

Assessment of Mechanical and Erosive Wear Behavior in Polyester Composites Reinforced with Curaua and Basalt Fibers

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Abstract. The current study investigated the erosion behavior of hybrid composites made from curaua and basalt fiber reinforced polyester. Three distinct composite types such as Curaua composites (CU), Curaua/Basalt composites (CU/BA) and Basalt Composites (BA) were produced utilizing Resin Transfer Molding (RTM) with a fiber reinforcement of 40%. For these three composite variations, tensile and hardness testing have been performed in accordance with ASTM standards. The findings indicated that the hybrid composites possess intermediate characteristics, with selected hybrids demonstrating properties close to those of pure basalt fiber composites. A solid erosion test was conducted following ASTM G-76, varying the impact angle while maintaining a constant velocity of 100 m/s on the fiber reinforced composites. Result shows that the increase in their mechanical performance, the hybrid composites demonstrated reduced erosion rates compared to curaua fiber, with values closely aligning with those observed in basalt fiber.

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1. Introduction

Due to the environmental demand development of alternative material from renewable sources increase. Curaua is one of the less explored vegetable fiber used in polymer composite materials, widely available in Amazon zone of Brazil. Interesting chances on hybridization of vegetable fibers with synthetic fibers are encouraging research community towards strengthening the natural fiber composites. Basalt is one of such hybrid fiber can be compatible with natural fibers due to its bio-compatibility. Generally, fiber-fiber interaction and cohesion, entanglement and close-packing with polymer matrix are primary controlling factors of the strength of hybrid composites. Some examples of Erosive wear are damage in airplane turbine blades which are caused by contaminated air and mixture of elements mixture, gas pipeline damage because of effect of air or water medium. Many researchers stated that the hybrid fiber in polymer composites will increase the erosion characteristics. [1-3].

José Humberto Santos Almeida Júnior et al [4] stated that Curaua fibers can be easily mixed with synthetic fibers. At the same time, glass fibers can be replaced by up to 30% curaua fibers, which then show properties comparable to pure glass fibers. Clarissa C Angrizani et al [5] studied the Analysis of curaua/glass hybrid interlayer laminates, reported that curaua fiber was easily bonding with synthetic fiber and exhibited an intermediate property in the mechanical properties in some properties are very close to the synthetic fiber.

Soares et al. [6] observed that basalt fiber composites exhibited mechanical properties comparable to those of carbon and glass fibers, which highlighting their potential for diverse applications. This shift towards basalt fiber is not merely a trend; it reflects a broader movement in materials science towards more sustainable and efficient composites. The unique properties of basalt fibers, such as their superior thermal stability and chemical durability compared to traditional glass fibers, made them particularly appealing for various structural applications, including those in aerospace and civil engineering. Zhongyu Lu et al [7] stated that in the all the aspects like mechanical and thermal resistance basalt fiber are comparatively better than glass fiber.

Prithivirajan R et al [8] reported that Mechanical and Wear properties of the composite are increased by Hybridization in polymer composite. In addition to enhancing mechanical and wear properties, hybridization in polymer composites also plays a crucial role in optimizing their tribological performance. Recent work indicated that the specific wear rate can be significantly reduced through careful selection of fiber combinations, such as incorporating synthetic fibers like glass alongside natural fibers like curaua

Compression and resin transfer molded composite of Sisal/polyester have been compared by Srekumar et al. [9] concluding the benefit of making less porous composite produced through compression technique and fiber rich possibilities with transfer molding technique. Vigneshwaran et al. [10] reviewed that several researches are focused on the dry sliding wear performance on polymer composites are increased, but only few researchers are focused on the solid particle erosion wear of polymer composites. At the same time researcher are interested to know performance of hybrid composites are measure by solid erosion particle test is increase.

