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Advances in Composite Materials: A Review of Rice Husk, Jute Fiber, and Nano Powder-Based Composites

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ABSTRACT :

This study explores the synthesis and characterization of composite materials created by combining rice husk, jute fibre, and epoxy resin with two types of nano powders: Nano Powder A (Sio2) and Nano Powder B (ZNO). The composites are prepared in various ratios: A1 (0% Nano Powder A +25% jute +60% epoxy + 15% RH), A2 (2% Nano Powder A + 20% RH+30%jute+48% epoxy), A3 (4% Nano Powder A +35% jute +36% epoxy +25% RH), A4 (6% Nano Powder A +40% jute + 30%epoxy + 24% RH);B2 (2% Nano Powder A +30% jute +48% epoxy + 20% RH), B3 (4% Nano Powder A +35% jute +36% epoxy + 25% RH), B4 (6% Nano Powder A +40% jute +30% epoxy + 24% RH).The composite samples, fabricated to standard dimensions (ASTM D638, ISO 527, ISO 6892), have a gauge length of 64 mm, a width of 13 mm, and a thickness of 3.2 mm. Mechanical properties such as tensile strength, hardness, and impact resistance are rigorously tested to assess the structural integrity of the composites. This in-depth analysis aims to determine the optimal material formulations for enhanced performance, offering valuable insights into potential industrial applications of these RH, jute fibre, and epoxy resin-based composites.

Keywords: Epoxy Resin Jute Fiber Silicon Dioxide nano (SiO2) Zinc Oxide nano (ZnO) Rice Husk

Abbreviations

SiO2 Silicon Dioxide nano
ZnO Zinc Oxide
RHC Rice Husk Composite
RH Rice Husk
ASTM American Society for Testing and Materials

Introduction :

A composite material, commonly referred to as a composite, is created by combining two or more constituent materials with significantly different chemical or physical properties. The resulting material possesses characteristics that are distinct from its individual components. In composites, the separate elements remain distinct and identifiable, distinguishing them from mixtures and solid solutions. When a composite material consists of multiple distinct layers, it is termed a composite laminate.

A nano composite is a multiphase solid material where at least one phase has dimensions less than 100 nanometres (nm), or where the material has nano-scale distances between its different constituent phases. Composite materials are valued for their high strength-to-weight ratio, allowing them to be both stronger and lighter than traditional materials like steel, making them ideal for aerospace, automotive, and sports applications. They offer high stiffness, corrosion resistance, and fatigue resistance, as well as good thermal and electrical conductivity properties that can be tailored for specific uses. With excellent dimensional stability, low thermal expansion, and high energy absorption, composites are well-suited for harsh environments and protective applications. Their design flexibility allows for complex shapes, enabling innovation in industries where lightweight, durable, and efficient materials are critical. Additionally, composites can have a lower environmental impact due to their longevity and recyclability.

Literature Survey :

[1] This study assessed the mechanical viability of jute fiber-reinforced bioepoxy (JFRB) composites for ship hulls submerged in seawater, as a sustainable alternative to glass fiber-reinforced plastics. Results showed only a 4% variation in tensile modulus, 1.5% in tensile strength, and a 7% increase in elongation at break after seawater immersion. Finite element simulations indicated that increasing the thickness of a JFRB hull could match the mechanical performance of GFRP, with only an 11% increase in weight.

[2] The study explores the potential of jute-polypropylene (jute-PP) composites as sustainable materials for building insulation, highlighting their durability and reduced water absorption due to improved bonding. The composite was created by layering jute fabric and polypropylene sheets, compressed at 180°C under 5 tons of pressure. Mechanical properties were tested for tensile strength, flexural strength, burning behavior, and thermal conductivity. While the composites show promise for reducing carbon emissions in green building designs, challenges include insufficient adhesion

between jute fibers and the polypropylene matrix, leading to voids and weakened performance, as well as fiber degradation from high processing temperatures and pressures.

