

## Research Article

# Influence the Graphene Filler Addition on the Tensile Behavior of Natural Kenaf Fiber-Based Hybrid Nanocomposites

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In current centuries, emphasis has moved from previous resources and compounds to lightweight substances to generate softer, most effective components for particular needs. Using organic kenaf fibers with nanoreinforced epoxy polymers in a blended microbially nanocomposite can improve properties and be environmentally friendly. Adding graphene powder to the epoxy resin increases barrier and mechanical properties while maintaining rigidity without compromising toughness. To explore the impression of such parameters on the materials' properties of the construction, a mechanical test on nanocomposite features, such as size, filler content, and treatment effect, may be utilized. The elastic behavior, tension characteristics, and stress at vintage for three types of nanobased materials were calculated using the test results: graphite raw kenaf, nanosheets and sun-bleached kenaf fibers, salinized graphene oxide, and epoxy reinforced with salinized kenaf fibers. The impact of nanocomposite magnitude, filler concentration, and filler processing on mechanical properties is carefully investigated. According to the findings, the three-weight proportion of 75 nm-sized particles with salinized filler and kenaf fiber produces the maximum mechanical performance. Compared to other combinations, these combinations increase tensile strength by 16%. However, it appears to be beneficial when it comes to strength properties and deflection. Because of flaws and cavities at the micrometer level, the framework was less robust and distorted quickly after including a nanoparticle filler.

## 1. Introduction

The growth of the market for fiber-reinforced composites in the automotive industry has sparked a hunt for ecologically benign natural resources. Composite materials have been widely used in transport applications, substituting conventional metals for decades due to their many benefits to engineering structures [1]. Composite materials' lighter weight properties are particularly fascinating in transport applications since they might cut energy usage. Aside from being

lighter than steel, composite materials offer more unique traits. Composite materials have greater fatigue endurance than steel. This property has increased the appeal of composite materials used in structural usage [2]. Although they have numerous advantages, composites are primarily constructed of artificial fibers such as graphite, glass, and fiberglass. Natural fibers may offer an environmentally friendly alternative to synthetic fabrics. Since synthetic fibers are not recyclable, this circumstance has a detrimental impact on climate change [3]. Apart from lignocellulose fibers are being



FIGURE 1: Extraction of kenaf fiber from kenaf plant.

used to replace artificial fibers, which might make composite products more environmentally sustainable.

Furthermore, organic filaments offer numerous benefits over artificial materials, counting superior properties, lower price, low density, lower power consumption, and being environmentally benign, nonabrasive, nontoxic, and sustainable [4]. Lengthy kenaf bast fiber packs (*Hibiscus cannabinus* L., Malvaceous) are frequently used to create cables, rugs, floor coverings, broadsheets, and other products [5]. Shrub fibrils, such as sisal, coir, and kapok, have lower tensile strength, making them excellent for applications that require resilience and lightness [6]. Despite rising demand for these composite materials, fiber selection has been influenced more by operational viability than narcotic effectiveness. Composite materials are mixtures that contain multiple strands in a homogeneous material. Kenaf may have similar theoretical qualities to glass fibers because they are softer, more eco-friendly, and less expensive. In one study, injection-molded kenaf fiber and thermosetting polymer components containing 40% kenaf fiber and substances used to produce ductility properties comparable to glass fiber thermosets were tested [7].

The combination could significantly improve the mechanical strength of natural dispersion polymer composites by eliminating the shortcomings of independent blends [8]. Organic fiber-based composites provide a number of advantages over synthetic fiber composites, but they also have certain drawbacks [9]. One of their major flaws is their incompatibility with polymeric matrixes due to the hydrophobic nature of cellulosic fibers [10]. Moreover, lignocellulosic fiber-based composites were reported to have poorer notch sensitivity than artificial composites. The hydrophilicity of lignocellulosic materials causes a considerable amount of moisture to be absorbed from the environment. On the other hand, chemical methods can increase the interaction of fibers and polymer matrices [11]. Natural materials are typically pretreated during composites' manufacture to promote interaction in the composite and achieve remarkable mechanical strength [12]. Treatment processes alter the surface characteristics of the filaments, resulting in a strongly cross-linked interfacial area with covalent bonding connections between the reinforcement and matrix. Alkali treatment is among the most frequently used pretreatment processes for altering the fiber surface morphology and dissolving a large lignin content, waxes, and contaminants [13]. The hydroxyl groups of lignocellulosic materials are ionized particles to alkoxide during the

