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

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Abstract

Impact strength analysis of novel Kenaf fiber (KF) epoxy composite laminate with and without the reinforcement of stainless-steel wire mesh. Composite without stainless reinforcement is made using 5 plies of bidirectional composite laminate fabric, and composite laminate with reinforcement made using bidirectional fiber fabric and stainless-steel wire mesh stacked in alternate sequence. This research is aimed to achieve better impact strength with the addition of stainless-steel wire mesh reinforcement. The experimental and control group were taken with sample size as 20. The impact testing is done according to ASTM D3039 standard. The resulting impact strength of the samples of the experimental group is on average of the sample pieces. Strength of composites depends on several variables, including fiber and matrix strengths, fiber volume percentage, and fiber-matrix interfacial bonding. In a matrix, fibers serve as load transporters. Effective and consistent stress distribution is more important for good impact strength. The resulting impact strength analysis of the samples of the experimental group is an average of the sample pieces. Novel KF/stainless-steel wire mesh reinforced composite laminate had an average of the number of samples that were decided with a power of 80%. The results of the studies were assessed using 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 statistical significance between the two samples. The mean impact strength of the samples of experimental and control group, the resulting impact strength of the samples of experimental group is on average 45% higher than that of control group. The KF reinforcement laminate has good enough strength, when compared to the 5 layers KF laminate.

Keywords

Novel kenaf fiber, Impact strength, Environment, Stainless-steel, Epoxy, Composite

Introduction

KF (*Hibiscus cannabinus*), a member of the Malvaceae family, is a plant whose fibers are widely employed due to its environmental benefits and significant commercial interests. Due to concerns about the environment, lignocellulosic materials These businesses are using natural fibers and ramie as fillers or reinforcement components in composites [1]. The primary goal of this research is to compare the impact strength of composite laminate fiber epoxy composites with stainless-steel wire mesh reinforcement (kenaf stainless-steel wire mesh and KF) to that of composite laminate fiber epoxy composites without reinforcement (KF reinforced epoxy laminate). Owing to their extraordinary strength and modulus, polymer-matrix composites like carbon or glass fiber reinforced plastic (CFRP or GFRP) are frequently employed in industry. The fact that natural fibers have a similar specific modulus and a higher specific strength than glass fiber is one of the factors contributing to this increased interest. The development of the material for producers of automotive interior and exterior components has been motivated by research interest in beneficial composite properties such as lightweight and corrosion resistance [2]. The composite materials that nature has created are made of natural fibers [3].

A study of the composite material industry revealed that the usage of natural fibers as reinforcing materials for the creation of fiber-reinforced composite materials has gained substantial attention and increased awareness [4]. According to reports, natural fibers such as sisal, kenaf, banana, jute, and hemp have a few advantages when utilized as reinforcing materials in a few applications. For instance, they make it possible to significantly reduce the weight of common automobile parts (such as instrument panels, door panels, and center consoles) by up to 20% and lower the overall environmental effect of the components' lifecycle by 20 - 25%. It is clear that the composite material industry has become quite interested in natural fiber-based composites [5]. Natural fiber composites are recognized as materials with low environmental impact since the process of obtaining the raw materials has no detrimental influence on the environment.

KFs are a viable substitute material for synthetic fibers in reinforcing composites. They also produce less trash, which benefits the environment. Characteristics of novel KF composites have been the subject of several researchers' presentations [6]. Due to its contribution to the creation of eco-friendly materials in several areas, the use of novel KF has significantly expanded globally. It is possible to enhance natural fiber composites' mechanical qualities by hybridizing glass and natural fibers. Before beginning any molding operations, to prevent adhesion and create a smooth sample surface, a specific mold release agent was sprayed over the mold surfaces. The stacks of 19 layers of varied laminates were placed between two stainless-steel layers and the heated plates of a compression molding machine [7, 8]. The purpose of this study is to ascertain how different KF contents affect the mechanical characteristics of its composites. In this part, a thorough investigation of the mechanical properties of composites made from untreated KFs in terms of impact behavior is covered [9]. The literature study leads to the conclusion that the use of stainless-steel wire mesh as reinforcement within the stainless-steel fiber composite is very limited. Thus, stainless-steel wire mesh with novel KF is taken as raw material for composite laminate [10, 11]. It has been extensively documented in the literature that chemically treating natural fibers with epoxy and a hardener mix improves the mechanical properties of composites made of KFs and reinforced composites. However, there aren't many studies that take these composites' strengths into account [4].