[3] This paper investigates hybrid jute and hemp fiber composites with bio-epoxy as the matrix, focusing on their mechanical and thermal properties under different stacking sequences. As researchers move towards eco-friendly materials, the composite, with hemp as the skin layer and jute as the core, demonstrates higher tensile and flexural strength, though interlaminar shear strength decreases. Overall, the approach shows promise for enhancing tensile and flexural strength, making it suitable for lightweight structural applications.

[4] This study examines the effect of adding Nano-alumina to epoxy resins, showing a 64% improvement in fracture toughness as the weight fraction increases from 0.1% to 0.5%, enhancing toughness from 1.48 MPa to 2.43 MPa. This improvement is attributed to a larger fracture process zone, which grows from 0.28 mm to 0.93 mm, allowing for more energy dissipation during fracture. Controlled specimens are prepared by mixing thermoset polymer and hardener, curing for 72 hours, and then cutting and polishing the samples to introduce a sharp notch for testing.

[5] This study used waste jute bags to synthesize nano cellulose, which was incorporated into unsaturated polyester resin composites. Adding 0.2% (w/w) nano cellulose significantly improved the composites' mechanical properties. Exposure to 5.0 KGy gamma radiation further enhanced the properties, with a 210% increase in tensile strength and a 200% increase in bending strength. Composites were fabricated using the hand-lay-up technique, and mechanical properties like tensile strength, bending strength, and impact strength were measured. A challenge faced was the lack of new functional groups despite gamma radiation-induced free radical reactions.

[6] This study explores the use of wood varnish coating to reduce water absorption in jute fiber-reinforced epoxy composites, addressing the negative impact of water on mechanical properties. Four composite types were fabricated: Type 1 (no coating), Type 2 (composite surface coated), Type 3 (fiber coated), and Type 4 (both fiber and composite coated). Type 2 showed the best performance in water absorption and mechanical properties. Composites were made using the hand lay-up technique, with challenges in ensuring adhesion and minimizing air bubbles. Various mechanical tests, including water absorption, tensile, bending, shear, and impact tests, were conducted following ASTM standards.

[7] This study uses gradient boosting machine learning to predict surface roughness in machining, validating predictions with experimental and numerical methods. Turning experiments were designed using Taguchi's L27 orthogonal array, examining spindle speed, feed rate, and depth of cut. Optimal conditions for smoother surfaces included higher spindle speeds, lower feed rates, and shallower cuts. Additionally, a hybrid jute-basal epoxy composite was created by alternating jute and basalt fiber meshes, applying resin, and winding the composite around a mandrel using a filament winding machine.

[8] This paper investigates the low-velocity impact on jute/epoxy composites, using fractured samples for CT scanning to predict damage areas. Various energy absorption tests, including impact testing, were conducted. The results showed that material thickness significantly affected impact resistance, with 10 J causing more damage on the 3 mm thick plate and 15 J causing more damage on the 6 mm thick plate. The composites, made from jute fabric, epoxy resin (Araldite LY556), and hardener (HY951), were found to be well-suited for lightweight applications.

[9] This paper explores a hybrid laminate of jute and glass fiber reinforced with polyester resin, using Representative Volume Element (RVE) modeling in ANSYS. Tensile and bending tests, along with shear stress analysis, were conducted. The results showed that adding glass fiber to jute fiber enhanced the composite's mechanical properties, increasing the Young’s modulus. The glass fiber/polyester (S1) composite had the highest Young’s modulus at 6.44 GPa, while the jute fiber/polyester (S6) composite had the lowest at 3.86 GPa.

[10] This paper examines the impact of oxidative thermal decomposition on jute fiber quality during composite production. Jute fiber was modified with amino silicone oil and analyzed using thermogravimetric analysis. The study also explored how varying jute fiber content affects the mechanical and sound absorption properties of composites. Bending, tensile, and sound absorption tests were conducted, and the transfer function measurement method was used for analysis.

