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Jute fibre reinforced plastics: Evaluation of application based properties

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A fibre extracted from jute is a budding component identified for its potential application in composites. It is imperative to evaluate the parametric and property based features to determine its suitability. In this research study, considering the possible application of the fibre composites, the aptness of these fibres are examined with respect to their physical, mechanical [by layered manufacturing technique(LM)] and thermal properties. This study focuses on evaluating the properties and behaviour of raw Jute fibres and NaOH surface treated fibres. Subsequently, the fibres are subjected to thermo-gravimetry tests. The outcome of the thermal analysis clearly indicates that the temperature peak shifts to a higher region in the treated fibre compared to raw fibre. The overall observation strongly emphasize that the physical properties and the thermal behaviour of jute fibre are enhanced after surface treatments which makes it more feasible for its application in composite structures.

Keywords: fibre, polymer, composites, polyester, Jute

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1. **Introduction:** Fibre reinforced plastics are eco-friendly and hence a lot of research is focused of reinforcing fibres in composites. Jute Fibre Reinforced Plastics (FRP) structure has become popular in many vehicles on rail, road and sea. In many cases, the requirements of light weight and high flexural stiffness of these usually large structural parts lead to sandwich construction. Conventional and traditional fibre reinforced composite materials are composed of carbon fibres, glass fibres which are incorporated into polyester resin [1].

The trend towards more advanced, i.e., stiffer and stronger face laminates usually leads to thinner faces in the sandwich. This allows for a further reduction in the structural weight which in turn can yield higher performance, more economical operation or increased payload. However, the impact strength of FRP regardless of material and strength is also dependent on its thickness. Therefore, impact strength becomes an even more critical issue. In the past decade, extensive research work has been carried out on the natural fibre reinforced composite materials. Some of the prominent research papers that has established concrete facts and benefited conceptual understanding of natural fibres are briefly discussed [2]. It emphasized the assets of lignocelluloses natural fibres such as its high strength, lower weight, fairly economic and being a renewable material. The fact that these natural fibres are renewable, non-abrasive and their ability to incinerate for energy recovery since they possess a good calorific value was well documented by other authors [3]. The excellent price-performance ratio at low weight in combination with environmental friendly character is very significant for acceptance of natural fibres in large volume engineering market such as, automobile, ship-building and building industries [4]. However, a parallel discussion on the disadvantages of natural fibres such as, high moisture absorption, poor dimensional stability, low thermal resistance, anisotropic fibre resistance and variability was also reported [5]. The most governing difficulty stressed by the authors is that the natural fibre has lack of good adhesion to polymeric matrices forcing its prevention from use. In particular, the high moisture absorption capacity of natural fibres adversely affects adhesion with a hydrophobic matrix and as result it may cause material degradation and loss of strength. To prevent this phenomenon, surface fibres have been modified in order to promote adhesion.

When additional strength is needed, many types of plastics can be reinforced (usually with reinforcing) jute fibres. This combination of plastic and reinforcement can produce some of the strongest material for their weight that technology has ever developed. Therefore the definition of a fibre reinforced polymer (FRP) composite is a combination of a polymer (Plastic), Matrix (either a thermoplastic or thermoset resin such as polyester, isopolyester, vinyl ester, epoxy, phenolic), a reinforcing agent such as glass, carbon, aramid or other reinforcing materials. Such that there is a sufficient aspect ratio (length to thickness) provides a discernable reinforcing function in one more direction. FRP composite may also contain Fillers, Additives and Core Material of the commonly available annual crop fibres . Jute contains one of the highest proportion of stiff natural cellulose, 75 wt.% [6]. Reinforcement of plastics by fibres has been employed successfully as means of improving the mechanical properties of manufactured products. The reinforcing fibres can be introduced either in a continuous (long) or discontinuous (short) form. Recent research work has targeted improvement of the mechanical properties of polymer-based parts produced by layered manufacturing (LM) techniques utilizing fibre in mat form. jute may be combined with polyester resins [7]. Jute composites were developed and their mechanical properties are evaluated and compared with glass/fibre epoxy resin [8].

Jute/polymer and compared with glass fiber/epoxy. The authors concluded that jute has the potential to act as the reinforcing material for making low load bearing thermoplastic composites. It may be observed that in most of the available literatures, results have no continuity. Moreover, there is no specific methodology adopted which would establish the validity of the tests. Further, few procedures/ features appears hidden. Hence, this works is attempted to overcome those lacunas.

In this research work, jute fibre reinforced polypropylene matrix composites have been developed by hot compression moulding technique with varying process parameters, such as fibre condition (untreated and alkali treated), fibre sizes (1, 2 and 4 mm) and percentages (5%, 10% and 15% by weight). The developed jute fibre reinforced composites were then characterized by tensile test, optical and scanning electron microscopy [9]. The performance of structural sandwich parts under impact loading has to be considered in many cases.

2. Material preparation: Layered manufacturing technique (LM) has been employed to prepare moulded specimens, with the combination of polyester resin and natural fibre material of 3 mm thickness for a setting period 30 mins.

