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A Comparative Study on Shear Tension Strength of the Novel Carbon/S-glass/E-glass Fiber Reinforced Epoxy Composite Filled with and without Silica Nanoparticle Filler

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Abstract

To study experimentally the shear tension strength of a carbon/S-glass/E-glass fiber reinforced epoxy polymer composite with 2 wt.% of silica nanoparticle filler. Composites were made using the hand lay-up method, and test specimens were prepared into two unique groups, namely the control group (Without filler) and the experimental group (With filler). The test samples per group are calculated using ClinCalc and found to be n = 20 samples. The G-power used for this process is 80%, α = 0.05 per set for calculating sample size, and the total sample size calculated is N = 40. The samples are prepared in accordance with the ASTM-D2344 standard. The shear tension strength of the samples in each group were determined using a custom build fixture in universal testing machine. The samples in the experimental group and control group were tested, and their shear tension strengths were determined and compared. The samples in the experimental group with silica nanoparticles as filler materials showed higher shear tension strength compared to those in the control group without silica nanoparticles. Using the statistical software SPSS (Statistical Package for the Social Sciences) v26 an independent sample t-test was performed on the obtained results and the significance was ensured by the obtained (2-tailed) p value of 0.001 ($p < 0.05$). Within the constraints of the study's restrictions, the results demonstrate that the hybrid carbon/S-glass/E-glass fiber reinforced epoxy composite with 2 wt.% of silica nanoparticles had improved shear tension strength by 16.53% over the hybrid carbon/S-glass/E-glass fiber reinforced epoxy composites without silica nanoparticles.

Keywords

Shear tension strength, Novel carbon/S-glass/E-glass fiber, Epoxy, Polymer composite, Silica nanoparticles

Introduction

Polymer composite materials are frequently employed in advanced engineering applications because of their high demand for mechanical and environmental qualities. Due to increased fuel economy, increased material strength, and a focus on weight reduction, all engineering applications today are moving towards a lightweight, low-cost design philosophy. Because of these reasons, the existing polymer composite materials are investigated for their mechanical behavior, and another aspect is to improve the strength of the composite plates by adding the filler materials [1]. In this experimental investigation, innovative methodology, process techniques, and ideas were learned from the various previous literature results. Some of the related previous literature results were mentioned. The impact behavior of sandwich composite materials made of polyvinyl chloride foam

core and E-glass fiber-reinforced polymer face sheets was experimentally examined. The vacuum-assisted resin infusion molding technique was used to create sandwich composites (VARIM). Composite materials reinforced with natural fibers provide a wide range of benefits, including biodegradability, environmental friendliness, and the promotion of sustainable production [2]. Kevlar fiber with 0° orientation in a hybrid epoxy composite with 0° orientation and 45°, 60°, and 90° degrees of rotation the fabrication of E-glass fiber was successful, and its tensile, flexural, impact, interlaminar shear strength, and high-velocity impact characteristics were also examined. These findings are derived from the experiments: The composite with a 45° fiber orientation had the highest shear tension strength (about 232 MPa), which was 2.6% and 4.7% higher than the composite with a 0° fiber orientation and the composite with a 0° fiber orientation, respectively. The composite with a 0° fiber orientation had the highest failure strain (about 1.3%). The 60° fiber-oriented composite had a maximum shear tension modulus of around 26 GPa [3].

A total of 206 papers in Science Direct and 468 in Google Scholar have been published in the past five years that are directly related to this research project. The strength and durability of polymeric materials can be improved by nanoparticles [4]. The investigation of the shear tension properties of ductile and brittle epoxy polymers reinforced with dispersed silica nanoparticles examined. The shear tension performance of the hybrid polymer composite composites reinforced with sugarcane fiber [5].

The impact of fiber volume, fiber treatment time, and alkali concentration is investigated using the Analysis of Variance method. The results show that the time of the alkali treatment rises, decreasing the cellulose content of the fiber, increasing the ultimate shear tension stress of the composite, and the concentration of the alkali increases, increasing the ultimate shear tension stress of the composite [6]. The regression equations are independently developed for composites with sugarcane fiber reinforcement that include 5%, 15%, and 25% cashew nutshell liquid. The degree to which each parameter affects the final shear tension stress is shown by these equations [7].

