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Research Article

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Tensile Strength Analysis of Novel Kenaf Fiber Epoxy Composite Laminate with and without the Reinforcement of Stainless-steel Wire Mesh

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Abstract

Evaluating the tensile strength of novel epoxy composite laminates with and without stainless steel wire mesh reinforcing. Composite laminate without stain less reinforcement is made using five plys of bidirectional composite laminate fabric (kenaf-kenaf-kenaf-kenaf-kenaf (K-K-K-K-K), and composite laminate with reinforcement is made using bidirectional fiber fabric and stainless steel wire mesh stacked in the sequence K-S-K-S-K (kenaf-stainless steel-kenaf-stainless steel-kenaf). This research is aimed at achieving better tensile strength with the addition of stainless steel wire mesh reinforcement. The experimental and control groups were each given a sample size of 20. The tensile testing is done according to the ASTM D3039 standard. To analyze the tensile strength, T-independent tests were done using the SPSS statistical software tool. According to the experimental data, group 1, a novel kenaf fiber reinforced stainless steel wire mesh epoxy composite laminate, had an average of 20.8519 MPa, while group 2, a novel kenaf fiber-reinforced composite laminate, had an average of 16.2721 MPa. The number of samples was decided with a power of 80%. The results of the studies were assessed using the T-test, and it was found that the significance value of $p < 0.001$ was attained, which is less than ($p < 0.05$) indicating that there is a statistically significant difference between the two samples. The mean tensile strength of the samples in the experimental and control groups is 20.8519 MPa and 16.2721 MPa, respectively. The resulting tensile strength of the samples of the experimental group is on average 44% higher than that of the control group.

Keywords

Novel kenaf fiber, Tensile strength, Sustainable, Stainless steel, Epoxy, Composite

Introduction

Natural fiber has been used by humans since very early times [1]. Sustainable clothing materials are made of natural fibers that are environmentally friendly. The primary goal of this research is to compare the tensile strength of composite laminate fiber epoxy composites with stainless wire mesh reinforcement (kenaf-stainless-kenaf-stainless-kenaf-kenaf) to that of composite laminate fiber epoxy composites without reinforcement (kenaf-kenaf-kenaf-kenaf). Polymer-matrix composites like carbon or glass fiber-reinforced plastics (CFRP and GFRP) are frequently used in industry due to their high strength and modulus. In comparison to synthetic fiber-reinforced composites, natural kenaf fiber-reinforced polymer composites have proven to be more economical and cost-effective. Natural fibers from plants have a huge potential for use in the plastic, automotive, and packaging industries due to their attributes like environmental friendliness, low density, high specific stiffness, good mechanical properties, toxicological safety, biodegradability, and acoustic insulation. Typically, at least two materials are used to create a composite, one of which is the binding material, also known as the matrix, and the other being the reinforcement material (fiber, kevlar, and whiskers). Natural fiber has the potential to be an excellent material for composites due to its availability, environmental friendliness, and high strength and modulus [2]. In comparison to traditional materials, composite materials have a number of benefits, such as enhanced specific strength, stiffness, and fatigue qualities that enable more adaptable structural design. Novel kenaf fiber is superior to other plant fibers in a number of ways, including its quick growth, inexpensive cost, great mechanical strength, stiffness, and low density. The retting method can be used to create kenaf fiber. The bast and core of kenaf can be used to remove the fiber [3].

Natural fiber composites are finding more and more uses as a result of the growing interest in the subject. The most frequently referenced papers on this subject include There is proof that kenaf fiber epoxy composites often offer good mechanical qualities after examining various materials. The kenaf plant (*Hibiscus cannabinus*) has been identified as Malaysia's seventh commodity plant [4].

Based on the literature review, it can be concluded that the usage of stainless steel wire mesh as reinforcement in natural fiber composites is very limited. Thus, stainless steel wire mesh with natural fibers such as kenaf fiber is used as the raw material for composite laminate.

Materials and Methods

Epoxy resin of grade LY556 and hardener of grade HY951 are bought from heranba industries limited, Ambattur. These composites' high mechanical qualities have made them desirable in material design [5]. It is a hot-curing epoxy resin possessing good mechanical properties and chemical resistance. Natural plant fibers are sustainable and biodegradable. Bidirectional kenaf fiber fabric is bought from go green pvt. limited, Chennai. Stainless steel wire mesh of the expanded type was bought from Bokaria wire netting industries, Chennai. Sample size of 20 is used for each group, with the kenaf fiber composite without stainless steel wire mesh reinforcement serving as the control group and the kenaf fiber composite with stainless steel wire mesh reinforcement serving as the experimental group.

