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Influence of surface treatments on chopped strand mat E-glass fiber reinforced with Epoxy polymer matrix composites

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ABSTRACT

The present work revolves around the investigations carried out on Fiber surface Treated Chopped Strand Mat (CSM) E-Glass fiber reinforced Epoxy matrix composites. Hand lay-up technique was used to fabricate the Epoxy based polymer matrix Composites reinforced with treated CSM E-glass fiber with volume fraction of 3.42%. The three types of treatments were done on Chopped strand mat E-Glass fibers, namely no surface treatment, Heat treatment and Ethyl silicate coating on heat treated E-glass fibers were used to evaluate the mechanical properties of the epoxy composite. The composites were subjected to mechanical tests preferably to determine tensile, flexural and Impact strengths. The test results showed that there has been a marked improvement in mechanical properties of composites reinforced with fiber surface treated CSM E-Glass Fibers. E-Glass Fibers treated with Ethyl Silicate shows remarkable improvement in mechanical properties. Experimental results of mechanical properties for different surface treatment of E-glass fiber were evaluated and compared to conclude.

Keywords— *Epoxy, Chopped strand mat, E-glass fiber, Mechanical properties, Composites*

1.INTRODUCTION

Polymer matrix composites have replaced metals and pure polymer-based materials in many applications. In the present days, composite materials are the popular materials in demand because of their high strength to weight ratio. The fiber reinforced composites exhibit the excellent mechanical properties which are the most essential parameters to design the long sustainable structures or components. The glass fiber reinforced polymer matrix composites are in great demand [1]. Under various operating conditions, commercially available thermoset type of Epoxy polymers exhibits good mechanical properties. Epoxy resins have been used in a wide range of applications due to their advantageous properties like corrosion resistance, chemical resistance and low shrinkage on curing, high performance at various operating conditions [2].

The properties of the constituent materials such as the type of resin and fibers, quantity, fiber distribution and orientation are the parameters which define the mechanical properties of the polymer matrix composites [3]. The bonding at the interface and the transfer of load from the matrix material to fiber material is an important issue for defining the mechanical property of the fiber reinforced composite [4]. The interface bonding between the fibers and the matrix is a major issue in the mechanical properties of the composite materials. The stability and the strength of the interface are the defining parameters of life expectancy, toughness, fatigue resistance and strength of the composite materials [5].

The fiber reinforced composites are anisotropic in nature, this property of the fiber reinforced composites is not found in traditional isotropic materials. The fibers have the anisotropic region around them even when they are formed to isotropic when they are seen on the macroscopic scale. The properties like strength and rigidity are less in the direction perpendicular to the axis of the fibers but are extreme in the parallel direction of the fiber axis. The high performance and stability of the composite are obtained when the interface of fiber and matrix are having high strength and chemically stable [6]. The physical property of the matrix is changed due to the chemical reaction at the coupling agent and matrix interface, thus the morphology of the matrix is modified [7]. The overall fiber reinforced composite materials efficiency is measured by the conventional method of evaluating i.e. by conducting the mechanical evaluations at various temperature and environmental conditions by enhancing the fiber protection. Many investigations are been in the process to evaluate the improved fiber surface treatments. The stress transfer capability and fiber protection are been evaluated by using the experimental or theoretical technique [8,9,10]. The enhancement of the mechanical properties is possible with the surface treatment of glass fibers along with the filler materials [11]. In this present investigation, an attempt has been made to unveil the influences of fiber surface treatment of E-Glass fibers on the tensile, flexural and Impact properties of Epoxy/Treated Chopped Strand Mat (CSM) E-Glass fibers Polymer matrix composites.

2. EXPERIMENTAL PROCEDURES

2.1 Materials

Raw materials selected for the present study are as follows:

2.1.1 Matrix material

The epoxy resin diglycidyl ether of bisphenol-A (DGEBA) with trade name: LAPOX L-12 having a medium viscosity which is used with hardner to fabricate the composite laminates. Due to their ability to process under various conditions, epoxy is having a wide range of applications. The epoxy resin is used in holding things together, exterior casings, coating, potting and encapsulating the materials. Epoxy is the end product of the cured epoxy resin. Epoxy resins generally react with themselves through a reaction known as catalytic homopolymerization. Epoxy resins are the thermosetting polymers that are most widely used for their high-performance applications. Epoxy resins have found the wide application due to excellent corrosion resistance, high chemical resistance, and low shrinkage and due to their mechanical and thermal properties. Epoxy resins generally react with themselves through a reaction known as catalytic homo-polymerization.

2.1.2 Curing Agent

Triethylene tetra-amine (TETA) with trade name as K-6 with a viscosity of 10-23 mPas at 25oC is a low viscosity room temperature curing aliphatic amine curing agent. It is commonly employed for civil engineering systems where low viscosity and fast setting at ambient temperature is desired.

