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Development and Performance Analysis of Jute Fiber and Alumni Powder Reinforced Phenol Formaldehyde Hybrid Composites

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Abstract— Increasing worldwide environmental awareness is encouraging scientists and engineers to concentrate on eco - friendly components available in natural resources. Continuous search is on by academic research and Industrial research for new materials since 20 th century. Composites, the wonder material with lightweight, high strength-to-weight ratio and stiffness properties have come a long way in replacing the conventional materials like metals, woods etc. Therefore, Composites of polymers both (thermoset and thermoplastic) with available natural resources received greater focus. Combination of materials with identifiable interface is denoted as composite. Composite has really revolutionized the concept high strength and low weight concept. Further natural fiber reinforce components are strong, stiff, light weight, recyclable with high mechanical properties, high electrical insulation properties for breakdown resistance Filler reinforced material consists of fillers embedded in or bonded to a polymer matrix with distinct inter phases. The fillers can be in the form of plastics, fibers, whiskers or flakes. The combination of filler with the matrix and natural fiber produces enhanced values of mechanical properties that cannot be achieved by either of the constituents acting alone. Composite Polymers are extensively used in many engineering applications such as automotive, sports goods, marine, electrical, industrial, household appliances, more sustainable construction and packing materials.

General tendency of man is to lead a comfortable life. For this, he needs new and useful material. Composite materials allow a great versatility of designs and offer many advantages over conventional materials. Polymer matrix can be processed at room temperature compared to other types of matrixes. Due to the availability various thermosetting resins such as epoxy, viny Lester, polyester, phenolic polyamides, cyanate ester etc.

It is noted that though continuous search of composites is on at various Countries, scope for further requirements of human race is still to be explored in present work, Alumni powder with jute fiber reinforced phenol formaldehyde composites have been planned to make hybrid composite samples as per ASTM standards, using hand layup process. The treated and untreated samples of composites with variable percentage weights fiber loading will be used for testing the mechanical properties and thermal properties as per ASTM standards. Further evaluation of chemical resistance and electron microscopy (SEM) will be conducted for the performance of the composites.

Recently, the demand for reinforced plastics from natural, sustainable, biodegradable, and environmentally friendly fibers has been rising worldwide. However, the main shortcoming of natural fibers reinforced plastics is the poor compatibility between reinforcing fibers and the matrix. Hence, it is necessary to form a strong attachment of the fibers to the matrix to obtain the optimum performance. In this work, chemical treatments (acid pretreatment, alkali pretreatment and scouring) were employed on jute fibers to modify them. The mechanical properties, surface morphology, and Fourier transform infrared spectra of treated and untreated jute fibers were analyzed to understand the influence of chemical modifications on the fiber.

Then, jute fiber/epoxy composites with a unidirectional jute fiber organization were prepared. Basic properties of the composites such as the void fraction, tensile strength, initial modulus, and elongation at break were studied.
The better interfacial adhesion of treated fibers was shown by scanning electron microscope (SEM) images of fractured coupons. Hence, the chemical treatment of jute fiber has a significant impact on the formation of voids in the composites as well as the mechanical properties of jute fiber composites applications as in aerospace, automotive, medical science and marine industries. In this paper the mechanical behavior of jute fiber-aluminum (Al) powder polymer composite has been investigated experimentally.
The materials selected for the studies were jute fiber and aluminum powder as the reinforcement and epoxy resin as the matrix. The hand lay-out technique was used to fabricate these composites. Composite plates were prepared by incorporating jute fiber and aluminum powder at 8 and 16 volume percent in epoxy matrix. Results showed that the overall tensile strength, impact property, hardness, young's modulus and comparison of strength of hybrid composites (reinforced by both powder and fiber) is higher than other single reinforced composites.
By incorporation of natural fibers and metal powder into the polymer, the mechanical properties almost enhanced to greater extent. It can thus be inferred that jute fiber and Al powder can be a very potential candidate in making of composites for low load bearing.
***Keywords*— Jute fiber, composite, chemical, surface openness, physical properties, tensile properties, Polymer composite, mechanical property, phenol formaldehyde, alumini powder.**

I. INTRODUCTION

During the last few decades, composite materials have gained much attention from researchers in the fields of materials science and engineering materials. Broadly, composite materials can be categorized into three categories in terms of the matrix used: polymer matrix composites, metal matrix composites, and ceramic matrix composites. Among them, polymer matrix composites have various advantages over the other two, including a lower volume-to-weight ratio, a higher specific strength-to-weight ratio, the ability to be formed into different shapes and sizes, resistance to corrosion, as well as a simple manufacturing process, recyclability, and lower cost.

