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# Enhancing Mechanical and Viscoelastic Properties of Natural Fibre Reinforced Polymer Composites with Aluminium Oxide Nano Fillers

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**Abstract.**Due to its numerous benefits, such as their high strength-to-weight ratio, low weight, and lightweight construction, natural fiber reinforcing polymeric composites have lately become more popular. The present study involved the fabrication of six laminates. These laminates included natural fibers like palm and bamboo, as well as reinforcing fillers made of aluminum oxide ($Al_2O_3$) in an epoxy matrix. Composites with improved tensile qualities were obtained through mechanical testing by combining several types of natural fibers. Also, composites with extremely high energy absorption propertiescaused by carbon nanotubes' high specific energy absorptionshowed an impact enhancement of up to 80.6% when $Al_2O_3$ was used as a nanofiller. With a storage modulus that was 41% higher and a glass transition temperature ($T_g$) that was much higher, hybridized composites reinforced with $Al_2O_3$ demonstrated encouraging results in viscoelastic behavior. It should be mentioned that the mechanical properties were improved after treating the fibers in a NaOH solution before composite manufacturing. This strengthened the interaction adhesion among the epoxy matrix.

## 1 Introduction

Natural fiber reinforcing composites (NFRC) have been the subject of intensive research due to the promising prospect of creating lightweight composites with desirable particular properties.Natural fibers have several advantages, such as being inexpensive, easy to manufacture, abundant in nature, and kind to the environment [1]. Because natural fiber

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composites are lighter and have a specific modulus and strength comparable to glass fiber, they first supplanted glass-fiber reinforced polymer composites [2]. Hemp, flax, palm, and sisal-like agave leaf fibers are among the most popular plant-based reinforcing materials used in engineering. Researchers have turned their attention to developing hybrid composites that combine the ductility, stiffness, and strengths of NFRC with those of manmade materials in order to meet the rising demand for these types of composites in contemporary applications [3]. Furthermore, by combining the greatest traits of multiple fiber types whether synthetic or natural through hybridization, one might attain greater mechanical properties. Hybrid Palm-Bamboo fiber composites, for example, outperformed single-fiber reinforced composites in tests measuring tensile strength and modulus of elasticity [4]. The coefficient of sound absorption and maximum damping factor of hybrid composites are excellent qualities for non-load bearing buildings that must prioritize noise control. In addition, the scientists used bamboo to make hybrid polymer composites [5].A tensile strength of 48.6 MPa was achieved through the hybridization of Bamboo and graphite. Tensile moduli for CR composites were 11.94 GPa, for Palm composites it was 11.59 GPa, and for a hybrid composite it was 14.79 GPa. Research on the effects of using date palm fibers came to comparable conclusions [6]. Polymer composites can have their strength and load bearing capacity enhanced by adding hybridized fibers as reinforcing fillers, according to research. Alumina ($Al_2O_3$) nanofillers have many benefits, including a maximum expecting proportion, electrical characteristics, and mechanical characteristics, making them an excellent choice for polymer composites [7]. According to research, nanofillers can increase the strength of synthetic fiber hybrid composites by at least 30% [8]. The method of strengthening and experimental inquiry into micro-scale natural fillers and nano-scale fillers have received the bare minimum of attention. Incorporating bast fibers from palm trees and functionally graded, extremely lightweight bamboo into the epoxy matrix increased its toughness, strength, and stiffness and ultimate tensile strength related to other natural fibers [9]. The hybrid composites were fortified with aluminum oxide ($Al_2O_3$) because of their outstanding structural and functional qualities and high aspect ratio. Section 2 of the paper goes into great detail about the composites' mechanical properties, the process of fabrication, and the materials employed. Section 3 presents the results, and discusses the main conclusion.

# 2 Experimental Methodology

## 2.1 Fabrication of Samples

Reinforcing epoxy resin with bamboo and palm fibers and aluminium oxide ($Al_2O_3$) was the focus of the present study. Here, we tried every possible filler combination to learn more about the effects of hybridization and individual filler reinforcement. Kovai cheenu enterprises of Coimbatore, India, provided the epoxy HY951 and hardener LY956 that were utilized to connect the fibers (in a random order). A local provider in Chennai, India, supplied the untreated bamboo and palm mats with a density of 1.2 $g/cm^2$. Alkali treatment with 5% NaOH was used to increase the interaction bonding of the fiber and Epoxy and to prevent flaws [10]. After that, we rinsed the palm and bamboo fibers with distilled water and let them air dry. The present study utilized $Al_2O_3$ (the reinforcing fillers). The material's 98% purity was achieved during its synthesis by means of the catalytic chemical vapor deposition (CCVD) process [11]. It appeared as a dark powder with a nanoscale structure that looked like spaghetti. The material's length varied between 6 and 9 meters, and its average cross-sectional diameter was 10 nm. Laminates measuring 250 mm×250 mm×3 mm were produced using a 100-ton capacity compression moulding machine operating at 2500 psi and 230ºC. At room temperature, the chilling procedure was executed. Six composite laminates reinforced with natural fibers were developed, as shown in Table 1.

