Investigative Comparison of Jute-Polypropylene and Wood flour-Polypropylene Composites

A. Mr. G.V. Mahajan, Mechanical Engineering Department, AVCOE, Sangamner, INDIA-422101
B. Prof. V.S. Aher, Mechanical Engineering Department, AVCOE, Sangamner, INDIA-422605

***Abstract*— Jute fiber reinforced polypropylene PP-based composites (50% fiber by weight) were fabricated using compression molding and the physio-mechanical properties were evaluated. Tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus, and impact strength of the composites were found to be 43.59 MPa, 6382.01 MPa, 81%, 21.85 MPa, 2550.97 MPa, and 45.49 N/m respectively. Then wood flour reinforced PP-based composites (50% fiber by weight) were fabricated and mechanical properties were equated with jute based composites. Jute-based composites showed excellent mechanical properties as comparable to wood flour based composites. Also the thermal properties like heat deflection temperature and flammability were found significantly good for jute based composites as compared with that of wood flour based composites.**

***Index Terms*—Composites, Compression molding, Jute-PP, Wood flour-PP.**

I. INTRODUCTION

THE most principal types of natural fibres used in composite materials are flax, hemp, jute, kenaf, and sisal due to their properties and availability. Jute is a prime fibre with a number of benefits. Jute has high specific properties, low density, less abrasive behavior to the processing equipment, better dimensional stability, no toxicity and harmlessness. Jute fiber is a low cost eco-friendly product and is liberally available, easy to transport and has superior drapability and moisture retention capacity. The biodegradable and low priced jute products merge with the soil after using providing nourishment to the soil. Being made of cellulose, on combustion, jute does not generate toxic gases. Due to jute's low density combined with relatively stiff and strong behavior, the specific properties of jute fibre can compare to those of glass and some other fibres like polypropylene.

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G.V. Mahajan is pursuing ME in Design Engineering with the Amrutvahini College of Engineering, Sangamner, Savitribai Phule Pune university, Maharashtra, INDIA. (gokul.3688@gmail.com)

V.S.Aher Associate Professor, BE-Mechanical Engineer, M-Tech-Design Engineering, Ph.d (pursuing), PG Coordinator, Amrutvahini College of Engineering, Sangamner, Maharashtra, INDIA 422605. (vsa_arya@rediffmail.com)

Jute fibre is obtained from two herbaceous annual plants, jute originating from Asia and Tossa jute originating from Africa. Next to cotton, it is the second most common natural fibre, cultivated in the world and extensively grown in Bangladesh, China, India, Indonesia, and Brazil. The jute plant grows six to ten feet in height and has no branches. The stem of the jute plant is covered with thick bark, which contains the fibres. In two or three month time, the plants grow up and then are cut, tied up in bundles and kept under water for several days for fermentation. Thus, the stems rot and the fibres from the bark become loose. Then the cultivators pull off the fibres from the bark, wash very carefully and dry them in the sun.

The jute fibre possesses moderately high specific strength and stiffness. Therefore, it is suitable as reinforcement in a polymeric resin matrix. The properties of the fibre depend on factors such as size, maturity and processing methods adopted for the extraction of the fibre. Properties such as density, electrical resistivity, ultimate tensile strength and initial modulus are related to the internal structure and chemical composition of fibre. [1, 2]

Polypropylene is a polymer which combines versatility with a low price. It is a vinyl polymer and can be made with different toxicities. Polypropylene is commonly made from the monomer propylene by a Ziegler-Natta polymerization, the result is an isotactic polymer, in which all the methyl groups are on the same side of the chain. Polypropylene has good mechanical properties as well as low density. It is a non-polar material. The crystallinity is about 60 - 70%. The crystalline isotactic polypropylene is insoluble in all common solvents at room temperature, it starts swelling and is finally dissolved by specific solvents only at temperatures generally higher than 100°C. Its tensile strength, surface hardness and stiffness are higher than that of polyethylene. [3]

The interest in natural fibers reinforced polymer materials has multiple drivers such as, growing concern for environment, cost competitiveness, and concern around the sustainability of material production. Natural fibers show significant potential as environmentally friendly alternatives to reinforcements such as glass fibers. Many natural fibers have been identified which have some appropriate mechanical properties for structural purposes, being low density, high strengths, high stiffness and biodegradability.

The objective of this research is to fabricate the Jute-polypropylene and Jute-wood flour composites, evaluation of their mechanical properties and selection of suitable composite for automobile application.

