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DYNAMIC MECHANICAL ANALYSIS OF POLYMER COMPOSITES REINFORCED WITH NATURAL FIBERS AFTER ONE YEAR OF WATER IMMERSION

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Abstract

Natural fibre reinforced Comp.s are produced by reinforcing NFs with a ploy-mat. Depending on the specific needs, plant fibres can be reinforced with either a thermoset or thermoplastic ploy-mat. The objective of the research is to study +the dynamic mechanical analysis (DMA) of the polymer composites reinforced with natural fibers (PCRwNF) after one year of water immersion (WI). The data collection is done by using the Perkin Elmer Thermal analyzer (DMA 8000) was employed to conduct DMAs. The damping capability of the water-saturated jute/hemp/flax/epoxy specimen was reduced by 15.75% in comparison to the dried specimens. This reduction is very similar to the drop in tan δ of the water-saturated jute/hemp/epoxy specimen. Ultimately, this evaluation offers a guiding principle for the product design process that is founded on NFs, thereby resulting in a sustainable design.

Keywords: Natural fiber, Polymer composite, Dynamic mechanical analysis, Water immersion

1. Introduction

Natural fibres are excerpted from numerous natural resources, including plants, animals, and minerals (Ghalme, 2021). Wood fibres (soft and hard woods) and non-wood fibres, like straw fibres (rice, wheat, maize, etc.), seed fibres (cotton, coconut, etc.), leaf fibres (sisal, pineapple, etc.), and grass fibres (bamboo, elephant grass), are the four categories into which NFs can be divided (Singh et al., 2021). The formation of bio-Comp.s is facilitated by the utilisation of a thermoset matrix (epoxy, and polyurethane, and polyimides, and phenolic, etc.) and six thermoplastics (poly-lactic acids, and poly-vinyl chlorides, and cellulosic, and acrylic, and polypropylene, etc.) (Afzal et al., 2021). The aspects of the bio-Comp.s that were made are significantly influenced by the aspects of both the fibre and matrix. The MPs of the bio-Comp. that has been developed, including tensile, compressive, flexural, and impact strength, are contingent upon the fiber's rigidity, strength, density, ductility, and roughness, along with the volume fraction of reinforced fibres (Rajendran et al., 2021). The relative location of the fibre within the Comp. structure is managed by the matrix material (Nayak et al., 2021). The interfacial adhesion across the fibre and matrix interface is significantly influenced by the wettability of the ploy-mat with reinforced fibre (Das et al., 2021). The MPs of the bioComp.s that were made are boosted by the presence of a strong interfacial adhesion across the fibre and matrix (Saha et al., 2021).

Polymer Comp.s grounded in synthetic resources are toxic and non-biodegradable and contains petroleum based resources which is very harmful for humans and environment (Malakooti and Bowland, 2021). Due to several environmental issues, the application spectrum of the natural fiber based Comp.s is increasing globally in every field of engineering and commercial sectors (Radoor et al., 2021). Therefore, it becomes necessary to understand the technology behind the successful development of natural fiber reinforced PCs (Patel et al., 2024). Therefore, it becomes necessary to carry out the DMA of the PCRwNFs post one year of WI.

2. Material and method

Dynamic mechanical analysis (DMA)

The Perkin Elmer Thermal analyzer (DMA 8000) was employed to conduct dynamic mechanical analyses. In the three-bending point mode, the apparatus was operated at a heating rate of 20C/min and a frequency of 1 Hz, with a temp. range of 0 0C to 110 0C. The specimens for DMA were prepared in accordance with ASTM D7028. The dimensions of the samples were 22 × 6 × 2 mm3. The DMA analyzer was utilised to record the damping capability (tan δ), storage Mod. (E′), and loss Mod. (E") curves in relation to temp. Table 3.1 displays the specifications of the DMA 8000.Figure 1 illustrates the experimental setup for DMA.

Table 1. Specification of DMA machine

1. Instrument	Perkin Elmer Thermal Analysis (DMA 8000)
2. Deformation mode	Three bending point mode
3. Heating rate	20C/min
4. Temperature range	0 to 1100C
5. Frequency	0.5, 1, 2 and 3 Hz
6. Maximum load	Up to 18N
7. Sample dimension	Length (22mm), width (6mm), thickness (4mm)
8. Cooling	Liquid nitrogen with automated cooling

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Figure 1. Experimental set-up of Perkin Elmer Thermal Analyzer (DMA 8000)

3. Result and Discussion

Table 1 illustrates the glass transition (GT) temp. of all the Comp.s that were developed increased in comparison to the GT temp. of dried specimens post one year of WI. The max. increase in GT temp. (23.7%) was observed in the water-immersed jute/hemp/epoxy Comp. compared to the dried specimen, as illustrated in figure 6.5. Table 6.1 indicates that the water-saturated jute/hemp/epoxy Comp. exhibited a GT temp. of 76.20C, the fourth greatest value among all the Comp.s that were developed following water immersion.

