

Investigation on Hardness Properties, Moisture Absorption and Structural Analysis of Hybrid Polymer Composites

Sunil H V¹, E. Basavaraj²

¹Assistant Professor, Department of Mechanical Engineering, Sahyadri College of Engineering & Management, Mangaluru

²Professor and Head, Department of Mechanical Engineering, Jawaharlal Nehru New College of Engineering, Shivamogga

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Abstract—In this research article, the easily available natural fiber like Areca Sheath, Coconut Shell and Jute was used as a reinforcement material. The reinforcement was considered in the range of 5%, 10%, 15%, 20%. Initially the natural fibers like Areca, Coconut Shell, and Jute were collected from local regions and allowed it to dry for more than one week to remove unwanted moisture. Later that natural fiber was chopped into small pieces and exposed to mill to make a macro size particle. The Epoxy LY556 was used as a matrix and Hand Lay Up technique was adopted to prepare the Hybrid Composites. Four Combination of Hybrid Composites (Sample H1, H2, H3, H4) were prepared for testing. The Physical Properties like Hardness Test was conducted on Hybrid Composites. Water Absorption test was conducted by immersing a sample in a water for more than 300 Hours. Structural Analysis were carried out using Ansys by considering individual material like Areca, Coconut Shell and Jute to find Von Mises stress. The results show that as the reinforcement weight fraction increases, the hardness value increases. In moisture test, as the reinforcement percentage increases, Composite absorb more water.i.e. for 20% reinforcement, composites absorb water up to 288 hours and later remains constant. The maximum Von – Mise’s stress was found for Coconut Shell material (5.746×10^6 N/m²), whereas for jute material minimum Von – Mise’s stress was found.

Index Terms—D – Shore Hardness Test, Hybrid Polymer Composites, Natural Fiber, Structural Analysis

I. INTRODUCTION

Composites are materials that are formed by combining two or more different constituents to achieve enhanced properties compared to the individual constituents. The three main types of composites include metal matrix composites that are strong and can withstand high temperature; ceramic matrix composites that are resistant to thermal-induced damage; and polymer matrix composites. PMCs are the most widely used type of composites because of the properties of the material that includes low density that is good for lightweight, good workability, and cost-effective in industrial setting [8]. Polymer matrix composites are composites that utilize a polymer resin, a thermoset or a thermoplastic, along with fibers or fillers to improve performance. Fiber or polymer removal is employed for a lightweight, high-strength solution and design freedom [6]. In several instances, tensile strength and impact resistance were found to be highly affected by fiber orientation. The product is used in the aerospace, automotive and construction industries. It combines well physical and thermal properties. It, the meantime, lowers total hollow structure weight.

Hybrid composites are formed by the addition of mixture of two or more dissimilar fibers or fillers into one polymer matrix. The mixing increases strength, toughness, fatigue resistance, and endurance comparable to that of composites made up of mono reinforcements. It has been demonstrated by research that design inspired by large flexibility and compressive toughness can be achieved by copying

natural design, and their toughness can still be increased using nano reinforcements. As a result of applying conventional approaches during production procedure, such as additive manufacturing is used currently and naturalistic fibers, hybrid composites are becoming more flexible, ecologically sound, and accessible for utilization in a range of advanced engineering applications [20].

Natural fibers, such as coconut shell, areca, and jute, have been developing in their application as a substitute for synthetic fibers for composites. While synthetic fibers usually give composites better strength, natural fibers are degradable, renewable, cheap, and can mitigate the concerns on environmental pollution. Thus, properties can be improved with chemical treatment and mix ratio optimization. It has been proven that natural fibers, while combination of reinforcements helps in enhanced thermal stability and mechanical properties of the composites, but still under incipient stage. The light-weight, renewable, and agriculture waste-readily-available natural fibers are suitable for material development for sustainability. The present study included the natural reinforcements areca and coconut shell powder, and the reinforcements improve the strength, hardness, and toughness as well as the reduced environment, which leads to sustainable friendly and cheaper engineering applications [21].

