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EXPERIMENTAL INVESTIGATION ON MECHANICAL AND THERMAL CHARACTERISTICS OF FIBER-POLYMER COMPOSITES

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ABSTRACT

The demand for eco-friendly and lightweight materials in the automobile and structural sectors has focused the material experts to extend their research into the fields of natural fiber polymer composites. The present investigation is focused on the experimental investigation on mechanical and thermal characteristics of polymer composites. In this investigation, six different combinations of composites were selected for the evaluation of mechanical and thermal properties experimentally and their results were obtained. The better mechanical properties obtained in Banana-Rice Husk- Epoxy composites are comparable with Glass- Epoxy composites. The Banana- Rice Husk- Epoxy composites exhibited better values of tensile, flexural, impact and compressive strength of 39.7 MPa, 68.45 MPa, 40.8 kJ/m^2 and 898.79 MPa respectively. Similarly the Glass-Epoxy composites exhibit the values of tensile, flexural, impact and compressive strength are 99.5 MPa, 150.49 MPa, 280.2 kJ/m^2 and 3819.72 MPa respectively. Thus a hybrid particulate composite reveals the effective role played by rice husk in improving mechanical and thermal properties. Thus overall results revealed that hybrid natural fiber composites can be considered as a light weight material, and can produces better strength for the places where plastics are replaced.

Keywords: *Banana polymer composites, Polyester resin, Polypropylene, glass fiber, Rice Husk.*

1. Introduction

Composite Materials are combination of two phases in which one of the phase, called the reinforcing phase, which is in the form of fiber sheets or particles and are embedded in the other phase called the matrix phase [1]. The objective is to take advantage of the superior properties of both materials without compromising on the weakness of either. The reasons why composites are selected for such applications are mainly due to their high strength-to-weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness [2]. In composites, fiber and matrix retain their physical and chemical identities and at the same time it gives better properties which cannot be achieved either by fiber or matrix when they are used individually. The fibers can be incorporated into a matrix either in continuous (long) fiber lengths or in discontinuous (short) fiber lengths. Laminates are the stacking of a number of thin layers of matrix and fibers [3]. The study is made on the effect of environment on the mechanical properties of fly ash -jute-polymer composites in which the environmental effects were studied [4]. The investigation is made on the thermal and mechanical properties of chopped glass fiber reinforced epoxy composites filled with silicon carbide which is used to accelerate the bonding strength of epoxy [5]. Mechanical properties and tribological behavior of recycled polyethylene /cow bone particulate composite was evaluated to assess the possibility of using it as a new material for engineering applications [6].

2. Experimental Methods

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2.1. Materials

Banana fiber is extracted from the pseudo stem sheath of the plant. In this process the fiber is extracted by inserting the pseudo stem sheaths one by one into a Raspador machine. The Raspador machine removes non-fibrous tissues and the coherent material from the fiber bundle present in the sheath and gives the fine fiber as output. The photographic images of material used in the present investigation are shown in Figure 1.

Figure 1. Photographic images of materials used

2.2. Properties of Polyester Resin

The resin system consists of unsaturated orthophthalic polyester (Specific gravity@27°C: 1.136, Viscosity: 470 cPs and Mass per unit area: 449.96 g/m^2), Methyl Ethyl Ketone Peroxide (MEKP) catalyst and Cobalt Octoate accelerator were used. The resin properties such as specific gravity and viscosity were tested as per IS: 6746:1994 and mass was determined as per ISO 3374 test methods [9]. Polyester resins are unsaturated resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resin, tends to have yellowish tint, and is suitable for most backyard projects.

2.3. Rice Husk

Particles or fillers added to fiber reinforced polymer composites increases modulus, reduce mold shrinkage, control viscosity and produce smoother surface with improved stiffness, dimensional stability and better thermal properties. The rice husks have got no marketable interest but offers less weight and high stiffness when reinforced with polymers. The collected particles were sieved finely to obtain particle size in the range of 50-100 µm using sieve shaker.

