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Article



# Plain-Woven Areca Sheath Fiber-Reinforced Epoxy Composites: The Influence of the Fiber Fraction on Physical and Mechanical Features and Responses of the Tribo System and Machine Learning Modeling

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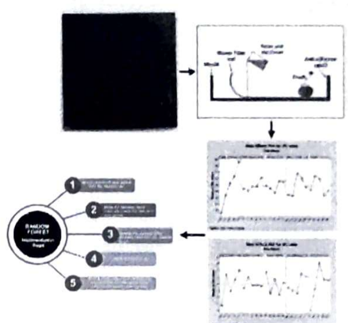

**ABSTRACT:** Recent studies focus on enhancing the mechanical features of natural fiber composites to replace synthetic fibers that are highly useful in the building, automotive, and packing industries. The novelty of the work is that the woven areca sheath fiber (ASF) with different fiber fraction epoxy composites has been fabricated and tested for its tribological responses on three-body abrasion wear testing machines along with its mechanical features. The impact of the fiber fraction on various features is examined. The study also revolves around the development and validation of a machine learning predictive model using the random forest (RF) algorithm, aimed at forecasting two critical performance parameters: the specific wear rate (SWR) and the coefficient of friction (COF). The void fraction is observed to vary between 0.261 and 3.8% as the fiber fraction is incremented. The hardness of the mat rises progressively from 40.23 to 84.26 HRB. A fair ascent in the tensile strength and its modulus is also observed. Even though a short descent in flexural strength and its modulus is seen for 0 to 12 wt % composite specimens, they incrementally raised to the finest values of 52.84 and 2860 MPa, respectively, pertinent to the 48 wt % fiber-loaded specimen. A progressive rise in the ILSS and impact strength is perceptible. The wear behavior of the specimens is reported. The worn surface morphology is studied to understand the interface of the ASF with the epoxy matrix. The RF model exhibited outstanding predictive prowess, as evidenced by high *R*-squared values coupled with low mean-square error and mean absolute error metrics. Rigorous statistical validation employing paired *t* tests confirmed the model's suitability, revealing no significant disparities between predicted and actual values for both the SWR and COF.

## 1. INTRODUCTION

The evolution of composites made of polymers and their ability to comply with the specified characteristics have made industries, researchers, and engineers pay high attention to it. Natural fiber polymer composites (NFPCs), too, have found their niche in the global market. The performance, relatively reduced cost, and the need for lighter parts or components have influenced the growth in the usage of NFs in the manufacturing of composites.[1] Nevertheless, it is observed from several studies that certain parameters of natural fibers (NFs), such as their durability, hydrophilicity,[2] and stability toward thermal applications, have barred their full-scale utilization in high-end applications.[3] To face such limitations, researchers have focused on obtaining the optimum benefit of a composite material by various approaches such as surface modification of the fibers, varying the lengths of fibers, hybridization, adding filler materials, weaving the fibers with different patterns, and so on.[4,5] One such approach is the plain weaving of NFs, which improves the mechanical and frictional features of the composite, which is of paramount importance to implement in tribological applications.[6−8] Complementary to the studies reported by various authors, the woven composites have exhibited explicit mechanical behaviors in orthogonal directions under various tests compared to the particle, short, or long fiber composites.[9,10]

According to a review article by Ivars et al.,[11] the most efficient and cost-effective method for producing composites is to use short, untreated fibers. On the other hand, it has been exposed by many researchers[12−14] that the stress transformation between long fibers (woven) and the matrix is superior to that of short and random-oriented fiber composites. When the fibers are weaved, the induced interlocking among the fibers enhances their strength to be greater than the binding strength between the fiber and the matrix. This is because the tightly attached

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