Engineering and Technology Journal e-ISSN: 2456-3358

Volume 08 Issue 11 November -2023, Page No.- 2974-2977

DOI: 10.47191/etj/v8i11.05, I.F. – 7.136

Effects of Reinforcement Ratio on Physical and Mechanical Properties of Corn Silk Reinforced Epoxy Composite

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ABSTRACT: Corn silk known as the waste product that can contribute to bad pollution neither air nor land. Therefore, corn silk was introduced as a nature fibre reinforcement in composite which can contribute to the positive environmental issues while developing new composite materials. 4 samples were fabricated by different composition at 0% to 6vol% employing the hand lay-up technique by mixing the natural fibre with epoxy and hardener at fixed ratio. The objective of this experiment was to fabricate the sample of composite materials with different reinforcement ratio of corn silk with epoxy and study their effects on physical and mechanical properties. Sample size prepared following ASTM DT 3039 standard (250mm X 25mm X 3mm) for tensile test. Tests conducted shows that the hardness were increase while the density value were fluctuating by increasing corn silk reinforcement ratio. The highest hardness and density values reflect on 6 vol% with 20.5 HV and 2 vol% with 1.22 g/cm^3 respectively. The result revealed the highest strength achieved by 0% of fibre with 22.6458 MPa and lowest at 6% of fibre with 13.2146 MPa. Moreover, the highest strain achieved by 0% of fibre with 1.085% and lowest at 6% of fibre with 0.6894% the pattern of result shows the value of strength and strain is increasing by decreasing the percentage of the fibre. The highest value of young's modulus achieved by 0% of fibre with 21.9742 MPa and for the lowest value of young's modulus at 6% of fibre with 18.8985 MPa.

KEYWORDS: Composite, Corn silk, Density, Hardness, Young Modulus.

I. INTRODUCTION

Green composite materials are currently at the forefront of the field of materials science and engineering due to the increasing demand for eco-friendly materials aimed at mitigating environmental degradation, curbing pollution, and safeguarding the planet. These materials, crafted from natural resources, make only a minimal ecological impact [1]. Plant fibers stand as a highly favored and exceedingly abundant natural resource for enhancing the structural integrity of composite materials. Incorporating plant fibers into bio-polymers or synthetic polymers yields top-tier composites renowned for their exceptional characteristics, including lightweight construction, biodegradability, and renewable sustainability [2]. The reinforcement primarily provides high strength and stiffness to the composite material. Fibre reinforced (continuous, discontinuous, aligned, and random) and particle reinforced are subcategories based on the reinforcing type and orientation (random, preferred orientation). Epoxy is a commonly selected material for manufacturing composites with natural fiber reinforcement. However, there are instances where epoxies exhibit limited impact strength, inferior fracture toughness, and reduced resistance to fatigue crack propagation. [3]. The toughness and strength of epoxies can be increased by reinforcing it with various materials such glass fiber, natural fiber, glass powder and etc. Natural fibers greatly affect the tribological properties of these composites. However, the hydrophilic characteristics of natural fibers lead to a significant moisture absorption, rendering them unsuitable for reinforcement in specific polymeric matrices. Composites incorporating lignocellulose fibers exhibit a notable susceptibility to moisture, presenting a significant impediment to their effective and efficient utilization. [4]. For this reason, it becomes paramount to alter the surface properties of natural fibers to reduce their water absorption and enhance their hydrophobic nature. This modification is essential to improve fiber compatibility with a variety of resin matrices. [4]. The treatment of fibers can significantly enhance their tribological properties by establishing a strong interfacial adhesion between the fibers and the matrix. [5]. There are certain factors which affect the mechanical properties of the composites fabricated with natural fiber reinforcement. Some of these factors and their effects are tabulated below:

Table 1: Factors affecting mechanical properties of epoxy composites

Factors	Effects
Moisture absorption	Poor interfacial boding between fiber and hydrophobic matrix polymer.[6]
Fiber alignment	Aligned natural fiber composites exhibit best tensile, flexural and impact properties[7]
Fiber treatment	Enhanced mechanical properties of the composite but lower concentration of NaOH improved tensile strength and hardness.[8]