alkaline chemical modification. That reduces the fiber's hydrophilic nature and enhances the fiber–matrix interaction. Moreover, due to the decreased amount of hydrophilic groups on the fibers, alkali-treated natural fibers have been shown to have superior fiber dispersal characteristics, leading to greater stress transmission throughout the fiber–matrix interaction. Silane is also a well-known coupling agent for a chemical modification that has been widely used to increase the connection between fibers and matrix [14]. One of the most trustworthy and recognized composites for producing models in the modern environment of materials and industrial engineering would be those built using nanoparticle-reinforced polymers [15].

On the other hand, hybridization based on carbon and natural fibers is advantageous for assuring high mechanical characteristics in composite materials. Graphite must be oxidized and exfoliated to yield graphene oxides, which must then be chemically reduced to yield graphene nanosheets [16]. Natural fibers and graphene nanosheets are combined to create hybrid nanocomposites. Carbon derivative-based nanocomposites exhibit essential mechanical qualities at a cheap production cost. Nanomaterials have substantially bigger exchanging surfaces than microscopic sizes for a particular load. On the other hand, these composites will get a superior load transfer inside a framework [17]. The inclusion of microfibrils increases the matrix's mechanical qualities, although at the expense of other features. According to the literature, nanocomposites generally exhibit qualities similar to regular composites but still at concentrations of up to 20% [18].

The proposal's primary objective is to create carbon nanocomposite and investigate one's material properties, like tensile. The surface morphology of a strained sample was examined using scanning electron microscopes (SEMs). The hand lay-up technique was then used to create the nanocomposite to test the effectiveness of fracture toughness predicated on filler size, composition, and other considerations.

## 2. Experimental Works

**2.1. Materials.** Ganga Fiber Products, India, supplied the stitched kenaf mates. The kenaf fiber mates have been delicately washed with drinkable water and dried in the oven for three different days to eliminate the moisture. The Globe Chemical products sector supplemented the matrix with nanoparticle additives in Kolkata, India. Figure 1 shows the extraction of kenaf from a kenaf plant.

**2.2. Alkaline Treatment.** To reduce contamination, the kenaf cellulose fibers were scrubbed in 2–3 wt% rinsing solvents for 60 min at 80°C, after which they were washed thoroughly with filtered water before exfoliating in an elevated electric furnace for 30 min. The same fibers were again engrossed in a 5% NaOH solution at ambient conditions for 240 min. The fibers have been kept clean by soaking them in a 1.5:1 combination of benzoic acid and alcohol for 60 hr at 55°C, followed by a comprehensive wash 1 day after solar drying.

**2.3. Bleaching Treatment.** Chemical agents such as hydrogen chloride, salt chalcopryrite, hypochlorite, and chlorine dioxide extract cellulose from natural fibers. The dissociation of NaClO<sub>2</sub> in distilled water produces hydrochloric acid, which is widely used as a bleaching reagent. After alkalization, whitening eliminates all chromophore groups and phenolic substances like hemicellulose and lignin. Finally, bleaching allows cellulose production with a superficial, encompassing H<sub>2</sub> linked to the component. The lignocellulosic surface must be chemically modified to provide complete interaction between the fiber and the polymer.

**2.4. Biochemical Superficial Alteration.** The complexation of a lignocellulosic surface allows for adding a compatibilizer that can interact with reinforcement and resin. The most prevalent bonding agents are silane, maleic anhydride, and adipate acrylate. Salinization of fibers, for example, improved interactions with polymers and distribution [19].

**2.5. Fabrication of Nanocomposites.** A broad range of techniques was utilized to create thermoplastic nanomaterials. Moreover, whenever the nanoparticles contain granules and short filament strengthening, a particular subtle case may be made in the case of ferroceement scattering as in epoxy that is been accomplished in a research lab before fabricating using the sonication beam technique. There are several primary phases in producing carbon natural firebase hybrid nanocomposite specimens. To obtain the intended functionality, the resin formulations first involve combining resins in appropriate quantities with additional chemicals such as agents, accelerates, responsive dispersants, and colors. To avoid the polymers from clinging to outer layer of the mold, the surface is coated with a release mucoadhesive chemical. The upper and lower sides of the mold plate are formerly covered with a thin sheet of plastic to create a flat surface for the product. The resin is combined with reinforcements and applied evenly on the mold's surface using a brush. The previous polymeric film is then covered with additional mats to eliminate entrapped air pockets and surplus polymers. After that, the mold is closed and the pressure in the steam environment is removed. After drying at ambient temperature, the mold is opened and the nanomaterials have been recovered from the mold's exterior. Table 1 lists the hybrid composite combinations.

