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Experimental Investigation on Mechanical Behaviour of Cactus Fiber Composites

Albert Allen D Mello
Assistant Professor, Department of Aeronautical Engineering, ACS College of Engineering, Bangalore, India

Siddesha HS
Associate Professor, Department of Mechanical Engineering, ACS College of Engineering, Bangalore, India

Supritha Kashya PMS and Supritha GS
Department of Aeronautical Engineering, ACS College of Engineering, Bangalore, India

Abstract
The use of composite materials field is increasing gradually in engineering. In the present day to reduce the carbon footprint a greater number of natural fibers are analysed. The accessibility of characterization of assembling inexpensive fiber and to learning their achievability of fortification determination and to what degree they fulfill the particulars of great strengthened natural composite aimed at structural requisition. Literature showed that Cactus fiber have excellent mechanical properties including good strength, hardness, impact resistance properties and in the present study a natural composite is prepared by using hand layup process by varying composition of filler material. The extraction of the fibre is in three different form and they are, the decomposition of fibres plant with caustic soda, the second type is by using dilute hydrochloric acid and the third type is by landslide the plant for 15 days. For this composite Extraction of fibers has done by soaking fibers in caustic soda and water. Then dried for ten days in sun light. Here the composite is prepared by varying the filler materials that is wood powder in the percentage variation of 5%,7%,9%,11%,13% and 15% variation, with matrix and fibres materials and the different mechanical characterization are carried out to analyses the mechanical behaviour pattern of the material for uniform increment in the wood powder variation. The results showed that adding wood powder has on increment in the property up to 11% then decrease also it was found that adding wood material as filler material has hindered the mechanical properties compared to base fiber composite without any filler material.

Keywords
Cactus, Natural Fiber, Tensile Strength, Wood Powder Filler

I. INTRODUCTION

In recent years, polymer-based reinforced materials have become increasingly popular across various industries due to their improved strength and the benefit of recycling waste products to reduce environmental pollution [1]. Natural plant fibers are commonly used as reinforcement materials because they are cost-effective, widely available, biodegradable, renewable, and strong, making them a viable alternative to synthetic fibers [2]. Research on polymer matrices reinforced with wood fillers is expanding, with studies showing that fillers can significantly enhance several properties of polymer composites [3].

The efficient use of natural fibers in composites to create a new and excellent thermal properties, and biodegradability is a rapidly growing field in polymer engineering and science

[4]. Author presented that natural fibers with cellulose, numerous fibers, are recognized for their excellent properties and are widely utilized as reinforcement fibers in different objectives [5]. From literature studied that the improving the composite strength is important by varying properties. It is studied that natural hard fibers are particularly valued for their reinforcing capabilities in thermoplastic matrices due to their low density, reduced wear on processing machinery, abundance, and affordability [6]. Materials like Natural fibers consist of chemical constituents which vary significantly between different types of fibers and influence their overall mechanical properties [7]. The use of composite is increasing, primarily due to their lower production costs and favourable properties [8].

II. LITERATURE STUDY

Bouakba et al. [1] developed an innovative fiber extraction process that yields cactus cladode fibers with three distinct microstructural morphologies. Their flexural tests demonstrated that cactus/polyester composites exhibit a significantly higher flexural modulus compared to their tensile counterparts, and they dissipate substantial energy per unit volume during low cycles and high loading levels. Vadivel et al. [2] observed that natural fiber composites are increasingly popular in various industries due to their specific properties. Fibers, which are plentiful and high at cellulose, are particularly suitable for polymer matrix composites. Another study explored the DTA of Pencil Cactus fibers and their polymer composites to evaluate alkali treatment and the effect on the fibers. The findings showed that treated fibers and their composites have greater heat resistance. Additionally, the experiments indicated that fiber-reinforced polymer composites processed below 300ºC perform more efficiently [7]. Dinesh et al. [3] studied the effect of Padauk wood dust particles and better adhesion with the matrix. Additionally, research has highlighted the potential of cactus plant fiber as a natural fiber in composite materials.

