

Experimental Investigations on the effect of Additive on the Tensile Properties of Fiber Glass Fabric Lamina

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Abstract. The main objective of this work is to investigate the effect of additives on tensile behaviour of fiber glass fabric at lamina level to explore an alternative skin material for the outer body of aerospace applications and machines. This experimental work investigates the effect of silica concentration in epoxy resin lapox L-12 on the tensile properties of glass fabric lamina of 4H-satin weave having 3.6 mm thickness. The lamina was prepared by using hand lay-up method and tests were conducted on it. Various tensile properties values obtained from experimentation were compared for four glass fiber lamina composites fabricated by adding the silica powder to resin bath. The effect of variations in silica concentration (0% SiO₂, 5% SiO₂, 10% SiO₂ and 15% SiO₂) on the tensile properties of prepared material revealed that maximum stiffness was obtained at 15% and yield strength at 10% SiO₂ concentration in glass fiber lamina. Increasing the silica concentration beyond 10% had led to deterioration in the material properties. The experimentation that was carried out on test specimen was reasonably successful as the effect of silica powder as an additive in glass fiber lamina enhanced the mechanical properties up to certain limit. The underpinning microscopic behaviour at the source of these observations will be investigated in a follow up work.

1. Introduction

Glass fiber/epoxy composites find extensive use in many applications such as aerospace, ship building, wind turbine blades, automotive sectors, thermal and electrical insulations, manufacturing sectors etc. These are used instead of metallic composites because of their inherent properties like low manufacturing cost, high strength, high stiffness, high chemical resistance, and good insulating properties [1].

Various studies have shown that glass fiber composites are excellent at handling tensile stress but are, however, weak in terms of enduring compression due to its brittle property and have some drawbacks like low elastic modulus, low fatigue strength and sensitivity to abrasion [2]. The silica content in glass fiber retains its strength at high temperature and has higher fatigue strength for that reason S-glass having high silica content is used extensively for aerospace applications [3].

The objective of the work is to investigate the effect of silica concentration in epoxy resin on the tensile properties of glass fabric lamina of 4H-satin weave having 3.6 mm thickness. Some advantages of the modified composites were anticipated such as improvements in tensile properties. The paper presents results associated with the influence of silica additive to glass fiber/Epoxy composite at lamina level on tensile behaviour.



2. Materials and Experimental Procedure

This study involved epoxy glass fabric as reinforcements whose specifications are shown in Table 1, epoxy resin lapox L-12 and hardener K6 as shown in Table2 and Table3 respectively.

Table 1. Glass Fibre Properties.

Description	Specification
Variety	13ml Fibre Glass Fabric (epoxy)
Type of weave	4H Satin
Width/Thickness	40"/3.6 mm
Construction	WARP 48 threads/inch; WEFT 36 threads/inch
Weight per sqm.	457.100 grams
Breaking strength per 50mm	WARP 366.000 grams; WEFT 275.000 grams

Table 2. Epoxy Resin Lapox L-12 Specifications.

Specification	ResultUnit	Requirementrange
Color on Gardnr Scale	GS	NMT 1
Viscosity @25°C by Brookfield	mPas	10000 to 12000
Epoxy value	Eq/kg	5.25 to 5.45
Hydrolysisable Chlorine-PO	%	NMT 0.1
Marten's value	25°C	145 to 200
Volatile content	% w/w	NMT 0.55

Table 3. Epoxy Hardner Lapox K-6 Specifications.

Specification	ResultUnit	Requirementrange
Color on Gardner Scale	GS	NMT 3
Refractive Index	NA	1.494 to 1.5
Water by KF	%	NMT 1
Shear Strength	Kg/mm ²	1.4 to 100

The epoxy glass fabric and epoxy resin were supplied by Harsh-Deep Industries and Atul Ltd, Gujarat. Silica powder was used as additive with varying concentration from 0% to 15% and its influence on the tensile properties of the epoxy glass fiber composite at lamina level of 3.6 mm thickness (single layer) was investigated by experimental method. The lamina was prepared by using hand lay-up method. The mould metal plate was cleaned with 80 grade fine emery paper in order to remove rust and unwanted particles, greased with acetone with cotton waste and applied mould release agent (wax polish) and allowed it to dry for few minutes. Laminate was fabricated by pouring mixture of epoxy resin of 66 grams and hardener of 9.9grams by weight in a glass fiber of dimensions 380 mm×380 mm×3.6 mm. The resin that was poured on the fiber should be distributed uniformly and rolling device was used for required bonding[4]. The samples were removed from mould and four test specimen were cut from glass fiber lamina (sample) as per ASTM-D882 standards as shown in Figure1 for various silica concentrations (5%, 10%, & 15% by weight) after a curing period of 24 hours at room temperature. To avoid degradation of material properties, a product called AGM-9 has been used as a stabilizer for fiber composite properties and prevent the fiber strength to drop due to the effect of moisture absorption from the air. Clear dimensions of test specimen for each silica concentration have been shown in Figure 2. Total 16 specimens were cut by using diamond tipped blade saw for good surface finish[5].



