 ⁰ C	163

1.4 METHODOLOGY

The methodology adopted to prepare the bagasse fiber (figure 3.5) from the niche bagasse is given below.

1.4.1 Drying

Raw bagasse fibers were collected from M/s Bajaj Hindustan Sugar Mills limited, Thana Bhawan near Shamli in Uttar Pradesh state. It contained lot of foul gasses, leaves residue, dust, pulp, pith, moisture and uncrushed sugar cane. So this nascent bagasse was first dried in sunlight for seven days to lesser its moisture and foul gases, moisture content was about 30 to 40% by weight.

1.4.2 Sieving

After complete drying, now sieving process was carried out by using 2.0 mm, 1.0 mm and 750 μ m sieve size to get desired bagasse fibers. Again bagasse was sieved through 2.0

Size sieve to separate uncrushed sugar cane, which was obtained as residue in the sieving process.

1.4.3 Washing

Sieved material was processed by sieve 750 μ m to separate the bagasse fiber from the dust and pith. Residue on 750 μ m sieve was collected, still it contained some pulp in uncrushed form attached to fibers therefore material was soaked in luke warm water for 2 hours.

1.4.4 Soaking

As pulp absorbs water, it starts floating on the surface and the fibers settled in the bottom of the buckets.

1.4.5 Drying

From the bucket, fibers were collected and kept in direct sun light for 3days for drying.



Fig 1.3 - Bagasse Fibers

1.5 EXPERIMENTATION WORK

Through study of research literature, it was found that the percentage of fiber = 20% by weight mixed with the matrix will be good for experimentation. Extrusion machine was used to produce pellets. These pellets were put in the Oven at 100 $^{\circ}$ C to remove moisture. After removing the moisture, 20% pellets by weight was fabricated by Injection moulding machine. This Injection moulding machine used was ENDURA-60, manufactured by M/s Electronica Plastic machine Limited, Pune is a shown in figure 1.4.



Fig. 1.4 Injection Moulding Machine

Table 1.4. Specification of Injection Moulding Machine

S.No.	Parameter	Value
1	Maximum Clamping Force	600 kN
2	Stroke Volume	68 cm ³
3	Screw L/D ratio	21
4	Injection Pressure	180 bar
5	Voltage	415 ± 10%
6	Phases	3+ N
7	Frequency	50Hz ± 5%
8	Maximum Current	36 AMP
9	Connected Power	15.75 kW
10	cos ϕ of Main Motor	0.81

The mould consists of two mould plate one of them is stationary plate having flat surface and other is movable plate having mould.



Fig. 1.5 The Mould Installed in the Machine

The dimensional specifications of specimen are given in table 1.5. Fig 1.6 depicts the manufactured samples used for tensile, flexural and impact testing.

Table 1.5. Dimensional Specification of Specimens

S. No.	Test	Standard	Size (in mm)
1	Tensile strength test	ASTM D 3039	150 X 15 X 4
2	Flexural strength test	ASTM D 7264	100 X 15 X 4



Fig -1.6.Specimen of Tensile, Flexural and Impact

1.5.1 Selection of Process variables

It was found from literature review that the process variables affect the fabrication properties of composites therefore by trial and error methods various variables were selected for this study. The variables taken into consideration during experimentation work percentage of fiber reinforcement, Injection temperature, pressure and holding time which are given in table 1.6

Table 3.6. Selected Process Variables

S.No.	Variable	Chosen value
1	Percentage of fiber by weight to polymer matrix	20% by wt. ratio
2	Temperature	180 ⁰ C
3	Injection Pressure	60 Bar
4	Holding Pressure	40 Bar
5	Cooling time	15 Seconds

1.6 TESTING OF NATURAL FIBER REINFORCED COMPOSITES

After reprocessing of natural fiber reinforced composite, fabrication work was completed by using above table 3.6 parameters. Testing was carried out to check mechanical properties of natural fiber reinforced composites and recycled NFRC.

1.6.1 Mechanical Testing

For checking mechanical properties of fabricated NFRC pellets, some tests on natural fiber composites were performed such as tensile, flexural and surface roughness measurement. Two types of testing were performed which are given below.

1.6.1.1 Tensile and Flexural Testing

For checking the tensile and flexural properties of fabricated composites sample, tests were performed on UTM (Universal Testing Machine) make INSTRON, model 5982, manufactured by Instron Inc., Norwood, USA. The specification of Universal Testing Machine is given in table 1.6.

Table 1.6. Specification of UTM

S.No.	Parameter	Value
1	Load Capacity	100 kN
2	Cross Head Speed	2 mm / min
3	Gauge Length	50 mm

4	Vertical Test Space	1430 mm
5	Data Acquisition Rate	Up to 2.5 kHz
6	Maximum Speed Range	1016 mm / min
7	Load Measurement Accuracy	±5% of reading down
8	Transducer for Load and Extensometers	Automatic

The extension rate was kept constant for each sample. Aluminium tabs were also used at the ends of specimen for improving the gripping.