In this study, the effects of introducing silica nanoparticle filler at a weight of 2% will be investigated in connection with the shear tension strength of a special carbon/S-glass/E-glass reinforced epoxy polymer composite. This composite plate was made up of two types of glass fibers, a carbon fiber with silica nanoparticles reinforcement agent, and an epoxy resin matrix concept. S-glass fibers, which are used to strengthen the composite since they are stronger than E-glass fibers. The composite plate is filled with silica nanoparticles to improve its shear tension strength. The addition of carbon, S-glass, and E-glass fibers raises the shear tension strength of strength materials structures, even if enhancing shear tension strength with silica nanoparticles, epoxy resin is beneficial. This study aims to enhance and compare the shear tension strength behavior of a unique hybrid carbon/S-glass/E-glass fibers epoxy polymer composite with silica nanoparticle filler structure to a standard composite structure.

Materials and Method

The study was conducted at the School of Engineering, Saveetha Institute of Medical and Technological Sciences, Chennai (Tamil Nadu, India). Using ClinCalc Software, the sample size needed for this study is determined using a threshold of 5%, a CI of 95%, and a G-power of 80%. The composite plates were fabricated using manual lay-up technique. Bidirectional carbon fiber, S-glass fiber, and E-glass fiber sheets were used along with epoxy resin LY556 (density 1.16 g/cm^3) and hardener HY951 (density 0.98 g/cm^3) in the right proportions to create the hybrid polymer composite for this investigation. The samples are divided into two groups namely experimental group (With silica nanoparticles filler) and control group (Without silica nanoparticles filler), each with 20 samples. G-power is assumed to be 80% in this study [8].

The hand lay-up technique was used to create the composite. This technique for creating hybrid composites is known as "open forming.". The silica nanoparticles of 2 wt.% are added to the epoxy matrix [9-11]. The epoxy and hardener mixture are done in a 10:1 ratio to get an epoxy matrix. Composite plates with measurements of 300 x 300 x 3 mm are produced using a standard mold. The bottom of the mold is lined with a mylar sheet, and then a layer of carbon fiber is applied on top. After pouring and evenly distributing the epoxy matrix, a layer of S-glass and E-glass fiber is added. This process is then repeated up to four times. and carbon fiber makes up the upper layer. Lastly, a roller is used to shut the mold, and even pressure is applied to seal any air spaces. The dry polymer composite plates are taken out of the mold after being given a 36-hour uniform loading curing period.

Using the manufactured composite laminate, experimental group test specimens with dimensions of (25 mm x 250 mm) in 20 numbers were made to test the shear tension strength in accordance with ASTM D2344 [12].

A similar fabrication procedure is carried out to prepare test specimens in the control group without adding silica nanoparticle filler materials. 20 specimens are cut from the fabricated novel carbon/S-glass/E-glass reinforced epoxy composite [13]. Test specimen (12.7 mm x 125 mm) prepared for shear tension strength as per ASTM D2344 standard. The shear tension strength of novel carbon/S-glass/E-glass fiber reinforced epoxy composite specimens with and without silica nanoparticles fillers in MPa, as shown in figure 1.

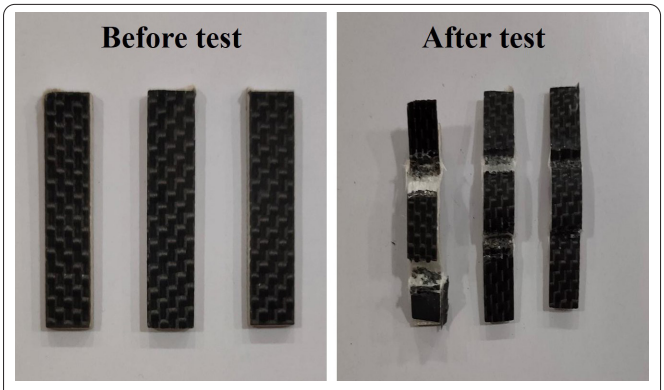

Figure 1: Test specimen (12.7 mm x 125 mm) prepared for shear tension strength as per ASTM D2344 standard.

The shear tension strengths of the test specimens were measured from the test data collected from the Dak Systems Inc. Universal testing machine available at Maeon Labs in Chennai (Tamil Nadu, India). All the test data were reported in table 1.

Statistical analysis

The significance of the test results was statistically evaluated using an independent t-test with the SPSS-v26 software application. To determine the statistical nature of the data, the relationship between the dependent (Shear tension strength) and independent (Sample composition) variables is examined. The study was completed successfully, and the graph was plotted against each sample's shear tension strength and trial numbers.

Results

Table 1 lists the shear tension strengths of two composite materials: carbon/S-glass/epoxy polymer and carbon/S-glass/epoxy polymer with 2% weight of nano-silica particles as filler. The test findings show that the shear tension strength of carbon/S-glass/E-glass epoxy polymer composites can be improved by adding wt. 2% nano-silica particles as filler. Using IBM-SPSS software, the independent t-test analysis of this data was carried out. Table 1 displays the specifics of the test outcomes.