[11] This study develops hybrid composites using jute and glass fibers, analyzed through statistical methods (ANOVA) to improve mechanical properties like flexural strength and hardness. Results show that composites with 90-degree fiber orientation and 5% nanoparticle content achieve a 40% increase in flexural strength and 20% in hardness. The composites were made by mixing glass, rice husk, and jute textiles with epoxy resin (LY556) and hardener (HY951) in a 10:1 ratio. After shaping in a steel die, the samples were cured at room temperature and post-cured at 60°C to remove moisture.

[12] The abstract highlights the benefits of natural fiber reinforced polymer composites, focusing on their eco-friendly, biodegradable, and cost-effective qualities. Jute, known for its durability and low cost, is used in hybrid composites with nonwoven glass fabric to enhance mechanical properties and reduce glass content, promoting sustainability. The process involves drying bleached jute fabric at 100°C for 60 minutes, followed by cutting both jute and glass fabrics into 8-inch squares for composite fabrication.

[13] This research evaluates the physical, mechanical, and thermal properties of hybrid epoxy resin composites reinforced with rattan, carbon, and jute fibers, using two types of rattan fibers. The composites were fabricated using the hand lay-up technique, with woven fiber layers bonded by epoxy resin, followed by high-pressure and temperature curing to ensure proper adhesion and reduce porosity. Mechanical tests, including tensile, flexural, and hardness tests, were conducted to assess the composites' performance. A key challenge faced was the presence of porosity and air bubbles, which could affect the mechanical properties.

[14] This review explores the growing interest in natural fiber epoxy composites as eco-friendly alternatives to synthetic materials, particularly for structural applications due to their impact strength. It examines factors affecting impact strength, such as fiber content, length, stacking sequence, and treatment techniques. The review highlights challenges like poor fiber/matrix bonding, fiber variability, moisture absorption, and manufacturing methods. It discusses techniques such as hand lay-up, compression molding, and vacuum infusion, noting that longer curing times, up to 108 hours, can improve impact strength. Poor bonding remains a key challenge, often due to fiber hydrophilicity and inadequate manufacturing processes.

[15] This paper explores the development of sustainable lightweight cementitious composites using untreated rice husk, embedded in foamed concrete and aged with acidic and basic solutions. The aim is to achieve long-term durability without expensive fiber treatments. Results showed that even after organic degradation, the rice husk composites maintained good mechanical performance, especially in axial compression, due to the formation of chemical compounds like calcium carbonate and calcium silicate hydrate, which help prevent strength loss.

[16] This paper investigates the effects of alkali and PVA binder treatments on the impact performance of jute composites at 3 J and 6 J impact energy levels. The study used jute fiber reinforcement, PVA binder, and alkali treatments, conducting low-velocity impact tests, fractographic image analysis, and damage analysis on the specimens.

[17] This study develops hybrid composites using jute and glass fibers, incorporating silica (NS) particles to enhance mechanical and dynamic properties. The inclusion of 3 wt% NS particles improved tensile strength by 20% and flexural strength by 35.7%. The interaction between NS, epoxy, and fiber enhanced interfacial stress, positively affecting the composites' dynamic properties, including natural frequency and damping ratio. Composites were made using a hand lay-up process, cured at 80°C and 120 KPa for 1 hour. Mechanical tests (tensile, flexural) and vibration tests (natural frequency, damping ratio) were conducted according to ASTM standards.

[18] This study develops lightweight, strong hybrid composites using a ductile epoxy resin matrix reinforced with jute fibers, silica nanoparticles, and nano-fillers, fabricated through solution casting and hot pressing. While nano-fillers improve strength and stiffness, they reduce toughness. The CNT/jute and silk fiber/epoxy composites show the highest tensile and impact strength, while CNF-reinforced composites exhibit the highest breaking energy. The composites are processed with mechanical stirring and ultrasonic dispersion to ensure uniform filler distribution. Mechanical tests, including impact, tensile, and three-point bending tests, evaluate strength, toughness, and stiffness, while thermogravimetric analysis assesses thermal stability.