3. Test procedure: ASTM D638-97 specimens are placed in the grip of the Universal Testing Machine at a specified grip separation and pulled off until it failed at a test speed of 50 mm/min for measuring strength and elongation. During the test, the tensile load as well as the elongation of a previously marked gauge length in the specimen is measured with the help of a load dial of the machine and extensometer respectively. After fracture, the two pieces of the broken specimen are placed as fixed together and the distance between two gauge marks and the diameter at the place of fracture are measured. Jute fibre specimens used for the test are shown in Figure (1).

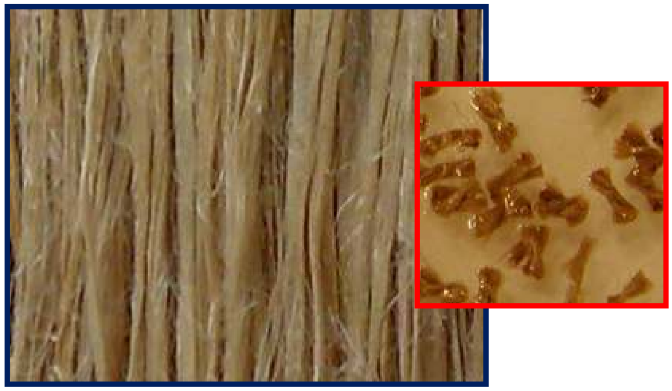

Figure (1): Specimens of jute fibre.

4. RESULTS AND DISCUSSION

4.1 Strength Analysis: Table (1) shows various combinations of polyester resin and jute fibre in wt.% specimens A, B, C, D, E, F were prepared by optimizing the polyester resin and change the wt.% of jute fibre. These moulded specimens were prepared as per ASTM D638-97 and tested in computerized universal testing machine in 50 mm/min at room temperature.

Table (1): Combination of polyester resin and jute fibre.

Specimen	Combinations	%	Weight(g)	Ultimate Tensile Strength (N/mm^2)	Elongation (%)	Young's Modulus (N/mm^2)	Poisson ratio
A	Polyester resin Jute Fibre	98 02	1470 30	240	7	2600	0.050
B	Polyester resin Jute Fibre	96 04	1440 60	260	10	2200	0.060
C	Polyester resin Jute Fibre	95 05	1425 70	310	12	2000	0.045
D	Polyester resin Jute Fibre	94 06	1410 90	320	14	1800	0.040
E	Polyester resin Jute Fibre	92 08	1380 120	320	15	1700	0.035
F	Polyester resin Jute Fibre	90 10	1350 150	350	16	1600	0.030

Apart from the weight and percent details Table (1). presents the ultimate tensile strength(uts) in N/mm^2 for specimens of various combinations. A desirable variation in the ultimate tensile strength is found when the proportion of fibre has been increased while specimen A has yielded 240 N/mm^2 for 2% of fibre, specimen B has produced uts of 270 N/mm^2 in increase of additional 2% of fibre.when 5% of fibre is mixed with polyester resin it produces the uts of 320 N/mm^2. The uts has raised from 322 N/mm^2 to 325N/mm^2. when 2 % of fibre is added to specimen D which consists of 6 % of fibre. The maximum uts of 350 N/mm^2 has been obtained for 10% fibre.which is denoted by specimen F it is obvious from the figure that the better bonding strength between fibre and polyester resin has been formed due to the increase of fibre content.

Table (1) shows represents the level of elongation in percentage for different specimens an additional of 2 wt.% of fibre in specimen A has yielded 7.3 % of elongation for 4 wt.% of fibre in specimen B, 5 % of fibre in specimen C and 6 wt.% of fibre in specimen d give rise to 9.5, 11.2 and 13.5 % of elongation respectively. 14.9 % of elongation is seen in specimen E for 8 % of fibre. Specimen F yields 15.9 % of elongation for 10 wt. % of fibre. When fibre is added with polyester resin, it increases the elongation of the materials.

Table (1) presents the young's modulus in N/mm^2 for different specimens. For 2 wt% of fibre, specimen A yielded 2.617x 10^3 N/mm^2 the addition of 2 wt. % of fibre yielded 2.124x10^3 N/mm^2 for specimen B. Specimen C yielded of 2.009 x 10^3 N/mm^2 for 5 wt. % of fibre. Specimen D yielded of 1.816 x 10^3 N/mm^2 for 6 wt. % of fibre. Specimen E yielded of 1.728x10103 N/mm2 for 8wt% of fibre and specimen F yielded of 1.636x103 N/mm^2 for 10 wt.% of fibre. The combination of polyester resin and fibre gives high ultimate tensile strength and high elongation leads to materials of high toughness.