**Table 1.** Composition of composite sample

| Sample Code | Composition | Resin (g) | Fibre (g) | Filler (g) | Total (g) |
|---|---|---|---|---|---|
| S1 | Bamboo - Epoxy | 95 | 5 | 0 | 100 |
| S2 | Palm - Epoxy | 95 | 5 | 0 | 100 |
| S3 | Bamboo - Palm - Epoxy | 95 | 2.5+2.5 | 0 | 100 |
| S4 | Bamboo - Epoxy -$Al_2O_3$ | 89 | 5 | 6 | 100 |
| S5 | Palm -Epoxy -$Al_2O_3$ | 89 | 5 | 6 | 100 |
| S6 | Bamboo - Palm - Epoxy -$Al_2O_3$ | 89 | 2.5+2.5 | 6 | 100 |

### 2.2 Characterizations

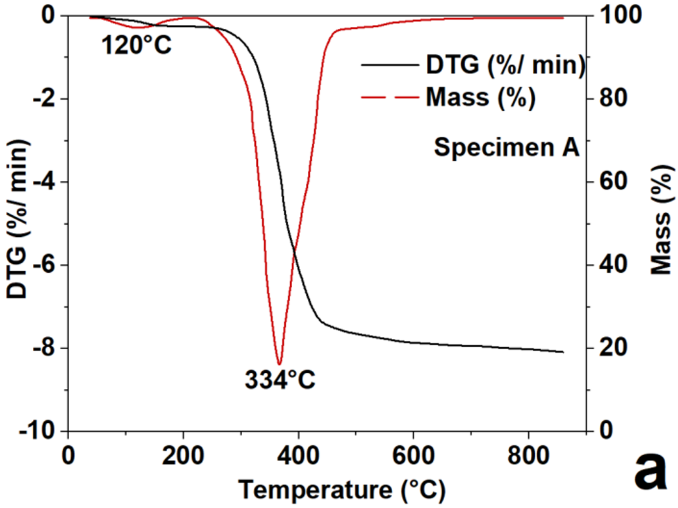
The stress-axial enduring capacities of the laminates were determined by cutting samples according to the dimensions specified by ASTM D3039, which are 120 mm×20 mm×3 mm. An equipment with a load cell capacity of 100 kN was used for tensile testing. The samples were secured from falling out by tabbing the ends. Their tensile strength was determined for every laminate. A machine that measures energy absorption in accordance with ASTM D256 criteria was used to measure each laminate. Using 100 mm×20 mm×5 mm samples, the laminates were twisted three times to test their transverse loading capacities according to ASTM D-790 standards. The TA Instruments DMA Q800 was used to conduct the DMA with a 3-point bending clamp configuration [12]. In the experimental setup, the following values were used: 15 mm amplitude, 0.1 Hz, 0.01N force, and 30-180°C. All lamination conditions were tested with three separate samples to guarantee repeatability, unless specified differently. The plastic deformation and expansion of the laminates, produced by the fibers growing from absorbing moisture, were measured using thermo gravimetric analysis (TGA) with a Netzsch STA 449F3 apparatus. With nitrogen flowing and air at 262.4 mL/min and 250.0 mL/min, respectively an alumina crucible from 40°C to 1050°C at 10°C/min. We used an FTIR-6300type, to look at the vibration spectrum of the composites. Sampledimension of 10 mm×10 mm×3 mm was tested for viscosity with the cantilever technique from 30°C to 170°C. An amplitude of 5 Hz was employed, with a heat rate of 100°C/min. A coating of approximately 4 nanometers of Pt was applied to the samples using the Hitachi S-3000N machine. The Raman spectroscopy investigation with an excitation wavelength of 633 nm, in conjunction with a Leica DM 2500 M optical microscope and the stellar-Pro ML150 laser.