P.M. Arun et.al [1] Investigated the effect of fiber orientation on the mechanical characteristics of hybrid polymer composites. They observed that fiber orientation greatly effects tensile strength and impact resistance. J. Liu et.al. [2] Focused on bioinspired design and production of hybrid composites. Their investigation indicated that natural structural patterns promote flexibility and toughness. F Mansouriet.al. [3] Evaluated polymer nanocomposites experimentally, highlighting increased mechanical performance for high-performance applications with the usage of nanoscale reinforcements. A.M. Strong and T.A.Payne[4] Reviewed aerospace uses of polymer-based hybrid composites, emphasizing their lightweight, high strength, and thermal stability for structural use. T.Q. Nguyen et.al. [5] Presented a review of materials and production improvements in polymer hybrid composites, including modern techniques like additive manufacturing and environment friendly materials. E. Hechtetal. [6] Explored composites with higher durability,

demonstrating resilience to environmental deterioration and mechanical fatigue due to innovative hybrid reinforcement. S.Kumar et.al [7] Studied thermal and mechanical performance, finding that hybridization with proper fiber combinations improves both thermal stability and strength. R.N.Raja and S.Das[8] Conducted comparative research of natural vs. synthetic fiber reinforced hybrids, indicating that while synthetic fibers give more strength, natural fibers are suitable for sustainable composites. Y. Wang et.al. [9] Used optimization strategies to improve mechanical properties of natural fiber-based hybrid composites, focusing on fiber treatment and mix ratios for better performance. R. Ramasubbu et al[10] Studied epoxy composites reinforced with Areca catechu fibers and silicon carbide. Results demonstrated enhanced stiffness, strength, and surface hardness due to consistent filler distribution. S. O. Adefemi and M. A. Yusuff [11] Optimized mechanical properties of polyester/coconut shell composites, showing enhanced hardness and wear resistance while keeping lightweight features. A. M. Abass [12] Investigated physical and mechanical properties of coconut shell particle reinforced epoxy composites findings demonstrated greater tensile strength and durability compared to neat resin. C. K. Ojong and S. B. Biswas [13] Evaluated composites reinforced by processed coconut husk powders. Results revealed enhanced flexural strength and moderate impact resistance. S. R. Prakash et al. [14] Explored biodegradable hybrid composites employing areca leaf sheath and tamarind seed powder in epoxy. Their investigation indicated greater stiffness, toughness, and eco-friendly possibilities. M. Ahmadietal.[15] Conducted an experimental investigation on polymer-based hybrid composites under mechanical loading. The results indicated higher mechanical strength and structural performance due to hybrid reinforcement.

K. Balaji et al. [16] Evaluated mechanical characteristics of biodegradable coconut shell powder-epoxy composites. The study identified appropriate filler ratios for increasing tensile and flexural strength. R. M. Reddy [17] Studied mechanical characteristics of coconut shell reinforced polymer matrix composites. The results demonstrated good wear resistance and surface hardness improvements. N. B. Choudhury and P. K Pal [18] Conducted a comparative investigation on epoxy-

based composites packed with pineapple, areca, and ramie fibers. The study concluded that hybrid fillers improve toughness and mechanical stability. The novelty of this research article is to explain the Physical and structural properties of Hybrid Polymer Composites and static analysis to find parameter on automotive component.

II. METHODS AND METHODOLOGY

Collection of Materials:

Areca Fiber: Waste Areca Sheath was collected from industries, exposed to sunlight for a week to remove unwanted moisture present in the Areca Sheath. Later by using sand paper it was rubbed to remove unwanted impurities. once it was dried Areca sheath was chopped into small pieces and exposed to a mill to convert into macro size Areca Powder.



Fig1: Areca sheath chopped into small pieces to make Particle.