Material and Methods

Epoxy resin of grade LY556 and hardener of grade HY951 are bought from heranba industries pvt. limited, Ambattur, as shown in figure 3. Epoxy resin LY556 and hardener HY951 are hot-curing epoxy resins possessing good mechanical properties and chemical resistance. Bidirectional stainless-steel 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.

A sample size of 20 is used for each group, with the stainless-steel fiber composite without stainless-steel wire mesh reinforcement serving as the control group and the new KF composite with wire mesh reinforcement serving as the experimental group. Bidirectional composite laminates 300 × 300 mm in size were cut to create the control group. Epoxy and hardener are combined in a 10:1 ratio. The order of stacking is K-K-K-K-K (kenaf-kenaf-kenaf-kenaf-kenaf) and K-SS-K-SS-K (kenaf-stainless-steel-kenaf-stainless-steel-kenaf). A 30 mm paint brush is used to evenly spread the epoxy resin over the layers throughout the laminating process, and any air bubbles that form are eliminated from the laminate with the use of a roller. After stacking is complete, a constant weight is maintained during the 24 h curing phase to ensure optimal adhesion.

Specimen of both groups of size 120 × 20 mm is tested according to ASTM D3039 for impact strength. The impact test is carried out using an impact testing machine at Saveetha University in Chennai. The samples of the control group and experimental group used for impact testing are shown in figure 1 and figure 2, respectively. The tests were carried out on 20 specimens from both groups, and the same results were obtained.

Statistics analysis

The standard deviation, standard error, and mean values were determined using SPSS V.26's statistical analysis. The

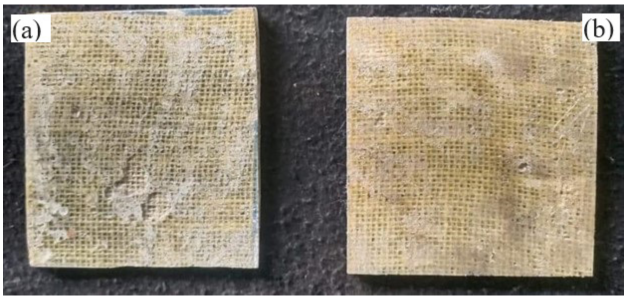

Figure 1: Composite specimen **(a)** with stainless-steel wire mesh reinforcement and **(b)** without stainless-steel wire mesh reinforcement.

Figure 2: Impact loading of the specimen.

Figure 3: (a) Epoxy resin LY556 and **(b)** Hardener HY951.

independent variables are KF, stainless wire mesh, and the properties of epoxy material, and the dependent variable is impact strength. Significance, descriptive tables, and a mean ultimate impact strength graph are obtained from the software. Compared to the laminate with stainless-steel wire mesh reinforcement, the laminate without stainless-steel wire mesh had a lower impact test analysis [12].

Results and Discussion

Figure 2 shows the testing setup for impact testing using a universal testing machine. In table 1, the impact strengths of the samples of KF composite with and without stainless-steel wire mesh obtained by testing is shown. The fibers were evenly dispersed and interacted with the epoxy resin to a suitable degree. The samples of composite with reinforcement show higher impact strength than composite without reinforcement. The mean, standard deviation, and standard error mean are shown in table 2, and table 3 shows the independent sample t-test for equality of means of the impact strength (KJ/m^2). The composite with stainless-steel mesh reinforcement showed a mean impact strength of 3.0035 KJ/m^2 and a standard deviation of 0.14046. The composite without stainless-steel mesh reinforcement showed a mean impact strength of 0.9295 KJ/m^2 and a standard deviation of 0.04673. The significance of the two groups is found to be 0.001. Figure 4 shows the graphic representation of impact strength (KJ/m^2) of the mean of two groups through a simple bar graph.