II. MATERIALS AND METHOD

Corn silk fibres were sourced from the farm in the northern region of Malaysia. The weight of the fibres was duly recorded, then the fibres were washed with distilled water to remove all impurities inside the fibres. Subsequently, the fibres underwent a drying process in the oven set at 35°C over a period of several days to eliminate the moisture content. Epoxy type- MIRACAST 1517 (A) and Hardener type- MIRACAST 1517 (B) were procured from MIRACON Sdn Bhd. A matrix fabricated by combining epoxy resin and hardener in a volumetric ratio of 100:30 and then pouring the resulting mixture into a mould. Three Aluminium plate used as a mould are in A3 size with 3mm thickness. Utilising short fibres distribution techniques, the 30mm fibres with different reinforcement ratio (0 vol%,2 vol%,4 vol% and 6 vol%) were dispersed around the mixture at random and the mixture was leave in the mould overnight. Dried mixture was sectioned into samples I accordance with the ASTM DT 3909 standard for subsequent tensile test.

Figure 1: Materials used in sample fabrication a) Corn silk fibre, b) Epoxy type- MIRACAST 1517 (A), c) Hardener type- MIRACAST 1517 (B)

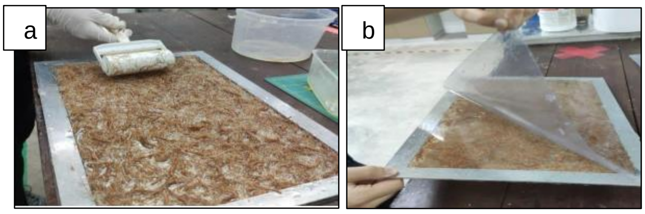

Figure 2: Sample fabrication process a) hand rolling process b) plastic cover removal of dried sample

III. RESULTS AND DISCUSSIONS

A. *Tensile Test (ASTM DT 3039)*

According to the data shown in Table 2, the tensile strength of 6% corn silk is the lowest with 13.21 MPa. According to the theory, the tensile strength increase by increasing the volume of reinforcement fibre but there is a possibility that it did not absorb the epoxy as effectively as it should have because of hydrophilic nature of natural fibres. Therefore, it is essential to modify the surface of natural fibres so that they are less absorbent of water and more hydrophobic, hence ultimately boosting the fibre compatibility with various resin matrices. [4].

The value for young's modulus at 0% of corn silk was the highest with 21.9742 MPa while the lowest is at 6% of corn silk with 18.8985 MPa. This result agreed by theoretically, where brittle materials tend to have high Young's modulus because of the ability of a material to withstand changes in length under lengthwise tension. Adding the reinforcement fibre contribute to decrease the impact strength might be due to low adhesion between the reinforcement and matrix [9].

Epoxy composites reinforced with NaOH-treated fibers exhibit improved tensile strength compared to untreated fibers. This enhancement can be attributed to the removal of cementing materials, specifically lignin and hemicellulose, from the fibers during NaOH treatment. Consequently, the surface area of the fibers increases, promoting better adhesion between the fiber and the matrix. This heightened adhesion contributes to the increased tensile strength of the composite. Additionally, the improved crystallinity of the NaOH-treated fibers may also be a contributing factor to the enhanced tensile strength observed in the composite. [10]. The tensile property of the composite increases only up to a certain limit of fiber loading,after that it gradually decreases.

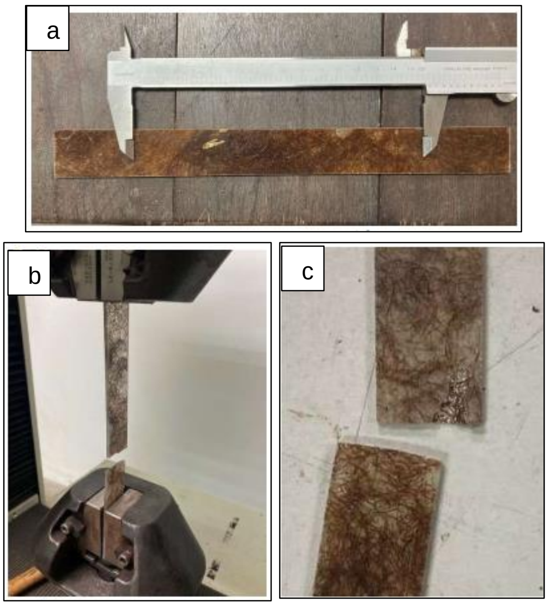

Figure 3: a) Tensile test sample before test b) tensile test sample during process c) tensile test sample after test

Table 2: Tensile strength and young's modulus at different reinforcement volume ratio.