Coconut Shell: Waste Coconut shell was collected from Mangalore local hotel and exposed to sunlight for a week to remove unwanted moisture present in the Coconut Shell. Later by using sand paper it was rubbed to remove unwanted impurities. once it was dried Coconut shell was chopped into small pieces manually by using a hammer and exposed to a mill to convert into macro size Coconut shell Powder.



Fig 2: Coconut Shell Powder

Jute Fiber: Jute is a natural fiber extracted from the stem of the jute plant. It is a long and flexible fiber and strong and is mainly used for ropes, bags, and mats. 1KG Jute was borrowed from Chennai. Allowed Jute fiber to dry by exposed to sunlight for more than a week, so that wet content present in the fiber was vanished. Later Jute fiber was cut into small pieces and is hammered manually to convert into macro size Jute Particle.

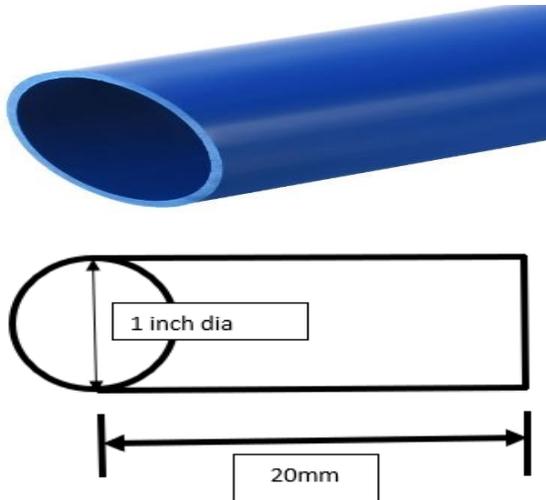


Fig 3: Jute Fiber Collected from Chennai

Epoxy Resin and Hardener: The resin is the precursor to a composite's structure. It is primarily a viscous liquid material that serves as a matrix to hold the reinforcement's particles or fibers the precursor to a composite's structure, transmits the stress applied to it, and gives it shape and helps to carry the applied loading[19]. Epoxy LY556 resin was chosen in this project due to the following reasons; high strength, good adhesion, chemical resistance, and dimensional steadiness.



Fabrication of Hybrid Composites



To Fabricate the Hybrid Composites Hand Lay Up technique was used. A PVC Pipe of diameter 1inch (25.4 mm) and length 20mm was used to prepare the Hybrid Composites.



Fig 4: Prepared Hybrid Composite

Table I: Hybrid Composites Combinations:

Sample Name	Epoxy (Matrix) %	Reinforcement%		
		Areca	Coconut Shell	Jute
H1	95%	2%	2%	1%
H2	90%	4%	4%	2%

H3	85%	6% Areca	6% Coconut Shell	3% Jute
H4	80%	8% Areca	8% Coconut Shell	4% Jute

III EXPERIMENTATION

Hardness Test: Four Samples (H1, H2, H3, H4) were prepared according to ASTM D2240. For each combination 3 Samples were prepared and carried 5 Trails and later calculate the average Hardness Value for all Combination.

Moisture Test: Water Absorption test was conducted for four samples (H1,H2,H3,H4). Initial weight was observed for all Samples before they were immersed in water. Specimen were kept in a water for 480 hours. Initial weight was observed for all Samples. After every 24 hours samples were taken out and wipe with the help of cotton cloth and then measured the weight. By taking the difference between initial weight and final weight, the Hybrid composites water absorption percentage was calculated.

Design of Brake Pad:

The design of a brake pad includes several critical elements to ensure functionality, safety, and durability. Using SolidWorks several analyses were made.



Fig 5: Design of Brake Pad

Analysis and Simulation: Analysis was carried out using Ansys software to find the parameter of deformation and stress induced in a brake pad by considering the individual properties of Areca Sheath, Coconut Shell, and Jute.