Table (1) provides the Poisson ratio in μ for the specimens of various combinations. It has been seen that the specimen A yielded 0.05μ for 2 % of fibre,B yielded UTS of 0.058 in increase of additional 2 % of fibre,specimen C yielded 0.044 for 5 % of fibre,specimen D yielded 0.041 for 6 % of fibre.specimen E yielded 0.035 for 8 % of fibre,and specimen F yielded 0.026 for 10 % of fibre this shows due to better bonding strength between fibre and polyester resin

4.2 Thermal Analysis: The thermal stability of jute fibres is investigated by thermogravimetric analysis. The high temperature degradation behavior of fibres are studied using TGA curves as shown in Figure (2).

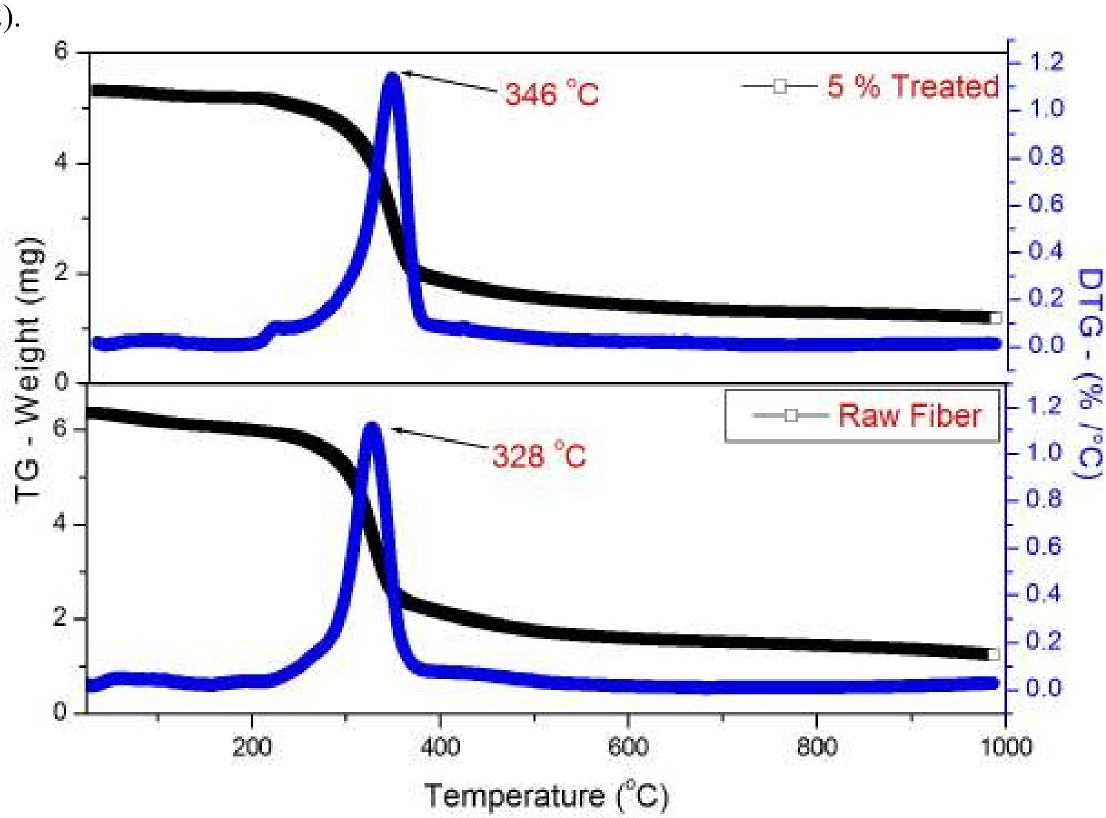

Figure (2): TGA/DTG analysis of raw fibre and 5% NaOH treated fibre.

In raw fibre, initial weight loss of the first stage is observed in the temperatures between 50 and 115^{0}C due to the vaporization of water from the fibre. The degradation for the fibre occurs at high temperature, particularly after 186°C. Above this temperature, it can be observed that the thermal stability is gradually decreased and degradation of the fibre occurs. In the second stage, the temperature between 186 to 260°C is corresponding to the thermal depolymerisation of hemicelluloses and the cleavage of glycosidic linkages of cellulose. Again thermal degradation takes place from the temperature 261 to 347°C in the third stage. These results are also confirmed by differential scanning calorimetry (DSC) curve in Figure (2a) wherein, the maximum decomposition rates for the weight losses are shown.

In 5% NaOH treated fibre, initial weight loss of the first stage is observed in the temperature between 50 and 218°C and is supposed to be due to the vaporization of water from the fibre and degradation for the fibre occurs at high temperature, particularly after 218°C. Above this temperature, it can be observed that the thermal stability is gradually decreasing and degradation of the fibre occurs.

5. Conclusions: In this study, the ultimate tensile strength , elongation, young's modulus, and Poisson ratio of the experimentally produced fibre reinforced plastics in various combination of polyester resin and fibre was investigated in room temperature. The results reveal that, the fibre reinforced plastic has considerable ultimate strength. It may be concluded from the above experiments that natural fibre has good mechanical properties. Besides, the thermal analysis curves revealed that the treated fibres are stable until around 218°C which is reasonably higher than that of raw fibres that are stable at around 175°C.

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