The innovative KF composite with wire mesh reinforcement is taken as the experimental group with a sample size of 20, and the stainless-steel fiber composite without stainless-steel wire mesh reinforcement is picked as the control group [13, 14]. The epoxy composite laminate that is reinforced with the stainless-steel wire mesh had the highest impact strength when performing the 20-piece samples compared to the laminate that has five layers (K-K-K-K-K) of KF reinforced with epoxy resin. For better quality material, composite fiber decided that the fiber material reinforced with stainless-steel wire mesh has good impact strength for long-lasting durability and is in good

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

S. No.	With stainless-steel mesh reinforcement	Without stainless-steel mesh reinforcement
1	2.89	0.99
2	3.30	0.89
3	2.99	0.88
4	2.94	0.93
5	2.86	0.96
6	2.96	0.94
7	2.94	0.86
8	2.95	0.89
9	3.40	0.88
10	2.90	0.95
11	2.99	0.97
12	2.92	0.99
13	2.94	0.85
14	3.00	0.87
15	2.97	0.92
16	2.94	0.95
17	2.93	0.99
18	2.95	0.95
19	3.20	0.99
20	3.10	0.94

Table 2: Mean flexural strength and standard deviation of KF composite with and without stainless-steel wire mesh reinforcement with a mean value of 0.14046 KJ/m^2 and 0.04673 KJ/m^2 respectively.

Impact strength in KJ/m^2	N	Mean	Std. deviation	Std. error mean
With stainless-steel wire mesh reinforcement	20	3.0035	0.14046	0.03140
without stainless-steel wire mesh reinforcement	20	0.9295	0.04673	0.01044

Table 3: Independent sample of t-tests for equality of means of the impact strength (KJ/m^2) represents the significance values p < 0.001.

Independent samples test										
Impact strength (KJ/m^2)	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	6.942	0.012	62.657	38	< 0.001	< 0.001	2.074	0.03310	2.0069	2.1410
Equal variances not assumed	-	-	62.657	23.156	< 0.001	< 0.001	2.074	0.03310	2.0055	2.1424

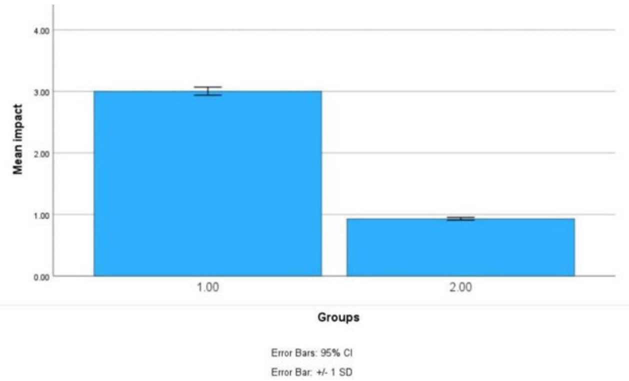

Figure 4: Graphical representation of impact strength (KJ/m^2).

condition for various purposes of usage. KF was added to the composite to strengthen its mechanical properties, enabling it to tolerate greater stresses during mechanical testing and avoid specimen failure [15]. Out of all the natural fibers now on the market for the creation of WPC, KF shows the best promise and is acceptable for the commercial market [16].

The process of fabrication used in this study is hand layup, which acts as a limitation by being a very time-consuming process and chemically releasing epoxy. The possibilities of irregularities and improper bonding within the composite are high in this process. This would, in turn, reduce the mechanical strength of the composites. Future work on the project can be improved by using more sophisticated manufacturing procedures, and the desired qualities can be obtained by modifying the stainless-steel wire mesh reinforcement's orientation, mesh size, mesh thickness, directional bonding, and number of layers. The load is carried by the fibers in a fiber-reinforced composite when it is loaded, and stress is transferred from the matrix along the fibers. As a result, the composite has superior mechanical properties and an effective and uniform distribution of stress. The uniformity of stress distribution depends on the fiber population. Low levels of fiber loading make it difficult for fibers to transfer load to one another, which lowers impact strength by causing stress to build up in certain areas of the composite [17]. Untreated fiber composites do not exhibit any improvement in impact strength over the matrix [18].

Conclusion

Within the limitations of this study, the impact strengths of the samples of epoxy composite laminate with and without the reinforcement of stainless-steel wire mesh are measured and compared. The samples of novel KF reinforced with a stainless-steel wire mesh showed higher impact strength (3.0035 KJ/m^2) compared to samples from the group without stainless-steel wire mesh reinforcement (0.8595 KJ/m^2). After performing all testing and evaluations, the average mean of the impact test was much higher compared to the two groups. The epoxy composites' heat stability and charring resistance are both improved by the addition of fibers.

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None.

Conflict of Interest

None.

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