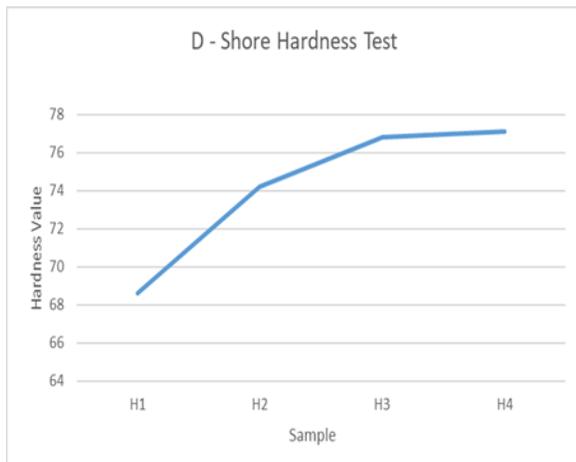
Table II: Properties of Material

Item No	Part	Material	Density	Young's Modulus	Weight (g)	Quantity
1	Brake Pad	Areca Sheath	1.81 g/cm ³	21.65 GPa	0.01	1
	Brake Pad	Coconut Shell	0.745 g/cm ³	2.93 GPa	0.01	1
	Brake Pad	Jute	1.15 g/cm ³	19.75 GPa	0.01	1

IV. RESULTS AND DISCUSSION

Hardness Test:

Sample	Hardness Value
H1	68.6
H2	74.2
H3	76.8
H4	77.1



From the above D SHORE Hardness test for all samples (H1, H2, H3, H4), it was found that for the increase in reinforcement from 5% to 20%, the hardness value keeps on increases. For 95% Epoxy and 5% reinforcement, the hardness value shows 68.6 and for 90% Epoxy and 10% reinforcement the hardness value shows 74.2. Again, for reinforcement 15% and 20% the hardness value shows 76.8 and 77.1. Because of good adhesion between Matrix and reinforcement their increase in hardness value after increase the reinforcement weight fraction (5%, 10%, 15%, 20%). So as per the experimental value obtained we can utilize the Hybrid composites by increasing the reinforcement weight fraction up to 20% for Various Automotive, Aerospace applications.

Moisture Test: Moisture percentage v/s Number of hours were plotted for all the samples (H1, H2, H3, H4). It was found that for all the samples water absorption percentage increases as the number of hours increases. For sample H1 water absorption percentage increases up to 96 hours and later it remains constant as shown in Fig 6(a). For sample H2 water absorption percentage increases up to 216 hours and later it remains constant as shown in Fig 6(b). For sample H3 water absorption percentage increases up to 288 hours and later it remains constant as shown in Fig 7(a). For sample H4 water absorption percentage increases up to 288 hours and later it remains constant as shown in Fig 7(b). From the graph we can observe that as the percentage of reinforcement increases the hybrid composite absorb the water for longer duration. This shows that the hybrid composite has hydrophobic in nature. For sample H1 (5% reinforcement), composite absorbs the water for shorter duration. up to 96 hours, but for sample H4 (20% reinforcement), hybrid composites absorb the water for longer duration .i.e. up to 288 hours. So as the percentage of reinforcement increases the hybrid composite will have hydrophobic nature.