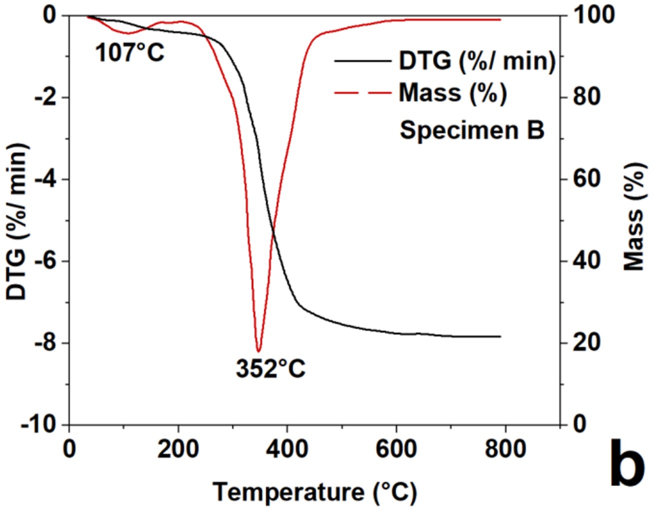
## 3 Results and Discussions

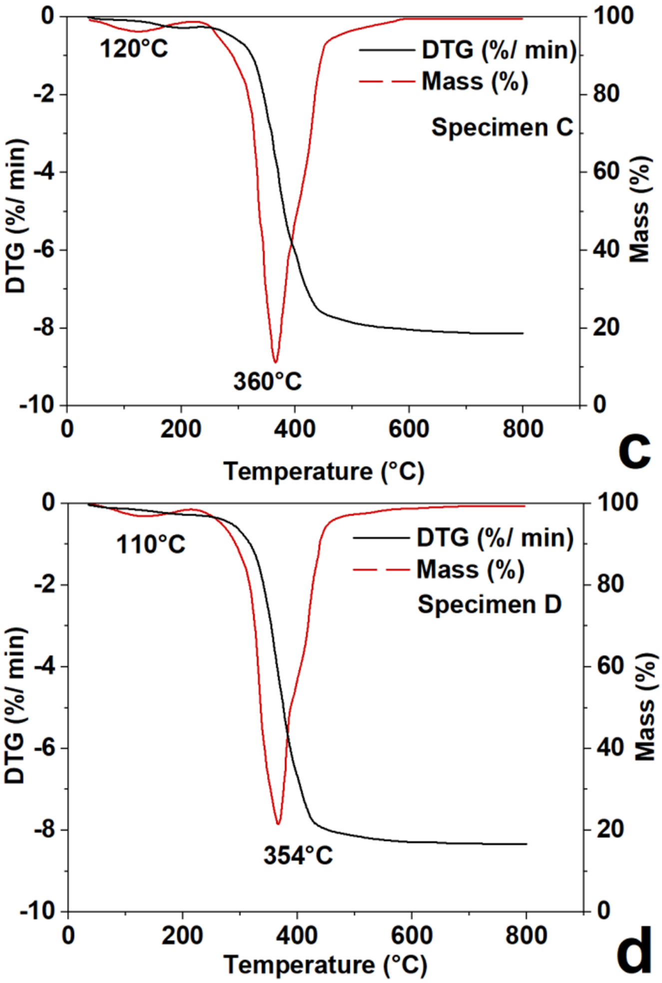
### 3.1 Results on TGA and DTG Analysis

Fig. 1(a) to Fig. 1(f) shows the results of the TGA and DTG testing of the six laminates made, which were run from 35°C to 800°C. The composites' first-derivative curve becomes longer as the heat increases from 311°C to 550°C. Table 2 shows the findings of the thermal oxidative deterioration of the samples. The laminates lost mass in two phases: from 37.8°C to 250°C to 850°C. The compounds' residual masses varied between 18.25% and

20.76%. Relative percentages of remaining mass and two-stage mass loss have been shown in previous research on composites based on bamboo [13]. Heat breaking down the fiber's lignocellulosic components, particularly cellulose, causes a dramatic decrease in mass in the second stage, which accounts for the massive weight loss in the initial step, which may be explained by water evaporation from the samples. It is possible that the char or other byproducts of the higher moisture content in palm fibers likely explains why laminates made of palm (b-f) lost more mass than laminates made of bamboo (a, c, e, and f). In terms of thermal stability, or the temperature at which they decompose, bamboo-based laminates outperformed palm-based laminates [14]. While the residual mass of $Al_2O_3$-reinforced laminates (d-f) was comparable to that of non-reinforced laminates, it is interesting to note that some of these laminates had a higher decomposition temperature (up to 363°C), suggesting that the addition of $Al_2O_3$ can achieve very high thermal stability [15].