Figure 1. Specimen prepared for experimentation

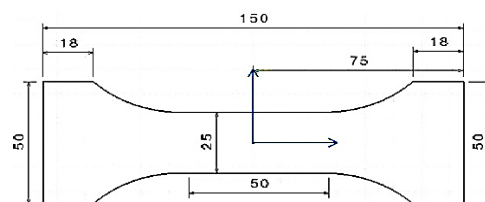


Figure 2. Dimensios of test specimen

The obtained specimens were provided high quality surface finish by using emery paper. The tensile specimens that were cut from the lamina were subjected to uni-axial tension using Universal Testing Machine having 20kN capacity as shown in Figure3 with the surrounding room temperature of 32°C.



Figure 3. Universal Testing Machine with 20kN capacity

The load was applied till fracture with a grip displacement rate was maintained at 1mm/min. Tests were conducted 4 times for each silica concentration and the average values of the tensile properties of composite laminas with varying silica concentration have been calculated and tabulated as shown in Table4.

Table 4. Average tensile properties obtained from tests conducted on specimen with variations in silica concentrations.

Silica Concentration	Max. elongation (mm)	Tensile strength @yield point(MPa)	Tensile strength @break point(MPa)	Elastic modulus (MPa)
0%	2.23	123.72	125.37	3728.13
5%	2.1	159.69	160.07	4004.13
10%	1.78	191.04	192.03	4432.56
15%	1.61	145.41	146.92	4872.22

3. Results and Discussions

The infinite number of combinations of fiber and matrix, enormous variety of spatial arrangements of the fiber and their volume fraction make mechanical characterization a complex scenario for composite materials [6]. Mechanical properties such as tensile, compressive, flexural, hardness, fatigue etc. have been investigated on various composite materials analytically and experimentally [7] to predict their behavior. The four types of laminas with varying additive concentration (0% SiO₂, 5% SiO₂, 10% SiO₂ and 15% SiO₂) have been tested by applying uniaxial tensile load. Table5 summarises the average values of various tensile properties of four test specimen per each silica concentration varying from 0% wt to 15% wt of resin bath. The results show that there is significant change in tensile properties with the change in additive concentration.

Table 5. Average values of various tensile properties of four test specimen.

Mechanical Property	Silica Concentration	Specimen 1	Specimen 2	Specimen 3	Specimen 4
Tensile strength at yield (MPa)	0%	127.63	124.68	112.78	129.80
	5%	152.35	164.23	155.66	166.52
	10%	194.46	200.38	177.70	191.61
	15%	152.48	138.00	142.00	149.13
Tensile strength at break (MPa)	0%	130.57	125.53	114.57	130.77
	5%	152.35	164.23	157.07	166.62
	10%	195.47	200.38	179.67	192.57
	15%	153.62	139.09	145.84	149.13
Modulus of elasticity (MPa)	0%	3778.75	3633.88	3711.24	3788.64
	5%	3994.97	3880.16	4028.45	4112.91
	10%	4346.87	4283.45	4526.54	4496.02
	15%	4793.19	4909.73	4804.00	4981.94

Maximum elongation (mm)	0%	2.38	2.44	2.03	2.06
	5%	2.32	2.06	2.01	2.01
	10%	1.48	1.64	2.06	1.95
	15%	1.85	1.53	1.43	1.64

For analysis purpose, the graphs were drawn to show the influence of silica additive on tensile properties. The changes in yield strength with respect to silica concentration have been shown in Figure 4. The yield strength was found to be maximum at 10% silica concentration with 200.389 MPa. Though there was drop in yield strength for 15% silica concentration, it was higher than 0% silica concentration (lamina without additive) by 17.52%.

The changes in tensile strength at breaking point with respect to silica concentration have been shown in Figure 5. As can be seen, this graph shows the same behavior as yield strength. The tensile strength at breaking was found to be maximum at 10% silica concentration with a value of 200.38 MPa. Though there was a drop in tensile strength at breaking for 15% silica concentration when compared with 5% and 10% silica concentration, it was higher than 0% silica concentration (lamina without additive) by 17.20%. It was observed that yielding strength and breaking strength values were found to be same for some specimen. This is due to the fact that brittle property of the composite. Further analysis has to be carried out to observe the yielding point for such specimens.