Therefore, fiber-reinforced plastics have successfully replaced their heavy metal and ceramic as well as expensive engineering plastic counterparts. In general, fiber-reinforced plastics are either made up of thermoplastic or thermoplastic resin as a matrix, with either synthetic or natural fibers as a reinforcing material. Due to the large amounts of debris they generate and the scarcity of fossil fuels, more and more attention has been paid to the use of sustainable, biodegradable, and green composites. Natural fiber-reinforced composites fulfill these requirements, however, there is still much to be explored to gain the full benefit of these composites.

Jute is the second most natural and biodegradable fiber. Jute fiber is an excellent alternative when strength, thermal conductivity, and cost are major concerns. In addition, jute fibers are eco-friendly. Nowadays, jute fiber-reinforced polymer composites have become an important area of research. Typically, jute fiber is used for basic and low-end textile products. If the properties of jute could be modified in favor of high value and technical textiles, not only the cost but also the environment would benefit a great deal. Jute is composed of cellulose (45–71.5%), hemicelluloses (13.6–21%), and lignin (12–26%) . Lignin, due to the many aromatic rings inside of it, is responsible for mechanical support Any material besides cellulose that hampers the smoothness, pliability, and fineness of jute is denoted as gum.

Incompatibility between natural fibers and the matrix affects the interaction adhesion of the fiber with the matrix, which results in a poor fiber–matrix interface. The weak interface reduces the fiber's reinforcing efficiency due to a lack of stress transfer from the matrix to the

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fibers. By opening the cellulose content and removing unnecessary materials, chemical treatment makes fibers smooth (by removing the gum), easy to adhere, durable, and flexible and has a lasting effect on the mechanical behavior of natural fibers, especially on their strength and stiffness. The chemical treatment of cellulose to obtain various new functions and properties is pervasive. Recently, some eco-friendly approaches have been reported for the deacidifying consolidation of cellulosic structures to make it suitable for long-term prevention. Alkaline treatment (or mercerization) is a widely used chemical treatment for natural fibers. It disrupts hydrogen bonding in the network structure and reduces fiber diameter, thereby increasing the aspect ratio. Different kinds of surface treatments of jute fibers have been reported recently, including saline treatment, alkali treatment, and saline + alkali treatment of jute fibers and their corresponding jute fiber- reinforced composites with epoxy resin as a matrix to study their thermal and mechanical properties using vacuum-assisted resin infusion. In another study, micro-silicone and fluorocarbon, two well-known finishing agents of textiles, were used to enhance the surface properties of jute fabric-reinforced composites with a polyester matrix and their flexural, tensile, and inter laminar shear strength were analyzed.

Herein, we treated the fibers chemically before making composites and compared the tensile properties of the produced composites with that of untreated jute fiber composites. Since voids greatly influence composite tensile properties, the volume fractions of voids of the treated jute fiber composites were also measured and compared with those of the corresponding raw jute composites. The quest for light weight and high strength materials, the polymer composites are an important member in the application of light structure. Because of their high strength-to-weight and stiffness-to-weight ratios, they are extensively used for a wide variety of structural applications as in aerospace, automotive and marine industries.

The fibers used are usually of glass, jute fiber or carbon. In particular, carbon and jute fiber fibers are usually used for high performance composites due to their properties and cost, while glass fibers are used for large volume production composites due to the good compromise between low cost and good performance. Due to so many advantages, they are widely used in aerospace industry, mechanical engineering applications (internal combustion engines, thermal control, machine components), electronic packaging, automobile, and aircraft structures and mechanical components (brakes, drive shafts, tanks, flywheels, and pressure vessels), process industries equipment requiring resistance to high- temperature corrosion and production, marine structures, sports, leisure equipment and devices Narayana Murthy. biomedical studied the hot working characteristics of sic and Al2O3 particulate reinforced polymer matrix composites. They proposed from productivity viewpoint that a high strain rate region in which high values of mass and efficiency are present should be selected for bulk working operations and the lower strain rate regions for secondary polymer working Evaluation of Mechanical Behavior of Jute Fiber-Aluminum Powder Reinforced Hybrid Polymer Composites 203 operations. Park et al. investigated the effect of Al2O3 in Aluminum for volume fractions varying from 5-30% and found that the increase in volume fraction of Al2O3 decreased the fracture toughness of the MMC. This is due to decrease in inter-particle spacing between nucleated micro voids.