III. FABRICATION

Fabrication of the composite is done by hand lay-up process initially the extracted fibers are cut and arranged maintaining the uniform dimensions is shown in Figure 1. Further two 5mm thickness metal sheets used as compressing moulds. Then wax is applied on the cleaned the surface (shown in figure 2) of the sheet followed by gel coat (shown in figure 3)as a good releasing agent on both compression moulds and left it for few minutes to dry. After the mixture of resin and wood powder is applied in 7 different composition of wood powder varing in volume percentage of one without wood powder, the other 6 are with 5%, 7%, 9%, 11%, 13%, 15% variation. This process is carried out for four layers with the fiber arrangement in 0^0, 45^0, 90^0 and 0^0 as shown in figures 4, 5 and 6. Then composite is compressed between the metal sheet under the hydraulic pressure on it to get smooth surface and remove the excess amount of resin and leave it for 48 hours expose to air that the composite become harder. Once the composite is cured it is cut for required dimension for testing the mechanical properties [2-5].

Wood is a natural resource derived from plants and trees, consisting of various tissues. The properties of wood powder are essential for understanding its behavior and reactions to different substances and temperatures. For producing new wood the vascular cambium layer located inside the bark is responsible. These properties include physical, chemical, and mechanical aspects, each providing a generalized understanding of wood characteristics. These refer to the inherent characteristics of wood that remain unchanged in terms of size, shape, color, etc., regardless of external conditions [6].

Epoxy laminating resign and hardener is 100% solids clear epoxy laminating system foe extreme performance and demanding visual application including cactus fiber skinning board manufacturing and wood finishing [7]. Epoxy resin and hardener is intended for use where laminates will remains unpainted, showcasing, reinforcements such as carbon fiber natural fiber, inlaid graphics, or wood grains epoxy resign and hardener will cure to a hard, durable finish which can be polished to a high gloss [8].

		
Figure 1 Extracted Fibers	**Figure 2 PVA Releasing Agent**	**Figure 3 Mould Releasing Agent**
		
Figure 4 0^0 Fiber Arrangement	**Figure 5 45^0 Fiber Arrangement**	**Figure 6 90^0 Fiber Arrangement**

IV. EXPERIMENTAL DETAILS

A. Tensile Test

The tensile test is a fundamental method for evaluating the mechanical properties of materials by subjecting a sample to controlled tension until it breaks. This widely used destructive test assesses a material's strength and its ability to stretch before failure. Specimens for tensile testing are prepared according to ASTM standards and dimensions [9]. The sample is secured in a universal testing machine using clamps or grips at both ends. An extensometer is attached to the specimen to measure strain. The machine gradually increases the force on the specimen until it fractures. The collected data is used to generate a stress-strain diagram, which helps determine tensile properties such as ultimate tensile strength, yield strength, and elongation at break. [10-11].

B. Flexural Test

The flexural test evaluates the mechanical properties of materials when subjected to bending or flexing. Typically applied to brittle or semi-brittle materials, this test involves placing a rectangular specimen (150 mm by 20 mm) on supports and applying a load at specific points to induce bending. The specimen is set up on the flexural testing machine supports, ensuring it is level and horizontal [12]. An initial preload is applied, followed by a gradual increase in load until the specimen fractures. The resulting data is used to plot a stress-strain diagram, and the flexural strength of the material is calculated.

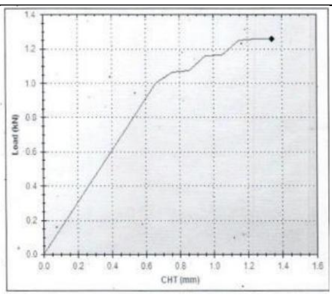
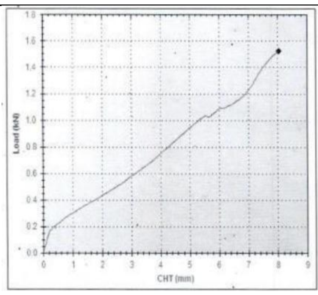
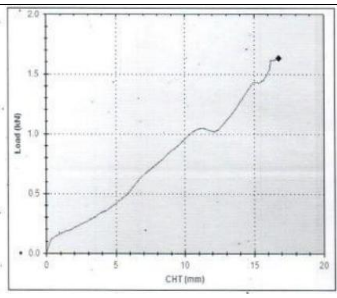
V. RESULTS AND DISCUSSION

The composite is prepared in seven different samples with 60% (weight percentage) of cactus fibres and remain with resin and wood powder. The variation of wood powder percentage is made to obtain the various samples of the composite the following specification shows the variation.