**2.6. Testing.** For tensile testing, the matrix composite samples were sliced and rendered to the ASTM standard of D 638-03 replicas with dimensions of 150 × 15 × 3 mm. To investigate the impact of these variables on the mechanical characteristics of the construction, a mechanical test on nanocomposites'

TABLE 1: Parameter and their combination used for nanocomposites.

Sl. no.	Symbol	Combinations
1	A	Pure epoxy
2	B	Epoxy + graphene + raw kenaf fiber
3	C	Epoxy + graphene nanosheet + salinized kenaf fiber
4	D	Epoxy + salinized nano oxide + salinized kenaf fiber

characteristics such as size, filler content, and treatment effect may be used. The elastic modulus, tensile strength, and stress at output were determined for three types of nanomaterials: graphite raw kenaf fiber-reinforced epoxy, epoxy reinforced with nanosheets and bleached kenaf fibers, epoxy reinforced with salinized graphene oxide, and epoxy reinforced with high saline kenaf fibers. The effect of size, filler content, and filler processing on nanocomposite mechanical properties has been thoroughly investigated.

**2.7. Microstructural Analysis.** Fracture surface studies on fissured reinforcement samples were carried out by using SEM. Before SEM clarity, the samples were laved, hydrolyzed, and the outer layer encapsulated with 10 nm of gold to significantly raise the electrical properties of the composites.

### 3. Result and Discussion

**3.1. Effect of Interfacial Bonding.** Figure 2 depicts the impact of kenaf fibers and graphite interfacial adhesion with a polymeric matrix. The findings of the chemical modification revealed an increase in the elastic modulus. When compared to graphite raw kenaf fiber composite samples, the values for combination reinforced composites by graphene sheets and lignocellulosic nanomaterials were enhanced by 20%–28% of the salinized graphene oxide, which was attributed to enhanced adhesion among silane-treated filler particles and the polymeric resin due to reactions between both the purposeful assemblage of silane chemical compound and the substituents of the resin [20].

In the hybrid composites, this resulted in greater filler dispersion and dissemination. On the other hand, the toughness of the graphene raw kenaf fiber-reinforced hybrid increased by 20% compared to the clean epoxy. Furthermore, bleaching kenaf fibers and sensation graphene (graphene nanosheets) showed an 18% increase, which has been attributed to the removal of the crystalline portion of fibers (pectins) and an improvement in fiber crystallization [21]. Both graphene nanosheets and bleached kenaf fibers are found to contain a large number of polar sites uniformly dispersed throughout their frameworks, leading to good interface between fillers, organic fibers, and the polymer system via hydroxyl groups between organic compounds of both constituents [22]. Integrating salinized filler and kenaf fibers into the epoxy matrix also resulted in an 8% increase, which has been ascribed to excellent interfacial adhesion created by the interaction between substituents of a silane particle and the