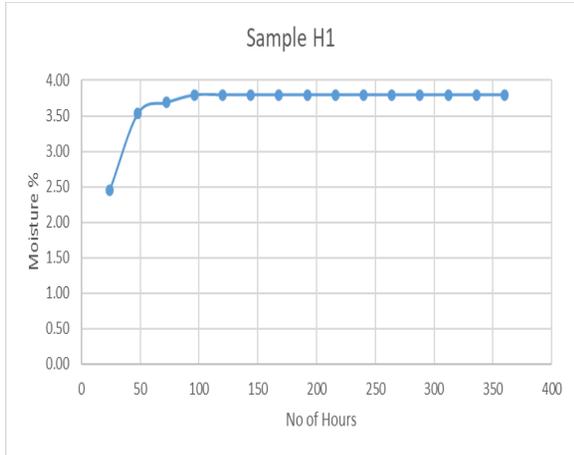


Fig 6: (a) Moisture % v/s No. of hours for sample H1

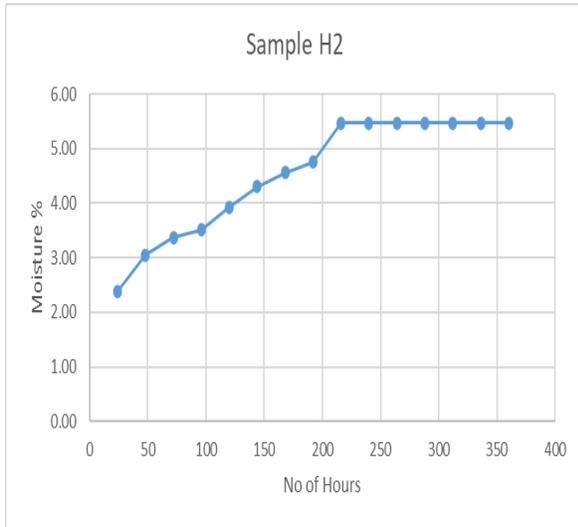


Fig 6: (b) Moisture % v/s No. of hours for sample H2

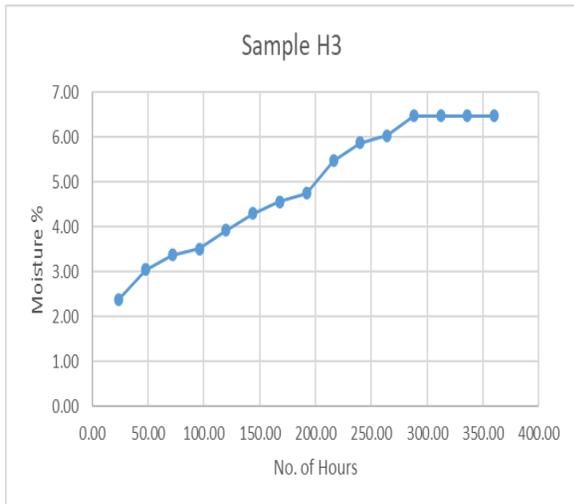


Fig 7: (a) Moisture % v/s No. of hours for sample H3

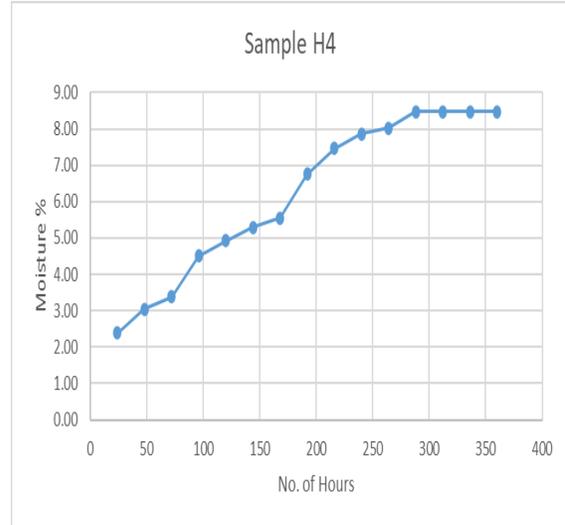


Fig 7: (b) Moisture % v/s No. of hours for sample H4
 Static Analytical Results: Von – Mises’s stress was calculated by structural analysis using Ansys by considering 3 material like Areca Sheath, Coconut Shell and Jute. The highest value of Von-mises stress. i.e. 5.746×10^6 N/m² was found for the material Coconut Shell as shown in Fig.9 whereas for the material jute lowest value of Von -mises stress was found i.e. 1.487×10^8 N/m² as shown in Fig.10.