II. EXPERIMENTAL

A. Materials

Row Jute-PP and Wood flour-PP fiber were purchased from Jindal Fibres Ltd. Ludhiana, India and final composite boards were prepared by compression molding. Then specimens are cut to perform various mechanical testing as per ASTM standards.

B. Fabrications of composites and test specimens

Jute-PP: Mixing of Jute fiber with polypropylene by weight percentage of 50:50 is done homogenously by manual blending. After mixing the fibers, they are passed through a carding machine four times to ensure homogenous blending prior to web formation. The webs are conditioned at 115^0 C for 24 hours to remove any moisture content. Composite boards are produced from the carded web by using the compression molding machine. Fibrous webs are cut into pieces and placed on the mold. Webs are stacked to get the required weight/unit area of 1200 GSM. The platens are pressed to desired specific pressure and temperature for a pre-defined time to get final product. After completion of the compression cycle, the platens are cooled to favourable temperature and then the pressure is released. A sample of composite board so manufactured after compression molding and specimen are cut as per ASTM standards for various mechanical tests. [4]

Wood flour-PP: The wood is sawn using a table saw and the Wood sawdust (400-500 µm) is collected. The sawdust is then oven dried at 75°C - 85°C to a moisture content of 3% - 5%, then stored in polyethylene bag. The particle sizes of the sawdust are in the range between 75 and 100 mesh. Before making composite the sawdust is dried at 105°C for about 24 hr until constant weight is reached to obtain 1% - 2% moisture content and then keep in a sealed container. The wood dust is compounded with the granules of polypropylene in the co-rotating twin-screw extruder with operating condition, speed of the screw 80 rpm, cycle time 3 min, temperature up to 195 °C. The operation conditions of the co-rotating twin-screw extruder compounding including extruder barrel temperature at different extruding zones, melt pressure, and screw speed employed for the compounding of both wood dust and PP. The wood dust and the PP are fed through feeders at the extruder. The PP pellets are firstly fed from the main feeding hopper at the end of the extruder, and then the wood dust is fed through a feeder. The extruded strand coming out from the die head is then passed through a water bath and subsequently palletized. The composite formulations are designed as per the mass proportion in percentage. The composition is 50% wt. of PP while 50% wt. of wood dust. Finally the specimens are cut after receiving the composite as per ASTM standards for various mechanical tests. [5]

C. Mechanical Testing

Tensile, Impact, Flexural, heat deflection and flammability tests were conducted. For each test and type of composites, four specimens were tested and average values were tabulated and compared.

D. Tensile Test

This test method evaluates the tensile properties of reinforced composites in the form of standard dumbbell-shaped test specimens when tested under stated conditions of pretreatment, temperature, humidity, and testing machine speed. Tensile tests were conducted according to ASTM D 638-03 using a Universal Testing Machine with a cross-head speed of 50 mm/min. The dimensions of the test specimen were 165 mm × 13 mm × 2 mm. [9]

E. Charpy Impact Test

These test methods are used to determine the resistance of composites to breakage by flexural shock as indicated by the energy extracted from standardized pendulum type hammers, mounted in standardized machines, in breaking standard specimens with one pendulum swing. The results of these test methods are reported in terms of energy absorbed per unit of specimen width. Tests were conducted on specimens having dimensions 127 mm × 12.7 mm × 2.7 mm according to ASTM D 6110-97 using a Impact tester. [11]

F. Flexural Test

This test method determines the flexural properties of reinforced composites in the form of rectangular bars molded directly or cut from sheets. The flexural test is carried out using the same testing machine mentioned above at the cross head speed of 4.1 mm/min and specimen of dimension 80 mm × 25 mm × 2.7 mm according to ASTM D 790-00. The strength and modulus was calculated. [10]

G. Flammability Test

This test method provides a standard laboratory procedure for measuring and comparing the burning rates of composite materials under specified controlled conditions. The rate of burning is affected by such factors as density, direction of rise, and type and amount of surface treatments. The thickness of the finished specimens must also be taken into account. These factors must be considered in order to compare materials on the same basis. The test was conducted as per ASTM D5132. A burn rate was calculated from the following formula:

$B= (60 \times D)/T$

Where,

B = Burn Rate in millimeter per minute

D = Length in millimeter the flame travels

T = Time in seconds for the flame to travel [11]