From the tests that were conducted, it was clearly found from Figure 6 that there was significant increase in the stiffness of the composite due to the fact that increase in silica concentration. The effect of variations in silica concentration (0% SiO₂, 5% SiO₂, 10% SiO₂ and 15% SiO₂) revealed that maximum stiffness is obtained at 15% SiO₂ concentration in glass fiber lamina.

The variation of maximum elongation of the test specimen with the variations in silica concentrations have clearly shown in Figure 7. It was observed that maximum elongation was found to be occurred at 0% silica concentration and gradually decreases as silica concentration increases. Though there was a raise in maximum elongation for 15% silica concentration, it was lower than 0% silica concentration (lamina without additive) by 27.8%.

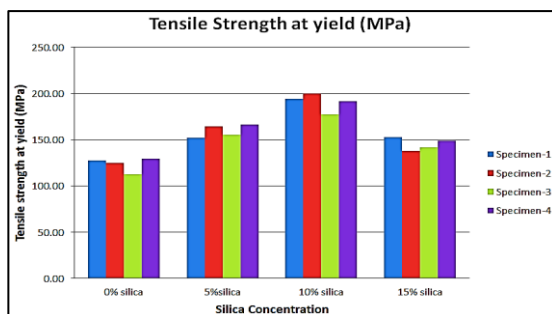


Figure 4. Variation of Tensile strength at yield with variations in silicon concentration

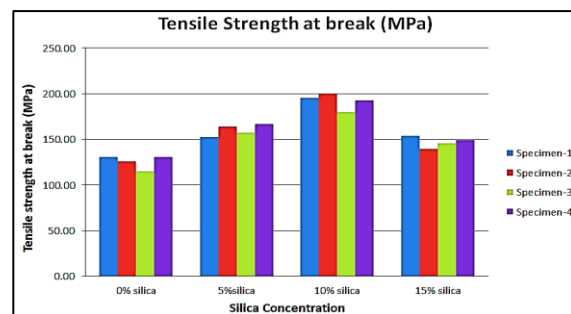


Figure 5. Variation of Tensile strength at break with variations in silicon concentration

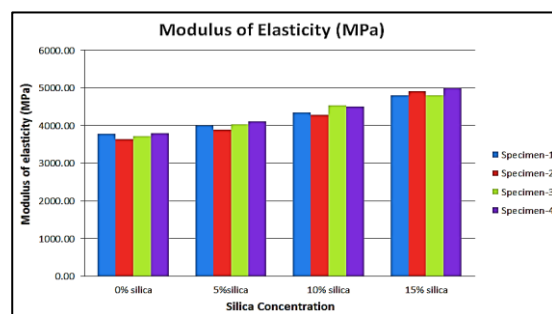


Figure 6. Variation of modulus of elasticity with variations in silicon concentration

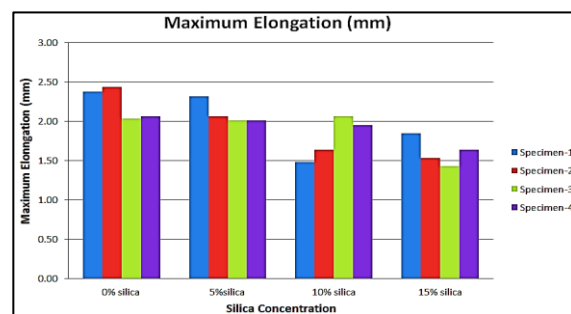


Figure 7. Variation of Maximum elongation with variations in silicon concentration

4. Conclusions

Based on the experimental results on tensile properties of glass/epoxy composite lamina with different additive concentration, the following conclusions were drawn. Intensity in increasing yield strength was observed with the increase in silica concentration up to 10%. Furthermore, there was a drop in yield strength for 15% silica, yet the yield strength obtained at 15% silica concentration was more than that of the composite without additive. The tensile strength at breaking was found to be maximum at 10% silica concentration. There were no significant changes in elongation percentage with the influence of additive. The elastic modulus was found to be increased with increase in additive concentration, stiffness of the composite was enhanced. The epoxy glass fiber lamina had shown good results for yield strength with 10% silica concentration and 15% for stiffness.

Acknowledgments

The authors would like to acknowledge SphoorthyEngg. College (Hyderabad, India) for providing all necessary facilities and also for giving us permission to use 20 kN capacity of Universal Testing Machine for our experimentation work. Authors would also thank Dr. Subramanian C.Pillai, Faculty of Mechanical Engineering, Bahrain Polytechnic, Kingdom of Bahrain for his inspirational and valuable inputs and continuous moral support given to us in completing this paper successfully.

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