2.1.3 E-glass fiber

In the present work Chopped strand mat E-glass fibers have been used as the reinforcing materials. The base materials of the mineral glass are silica, boron, sodium, iron, and aluminum. E-glass fibers or electrical glass fibers are the most widely used glass fibers, because of their stiffness, electrical resistance, weathering and good strength properties. They are used in circuit boards, tapes, PMC, and insulators due to their ability to high strength to weight ratio. Glass fibers are used in three conditions, namely untreated condition (condition in which the manufacturer has provided) and other two are in surface treated conditions as discussed in next section. Glass fiber from the manufacturer will be coated with polyvinyl acetate (PVA), this coating is done to protect the glass fiber from surface abrasion and damages caused by humidity.

2.2 Surface Treatment of E-glass fibers

2.2.1 Heat treated E-glass fiber

The E-glass fibers provided by the manufacturer will be having the layer of lubricating oil and polyvinyl acetate used in the process of manufacturing the glass fibers. The lubricating layer is provided to protect the glass fiber while handling and to protect from humidity. These layers have an effect on the overall performance of the composites. Hence to improve the adhesion at the matrix/fiber interface, these layers must be removed. This was achieved by heating the glass fiber at the temperature of 200^{o}C to 300^{o}C. The lubricants will burn and carbonize at this temperature.

2.2.2 Ethyl Silicate coated heat treated E-glass fibers

The heat treated E-glass fibers are further coated with Ethyl Silicate. This coating was provided by dipping the glass fiber in the Ethyl Silicate bath and allowing it to dry at ambient temperature. Ethyl Silicate coated heat treated E-glass fibers were evaluated to check for the performance of Ethyl Silicate coating over the manufacturer provided a coating.

2.3 Fabrication of Composites

The epoxy polymer composites laminates are fabricated by hand layup technique, by using the three types of treated chopped strand mat E-glass fiber with vol% of 3.42 %. The bi-product Epoxy is mixed with Hardener at the ration of 100:10 to form the resin. The resin is poured into the mould within the pot life of the resin i.e. 30 mins at 25^{o} C. the laminates of dimension 250 mm x 250 mm x 3 mm are fabricated and the test coupons are cut as per the ASTM standards for the testing.

Table 1: Specimen Details

Composite	Specimen Designation	Vol. Fraction of Epoxy (%)	Vol. Fraction of CSM E-glass fiber (%)
Pure Epoxy	EPOXY	100	0
Epoxy + Untreated CSM E-glass fiber	UTCSM1	96.58	3.42
Epoxy + Heat treated CSM E-glass fiber	HTCSM1	96.58	3.42
Epoxy + Ethyl Silicate coated Heat treated CSM E-glass fiber	ETCSM1	96.58	3.42

2.4 Tensile test

The capability of a material to overcome the forces nurturing to pull it separately is known as ‘tensile strength’. The tensile test of the specimen is conducted at controlled loading at the speed of 5 mm/min. ASTM D-3039 was the standard method of testing used for tensile testing of polymer matrix composite materials. In this test, the material will be subjected to a uniaxial tensile force with continuous increase in load. Meanwhile, an observation will be made on the elongation of the specimen. The test will be conducted on the specimen until it breaks.

2.5 Flexural test

The flexural strength is determined by a three-point bending test. It is the strength of the material to resist flexural bend on the application of load. ASTM E-190-14 is the standard testing procedure to determine the flexural strength of the polymer matrix composite. At the deflection of 5%, the specimen must fail and this is considered as the maximum deflection and the application of load is stopped. The specimen is supported between the two support at the span of 50 mm and the load is applied at the center of the specimen.

2.6 Impact test

The impact test is conducted to determine the energy absorbed by the specimen before it fails. Charpy impact testing is done to evaluate the impact energy absorption. ASTM D-6110 is the standard testing procedure used to evaluate the impact strength of the polymer matrix composites. The impact energy in the Charpy test is determined by dropping the striker on to the specimen which is clamped at one end and the other end left free to take up the strike and to absorb the energy of impact.