Table 1 Sample Composition Details

Sample 1	0% of weight percentage of wood powder
Sample 2	5% of weight percentage of wood powder
Sample 3	7% of weight percentage of wood powder
Sample 4	9% of weight percentage of wood powder
Sample 5	11% of weight percentage of wood powder
Sample 6	13% of weight percentage of wood powder
Sample 7	15% of weight percentage of wood powder

The tensile test is conducted on each specimen and each showed the following results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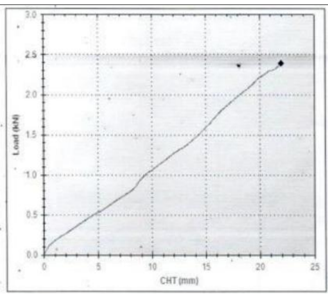	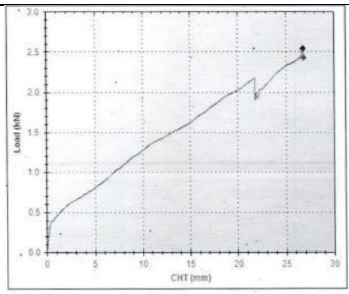	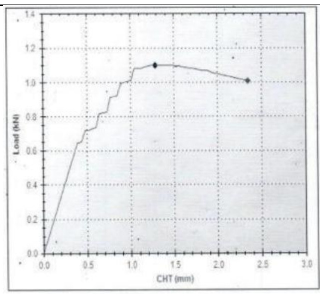
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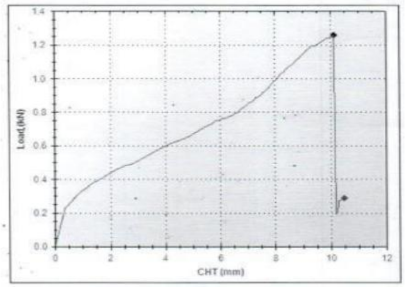
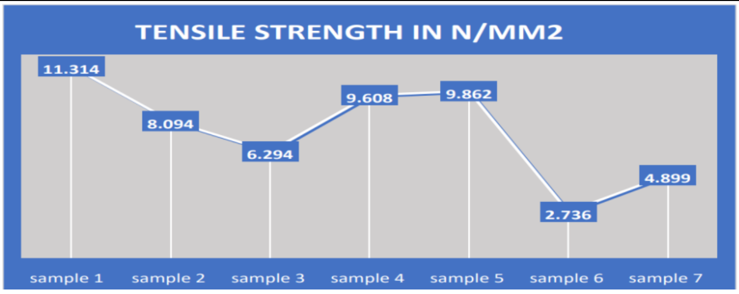
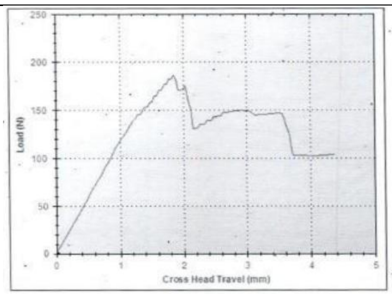
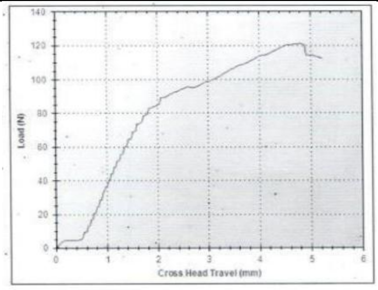
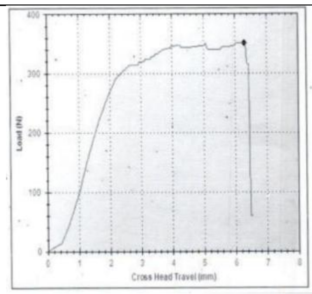
	