For the fabrication of the control group, bidirectional composite laminates were cut into sheets of 300 mm by 300 mm. Epoxy and hardener are mixed in the ratio of 10:1. The stacking sequence is K-K-K-K-K. During the laminating process, the epoxy resin is uniformly spread over the layers by using a 30 mm paint brush, and an air bubble that forms is removed with the help of a roller on the laminate. After the stacking is done, a uniform weight is kept upon it for the entirety of the curing period to ensure proper adhesion for 24 h.

For fabrication of control group, stainless steel expanded wire mesh is cut into size of 300 × 300 mm. The stacking sequence is K-S-K-S-K. The stainless steel wire mesh is rubbed with 400-grit paper, which moves uneven epoxy onto the laminate for good adhesion. Composite are cured for 48 h at room temperature. The composite is subsequently cut by water-cutting machining into the necessary specimen size. Specimen of both groups of size 120 × 20 mm is tested according to ASTM D3039 for tensile strength. The tensile test is carried out using a universal testing machine in Micro Labs (Metmech analytical engineers), Chennai. The samples of the control group and experimental group used for tensile testing, which are kenaf fiber and stainless steel wire mesh, are shown in figure 1 and figure 2, respectively. The tests were performed on 20 specimens from both groups, and the results were identical.

Statistics analysis

Like other natural fibers, kenaf fiber is used to create composite materials that are sustainable. However, because of the porosity of the fibers, which causes them to become mechanically and physically weaker with time, natural fibers are often weaker than synthetic fibers [6]. The standard deviation, standard error, and mean values were determined using SPSS V.26's statistical analysis. The independent variables are kenaf fiber, stainless wire mesh, and the properties of epoxy material,

Figure 1: Kenaf fiber sheet.

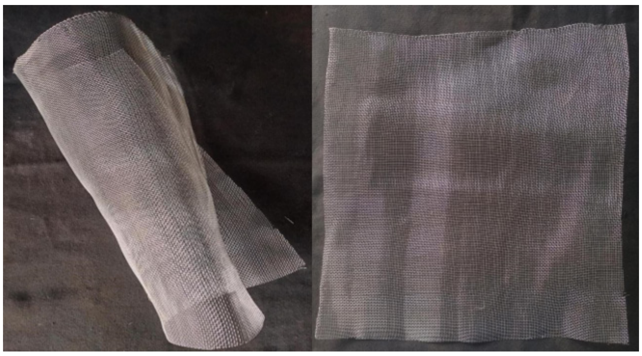

Figure 2: Stainless steel wire mesh.

and the dependent variable is tensile strength. Significance, descriptive tables, and a mean ultimate tensile strength graph are obtained from the software.

Result and Discussion

Figure 2 shows the testing setup for tensile testing using a universal testing machine. In table 1, the ultimate tensile strength of the samples of kenaf fiber composite with and without stainless steel wire mesh obtained by testing is shown. The samples of composite with reinforcement show higher tensile strength than composite without reinforcement. The mean, standard deviation, and standard error mean are shown in table 2.

Table 1: Tensile strength for group 1 and group 2.

S. No.	Tensile strength in MPa	
	With stainless steel wire mesh	Without stainless steel wire mesh
1	22.606	17.296
2	20.216	13.124
3	21.839	16.144
4	22.136	17.224
5	19.956	19.234
6	20.028	16.223
7	22.796	18.104
8	18.456	15.344
9	20.258	16.336
10	19.768	15.654
11	20.875	16.006
12	23.456	17.203
13	19.069	15.299
14	22.248	16.658
15	21.676	16.768
16	20.34	14.343
17	18.846	15.134
18	19.088	16.658
19	20.202	16.344
20	23.178	16.346

As can be seen in figure 3 before and after testing, the samples were prepared in accordance with ASTM criteria for machining [7]. The composite with stainless steel wire mesh reinforcement has a mean tensile strength of 20.8518 MPa and a standard deviation of 1.5295, according to the graph. The composite's mean tensile strength was 16.2721 MPa, with a standard variation of 1.3122, when stainless steel wire mesh reinforcement was not present. As can be seen from the graph, kenaf fiber laminate has a higher tensile strength than kenaf fiber reinforced with stainless steel wire mesh composite [8, 9]. Using the statistical program SPSS v2.6, a one-way analysis of the results was performed. According to table 3, p = 0.001 is the significant level for the surface roughness. Statistical significance was found for the difference in surface roughness between the kenaf fiber composite with stainless steel wire mesh and the kenaf fiber composite without stainless steel wire mesh.