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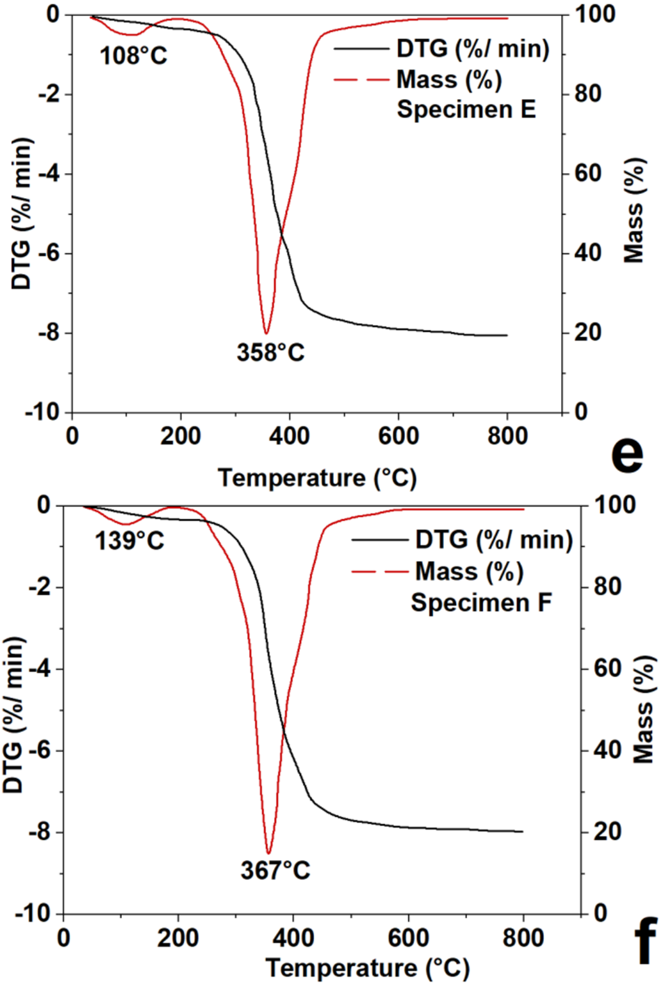

**Fig.1.**Evaluation of TGA and DTA curves of samples (a) S1 to (f) S6 composites between 0$^{o}$C and 850$^{o}$C

**Table 2.** Results on TGA/DTG data for various composites

| **Specimen code** | **Mass Change (%)** | | **DTG Peak Values ($^{o}$C)** | | **Residual Mass (%)** | **Onset Temperature ($^{o}$C)** |
|---|---|---|---|---|---|---|
| | **37.8$^{o}$C to 250$^{o}$C** | **250$^{o}$C to 850$^{o}$C** | **37.8$^{o}$C to 250 $^{o}$C** | **250$^{o}$C to 850$^{o}$C** | | |
| S1 | 2.24 | 78.72 | 120 | 334 | 16.2 | 320.8 |
| S2 | 3.54 | 76.90 | 107 | 352 | 19.32 | 312.3 |
| S3 | 2.61 | 79.24 | 120 | 360 | 18.62 | 319.8 |
| S4 | 3.13 | 78.15 | 110 | 354 | 21.6 | 312.1 |
| S5 | 2.32 | 81.26 | 108 | 358 | 20.08 | 322.8 |
| S6 | 3.07 | 77.17 | 138 | 367 | 18.88 | 315.8 |

## 3.2 FTIR Characterization

Table 3 shows the maximum values that were later calculated, and Fig. 2(a) shows the vibrational frequencies that were obtained from the FT-IR analysis. The hydroxyl stretched vibrations of cellulosic fibers, like those found in bamboo and palm, are represented by the vibrational broad band ranging from 3600 to 3200 cm$^{-1}$. C-H deformations, C-O stretch (1248cm$^{-1}$), C-O stretching of lignin (1180 cm$^{-1}$), C-O deformations (1018 cm$^{-1}$), aromatic ring (1591, 1511, 1473cm$^{-1}$), C=O stretching (1648cm$^{-1}$), C-H stretching, C-O stretching of the composites, ester groups (1180 cm$^{-1}$), and p-hydroxyphenyl C-H out of plane (830, 828, 702cm$^{-1}$). By exposing the C=C bonding peaks at 1641cm$^{-1}$, $Al_2O_3$ has demonstrated its interaction (adhesion) within the composites. All of the composites' spectra have shown that the Epoxy resin interacts with functional groups in bamboo, palm, and natural cellulose. The lack of a notable peak at 920cm$^{-1}$ for epoxy resin further demonstrated its polymerization and product oxidation. You can find a comprehensive FT-IR spectrum of each laminate, along with its associated vibrational bands.