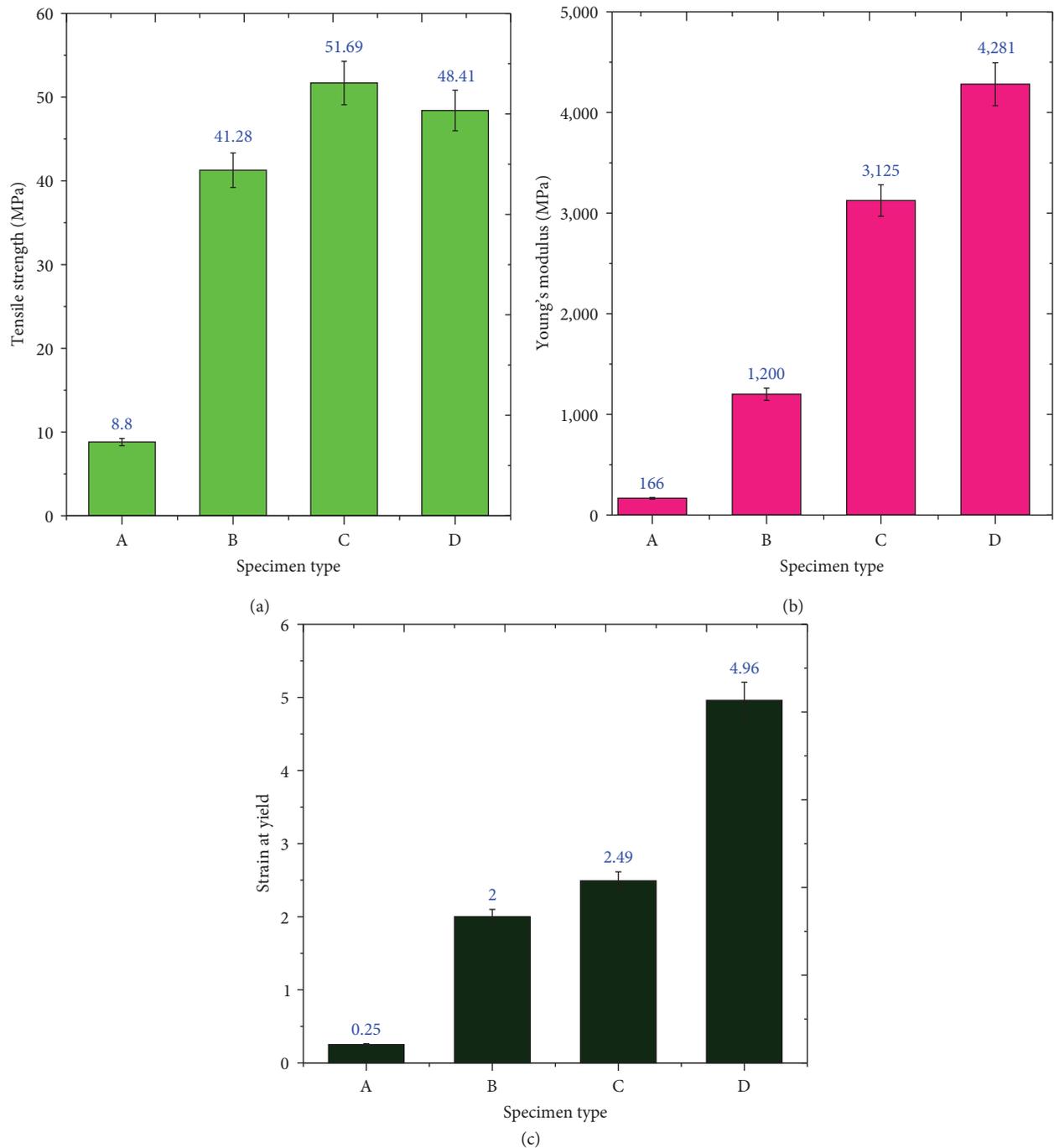


FIGURE 2: Material belongings of nanofiller/kenaf/epoxy combination: (a) tension, (b) elastic behavior, and (c) strain values.

carboxylic groups of the polymeric system [23]. Figure 2(a)–2(c) demonstrates the tension, elastic behavior, and strain values of kenaf/graphene/epoxy-based nanocomposites.

**3.2. Effect of Filler Content.** Investigators and industrialists may be using the term “graphene” to mention a solitary atoms two-dimensional carbon nanostructure, that is challenging to achieve in practice. For those reasons, graphene sheets with a limited coatings or multilayers are similarly

known as graphite [24]. Bleaching treatments, on either hand, allow the crystalline sections of kenaf fibers (lignin) to disintegrate, exposing crystal elements in the kenaf fiber structure (cellulose), which has a high stiffness and so leads to increased fiber tensile [25]. The polymorphs of graphite thickness and derivatives of kenaf fiber size are therefore the essential factors in the characteristics of hybrid thermoplastics. Figure 3 shows the tensile strength of nanocomposites based on the graphene filler content.