2.3. Glass fiber

They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fiber properties such as strength, flexibility, and stiffness. Glass fibers are used in the manufacture of structural composites, printed circuit boards and a wide range of special-purpose products.

The physical properties of Glass Fiber are as Boron-free E-glasses have a slightly higher density (2.62 g/cm^3) than boron-containing E-glasses (2.55 g/cm^3), but the density of both fibers is lower than that of ECR glass (2.66 to 2.68g/cm^3), a corrosion-resistant special-purpose fiber. Boron-free E-glasses have a higher refractive index and linear expansion coefficient than boron-containing E-glass fibers.

2.4. Epoxy Resin

Epoxy is a co-polymer and is formed from two different chemicals namely, resin and the hardener. The resin consists of monomers of short chain polymers with and epoxide group at either ends. The hardener comprises polyamide monomers, for example tri ethylene tetramine. When these compounds are mixed together, the amine groups react with the epoxide groups to form a covalent bond. Amine hardeners react with the epoxy resins, infusing it with the ultimate properties of the cured epoxy resin system.

2.5. Polypropylene

Polypropylene is in many aspects similar to polyethylene, especially in solution behaviour and electrical properties. The additionally present methyl group improves mechanical properties and thermal resistance, while the chemical resistance decreases. The density of PP is between 0.895 and 0.92g/cm^3. Therefore, PP is the commodity plastic with the lowest density. The young's modulus of PP is between 1300 and 1800 N/mm^2. Polypropylene is normally tough and flexible, especially when co-polymerized with ethylene.

3. Testing Standard And Equipments

3.1 Tensile Testing

The mechanical testing of specimen requires some standardization. The static tensile test samples were cut according to ASTM D 3039 standard for the specimen dimensions of 165 mm × 25 mm × 3 mm and the tensile properties of hybrid particles reinforced coir-polyester composites were measured using Digital Universal Testing Machine (Make :Tinius olsen, Model : H10KL).

3.2 Flexural testing

The three point flexural test samples were cut according to ASTM D 790-10 for the specimen dimensions of 125 mm × 12.5 mm × 3 mm. The flexural test was conducted as per homogeneous beam theory with the span length of 112 mm and span to depth ratio of 34:1 using Digital Universal Testing Machine (Make:Tinius olsen, Model : H10KL).

3.3 Impact testing

The impact properties of a material represent its capacity to absorb and dissipate energies under impact or shock loading. Energy absorbed (σ_{ui}) by the specimen of 62.5 mm × 12.5 mm × 3 mm dimensions was calculated by conducting Izod test with the help of Tinius Olsen Impact tester as per ASTM D 256-10. The photographic image of tensile, flexural and impact test machines are shown in Figure 2.

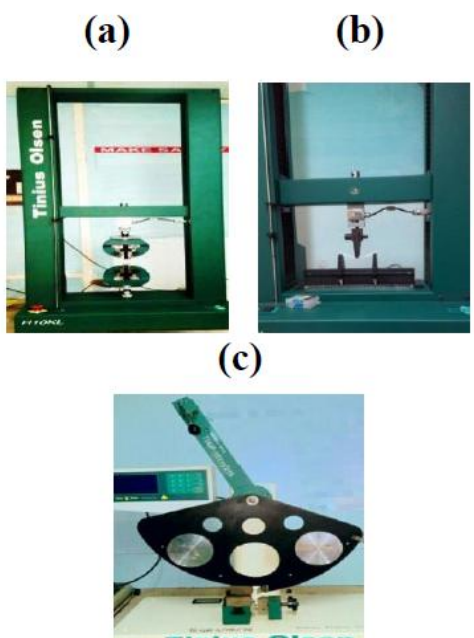


Figure 2. Photographic image of (a) Tensile, (b) Flexural and (c) Impact test machines

4. Results and Discussion

4.1 Mechanical strength of Polymer composites

The experimental results for tensile properties of fibers in which the results shows best for the synthetic fiber of glass and epoxy of 99.5 MPa and natural fiber impregnated with epoxy show the ultimate stress of 39.7 MPa.