Johnson et al. [11] highlighted that the scarcity of research investigating the combined influence of fiber (*sansevieria cylindrica*) reinforcement and particulate fillers on the erosion resistance of polymer composites. N Miyazaki [12] reviewed that Matrix and reinforcement are strongly bonded in the polymer matrix composites that showed the erosion rate has been increased. Hybridization of the composite resulted in increasing the mechanical as well as erosion rate. Volume content also plays important role in the erosion rate. Senthilkumar Krishnasamy et al. [13] focused on fiber lengths (4, 8, 12 mm) and loadings (25%, 50%, 75%) to enhance mechanical properties. The interaction effects were analyzed with ANOVA. They indicated that 8 mm fiber length at a 75:25 basalt-to-curaua ratio resulted in an increase in the tensile and flexural strength while the 25:75 ratio resulted in an increase in impact strength. This work fills the gap in the study of hybrid natural-mineral fiber composites. Ganesan [14] et al. reported on the study of sugarcane biochar as a green filler in Curaua fiber/polylactic acid hybrid composites to increase sustainability. The fibers were pretreated with sodium bicarbonate and the mechanical properties were improved up to 60 hours with tensile and flexural strengths of 56.32 MPa and 74.69 MPa respectively. However, if the treatment time was increased above 60 hours, the reduction in mechanical properties was due to the brittleness of the fiber. These findings highlight the complexity of optimizing polymer composites for enhanced erosion resistance, suggesting that careful consideration of both fiber and particle content is crucial in developing effective materials.

2. Materials and Methods

2.1 Materials

The composites have been prepared by imported Brazilian curaua and locally sourced basalt fibers as reinforcements, combined with an unsaturated polyester resin matrix which is supplied by Vasavibala, Chennai. Curing is initiated using Methyl Ethyl Ketone Peroxide (MEKP) as the catalyst, with Cobalt Naphthenate serving as the accelerator

2.2 Composite Fabrication

From the taken fibres, the dust is removed perfectly from its surface by combing. Those are then cut into 12mm pieces. In the same way, basalt fibres are currently into 12 mm. Both are placed into mould cavity of 300mm × 300mm × 3mm. Fabrication is done through Resin transfer moulding technique. Compressed air at 1.5 bar was introduced into the pressure chamber, facilitating the transfer of resin from the pressure vessel into the mold cavity. The composites were then allowed to cure for four hours. The erosion test was then carried on the particles which were cut as per the ASTM standards.

2.3 Test Details

In the universal testing machine with a 100KN load cell and constant loading rate 1 mm/min tensile test is carried as per the ASTM D3039 standards. The dimension of the sample is cut 180 X 20 X 3mm and conduct the experiments for five sample and the average value is reported

Hardness value of the three dissimilar composites is taken by Durometer as per ASTM D-2240 standard. The hardness value was taken from five dissimilar points of every composite. Average hardness value was calculated for these hardness values.

Erosion tests were performed using the DUCOM TR 470 Air Jet Erosion Tester, featuring a 1.5 mm diameter, 50 mm length tungsten carbide nozzle. The system propels a mixture of air and erodent particles, delivering an impact velocity of up to 100 m/s onto the sample. Sample are cut to the size of 25 x 25 x 5mm by using the abrasive waterjet machine. During the experimental run, the standoff distance was set at 10 millimetres, and the erosion duration was held constant at 10 minutes. Prior to and following the erosion test, specimens were gently cleaned using a soft cloth to remove any contaminants. The initial and final weights were measured using a precision balance with an accuracy of ±0.1 mg. Weight loss was determined by averaging the measurements taken at three different time intervals. The erosion rate was then calculated using the following formula.

$$\text{Erosion rate} = \text{weight loss} / \text{discharge} \times \text{time} \quad (1)$$

3. Results and Discussion

3.1 Hardness

Hardness is used to determine the material that suffers plastic deformation due to the influence of external stress. Thus, resistance of plastic deformation increases in the material due to basalt fiber increase in the reinforcement. This enhancement in resistance not only improves the structural integrity of the material but also extends its lifespan and performance under various loading conditions.