Each Comp. specimen that has been developed is capable of absorbing moisture when submerged in water. Natural fibres are hydrophilic, denoting they have the ability to absorb water. The reinforced fibres determine the moisture absorption capacity of PCs. In the DMA of water-immersed specimens, the temp. is initially consumed to reduce the moisture content

of the test specimen as the load is applied with respect to temp. This process increases the GT temp. of all the developed Comp.s.

The GT temp. of the hemp/epoxy Comp. that has been submerged in water has shown a minimal increase (8.56%) in comparison to the dried specimen. According to Table 2, the GT temp. of the water-saturated hemp/epoxy Comp. was 78.60C, which is the third greatest value among all the Comp.s that were made following water immersion. The GT temp. of the jute/hemp/flax/epoxy Comp. that is submerged in water has been observed to increase by 13.8% in comparison to the dried specimen. Table 4.6 indicates that the GT temp. of the water-saturated jute/hemp/flax/epoxy Comp. was 89.10C, were developed during WI.

Table 2. Glass transition temp. and damping capability of all the developed Comp.s before and after water immersion

Sample	Glass transition temp. Tg (oC)		Damping capability (tan δ)		Storage Mod. (GPa)		Loss Mod. (GPa)	
Dry specimen	Water saturated specimen	Dry specimen	Water saturated specimen	Dry specimen	Water saturated specimen	Dry specimen	Water saturated specimen
Jute/ epoxy	67.1	80	0.568	0.588	2.56×10 7	2.21×10 8	1.58×10 7	1.09×10 8
Hemp/ epoxy	72.7	78.6	0.632	0.605	6.03×10 7	1.74×10 8	3.81×10 7	8.41×10 7
Flax/ epoxy	64.4	73.7	0.618	0.652	2.11×10 8	6.35×10 8	1.30×10 8	3.75×10 8
Jute/ hemp/ epoxy	61.6	76.2	0.661	0.555	6.17×10 7	1.26×10 8	2.31×10 7	6.91×10 7
Hemp/ flax/ epoxy	60	69.9	0.682	0.647	5.47×10 7	1.74×10 8	3.34×10 7	8.72×10 7

Jute/ hemp/ flax/ epoxy	78.3	89.1	0.476	0.401	1.30×10 8	3.37×10 8	5.64×10 7	1.29×10 8