II Materials and Methods

A. Materials

1. **Jute Fiber**: Jute fibers were obtained from a local supplier. The fibers were cut to a consistent length of 10 cm and subjected to chemical treatments to enhance the fiber-matrix adhesion.
2. **Aluminum Powder**: Aluminum powder with an average particle size of 40 microns was used as the second reinforcement material.
3. **Phenol Formaldehyde Resin**: A thermosetting resin was used as the matrix material for the composites.

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4. **Chemical Treatments for Jute Fiber**: The jute fibers were treated with three different chemicals:
- **Alkali Treatment**: Fiber was soaked in a 5% NaOH solution for 2 hours.
- **Acid Treatment**: Fiber was soaked in a 2% HCl solution for 1 hour.
- **Scouring**: The fiber was washed with distilled water to remove impurities.

B. Composite Fabrication

The hybrid composites were fabricated using the hand lay-up method. The fiber was placed in the mold, followed by the matrix material. The aluminum powder was mixed into the phenol formaldehyde resin at different volume fractions (8% and 16%). After curing, the composites were removed from the mold and cut into test specimens as per ASTM standards.

C. Mechanical Testing

The following tests were conducted to evaluate the mechanical properties of the composites:
- **Tensile Strength**: ASTM D638 was used to measure the tensile properties.
- **Impact Strength**: ASTM D256 was followed to assess the impact resistance.
- **Hardness Test**: ASTM D785 was used to determine the hardness of the composites.
- **Flexural Strength**: ASTM D790 was employed to measure the flexural properties of the composites.

D.Thermal and Chemical Resistance Testing
- **Thermal Conductivity**: The thermal properties were evaluated using a Differential Scanning Calorimeter (DSC).
- **Chemical Resistance**: The composites were immersed in acidic, alkaline, and saline solutions, and the changes in weight were measured to evaluate chemical resistance.

E.Scanning Electron Microscopy (SEM)

To analyze the fiber-matrix interface and the fracture surface morphology, SEM was used.

III. RESULTS AND DISCUSSION

A. Mechanical Properties

The mechanical tests revealed that the hybrid composites, which were reinforced with both jute fiber and aluminum powder, exhibited significantly higher tensile strength, impact resistance, and hardness compared to the single-reinforced composites. The tensile strength of the composite increased with the addition of aluminum powder, particularly at 16% powder content. The hybrid composites also demonstrated better impact resistance, likely due to the enhanced fracture toughness imparted by the aluminum powder.

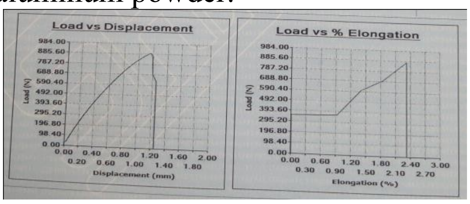

Figure 1: Tensile Strength

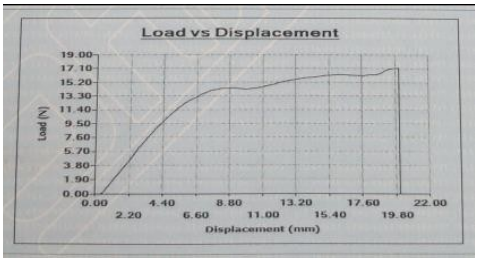

Figure 2: Flexural Test

B. Thermal Properties

The thermal analysis showed that the incorporation of aluminum powder helped in improving the thermal stability of the composites. The thermal conductivity increased with higher aluminum

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powder content, which suggests that the hybrid composites could perform well in applications requiring heat resistance.

C. Chemical Resistance

The chemical resistance of the composites was found to improve with the addition of aluminum powder. The hybrid composites exhibited minimal weight loss when exposed to acidic and alkaline solutions, indicating their robustness in harsh environments.

D. SEM Analysis

SEM images of the fractured surfaces revealed that the interface between the jute fiber and phenol formaldehyde matrix was significantly improved by the chemical treatments. The treated jute fibers showed better adhesion to the resin, reducing the formation of voids in the composite and improving its overall mechanical properties.

IV. CONCLUSION

The results from this study demonstrate that jute fiber and aluminum powder reinforced phenol formaldehyde hybrid composites possess enhanced mechanical, thermal, and chemical properties compared to single-reinforced composites. The incorporation of aluminum powder significantly improved the tensile strength, impact resistance, and thermal conductivity of the composites. Chemical treatments on jute fibers also played a crucial role in improving fiber-matrix adhesion, leading to better overall composite performance.

These hybrid composites have promising applications in industries such as automotive, aerospace, and marine, where lightweight materials with high strength and thermal resistance are required. Future work could focus on optimizing the reinforcement ratios and exploring additional surface treatment methods for further improvements in composite performance.

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