H. Heat Deflection Test

The deflection temperature is a measure of a composites ability to bear a given load at elevated temperatures. The deflection temperature is the temperature at which a test bar, loaded to the specified bending stress, deflects by 0.25 mm. It is used to determine short-term heat resistance. It differentiate between materials that are able to sustain light loads at high temperatures and those that lose their rigidity over a narrow temperature range. The bars are placed under the deflection measuring device. A load of 1.8 MPa is placed on each specimen. The specimens are then lowered into a silicone oil bath where the temperature is raised at 2° C per minute until they deflect 0.25 mm. The test were done according to ASTM D 648 standard for the specimen of dimension 127 mm x 12.7 mm x 2.7 mm. [12]

III. RESULTS AND ANALYSIS

A. *Mechanical Properties of Composites*

Jute-polypropylene (J-PP) and Wood flour-polypropylene (W-PP) composites (50% fiber by weight) were made by compression molding. The mechanical properties such as tensile, flexural, impact, flammability and heat deflection test (HDT) of J-PP and W-PP composites were evaluated and compared. Four specimens were prepared for each composite and average values of all mechanical properties were taken for comparative analysis. The results are presented in following tables. It was found from table 1and 2 that tensile strength, tensile modulus, % elongation at break and impact strength of J-PP composite were found to be 4.358×10^7 N/m^2, 6382.018 Mpa, 0.81, 45.49 N/m respectively. Specimen found unbroken against flexural testing. On comparing these values with W-PP composites we observed that J-PP composites gained a significant improvement of the mechanical properties. Further from table 3 it is observed that the Heat Deflection Temperature (HDT) for J-PP composite was 135.1^0 C which is much more as compared with W-PP composite. Also the Flammability of J-PP was noted 20.5 mm which is higher than W-PP composite.

TABLE I
TENSILE TEST DATA

	Tensile properties		
Material	Strength (N/m^2)	Modulus (Mpa)	% Elongation at break
WS-PP	3.295×10^7	5624.244	0.77
J-PP	4.358×10^7	6382.018	0.81

TABLE II
IMPACT AND FLEXURAL TEST DATA

		Flexural properties	
Material	Impact Strength (N/m)	Strength (N/m^2))	Modulus (Mpa)
WS-PP	34.01	2.185×10^7	2550.975
J-PP	45.49	Specimen does not break	

TABLE III
HDT AND FLAMMABILITY TEST DATA

	Properties	
Test	HDT	Flammability
Material	Temperature (^{0}C)	Burn Rate (mm)
WS-PP	72.8	15.23
J-PP	135.1	20.5

IV. TEST DATA ANALYSIS

A. *Tensile Test*

This test method involve the determination of the tensile properties of composites in the form of standard dumbbell-shaped test specimens when tested under stated conditions of pretreatment, temperature, humidity, and testing machine speed. The test was done for four specimens of each composites and result were noted. From Fig.1 and Fig.2 it has been seen that the average value of break load for W-PP and J-PP were 87.35 Kg and 115.55 Kg respectively. Hence obviously the tensile strength of J-PP composite was greater than that of W-PP composite.