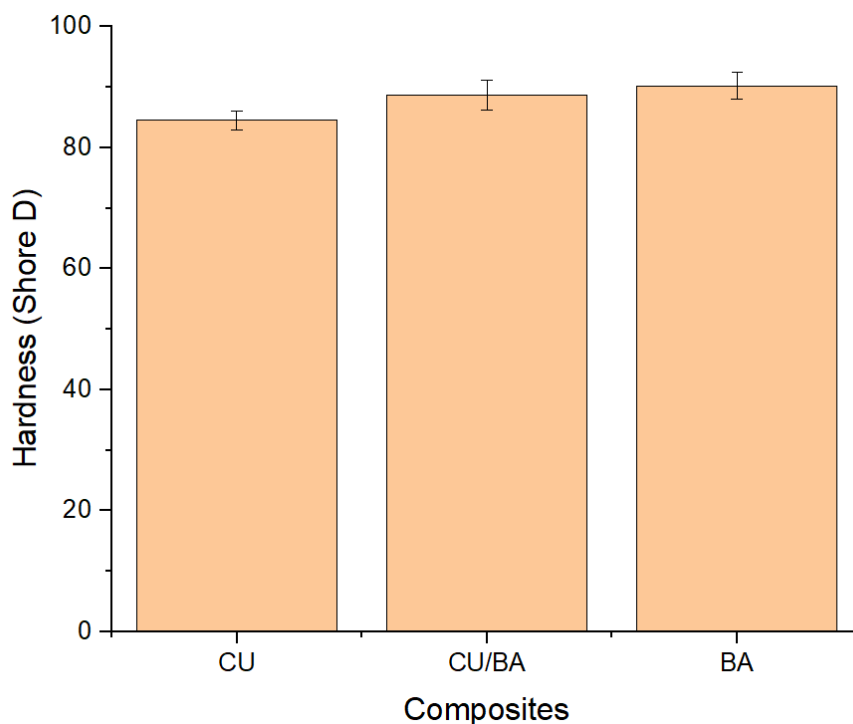


Fig. 1. Hardness of the composite

3.2 Tensile Strength

From Fig. 2 it is clearly observed, basalt has a higher strength compare to the curaua but the interesting fact that if the basalt fiber content increases in the hybrid composite, the strength of the composites is higher than the pure curaua. Other important factor for increase in the tensile strength is fiber orientation here fiber is randomly placed and mix between basalt and curaua could be one of the motivations to development in the tensile strength of the composites. The presence of lignin content in the curaua exhibits the property of binding the matrix material and fiber together could be the reason for increasing the tensile strength of the composites. The hybrid composites have the highest tensile modulus in CU/BA composite materials compare to other materials. Because the combinations of CU/BA structure have highest load bearing capability on its internal structures due good interfacial bonding between the fibers and matrix