Table 1: The shear tension strength of novel carbon/S-glass/E-glass fiber reinforced epoxy composite specimens with and without silica nanoparticles fillers in MPa.

Specimen number	Shear tension strength without silica nanoparticles (MPa)	Shear tension strength with 2 wt.% of silica nanoparticles (MPa)
1	144.74	172.22
2	147.54	173.46
3	148.29	175.14
4	143.78	176.70
5	145.83	173.18
6	147.49	177.56
7	146.11	176.85
8	145.98	172.94
9	144.87	177.27
10	147.06	175.16
11	146.17	177.48
12	145.04	177.24
13	144.89	176.62
14	148.18	174.03
15	144.64	176.73
16	147.19	174.49
17	146.96	172.78
18	145.43	174.84
19	148.03	176.71
20	148.37	174.93

Table 1 compares the shear tension strength measurements for hybrid composites made with and without filler. Test setup to find shear tension strength on the prepared test specimen as shown in figure 2. Comparison of shear tension strength of specimens in experimental group (With silica nanoparticles) and control group (Without silica nanoparticles) as shown in figure 3. Mean and standard deviation of shear tension strength analyzed using SPSS software shown in table 2. The shear tension strength of hybrid composites fabricated with and without filler are compared and accompanied with a standard deviation error bar. With a standard deviation of ±1, the mean accuracy of readings obtained. The shear tension strength of the samples in the experimental group with novel silica nanoparticles (146.33 MPa) are found to be high compared to the other samples in the control group without novel silica nanoparticles filler (175.32 MPa). EG - Experi-

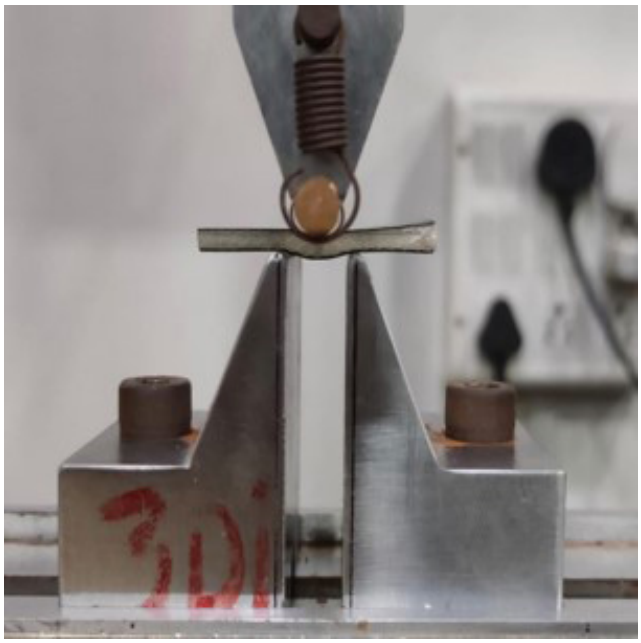

Figure 2: Test setup to find shear tension strength on the prepared test specimen.

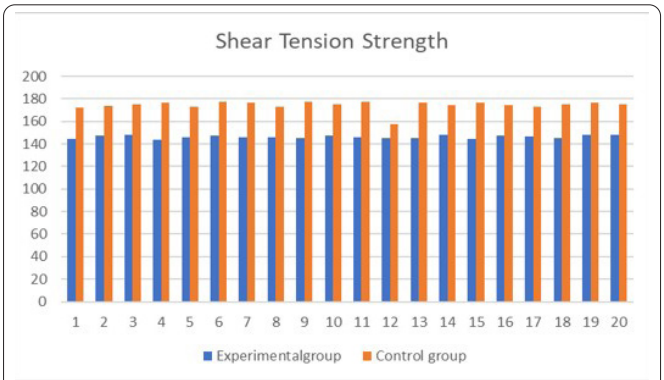

Figure 3: Comparison of shear tension strength of specimens in experimental group (with silica nanoparticles) and control group (without silica nanoparticles).

Table 2: Mean and standard deviation of shear tension strength analysed using SPSS software shown below.