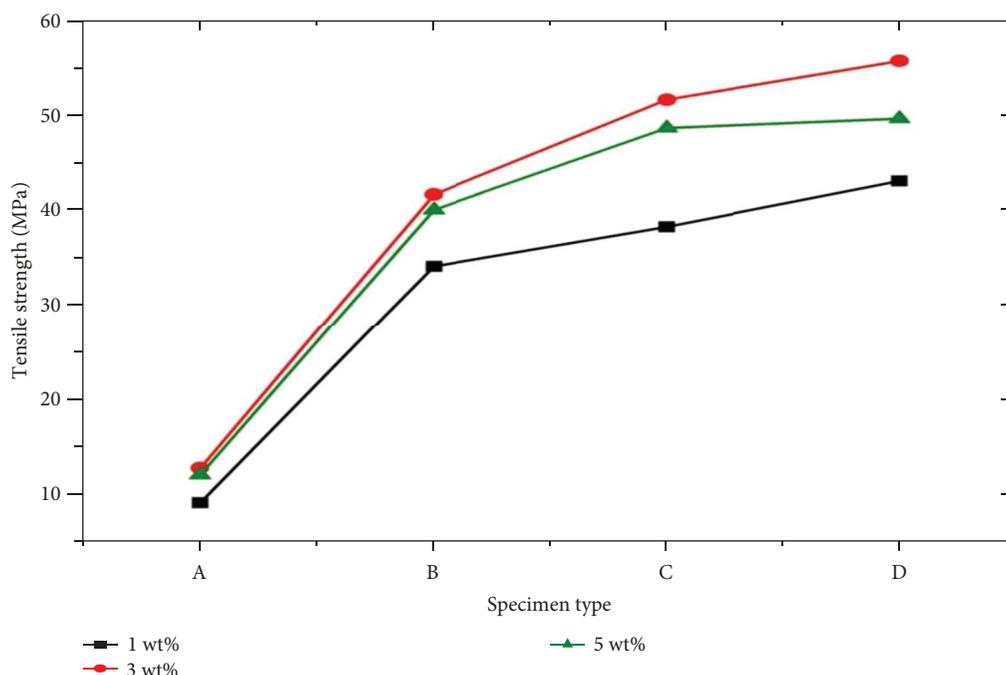


FIGURE 3: Tensile strength of nanocomposites based on the graphene filler content.

According to the tension test, the elastic modulus of graphene raw kenaf fiber-based composite samples is much higher than that of nanocomposites. The high specific surface area of graphene and raw kenaf fibers appears to explain this outcome. Notwithstanding this, the low content (3 wt%) appears to be quickly dispersed along the adhesive bonds and to improve resistance [26]. However, an increased fiber composition creates something of a propensity for aggregates, which again restricts performance improvement in material characteristics, in contrast to nanoparticles, which maintain excellent material strength through a greater additive loading (greater than 3 wt%). Nonetheless, strengthening the nanofiller with a 3% addition resulted in a 26% increase on average. When it comes to strength properties as well as deflection, however, it appears to be beneficial. Because of flaws and cavities at the micrometer level, the framework was less robust and distorted quickly after the inclusion of a nanoparticle filler. At the nanoscale level, where nanoparticles were retained and provided structural cohesiveness, that singularity was no lengthier pragmatic [27]. Tensile tests demonstrated that adding 3 wt% nanoparticles enhanced the materials' characteristics of the mixture, particularly when the fibers and graphene were chemically modified with siloxane as a compatibilizer.

**3.3. Impact of Filler Dimension.** The manner of distribution, the impact of the polymer additives, the topology, and their interconnections inside the polymer matrices are all affected by the rate and shape of the filler used. The tensile characteristics of the three kinds of hybrid composites investigated showed a clear and considerable increase in elastic modulus [28]. The restrictive actions of both types of fiber-strengthened heterogeneous mixtures were observed to reduce as the dimension of the particles augmented when 3 wt% graphite raw natural fibers were added, trying

to reach around 33%, which seems inspirational and is undeniably described by the significantly effective surface area of the constrictive actions of both kinds of fiber-based nanocomposite [29].

The stiffness of an additive clarified why the elastic modulus of nanomaterials bolstered by nanosheets as well as lignocellulosic nanomaterials was enhanced by 14% with the addition of 3 wt%. The ingredients, on the other hand, acted as just nucleation sites and accelerated the crystallizing method at small doses, which is regarded as a miscalculation, as well as lowered the elastic properties of the materials. The adhesive to saline soil graphene perishable goods lignocellulosic nanoparticles has been reinforced by 20% by incorporating 3% material to a nanosheet nanostructured lignocellulosic biomass nanofibrous biocomposites [30]. Figure 4 represents how enhancing reassurance managed to make the nanomaterials extra durable, which would have been largely attributable to the rigid disposition of additional troops. This very same verification has been supplied by measuring stress at the profit margin, which also showed a gradual decline even as reinforcement material content went up [31]. This was constantly attributable to graphene's rigidity as well as natural fiber's poor stretchability [20, 26]. Deformation is diminished because once tough additives are added to an adhesive, less of it can be retrieved. Because once tough additives are present in a flexure thermoplastics mixture, the stream and reorganization of molecular chains previous to one another, which is the defining feature of an epoxy composite, is confined [28, 29].