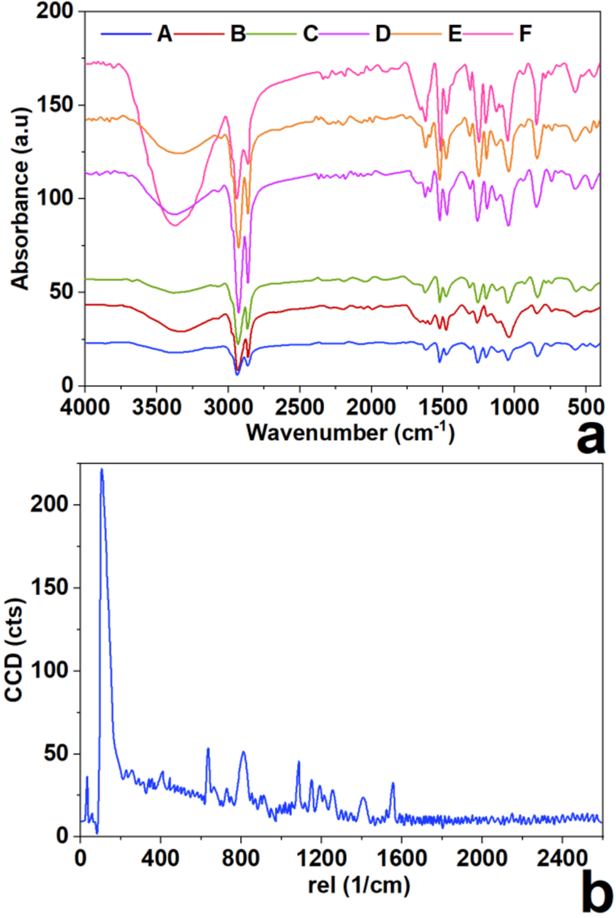

**Fig. 2.**(a) The Fourier transform infrared spectra of epoxy laminates with fillers made of $Al_2O_3$ and natural fibers (b) Raman analysis of epoxy composites enhanced with $Al_2O_3$ filler

**Table 3.** Frequency-domain infrared spectra of the manufactured composites

| Sample Code | FTIR Frequencies (cm$^{-1}$) | Observation |
|---|---|---|
| S1 | 3368, 2929, 2861, 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702 | Epoxy ring peak 920 cm$^{-1}$ vanished |
| S2 | 3368, 2929, 2861, 1646 (broad), 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702. | Epoxy ring peak 920 cm$^{-1}$ vanished |
| S3 | 3368, 2929, 2861, 1646 (broad), 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702. | Epoxy ring peak 920 cm$^{-1}$ vanished |
| S4 | 3368, 2929, 2861, 1646 (broad), 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702. | Epoxy ring peak 920 cm$^{-1}$ vanished |
| S5 | 3368, 2929, 2861, 1646 (broad), 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702. | Epoxy ring peak 920 cm$^{-1}$ vanished |
| S6 | 3368, 2929, 2861, 1646 (broad), 1595, 1511, 1473, 1248, 1184, 1022, 830, 828, 702. | Epoxy ring peak— 920 cm$^{-1}$ vanished |

### 3.3 Raman Spectroscopic Analysis

Raman spectroscopy was employed to investigate the structural alterations of epoxy composites derived from $Al_2O_3$ at the molecular level. Fig. 2(b) shows that the vibrations of the resin backbone are represented by Raman bands at 881cm$^{-1}$ and 1132cm$^{-1}$, while the deformations of the epoxy ring are represented by bands at 692cm$^{-1}$ and 1254cm$^{-1}$, respectively. The amide I vibration is responsible for the Raman band at 1673cm$^{-1}$, which is primarily caused by the C=O stretching of the amide group. Bamboo and palm fibers have a highly crystalline cellulose structure, which may be linked to hydrogen bonding between cellulose molecules, as seen by the 176cm$^{-1}$ band. The two noticeable peaks at 1354cm$^{-1}$ and 1533cm$^{-1}$ in the Raman spectra of graphene platelets, which correspond to the D-bands and G-bands, respectively, validate the characteristic properties of graphitic $Al_2O_3$. Found in the band G-band of $Al_2O_3$, crystalline graphite, sp2, demonstrates that nanotubes are strongly graphitized.For a semi-quantitative evaluation of the $Al_2O_3$ structural integrity in the Epoxy matrix, the intensity measured from the D-band to the G-band (ID/IG) is useful. The relatively low ID/IG ratio of 1.14in this investigation suggests that the $Al_2O_3$ did not experience a high number of flaws.