[19] This study examines the fabrication of basalt fiber-reinforced composites with silicon dioxide (SiO_2) nanofillers, using a hand layup technique and vacuum bagging. The composites, measuring $300 \times 300 \times 3$ mm^3, showed a 178% increase in flexural strength and a 26% increase in flexural modulus with the addition of SiO_2 nanofillers. These nanofillers also enhanced the composites' ability to withstand tensile stress and deformation, leading to greater yielding and plastic deformation before failure.

[20] This study explores the effect of zinc oxide nanoparticles (ZnONPs) surface treatment on the flexural properties of kenaf fiber (KF)-reinforced unsaturated polyester (UPE) composites. It was found that KF composites treated with 2% ZnONPs exhibited a higher flexural modulus compared to untreated composites. The process involved preparing a ZnONPs solution, submerging the KF in it, and then drying before fabricating the composites. Flexural properties were tested to evaluate the improvements.

[21] This study examines the mechanical and thermal properties of Prosopis juliflora fiber composites reinforced with ZnO nanofiller, focusing on their potential for environmental sustainability. The composite is made by mixing PLA resin and ZnO nanofiller in a 10:2 ratio, layering the mixture with fiber in a mold, and applying pressure to minimize air pockets. The composite is cured at 135°C for 3 hours and post-cured at 115°C. Thermal properties, including linear thermal expansion and VICAT softening temperature, are measured according to ASTM standards. Scanning electron microscopy (SEM) and thermo gravimetric analysis (TGA) assess thermal stability and failure modes.

[22] This study enhances jute-cotton fabric properties by applying TiO_2 and ZnO nanoparticles, synthesized via the sol-gel method and applied using a dip-pad-dry-cure technique with an acrylic binder. While the treatment improved certain properties, it slightly reduced mechanical strength, with tensile strength decreasing from 483.87 N to 432.87 N, highlighting a trade-off between enhanced functionality and mechanical integrity.

Conclusion:

The experiments focused on enhancing the mechanical properties of various composite materials, revealing significant improvements in surface roughness, mechanical strength, and durability. A minimum surface roughness of 0.773 µm was observed experimentally, while machine learning models predicted slightly higher values. The maximum and average prediction errors for these models were 3.78% and 2.24%, respectively. The study also demonstrated that adding 0.5 wt% nano-silica increased the natural frequency of the composite by 20.5%, from 77.62 Hz to 93.6 Hz. Notably, a hybrid composite with a 90-degree fiber orientation and 5% nanoparticle content exhibited a 40% increase in flexural strength and a 20% improvement in hardness compared to earlier configurations. Jute-polypropylene composites were shown to be highly sensitive to fiber arrangement and adhesion to the matrix, while epoxy composites reinforced with natural fibers like banana fibers had a 40% higher impact strength. Chemical modification of fibers significantly enhanced the bonding with the epoxy matrix, further improving mechanical properties. Additionally, composites with 20% jute fiber content were found to exhibit the best overall mechanical performance. Nano-materials such as SiO_2 and CNTs also played a crucial role in enhancing hardness, tensile strength, and impact resistance. Specifically, composites with 6 wt% SiO_2 achieved the highest hardness of 86, while the inclusion of nano-alumina in epoxy resins improved fracture toughness and durability. Zinc oxide nanoparticles (ZnONPs) were particularly effective in improving the flexural properties of unsaturated polyester/kenaf composites and demonstrated a sustainable approach to enhancing natural fiber-reinforced materials, although excessive ZnONPs concentrations led to a decline in flexural modulus. The use of ZnONPs in Prosopis juliflora composites resulted in a 27.9% improvement in mechanical performance, underscoring the material's potential for various applications.

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