#### 4. Microstructural Analysis

SEM examination was utilized to investigate the superficial properties of the tension fragmented amalgamated substance employed in the experiment, as shown in Figure 5(a)–5(d).

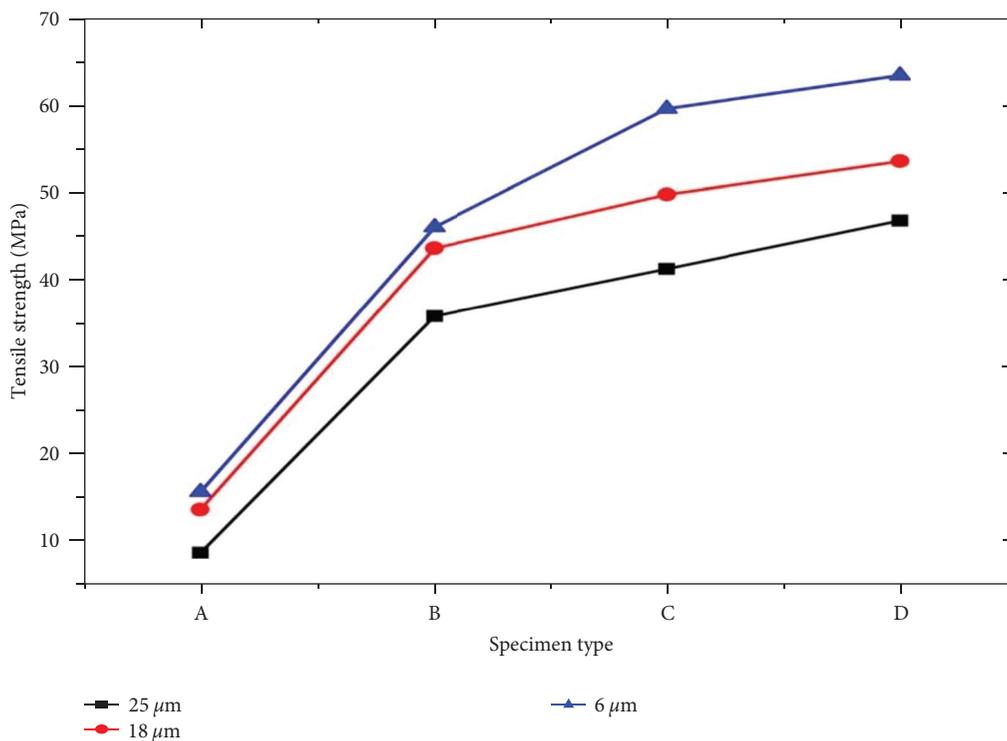


FIGURE 4: Tensile strength of nanocomposites based on the graphene filler size.

Figure 5(b) depicts a SEM micrograph of kenaf/epoxy composites, whereas Figures 5(c) and 5(d) depict nanographene/kenaf hybrid nanocomposites, respectively. The picture clearly reveals a large number of fiber traces dragged out, owing to mid-air foams inside the matrices, and a massive number of holes owing to the unavailability of epoxy. Figure 5(a) shows the uniform dispersion of graphene particles in the epoxy resin [32].

Due to weak interfacial adhesion, fibers separate from the physical and esthetic in reaction to external stress, and so are unable to deliver an effective load distribution from the matrices to the fiber, resulting in inferior mechanical features. The loss in tensile characteristics is assumed to be caused by the formation of additional fibers and vacuums in the epoxy composite. Figures 5(c) and 5(d) show SEM images of nanographene-filled kenaf heterogeneous polymeric materials with fewer cavities, gaps, and bubbles due to enhanced fiber content interaction.

Throughout the comparison to kenaf/epoxy blends, the acquired SEM pictures demonstrated that the introduction of nanographene filler enhanced mechanical strength. As a result, rather than being dragged away from the surface by applied force, the fiber breaks, or bends, demonstrating superior stress transmission from the epoxy matrix. To confirm the SEM surface characteristics of a manufactured nanomaterials packed fiberboard chemical bio composites, a harsher as well as globular topic of interest has been created [33]. We can conclude that a 3 wt% applied load of micronanostructure padding inside the combination nanostructure substance improves the interplay between polymer matrices and the natural fiber lamellae.