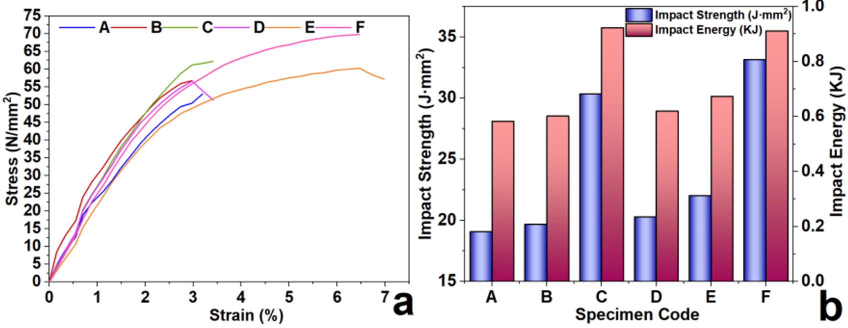

**Fig. 3.** (a) Evaluation of tensile Stress-strain curves of laminated samples (b)Results on IS of various composites

## 3.4 Mechanical Properties

### *3.4.1 Tensile Properties*

The stress-strain curves of the laminates, as shown in Fig. 3(a), show that initially, the tensile stresses change in a linear fashion with distortion or increasing strain. However, proportion persists all the way to the maximum value, even while linearity starts to loosen at the stress point. A catastrophic fracture happens when the load continues to rise beyond a certain point, at which point the proportionality stops and the load becomes disproportionately high. Laminate 6 (Palm + Bamboo + $Al_2O_3$ + Epoxy) had the highest tensile strength at 68.21 N/mm$^2$, whereas Laminate 1 (Bamboo + Epoxy) had the lowest at 47.32 N/mm$^2$. Other research has also shown high tensile strengths for epoxy composites reinforced with palm, bamboo, and $Al_2O_3$. A study found that palm fibers had a higher mechanical strength and better stress uptake because they are stiffer and stronger in the longitudinal direction. Incorporating both types of fibers into an epoxy matrix allows for the engineering of a micromechanical fracture arrestor from the higher-elongation fiber. Because of this, the strain threshold required for fiber breaking to propagate is raised.

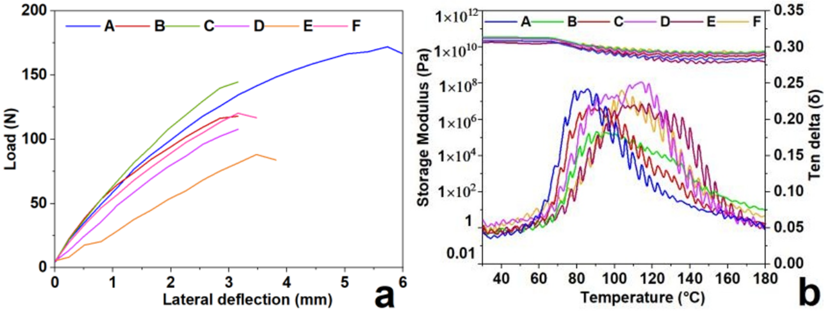

**Fig. 4.**(a) Evaluation of flexural strength of various samples (b) Evaluation of storage modulus and tan delta with respect to temperature.

In terms of tensile strength, palm reinforced composites outperformed bamboo reinforced composites by a wide margin. Since compressing the entire stack produces long punched fibers, palm fibers have an advantage when putting up composites over bamboo fibers since they can retain their length when crushed. Improved mechanical properties and a higher load-bearing capacity are the results of using longer fibers in composites. This is because longer fibers have a longer transfer length and protrude more from the matrix. Without the addition of $Al_2O_3$ fillers, an Epoxy matrix could be produced using only palm oil, which has a maximum TS of 51.4 N/mm$^2$. The composite's strength increased by 3.7% after adding $Al_2O_3$. This is because the Epoxy matrix, various fillers, and $Al_2O_3$ all connect well with one another, which improves load transfer. Efficient stress transfer from the epoxy matrix to the fibers is crucial for maximizing the fiber's strength in the composite. Because $Al_2O_3$ has a high surface area relative to its volume, the two surfaces bonded strongly. Fibers treated with a NaOH solution before manufacture improve the composite's tensile characteristics. This is because the epoxy matrix bonds better with the interfacial surfaces. This is because the NaOH was able to effectively remove the lignin from the fibers. Because of this, the fibers snapped into shorter pieces, which strengthened the bond between the fibers and the Epoxy matrix and decreased the number of voids. However, the length of time the fibers are exposed to the NaOH solution is crucial, since overly extended exposure can diminish their strength and quality.