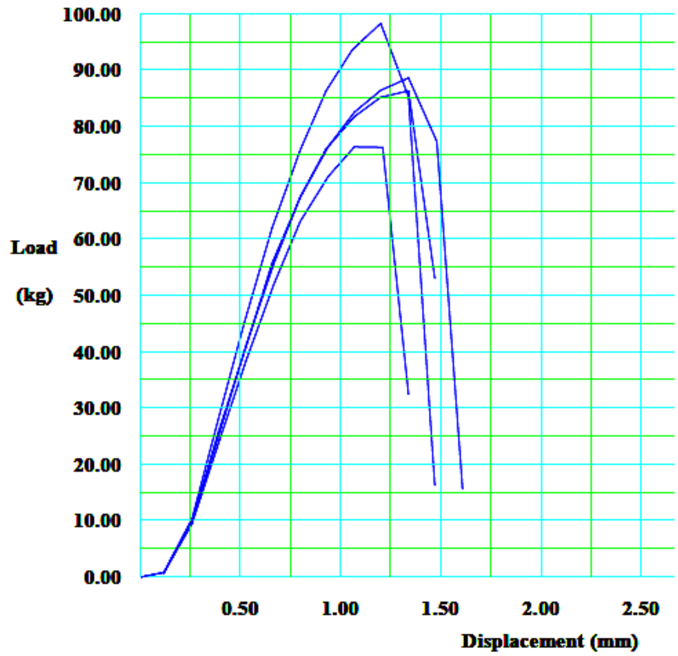

Fig. 1 TENSILE CHARACTERISTICS OF WOOD FLOUR-PP

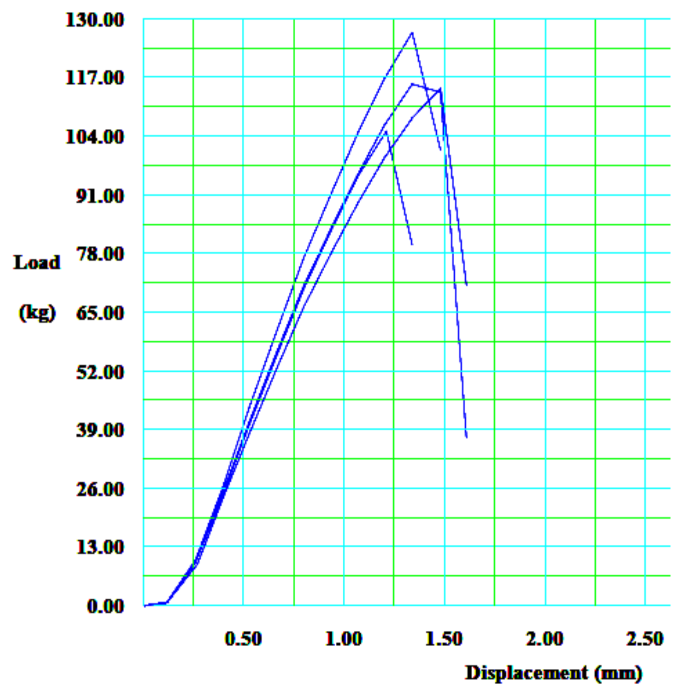

Fig.2 TENSILE CHARACTERISTICS OF JUTE-PP

B. *Charpy Impact Test*

This test method covers the determination of the resistance breakage by flexural shock of composites by energy extracted from standardized pendulum type hammer in breaking standard four specimens with one pendulum swing.

The result of test was reported in terms of energy absorbed per unit specimen width. From Fig. 3 and Fig.4 it is observed that impact energy for J-PP composite is higher than that of W-PP composite. Hence Charpy impact strength of J-PP is greater than W-PP.

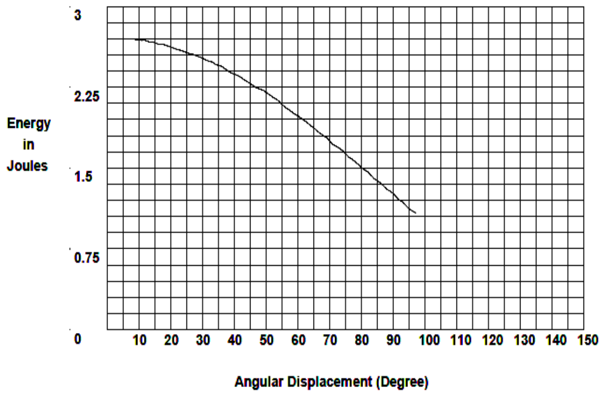

Fig.3 IMPACT TEST CHARACTECS OF WOOD FLOUR-PP

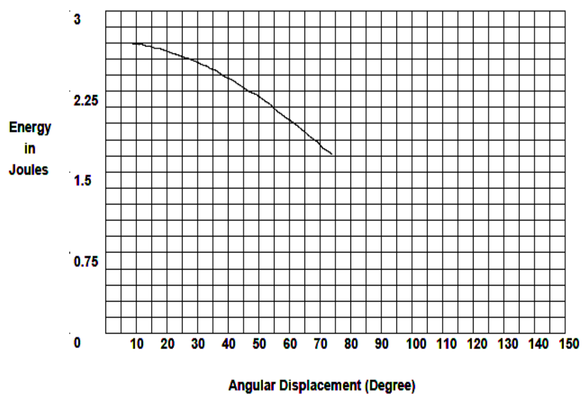

Fig.4 IMPACT TEST CHARACTECS OF JUTE-PP

C. *FLEXURAL TEST*

This method is used to investigate the flexural behavior of composite test specimens and for determining the flexural strength, flexural modulus and other aspects of flexural stress-strain relationship under the defined atmospheric conditions. The load-deflection and stress-strain characteristics for W-PP composite are shown in Fig. 5 and Fig. 6 respectively. For J-PP composite the specimens were found unbreakable. Obviously the flexural strength of J-PP was realized much more higher than that of W-PP composite.