The thermoplastic of polypropylene shows the lowest stress values of 24.3 MPa followed by thermoset epoxy resin of 26.5 MPa and the combination of banana-epoxy and particulate-epoxy shows the stress of 30.5 MPa and 36.6 MPa respectively.

The random distribution of particles inside the composites helps in increasing the mechanical properties of the composites. In addition, the particle size of 50 µm lends better bindability with resin, which further increases the mechanical properties (Mohd Firdaus Omar et al. 2013). Therefore in order to enhance the better mechanical strength of prepared composites average strength of 50 µm was maintained during the fabrication.

The result for flexural strength of the composites concluded that the better result is produced for the glass and epoxy fiber of 150.49 MPa since it is synthetic fiber. Thus natural fiber with particulate shows the flexural strength of 68.45 MPa compared to other composite materials. The impact behavior of material directly relates to the toughness of the material.

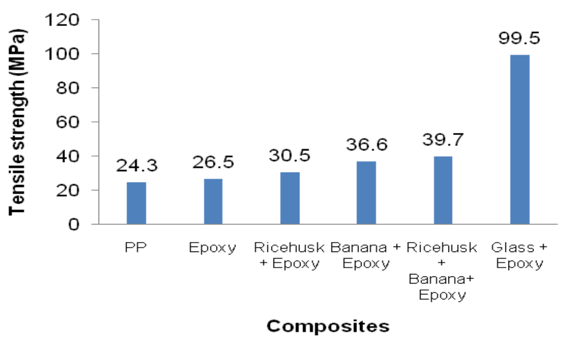
The impact strength of polypropylene (19.8 kJ/m^2) which is very low compared to other composites followed by thermoset resin of epoxy (22.5 kJ/m^2). The obtained results indicate a gradual improvement in impact strength of composites upon the introducing rice husk particles to the banana epoxy composites (46.8 kJ/m^2), even though the impact strength of pure banana epoxy composites is higher compared with pure rice husk composites (30.8 and 37.5 kJ/m^2) respectively. The synthetic fiber shows the maximum impact strength (280.2 kJ/m^2).

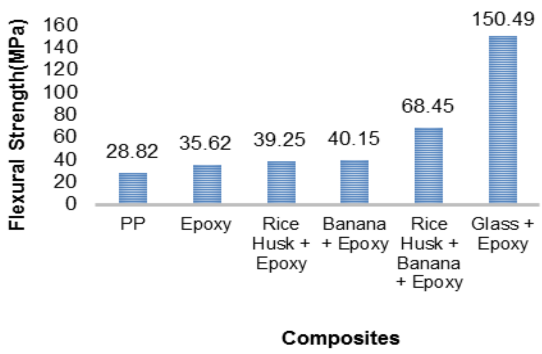
The ultimate stress values of different compositions of natural fiber impregnated epoxy composites. The compressive strength of thermoplastic resin of polypropylene was found to be very low (381.97 MPa) compared to thermoset resin of Epoxy (424.47 MPa). However, the compressive strength of banana impregnated epoxy composites shows improving trend with addition of rice husk and reports a maximum value of 898.79 MPa.

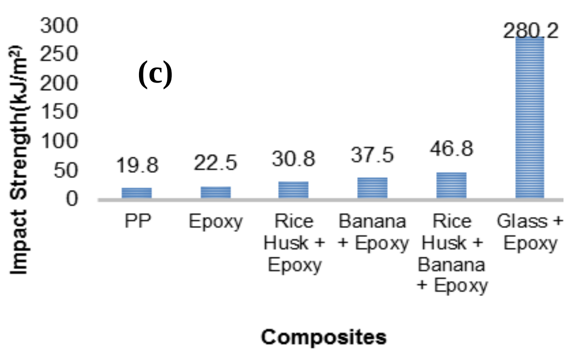
Similarly, the rice husk and banana fiber epoxy composites show a compressive strength of 574.17 MPa and 592.97 MPa respectively. This investigation also shows that thermoplastic resin decreases the compressive strength compared to thermoset resins also