### *3.4.2 Impact Strength*

To determine the composite samples' capacity to endure abrupt load, Izod's test was performed on them. Fig.3(b)indicates that the impact strength (IS) of sample 2 (Bamboo + Palm) was 14.4 J/mm$^2$ and that of Laminate 1 (Bamboo + Epoxy) was 13.9 J/mm$^2$. Palm reinforced composite has somewhat more impact strength (IS) than non-woven bamboo because its palm fibers are interwoven rather than randomly arranged, which results in a stronger structure. Laminate 3, which is a hybrid of Bamboo and Palm with epoxy, had an impact strength that was 80.6% more than Laminate 1 and 74.3 percent higher than Laminate 2, respectively, after the hybridization process. Due to the enhanced energy absorption capacity brought about by the palm and bamboo additions to the epoxy, which resulted in better interfacial bonding, the hybridized composite saw a marked improvement. Because the Palm and Bamboo fibers have such good interfacial bonding with the Epoxy matrix, it is difficult for the break pinning mechanism, internal crack extension, and first break to occur. In terms of energy absorption and resistance to abrupt shock, laminate 6 (Palm + Bamboo + $Al_2O_3$ + Epoxy) outperformed all other composites. Its strength was 100% higher and its impact energy absorption -99.8% higher than the average values reported by laminate 2 and laminate 1. Adding $Al_2O_3$ to the Epoxy matrix considerably improves the composite's impact properties due to $Al_2O_3$'s substantially superior capacity to absorb impact energy compared to the Epoxy matrix alone. Composites that are able to absorb more energy are stronger overall. Polymer blends can be described as going from brittle to tough depending on parameters like interparticle distance or matrix ligament thickness. Thus, it is possible that the present study's fillers contributed to a reduction in interparticle spacing, leading to a tough ERP matrix. Reduced particle size purportedly makes dominant toughening mechanisms like stress concentration and shear yielding work better to toughen the polymer matrix. Nanofiller $Al_2O_3$ was crucial in this study because it absorbed stress from the matrix and dissipated energy through fracture, both of which worked together to boost the matrix's strength. Composites having interpenetrating phase structures have plastic deformation that can be enhanced by the reinforcing phase, leading to enhanced strength and toughness, according to reports. The polymer matrix's crystallinity implies that toughening efficiency could be enhanced. One method to increase the composite's resistance to damage is to introduce a β-crystal structure, which alters the crystalline state of polypropylene and creates a bundle-like arrangement that enhances energy dissipation. This study lends credence to the idea that $Al_2O_3$ migrated to the Epoxy interface after being added to the Epoxy matrix. The higher impact strength data demonstrate that the migration created a network structure that enhanced fracture toughness. For the goal of reinforcing composites, additional research into how micro- and nano-scale fillers influence crystallinity, phase transitions, and nucleation in Epoxy matrices is required. Laminate 1 is made of bamboo and epoxy, whereas Laminate 6 is a combination of bamboo, palm, epoxy, and aluminum oxide. Epoxy binds strongly to bamboo, palm, and $Al_2O_3$ fibers at the interface. Composites reinforced with bamboo fibers experienced higher fiber breakages than those reinforced with palm fibers. S3 and S6 palm fiber reinforced composites are exceptionally strong and absorb a lot of energy because the long fibers stick firmly to the epoxy matrix. Finally, bamboo fibers, in contrast to palm fibers, have a tendency to snap when layered due to compressive stresses. The composite's reduced energy absorption capacity is a result of the shattered bamboo fibers creating a space between the Epoxy matrix and the shattered fibers. The composites' impact strength and energy absorption capability were enhanced by adding $Al_2O_3$ fillers. Because of $Al_2O_3$'s high specific energy absorption of 1.78 GJ m$^{-3}$ and its load transfer efficiency, the composite is able to absorb a lot of energy.

### *3.4.3 Flexural Properties*

The maximum bending force that can fracture a beam in a three-point bending test is the flexural strength of the material. The composites that were made for this investigation demonstrate their flexural behavior in Fig. 4(a). In sample 1, the transverse load was 177.82 N and the deflection was 6.1 mm for the bamboo and epoxy composite, while in sample 5, the transverse load was 95.65 N and the deflection was 3.86 mm for the palm and epoxy with $Al_2O_3$ composite. With a minimal deflection of 3.12 mm and a transverse load of 151.08 N, the third laminatemade of bamboo, palm, and epoxywas equally impressive.