Corn silk vol %	Tensile strength (MPa)	Young's Modulus (MPa)
0	22.649	21.9742
2	19.0875	20.8717
4	16.3708	19.1683
6	13.2146	18.8985

B. Archimedes Test (ASTM B962)

Based on Figure 4, the trend line of the graph decreasing proving that the density of the composites decreasing when the fibres percentage increase. The highest value spotted at 0 vol% with 1.222 g/cm^3 and lowest at 4 vol% with 1.08 g/cm^3. At 6 vol% the value was slightly increase might be contributed from uneven manually reinforcement fibre distribution and inconsistence in thickness during sample fabrication process effected. Therefore, the weight of the materials has been altered by adding the reinforcement fibre while maintaining the physical properties.

Figure 4: Samples for Archimedes density and Vickers hardness test.

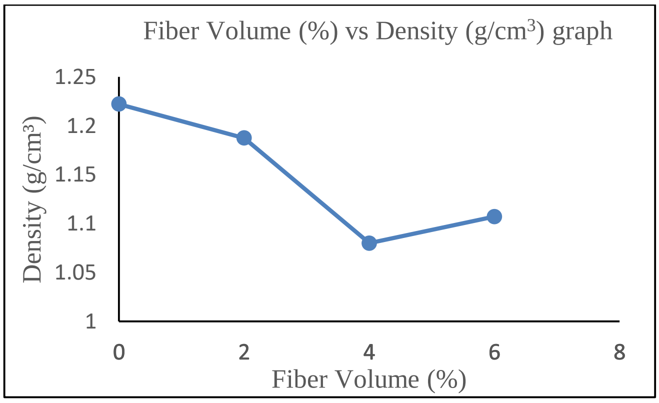

Figure 5: Graph of density on different fibre volume ratio

C. Vickers Hardness Test (ASTM E384)

The results, as depicted in Figure 6, reveal a consistent trend of increasing hardness values with the addition of a higher percentage of fibers. This pattern closely mirrors the findings reported by Ranakoti et al. in 2022 and Patel et al. in 2020. Additionally, the researchers observed that fiber length played a significant role in impact strength. Longer fibers were found to possess a greater capacity for energy absorption and more effective distribution of impact energy compared to shorter fibers. [11]

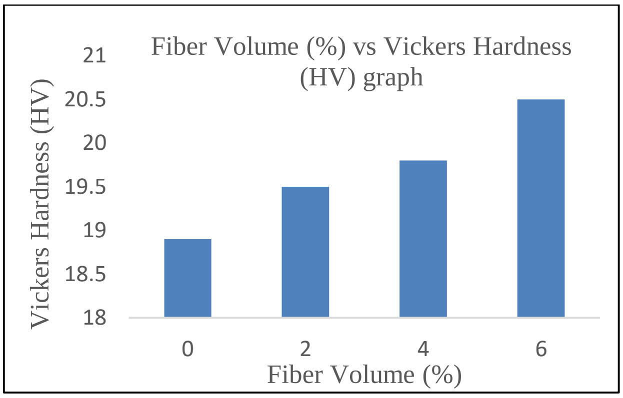

Figure 6: Graph of hardness on different fibre volume ratio

CONCLUSIONS

The study's findings lead to the conclusion that natural fibers hold significant promise as a potential replacement for synthetic fibers within the composite manufacturing industry. This potential is evident through improvements in a wide range of physical and mechanical properties. Moreover, the treatment of these fibers is of paramount importance to establish a robust compatibility bond between the fibers and the resins. The properties exhibited by corn silk-reinforced composites make them well-suited for low-load applications, such as decorative items, food trays, interior panels, and more. Consequently, these composites have the capacity to supplant conventionally used materials in such applications, enhancing the overall product quality.

ACKNOWLEDGEMENT

The authors would like to thank to the Centre for Mechanical Engineering Studies, Universiti Teknologi MARA, Cawangan Pulau Pinang, Permatang Pauh Branch for facilitating this project.

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