(a)

synthetic fiber of E-glass was selected to compare the property with natural fiber reinforced epoxy composites and the results report for 3819.7 MPa. The comparison of mechanical properties of Polymer composites are shown in Figure 3.Therefore it can be stated that addition of rice husk in the composites may combine with fibers to increase the compressive strength of the composites up to the level of synthetic fibers.







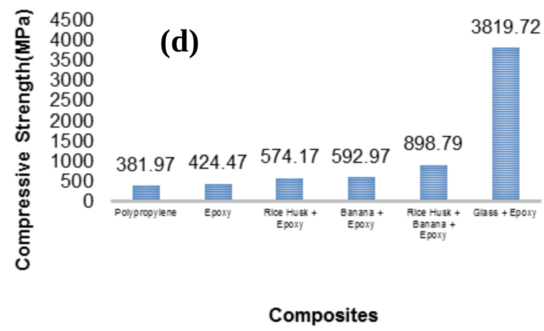


Figure 3. Comparison of mechanical properties of Polymer composites (a) Flexural (b) Impact and (c) Compressive strength.

4.2 Thermal Properties of Polymer Composites

TGA is performed to characterize the thermal stability of natural fiber impregnated epoxy composites. The thermo gravimetric curve showed in Figures 4 (a) to (f). The figures indicated the weight loss percentage of natural fiber epoxy composites at temperature ranges from 50^0C to 900^0C. The composition (gm) manifests weight loss in four consecutive steps.

The composition show weight loss between room temperature at 90^0C, which is supposedly due to evaporation of moisture, water soluble hydroxyl and carboxyl groups present in particles. The slow degradation profile 100^0C and 250^0C is attributed to breakage of glycosidic bonds and thermal de-polymerization of non cellulose groups such as hemicelluloses and pectin. The DTA curve of thermoplastic polypropylene resin is given in Figure 4(a). The peak temperature inferred for PP is 275.34^0C and peak value of weight percentage is observed at 384.96^0C. Similarly for thermoset resin is given in Figure 4 (b). The peak temperature inferred for Epoxy is 678.90^0C and peak value of weight percentage is observed at 442.61^0C. The weight loss started in glass-epoxy composites after 2000^0C as shown in Figure 4(f). The thermal properties of banana-ricehusk-epoxy composites is comparable with the glass-epoxy composites. The better mechanical and thermal properties of hybrid natural fiber and agricultural residues impregnated epoxy composites initiated new platform for scientist to carry out research for the replacement of synthetic fiber-polymer composites.