Fiber hybridization improves the composites' transverse load-carrying capacity and decreases deflections, as demonstrated by this specific feature. However, adding $Al_2O_3$ did not considerably increase the composites' flexural strength. One probable reason is that the flexural properties of the composite network are reduced to an unsatisfactory level due to $Al_2O_3$ clumping together within the epoxy matrix. A single cluster, no matter how small, can concentrate failure. The high aspect ratio of >1000 and the nano-scale diameter of $Al_2O_3$ allow for its aggregation because of the vast surface area.The mechanical properties of the laminates, as summarized in Table 4, are based on all of the results discussed earlier. The addition of $Al_2O_3$ to the hybrid polymer composites greatly improved their TS and IS, but had the opposite effect on their FS, as already indicated.

**Table 4.** Mechanical properties of the laminates

| Specimen code | Laminates | Tensile Test | | Impact Test | | Flexural Test | |
|---|---|---|---|---|---|---|---|
| | | Stress (N/mm$^2$) | Strain (%) | Impact Energy (kJ) | Impact Strength (J/mm$^2$) | Maximum Load (N) | Deflection (mm) |
| S1 | 49.53 | 3.22 | 0.471 | 17.57 | 177.11 | 6.37 | 49.53 |
| S2 | 55.08 | 3.18 | 0.487 | 18.12 | 123.74 | 3.60 | 55.08 |
| S3 | 61.41 | 3.25 | 0.806 | 28.74 | 148.76 | 3.42 | 61.41 |
| S4 | 56.93 | 3.29 | 0.504 | 18.68 | 148.76 | 6.27 | 56.93 |
| S5 | 62.17 | 7.37 | 0.554 | 20.35 | 94.71 | 4.16 | 62.17 |
| S6 | 71.03 | 6.79 | 0.887 | 31.46 | 127.57 | 3.73 | 71.03 |

### *3.4.4 Dynamic Mechanical Analysis (DMA)*

Fig.4(b)indicates the correlation between temperature, storage modulus (E′), and tan $\delta$ for all six laminates produced for this study. Sample 6 clearly outperformed the others while testing laminates with storage modulus values ranging from 30 to 180 degrees Celsius. As an example, the fact that laminate 6 showed a 41.8% improvement inE-′ compared to laminate 1 (Bamboo + Epoxy) proves that the $Al_2O_3$ and Epoxy matrix adhere very well to each other through intermolecular forces. Natural fibers, such as palm, which has a high stiffness (40GPa), could have also added to the composite's total rigidity. Another research showed the same thing when they used natural fibers like pine, rice husk, bagasse, and rice straw. Consequently, the extremely rigid Bamboo + Palm + Epoxy + $Al_2O_3$ has demonstrated outstanding stress-transfer properties when subjected to sinusoidal dynamic force.The glass transition temperatures (Tg) of the laminates were found by finding the greatest value of tan $\delta$ using DMA analysis. The addition of palm, bamboo, and $Al_2O_3$ to the epoxy matrix caused the laminates' $T_g$ to skyrocket from 86.3ºC to 116.85ºC. Comparing laminates 1, 2, and 3 (i.e., those without $Al_2O_3$) to samples 4, 5, and 6 (i.e., those reinforced with $Al_2O_3$), a greater Tg was noted. The rise in the composites' Tg is clearly attributable to the incorporation of $Al_2O_3$. The reinforcing activity of $Al_2O_3$ causes the Tg to increase because it tightens the network as a whole and prevents the polymer chains from moving about. Some positive indicators include the fact that the $Al_2O_3$, bamboo, and palm fibers adhere well to the epoxy matrix.

## 4 Conclusions

Epoxy composites incorporating a mixture of natural fibers and the reinforcing effect of $Al_2O_3$ demonstrated enhanced mechanical characteristics. Examples of composite materials include palm, bamboo, epoxy, and $Al_2O_3$, which together reached a maximalTS of 70.03 MPa. When high- and low-elongation fibers were mixed in an epoxy matrix, the strain needed to propagate a fiber breakage was reduced, and the micromechanical level of crack arrest was achieved by the higher-elongation fibers. Additionally, due to $Al_2O_3$'s exceptional load transfer efficiency, hybrid composites made of palm, bamboo, epoxy, and $Al_2O_3$ demonstrated superior energy absorption qualities and robustness to abrupt shock compared to other composites. A tightening impact on the overall system, this causes the polymer chains to become less moveable, is another way that $Al_2O_3$ inclusion increased the $T_g$ of the composites. Based on our study's findings, a material that combines natural fibers with an epoxy matrix and nanofiller reinforcement of $Al_2O_3$ could be a game-changer in fields that demand very maximum strength and IS absorption.

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