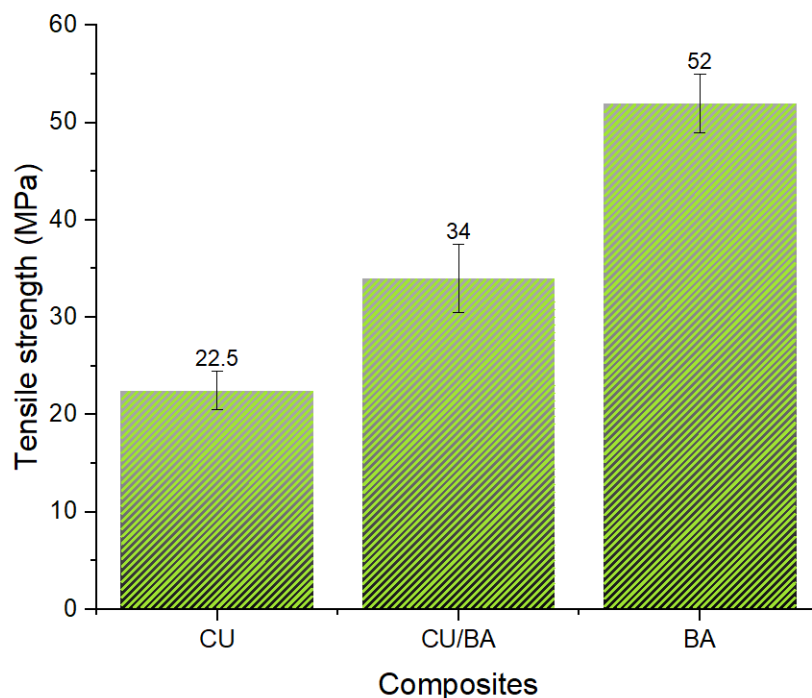


Fig. 2. Tensile strength of the composites

3.3 Erosion

Fig. 3 shows the erosion rate of pure and hybrid composites concerning impact angle. Among the studied pure curaua composite shows severe material losses during the erosion test. Basalt/polyester composites sustain greater than other studied composites. Hybrid composite shows intermediate behavior between curaua and basalt; such a result encourage the hybridization scope on the curaua composites.

N. M. Barkoula et al [15] stated that solid particle erosion GF/PP composites properties are depend upon the fibre content in the composites as well as relative fibre orientation most erosion will occur between 15° to 30° in ductile materials and similarly 90° impact angles indicate the brittle materials nature. Moreover, the influence of fiber length and orientation on wear behavior cannot be overlooked, as these factors significantly impact the material's overall performance under erosive conditions. Research has been shown that composites with longer fibers tend to exhibit enhanced resistance to erosion due to improved load transfer capabilities within the matrix

But in this study, the erosion rate maximally arises at 30_40° impact angle for all the three distinctive composites. Hence, semi ductile nature of the hybrid composites is proven, indicating that the material's ability to absorb energy and deform under stress contributes significantly to its overall performance in erosion resistance

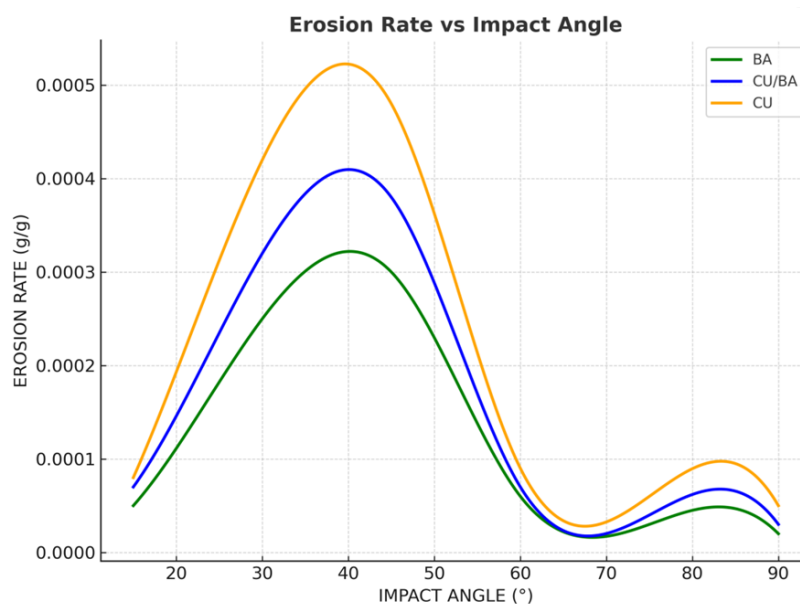


Fig. 3. Variation in erosion resistance with respect to erodent impinging angle.

4. Conclusion

The study examined the mechanical and erosive wear characteristics of composites reinforced with natural curaua fiber, synthetic basalt fiber, and hybrid combinations of 50% curaua and 50% basalt. The following conclusions were drawn based on the experimental findings.

- Hybrid composites, evaluated at both standard and mixed fiber ratios, resulted in enhanced tensile strength and hardness compared to pure curaua composites."
- CU/BA hybrid composites showed minimum erosion rate when compared with curaua composites.
- The highest erosion rates for all three composite configurations occurred at impact angles between 30° and 40°, indicating a semi-ductile erosion behavior of hybrid composites.

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