7	Compression of tensile strength of all seven Specimens

The flexural test is conducted on each specimen and each showed the following results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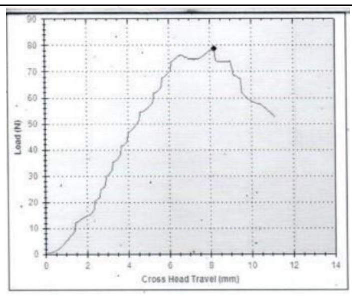	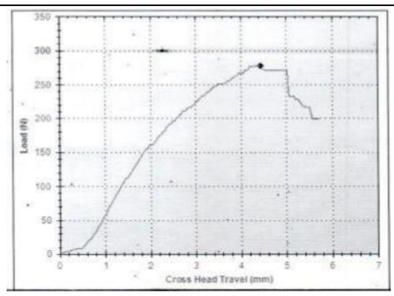	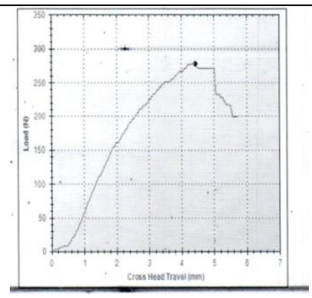
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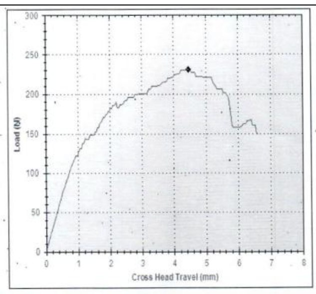	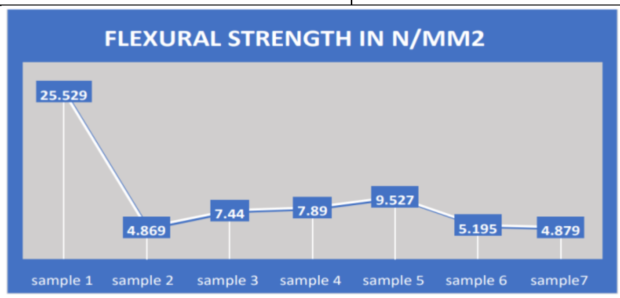	
7	Compression of flexural strength of all seven Specimen	

From the above results when the wood powder is used as filler material, we can see that the tensile strength is gradually increased up to sample 5 that is up 11% of wood powder and then drops suddenly [14-16]. Even though the literature suggested the using filler material increase bonding strength which eventually increase the tensile strength and flexural strength of the specimen without any filler material is noticed the higher tensile strength comparatively [15]. So, it can be stated that the cactus fiber bonds bonded with epoxy resin there is no need of any filler material however we can increase the strength of the material by increasing the layers of the composite [16]

VI. CONCLUSION

After comparing all the results, it is observed that the wood powder used as filler material, instead of improving the bonding capability it has eventually reduced the binding strength intern affecting the basic mechanical properties like tensile strength and flexural strength. Any way by adding the wood powder as the filler material the deflection at peak increased with increase of filler materials that is wood powder for certain value of 11% then decreases due to the generation of porous and the bonding between the fibre arrangements has got decreased. This increase in the wood powder will even cause in lowering load absorbing capacity the material will lose its strength at the lower level of load. Similarly, the flexural strength of the sample without wood powder has showed high strength due to the high bonding between the fibre arrangements. In the comparison graph deflection is increased with increase of filler materials that is wood powder for certain value of 11% then decreases due to the generation of porous and the bonding between the fibre arrangement has got decreased. Finally, we can conclude by suggesting trying with different filler materials to increase the strength of the natural fiber.