3. RESULTS AND DISCUSSIONS

3.1 Tensile Strength

Table 2: Tensile properties of Treated CSM E-Glass fiber Polymer Matrix Composites

Composite	Specimen Designation	Ultimate Tensile Strength MPa
Pure Epoxy	EPOXY	64.32
Epoxy + Untreated CSM E-glass fiber	UTCSM1	72.03
Epoxy + Heat treated CSM E-glass fiber	HTCSM1	91.97
Epoxy + Ethyl Silicate coated Heat treated CSM E-glass fiber	ETCSM1	83.61

The tensile strength of the Treated Chopped Strand Mat reinforced epoxy matrix composites are shown in Figure 1. The heat treated CSM E-glass fiber reinforced epoxy laminate exhibited the maximum strength. The Ethyl Silicate coated Heat treated CSM E-glass fiber reinforced laminates have shown the next value of strength and with the lesser strength values of untreated E-glass fibers followed by the plain epoxy laminates. This type of behaviour in tensile strength is due to the treatment of glass fibers. Glass fiber from the manufacturer will be coated with polyvinyl acetate (PVA), when this glass fiber is heat treated the coating is burnt and carbonized which leads to good bonding at the interface of fiber and matrix resulting in good tensile strength. Further, the coating of Ethyl Silicate on heat treated glass fibers has shown the lesser strength than the heat-treated glass fiber, but they are exhibiting good strength compared to manufacturer supplied E-glass CSM fibers.

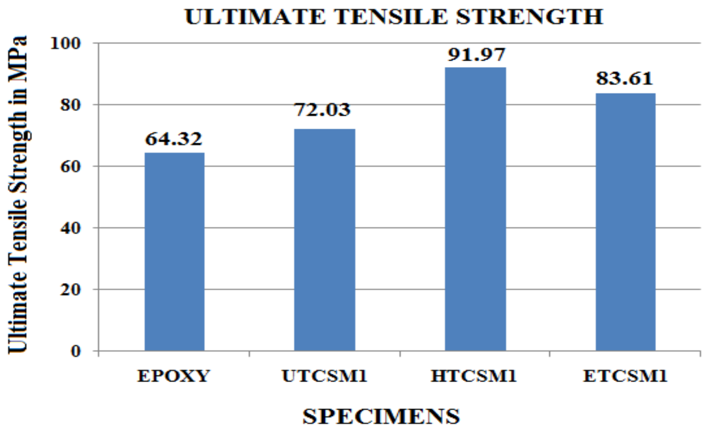

Fig. 1: Tensile Strength of Epoxy/Treated CSM E-Glass PMC's

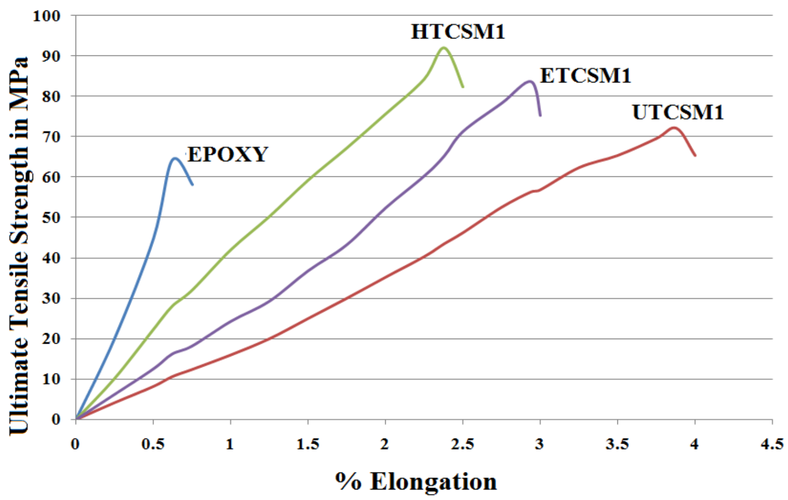

Fig. 2: Tensile Strength v/s % Elongation of Epoxy/Treated CSM E-Glass PMC's

3.2 Flexural Strength

Table 3: Flexural properties of surface Treated Epoxy /CSM E-Glass fiber PMC's

Composite	Specimen Designation	Flexural strength MPa
Pure Epoxy	EPOXY	27.78
Epoxy + Untreated CSM E-glass fiber	UTCSM1	30.55
Epoxy + Heat treated CSM E-glass fiber	HTCSM1	38.89
Epoxy + Ethyl Silicate coated Heat treated CSM E-glass fiber	ETCSM1	34.72

The Flexural strength of the Treated Chopped Strand Mat reinforced Epoxy matrix composites are shown in Figure 3. The heat treated CSM E-glass fiber reinforced epoxy laminate exhibited the maximum strength followed by Ethyl Silicate coated Heat treated CSM E-glass fiber reinforced laminates and with the lesser strength values of manufacturer-supplied untreated E-glass fibers followed by the plain epoxy laminates. This type of behaviour in flexural strength is due to the surface treatment of glass fibers. The results show that the surface treating of the E-glass fibers will influence the interface bonding at the matrix and fiber interface, which leads to the enhancement of the properties. Heat treatment followed by Ethyl Silicate coating exhibited the good strength compared with manufacturer supplied E-glass fiber