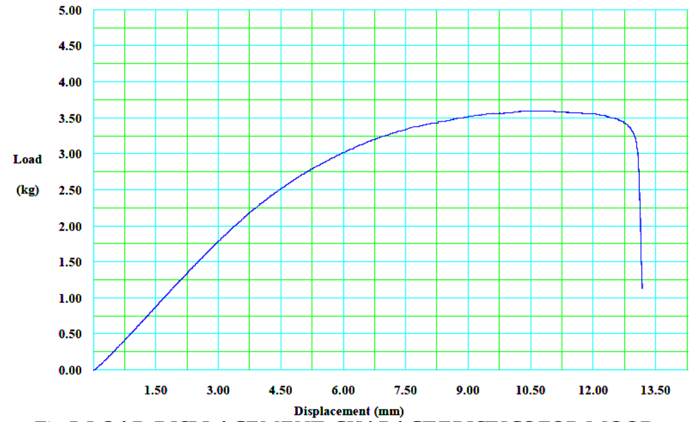

Fig.5 LOAD DISPLACEMENT CHARACTERISTICS FOR WOOD FLOUR-PP

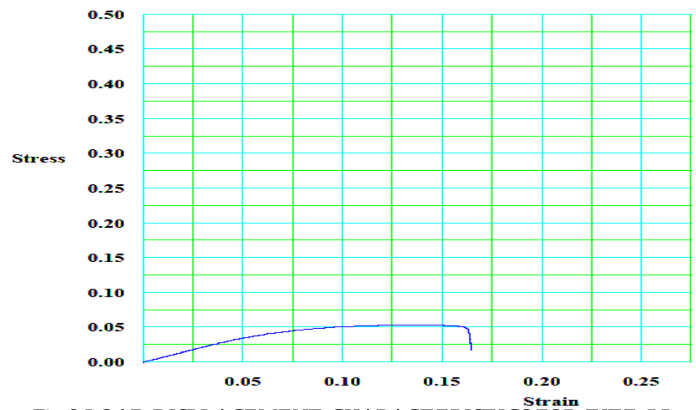

Fig.6 LOAD DISPLACEMENT CHARACTERISTICS FOR JUTE-PP

D. *Heat Deflection Temperature Test*

The heat deflection temperature is a measure of a composites ability to bear a given load at elevated temperatures. This method is used to determine the temperature at which the deformation occurs when specimens are subjected to defined set of testing conditions. From Fig.7 and Fig.8 it is seen that the HDT of J-PP is higher than HDT of W-PP.

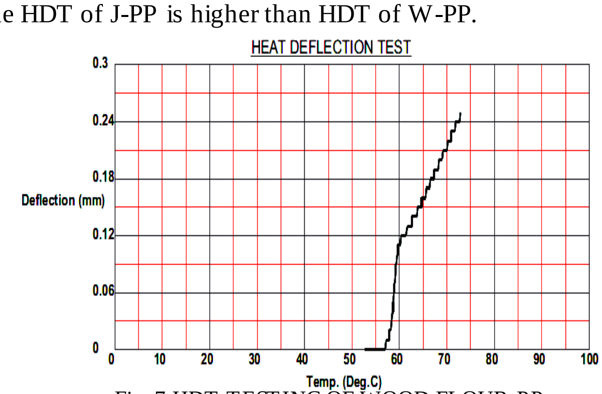

Fig. 7 HDT TESTING OF WOOD FLOUR-PP

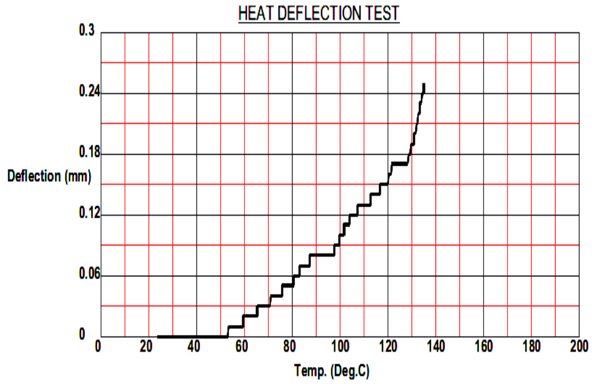

Fig. 8 HDT TESTING OF JUTE-PP

V. CONCLUSION

We have successfully developed biodegradable composites with polypropylene as the matrix and jute fibers as reinforcement without using any chemicals. The jute based composites have excellent tensile strength, impact strength, flexural strength, HDT and flammability than wood flour based composites. The jute based composites could be useful for various applications in automobiles interior components like center console and trim, roof head, pillar trim, rear parcel shelf, door trim panels etc. Further research is in progress to improve the properties of the jute based composites by varying the percentage of fiber and adding various coupling agents.

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