VII REFERENCES

[1] M. Bouakba, A. Bezazi, K. Boba, F. Scarpa, and S. Bellamy, "Cactus fibre/polyester biocomposites: Manufacturing, quasi-static mechanical and fatigue characterisation," *Composites Science and Technology*, vol. 74, pp. 150-159, 2013.

[2] K. S. Vadivel, and P. Govindasamy, "Characterization of natural cellulosic fiber from treated acacia arabica and pencil cactus fiber," *Materials Today: Proceedings*, vol. 46, pp. 3392-3397, 2021.

[3] G. Ramanan, and H. M. Ranjan, "Growth of Ni–Cu–Zn electrolyte coated thin layer carbon fiber reinforced aluminium composite," *Materials Research Express*, vol. 6, no. 12, 2020.

[4] V. K. Thakur, M. K. Thakur, and R. K. Gupta, "Review: Raw Natural Fiber–Based Polymer Composites," *International Journal of Polymer Analysis and Characterization*, vol. 19, no. 3, pp. 256-271, 2014.

[5] A. Valadez-Gonzalez, J. M. Cervantes-Uc, R. Olayo, and P. J. Herrera-Franco, "Effect of fiber surface treatment on the fiber–matrix bond strength of natural fiber reinforced composites," *Composites. Part B: Engineering*, vol. 30, no. 3, pp. 309-320, 1999.

[6] G. Ramanan, R. D. Akshatha, A. U. Manvi, B. A. Suhas, and D. K. Pruthvi, "Investigation of bio degradable natural fibers reinforced hybrid composites for aircraft structures," *Materials Today: Proceedings*, vol. 52, pp. 1211-1215, 2022.

[7] U. Victoria-Martinez, S. Loera-Serna, and E. R. Vazquez-Ceron, "Acoustic properties of composites materials based on bentonite and coconut or cactus (nopal) fibers. *Journal of Composite Materials*, vol. 57, no. 20, pp. 3173-3187, 2023.

[8] K. S. Vadivel, and P. Govindasamy, "Thermal analysis of Acacia Arabica and Pencil Cactus fiber hybrid polymer composites," *Research Journal of Chemistry and Environment*, vol. 24, 2020.

[9] M. Jawaid, and H. P. S. Abdul Khalil, "Cellulosic/synthetic fibre reinforced polymer hybrid composites: A review," *Carbohydr. Polym.*, vol. 86, no. 1, 2011, pp. 1-18.

[10] A. Benhamou, A. Boussetta, N. Grimi, M. E. Idrissi, M. Nadifiyine, F. J. Barba, and A. Moubarik, "Characteristics of cellulose fibers from Opuntia ficus indica cladodes and its use as reinforcement for PET based composites," *Journal of Natural Fibers*, vol. 19, no. 13, pp. 6148-6164, 2022.

[11] G. Ramanan, R. R. Neela Rajan, S. Suresh, J. Cho, and V. E. Sathishkumar, "Effect of Al7075 and activated carbon reinforced composite on optimizing WEDM responses," *Materials Research Express*, vol. 11, no. 5, 2024.

[12] G. D. Samuel, G. Ramanan, R. A. Raj, and D. B. P. Raja, "Parametric study of FSW process on AA6061-Activated carbon composite using particle swarm optimization," *Materials Today: Proceedings*, 2023.

[13] Oldfield, S. *Cactus and Succulent Plants: Status Survey and Conservation Action Plan*. IUCN, 1997.

[14] A. Novoa, J. J. Le Roux, M. P. Robertson, J. R. Wilson, and D. M. Richardson, "Introduced and invasive cactus species: A global review," *AoB Plants*, vol. 7, 2015.

[15] F. B. Rebah, and S. M. Siddeeg, "Cactus an eco-friendly material for wastewater treatment: A review," *Journal of Materials and Environmental Sciences*, vol. 8, no. 5, pp. 1770-1782, 2017.

[16] H. G. Gebretinsae, M. G. Tsegay, and Z. Y. Nuru. "Biosynthesis of nickel oxide (NiO) nanoparticles from cactus plant extract," *Materials Today: Proceedings*, vol. 36, pp. 566-570, 2021.