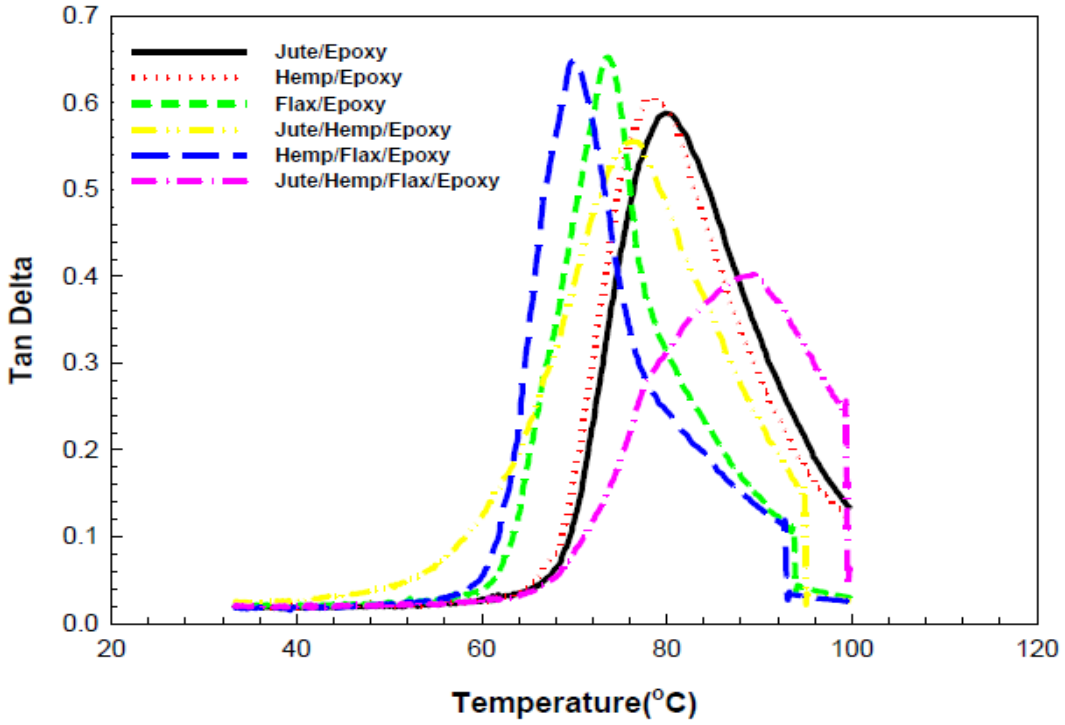

Figure 2. Damping curve of the developed Comp.s after water immersion

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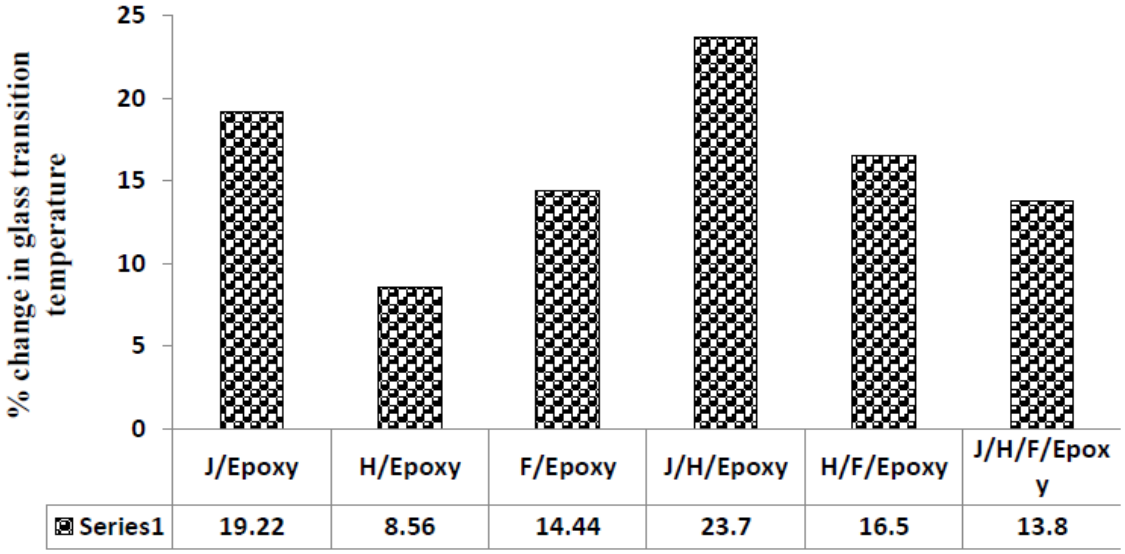

Figure 3. Percentage change in glass transition temp. (J-Jute, H-Hemp, F-Flax)

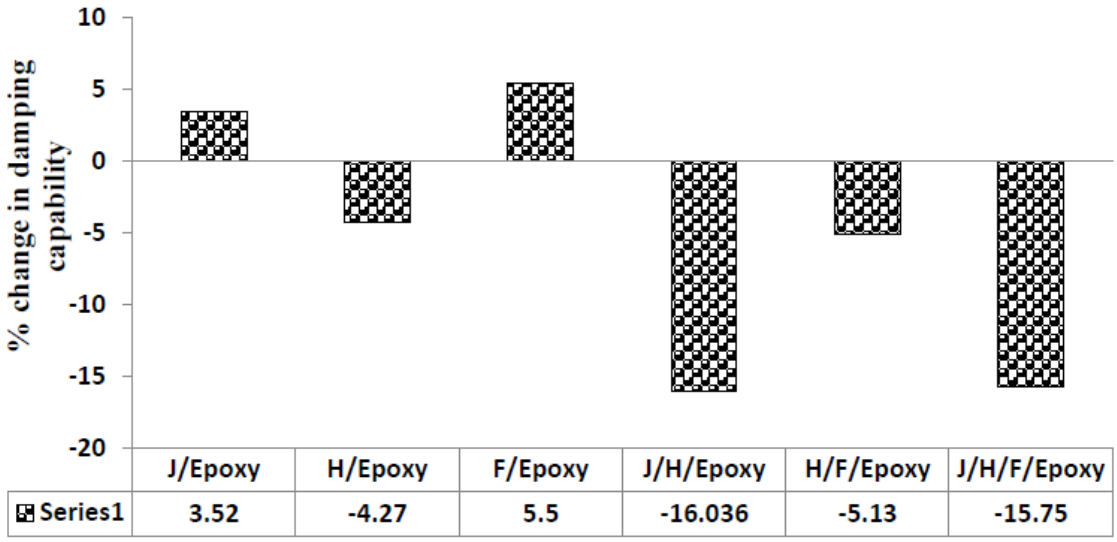

Figure 4. Percentage change in damping capability (J-Jute, H-Hemp, F-Flax)

Figure 2 illustrates the % change in attenuation capability (tan δ) of all Comp.s that were made post one year of WI. The damping capability of the jute/hemp/epoxy Comp. was reduced by the most (16.03%) when it was saturated with water, as compared to the dried specimens. In comparison to dried specimens, the tan δ of water-saturated jute/epoxy and flax/epoxy Comp.s increased by 3.52% and 5.53%, respectively. In comparison to all other water-saturated specimens, the jute/hemp/flax/epoxy hybrid Comp. that was water-saturated attained the lowest tan δ value (0.401). This may be attributed to the robust interfacial adhesion across the fiber/matrix interface in hybrid Comp.s, which have varying aspects owing to the three distinct layers of jute, hemp, and flax fibres.

4. Conclusion:

As a result of the increased fiber/matrix interfacial adhesion, the molecular movement at the fiber/matrix interface is reduced, resulting in a diminished attenuation capability (tan δ). It was determined that the fiber/matrix interfacial adhesion of the developed Comp. was improved by the incorporation of ramie fibre, a property that is not present in plain epoxy. The damping capability of the Comp.s that were developed was diminished owing to the strong interfacial adhesion, as demonstrated by the results of DMA.

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