Group		N	Mean	Std. deviation	Std. error mean
Shear tension strength (MPa)	Without filler	20	146.3295	1.41062	0.31542
	With filler	20	175.3165	1.77091	0.39599

Table 3: Details of independent sample test results are shown below. The significance of the independent sample test is found to be 0.001.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
									Lower	Upper
Shear tension strength (MPa)	Equal variance assumed	1.814	0.186	-57.257	38	<0.001	-28.987	0.5026	-30.01187	-27.96213
	Equal variance not assumed			-57.257	36.19	<0.001	-28.987	0.5026	-30.01355	-27.96045

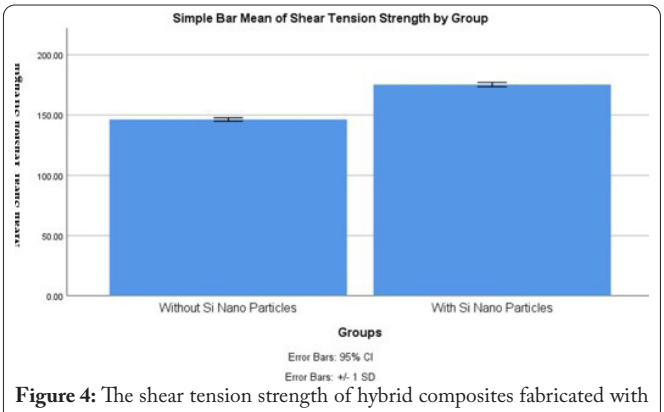

Figure 4: The shear tension strength of hybrid composites fabricated with and without filler are compared and accompanied with a standard deviation error bar. With a standard deviation of ±1, the mean accuracy of readings obtained. The shear tension strength of the samples in the experimental group with novel silica nanoparticles (146.33 MPa) are found to be high compared to the other samples in the control group without novel silica nanoparticles filler (175.32 MPa). EG - Experimental group with filler, CG - Control group without filler.

mental group with filler, CG - Control group without filler as shown in figure 4.

Discussion

In this study, hybrid composite with nano-silica particles as filler showed better shear tension strength when compared with composite without nano-silica filler. The mean value of shear tension strength calculated for the experimental group is found to be 146.33 MPa. The maximum and minimum value calculated for the experimental group is found to be 148.37 MPa and 143.78 MPa. The mean value of shear tension strength calculated for the control group is found to be 175.32 MPa. The maximum and minimum value calculated for the control group is found to be 177.56 MPa and 172.22 MPa.

It is expected that the addition of silica nanoparticles to a novel carbon/S-glass/E-glass epoxy polymer composite would have a positive effect on the shear tension strength of the composite. This is because the addition of nanoparticles can lead to improved mechanical properties due to their unique structural and chemical characteristics. Nanoparticles can fill in the voids between the matrix and the reinforcement which can lead to better interfacial bonding and higher mechanical properties. This improved interfacial bonding allows for greater load transfer from the matrix to the reinforcement, resulting in improved shear tension strength. Additionally, the introduction of silica nanoparticles to the composite can also lead to a decrease in voids and air pockets which can lead to improved compaction of the composite and better mechanical properties. The obtained test findings are similar to the test results of other researchers. Using SPSS, the statistical significance of shear tension strength data is determined by independent samples t-test and the results data significance is confirmed with the obtained p-value of 0.001 ($p < 0.05$) as shown in table 3.

However, it is important to note that the exact effect of the silica nanoparticles on the shear tension strength of the composite will depend on the amount of silica nanoparticles that are added, as well as the specific composition of the composite. Therefore, it is recommended to perform experiments with various weight percentages of silica nanoparticles to determine the exact effect of the silica nanoparticles on the shear tension strength of the composite laminate.

The composite's quality is not as consistent as the machine's fabrications. Because of differences in operator level and production environmental conditions, composite quality stability is not very good in hand lay-up methods. The use of the hand lay-up method for fabrication was found to have higher rates of gas spaces in laminates, which is a major limitation of this research: the hand lay-up method is a time-consuming procedure, thereby making it unsuitable for use in mass production. The future scope of this research is to develop a composite using compression molding and evaluate it for characteristics that make mass production possible.

Conclusion

Based on the results of the aforementioned tests and within the constraints of the study, a unique carbon/S-glass/E-glass epoxy polymer composite has shear tension strength of 2 wt.% silica nanoparticles added that is 16.53% greater than samples without filler components. The shear tension properties of the hybrid carbon/S-glass/E-glass epoxy polymer composites were therefore found to be significantly influenced by the silica nanoparticle filler. The results of the study suggest that silica nanoparticles can be added as fillers to hybrid carbon/S-glass/E-glass/epoxy polymer composites to enhance their mechanical properties.

Acknowledgements

None.

Conflict of Interest

None.

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