Flexural specimens were fabricated as per ASTM D 7264 standards, having dimensional specification of 100 x 15 x 4 (mm). The tests were carried out at cross head speed of 2 mm/ minute with a span length of 60 mm. The extension rate was kept constant for each sample.

1.6.1.2 Surface Finish Analysis

Surface Roughness of the fabricated composite was measured at room temperature using surface roughness tester, model: SURFTEST SJ-301 has been used to determine the surface finish. Table 3.8 shows the specification of Surface Roughness Tester which has been used for surface roughness measurement.

Table 1.7. Specification of Surface Roughness Tester

S.No.	Parameter	Value
1	Measuring Range	350 μ m
2	Drive Speed	0.25 mm / s
3	Material of the Stylus	Diamond
4	Stylus Tip Radius	5 μ m

5	Measuring Force	0.4mN
6	Skid Radius of Curvature	40 mm
7	Skid Force	< 400mN
8	Detecting Method	Differential Inductance
9	Cutoff Filter	2CR/PC75/Gaussian
10	Cutoff Length	0.08-8mm
11	Printing Width	48 mm

1.6.2 Microstructure Analysis

Microstructure analysis was carried out at room temperature to observe the micro structure of the fabricated composite sample (20% fiber content by weight). For microstructure analysis Scanning Electron Microscope (SEM), make LEO model: 435 VP was used. The Specification of Scanning Electron Microscope is given in table 1.7.

Table 1.7. Specification of Scanning Electron Microscope

S.No.	Parameter	Value
1	Resolution	4nm in HV and 6nm in VP
2	Accelerating Voltage	up to 30 kV
3	Magnification	10x to 300,000x
4	Detection Mode	Secondary Electrons and Backscattered Electrons
5	Image Recording	Printer and Camera
6	Stage	5 Axis Computer Controlled Eccentric Goniometry

7	Specimen Chamber	300 x 265 x 190 mm
8	Maximum Specimen Weight	0.5kg
9	Filament	Tungsten Hairpin Filament
10	Tilt	0 to 90 degree

By using sputter coater (BAL-TEC-SCD-005), very thin film of gold was coated on the specimen for increasing the conductivity before taking the micro graphs.

III. OBSERVATION RESULTS AND ANALYSIS

1.7 Analysis of Mechanical Properties

Mechanical properties of PP/Bagasse composites were investigated. Using fiber content of 20% and polypropylene based composites were fabricated by Injection moulding. Mechanical properties of pure polypropylene matrix, bagasse fiber based composite and recycled composites were compared.

1.7.1 Tensile Strength Analysis

The tensile strength of PP, reinforced PP and recycled reinforced PP were observed on UTM and different values obtained are depicted in table 1.8. It is observed that the tensile strength of pure PP is more as compared to reinforced PP. There is a reduction of 19.60 % in the tensile strength of the reinforced PP and even the effect of re-cycling the reinforced PP doesn't make any significant change in the value of tensile strength of reinforced PP.

Table 4.1. Observation of Tensile Strength and Modulus

Sample		Tensile Strength (MPa)	Tensile Modulus (MPa)
	Pure PP	30.004	687
	Batch		
Reinforced PP	1B	24.124	824
Recycled	2B	23.571	809
	3B	23.911	818

Reinforced PP	4B	24.322	829
	5B	24.857	867

V. CONCLUSION

1. The power of pure PP is greater than that of enhanced PP. The reinforced PP's tensile strength has been decreased by 19.60%, and even the reinforced PP's recycling influence has had no effect on the reinforced PP's tensile strength. The value of the tensile modulus increases by 19.94% as a result of the improved pp. Following the recycling of improved PP, the tensile module is increased by another 26.20 percent.

2. As compared to enhanced PP, enhanced PP has a 5.08 percent higher bending power. The advantage of the composite material's flexural strength is reduced due to the recycling impact on bending strength. This means that recycling composites does not result in an improvement in bending ability.

3 The bending modulus of pure polypropylene rises by 41.60 percent when it is reinforced. When comparing pure polypropylene to more reinforced PP, the bending modulus of composite materials increased by 34.01 percent.

4. Ruggedness of reinforced plastic surface (1 B). The bagasse's strength increased by 191.05% when it was strengthened with solely polypropylene. However, it is clear.

5. The incorporation of pure PP of bagasse fibre reduces the surface roughness of the composite, and the recycling of the composite material worsens the surface roughness.

6. The SEM images show fracture microstructure and surface attachment in the matrix, as well as fibre formation.

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