## 5. Conclusion

The investigation's foremost intention was to increase the mechanical characteristics of nanostructured polymer materials. Mixing the two fillers in the same matrices resulted in epoxy-based nanocomposites and hybrid reinforcement.

- (1) The kenaf fibers were treated chemically with alkaline solution, lightened, and salinized. Afterward, graphene oxide was made by exfoliating plumbago, and graphene nanosheets were made by chemically reducing graphene oxide.
- (2) The nanocomposites were then created using a melt compounded liquid and mixed. A tensile test was performed on samples with varying amounts of nanoparticles (0, 1, 3, and 5 wt%).
- (3) The stress results revealed that adding nanoparticles enhanced the mechanical characteristics of the various nanocomposites by about 16%, with a 3% filler particle inclusion. Deformation is diminished because once tough additives are added to an adhesive, less of it can be retrieved. Because once tough additives are present in a flexure thermoplastics mixture, the stream and reorganization of molecular chains previous to one another, which is the defining feature of an epoxy composite, is confined.
- (4) Due to the obvious better distribution of fillers all across the polymer, the elastic modulus of composite materials made from raw fiber and graphite fibers improved significantly. However, this consequence has been less than satisfactory due to the weakening

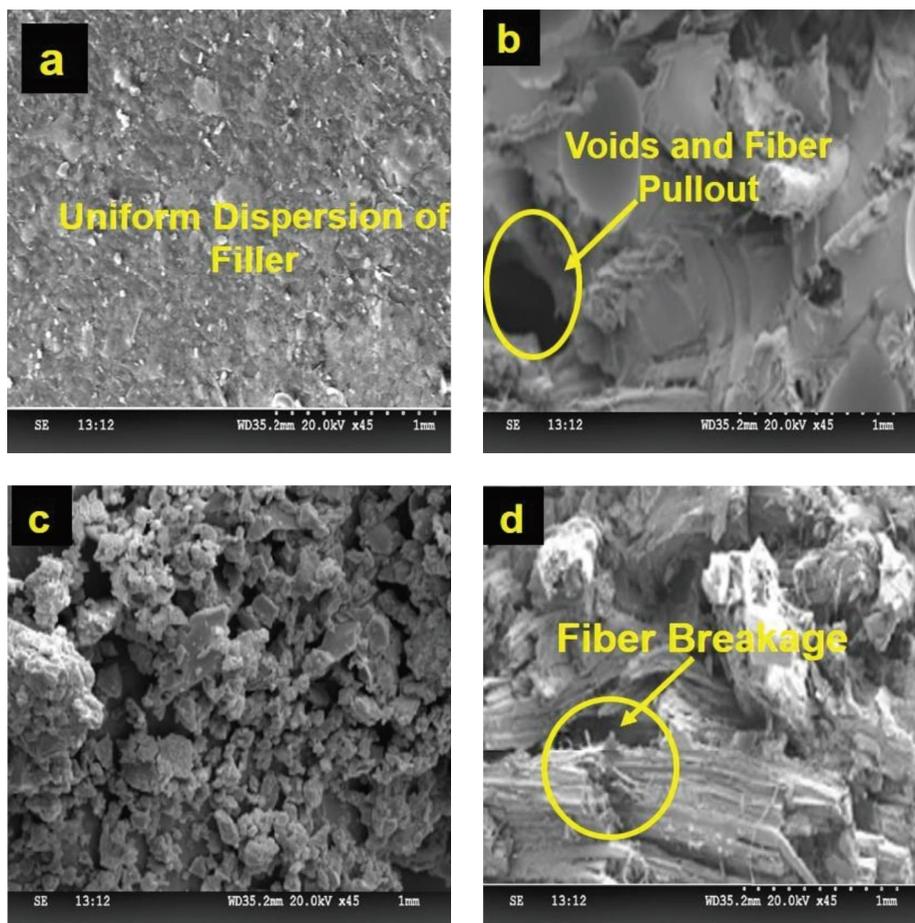


FIGURE 5: Microstructural images of graphene/kenaf/epoxy-based nanocomposites.

of the displacement affected by the addition of deficiencies and porosity at the submicron level.

### Data Availability

The data used to support the findings of this study are included within the article. Should further data or information be required, these are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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