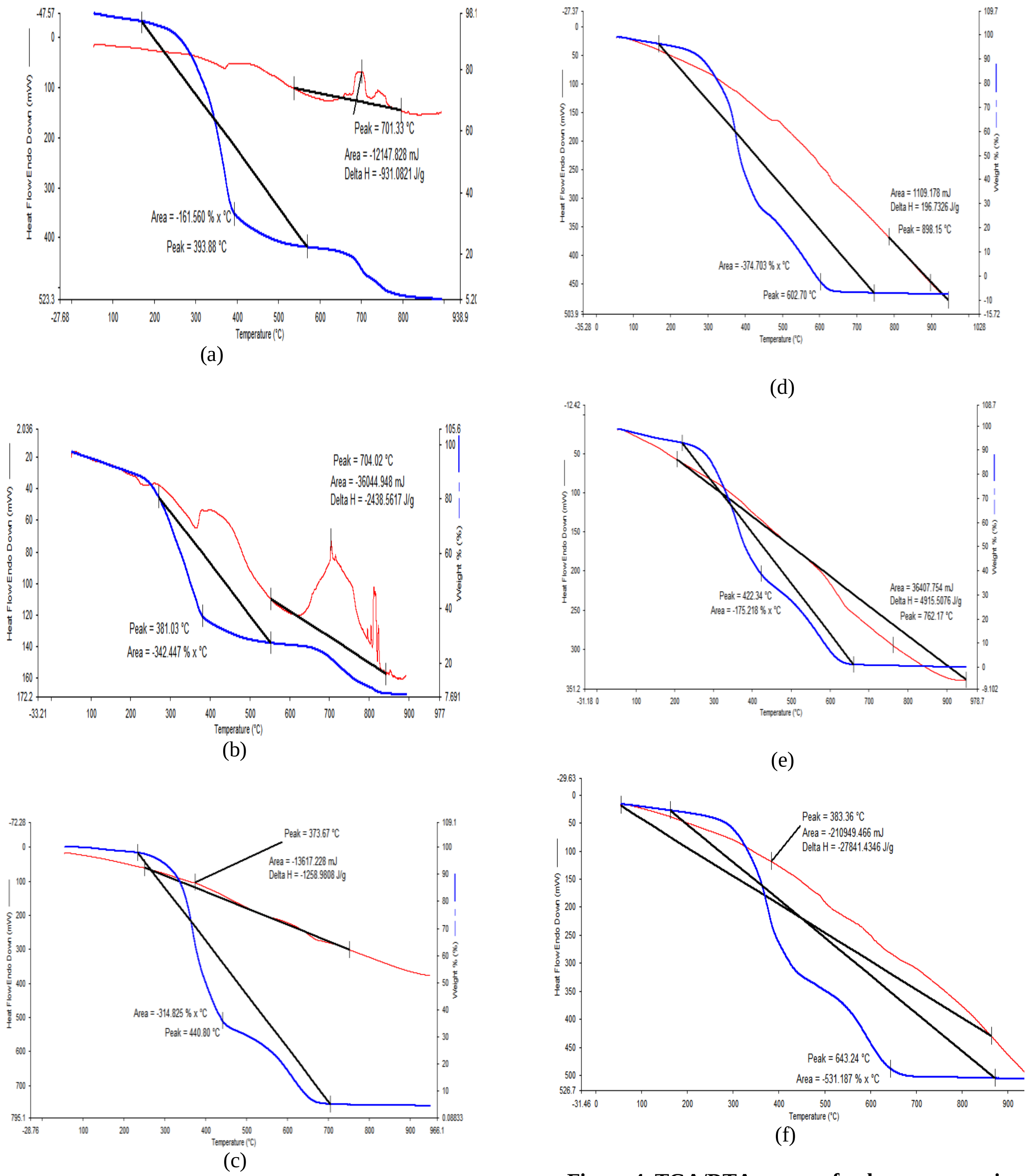


Figure 4. TGA/DTA curves of polymer composites (a) Polypropylene, (b) Epoxy (c)Rice Husk+ Epoxy, (d)Banana + Epoxy, (e) Banana + RH+ Epoxy and (f) Glass fiber + Epoxy

5. Conclusions

The research work has preponderantly investigated on the mechanical performances and thermal properties of the polymer composites and the comparison of their experimental results.The mechanical properties such as compressive, impact, flexural and tensile properties are evaluated for six different composition of composites materials and was observed that the better mechanical properties was shown by natural hybrid composites and synthetic composites. Thus the results demonstrates that the banana impregnated rice husk epoxy composites shows the better values for all the mechanical properties which may compared to synthetic fiber of glass fiber.The thermal properties for the composition have been done by the following procedures. GA/DTA/DSC has taken for all the polymer fiber impregnated epoxy composites. From the TGA curve, maximum degradation has occurred after the 410^{o}c for all the composition are shown. From the DTA curve, the heat flow of the particles will be at the range of 450^{o}c to 570^{o}c for the compositions obtained. For the best result of thermal stability will be banana fiber is impregnated with rice husk for natural fibers and for synthetic glass epoxy shows better result.

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