The epoxy composite laminate that is reinforced with the stainless steel wire mesh had the highest tensile strength when performing the 20-piece samples compared to the laminate that has the 5 layers (K-K-K-K-K) of kenaf fiber reinforced with epoxy resin [10, 11]. At various loading rates,

Table 2: Mean tensile strength and standard deviation of kenaf fiber composite with and without stainless steel wire mesh reinforcement with a mean value of 1.5295 MPa and 1.3121 MPa respectively.

Tensile strength in MPa	N	Mean	Std. deviation	Std. error mean
With stainless steel wire mesh reinforcement	20	20.8518	1.5295	0.3420
without mesh reinforcement	20	16.2721	1.3121	0.2934

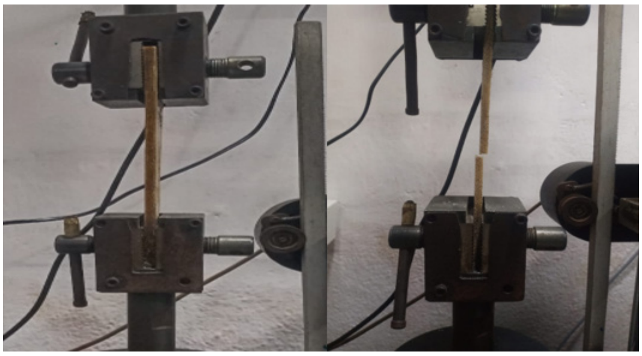

Figure 3: Specimen during and after tensile loading.

Table 3: Independent sample of t-tests for equality of means of the tensile strength represents the significance values p < 0.001.

Independent samples test										
Tensile strength in MPa	Levene's test for equality of variances		t-test for equality of means							
	F	Sig.	t	df	Significance		Mean difference	Std. error difference	95% confidence interval of the difference	
					One-sided p	Two-sided p			Lower	Upper
Equal variances assumed	2.319	0.136	10.163	38	< 0.001	< 0.001	4.57975	0.45063	3.66748	5.49202
Equal variances not assumed	-	-	10.163	37.141	< 0.001	< 0.001	4.57975	0.45063	3.66679	5.49271

kenaf fiber-epoxy composite strands were assessed for better quality material composite fiber decided that the fiber material reinforced with the stainless steel wire mesh is having good tensile strength for long lasting and with good condition for various purposes of usage [12, 13]. The addition of woven kenaf reinforcement improved the material's general characteristics [14]. The ultimate tensile strength of the stainless-steel wire mesh reinforced composite structure decreases with the increase in temperatures [15, 16]. When the number of layers is increased, the strength of the porous plate of stainless-steel wire mesh improves, according to research done on its mechanical properties [15, 16]. In terms of tensile strength and elastic modulus, stainless steel wires are superior mechanically [17]. According to testing data, the high-strength stainless steel strand mesh provided specimens with excellent ductility. The damage mechanics theory was used to update the bond-slip model based on experimental results, fully accounting for how the steel strand diameter affected the bond-slip curve's initial tangent stiffness [18]. Figure 4 shows the graphical representation of tensile strength.

The limitations of the current study are that the bonding between the metal layer and epoxy is not achieved to the expected level; hence, in a future study of similar scope, thermoplastic resins can be used to fabricate the composite laminates that provide better bonding between the metal and fiber layers. The desiccator was used to store the dried kenaf fibers for use in the manufacturing process [19].

Conclusion

As fiber loading increased, the tensile modulus increased as well. With an increase in fiber loading, tensile strain exhibited a trend toward decrease. The tensile strength of epoxy composite laminate samples with and without the reinforcement of stainless-steel wire mesh is tested and compared within the parameters of this investigation. The samples of novel kenaf fiber with a stainless-steel wire mesh of 20.8518 MPa showed higher tensile strength compared to samples from the group without a stainless-steel wire mesh of 16.2721 MPa. The kenaf composite laminate materials, which have good tensile strength, are used in vehicle bodies and other stainless steel-based materials.

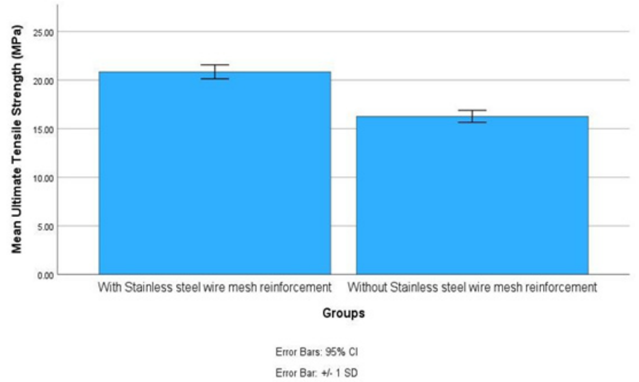

Figure 4: Graphical representation of tensile strength.

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None.

Conflict of Interest

None.

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