Table III: Von Mises Stress

Material	Von Mises Stress(N/m ²)	
	Maximum Value	Minimum Value
Areca Sheath	3.324×10^6	2.905×10^1
Coconut Shell	5.746×10^6	3.204×10^1
Jute	1.487×10^6	1.397×10^3

Material: Areca Leaf Sheath

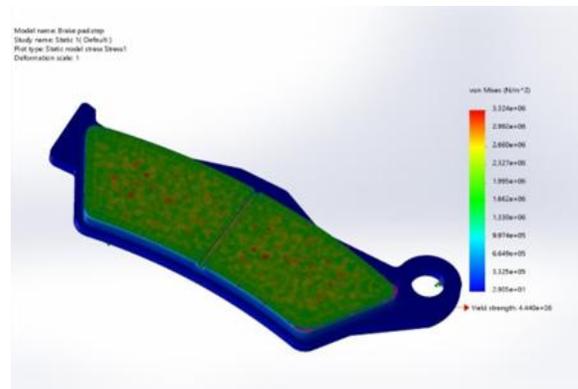


Fig 8: Structural Analysis by using Areca Sheath material.

Material: Coconut Shell

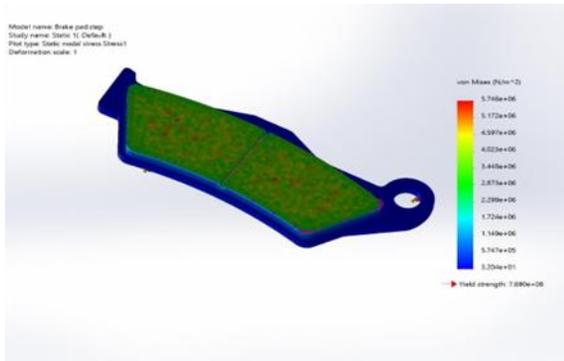


Fig.9: Structural Analysis by using Coconut Shell material.

Material: Jute

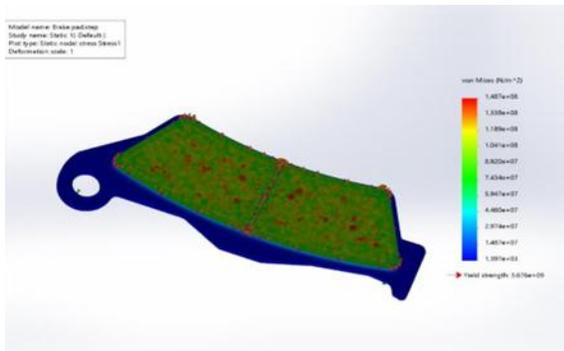


Fig.10: Structural Analysis by using Jute material

V CONCLUSIONS

In this research article, Experimental investigation was conducted on Hybrid Composites. The Physical properties like Hardness test were conducted on Hybrid Composites. The results show that for increasing the reinforcement weight fraction, i.e from 5% to 20%, the Hardness value of hybrid composites increases. Because of good bonding exist between Epoxy and Reinforcement the hardness value increases for increasing reinforcement percentage. The water absorption test was conducted on Hybrid composites to check the nature of composites. It was found that, more moisture percentage exist for 20% of reinforcement. For 5% of reinforcement, there was little absorption of water up to 96 hours and later for remaining number of hours the moisture percentage remains constant. For 20% reinforcement, the moisture percentage increases upto 288 hours and later remains constant. This shows that, the prepared hybrid

composites have hydrophobic nature as the percentage of reinforcement increases.

Structural Analysis was conducted by using Ansys software by considering individual properties of Areca Sheath, Coconut Shell and Jute to find the Von Mises stress induced on a brake pad. For the material Coconut Shell, the highest value of von -mises stress found and lowest value of Von mises stress was found for the material Jute.

So, by inclusion of more percentage of Areca and Coconut shell, hybrid composites can build and it has a good hardness value and these hybrid composites can be utilized for individual component of Automotive components.

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