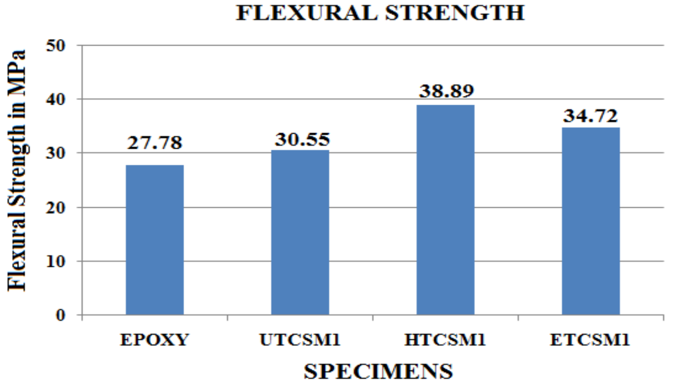

Fig. 3: Flexural Strength of Epoxy/Treated CSM E-Glass PMC's

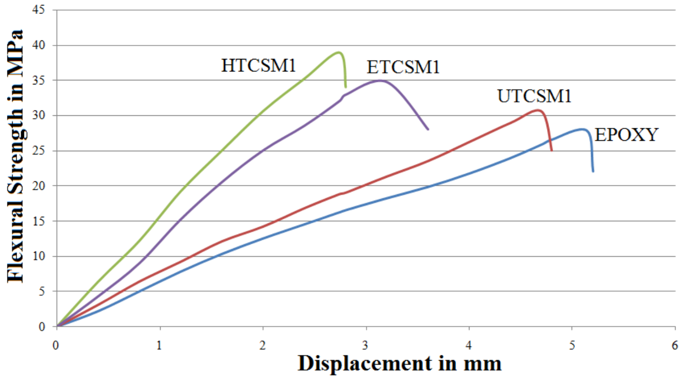

Fig. 4: Flexural Strength v/s Displacement Epoxy/Treated CSM E-Glass PMC's

3.3 Impact Strength

Table 4: Impact Strength of Epoxy/Treated CSM E-Glass PMC's

Composite	Specimen Designation	Impact Energy in J	Impact Strength in J/mm^2
Pure Epoxy	EPOXY	17.5	0.4575
Epoxy + Untreated CSM E-glass fiber	UTCSM1	19	0.4967
Epoxy + Heat treated CSM E-glass fiber	HTCSM1	19.3	0.5007
Epoxy + Ethyl Silicate coated Heat treated CSM E-glass fiber	ETCSM1	18.5	0.4848

The impact energy absorbed by the Treated Chopped Strand Mat reinforced Epoxy matrix composites have been shown in Figure 5. The heat treated CSM E-glass fiber reinforced epoxy laminate exhibited the maximum strength followed by of manufacturer-supplied untreated E-glass fibers reinforced laminates and with the lesser strength values of Ethyl Silicate coated Heat treated CSM E-glass fiber reinforced laminates followed by the plain epoxy laminates. This type of behaviour in Impact strength is due to the surface treatment of glass fibers. Heat treatment followed by Ethyl Silicate coating exhibited the less strength compared with manufacturer supplied E-glass fiber.

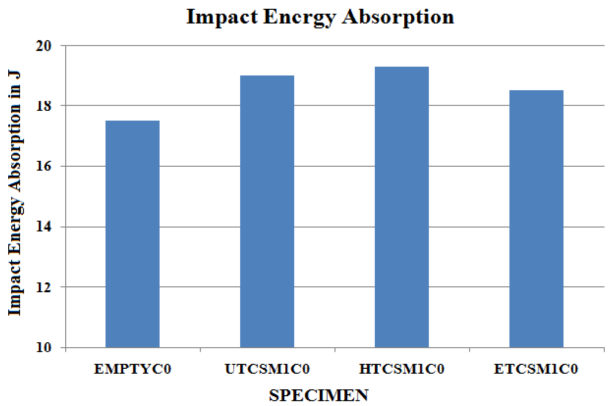

Fig. 5: Impact Energy absorption of Epoxy/Treated CSM E-Glass PMC's

4. CONCLUSIONS

This experimental investigation of Treated Chopped Strand Mat E-glass fiber reinforced epoxy polymer matrix composites has led to the following specific conclusions:

- Surface Treated E-glass fiber reinforcement composites exhibit good bonding at the matrix and fiber surface interface.
- Surface treatment of the E-glass fiber has improved the tensile, flexural and impact strengths of the composites.
- Usage of heat treated CSM E-glass fiber as the reinforcement in the composites will increase the properties of fiber reinforced composites at the expense of.
- Usage of Ethyl Silicate coating on heat treated CSM E-glass fiber has improved ~~reduced~~ in mechanical properties when compared with commercially available E-Glass fibers of CSM variety.
- The work concludes that with glass fibers treated with Ethyl Silicate, the mechanical properties of the composites can be enhanced.

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