Effect of rubber particulate inclusion on the mechanical properties of epoxy Fiber Reinforced Composite (FRC) plates and Regression analysis

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Abstract *:* Composites materials are a combination of two or more materials, one of which is made up of stiff, long fibres and the other is a matrix, which holds the fibres in place. Such combinations exhibit the best properties of the individual materials and include other qualities that none of the individual materials possesses. In aerospace application, the term composite structure refers to fibre/resin combination wherein the fibre is embedded in the resin called matrix but retains its density. Fibre-reinforced composites are receiving greater importance in the present day industries like aerospace, automobile because of their low density, high stiffness, high strength and damping characteristics. The aim of the present work is to study, test and analyses the tensile strength of the glass epoxy fibre reinforced composites particularly by introducing the natural rubber particles of different size in the glass fibre mat of different orientations. The present work deals with the fabrication of the samples in the form of plates with particular rubber inclusions of different sizes in the form of weight fractions. Tensile test was carried out for all fabricate sample plates, the results revealed that tensile strength showed good result for rubber inclusions of 225 microns in both 5mil and 8mil. While comparing with 8mil, 5mil showed better results. Finally analysis is made by using SPSS 14.0 for obtaining the equation, Which is used to compare the actual values with theoretical values.

Keywords: Composite plates, Glass epoxy fibre reinforced, GFRP,Tensile test, SPSS analysis.

I. INTRODUCTION

1.1COMPOSITE MATERIAL:

Over the last forty years, composite materials, Plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials has grown steadily, penetrating and conquering new markets relentlessly. Composites materials are a blend of two or more components, one of which is made up of stiff, long fibres and the other is a matrix, which holds the fibres in place [1]. Such combinations exhibit the best properties of the individual materials and include other qualities that none of the individual materials possesses. Thus composite materials are macroscopic combination of two or more distinct materials having discrete and recognizable interface separating them. The narrower definition of composites, therefore, becomes more specific and can be restricted to those combinations of materials that contain high strength/stiffness fiber reinforcement supported by a high performance matrix material.

1.2 FIBRE:

In aerospace application, the term composite structure refers to fiber/resin combination wherein the fiber is embedded in the resin called matrix but retains its density. Fibre-reinforced composites are receiving greater importance in the present day industry because of their low density, high stiffness, high strength and damping characteristics. The fibres are strong and stiff relative to the matrix and are generally orthotropic i.e., having different properties in two different directions. Fibers provide strength and stiffness while having low density, constrain the creep of the matrix, reduce thermal expansion, and they can be used to either increase or decrease other physical properties such as thermal conductivity, electrical conductivity, and radiation transparency. The matrix provides stress transfer among fibers and protects them from chemical attack and abrasion. In any product, a key role is played not only by physical properties, but also by cost. Fiber reinforcements are a major component of the tradeoff between performance and cost. High performance can be achieved by a judicious design and manufacturing of the product, but more than one solution often exists; the final choice governed by cost. A large variety of fibers exists in order to satisfy the requirements of various processing methods. Fiber reinforcements may be obtained as continuous or discontinuous fibers, unidirectional aligned fibers or textile products. Among textile products it is possible to use woven, knitted, and braided fabrics, to name a few. The reinforcement form is a design parameter and it affects both the quality and cost of the composite material. There are various types of fibers namely glass fibers, silica fibers, boron fibers, silicon carbide fibers, alumina fibers, carbon fibers. In the present work glass fiber mat is used.

Glass fiber: It is also called fiberglass shown in fig.1. It is a material made from extremely fine fibers of glass Fiberglass is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. Glass is the oldest, and most familiar, performance fiber. Glass fibers are processed from bulk glass- an amorphous substance fabricated from a blend of sand, limestone, and other oxide compounds. Hence, the main chemical constituent of glass fibers (46-75%) is silica ($SiO2$). Controlling the chemical composition and manufacturing process, awide variety of glass fibers for different types of applications can be obtained, but they exhibit the typical glass properties of hardness, corrosion resistance, and inertness. Furthermore they are flexible, lightweight, and inexpensive. These properties make glass fibers the most common type of fiber used in low-cost industrial applications.

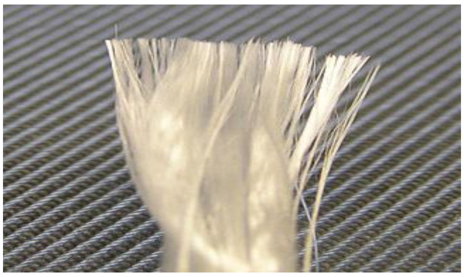


Fig1. Glass fibre

1.3 MATRIX MATERIAL:

It is undoubtedly true that the high strength of composites is largely due to the fibre reinforcement, the importance of matrix material cannot be underestimated as it provides support for the fibres and assists the fibres in carrying the loads. It also provides stability to the composite material. Resin matrix system acts as a binding agent in a structural component in which the fibres are embedded. When too much resin is used, the part is classified as resin rich. On the other hand if there is too little resin, the part is called resin starved. A resin rich part is more susceptible to cracking due to lack of fibre support, whereas a resin starved part is weaker because of void areas and the fact that fibres are not held together and they are not well supported.

The fibres are saturated with a liquid resin before it cures to a solid. The solid resin is then said to be the matrix for the fibres. In general, following types of matrix materials are available:

- Thermosetting material.
- Thermoplastic material.
- Carbon.

The needs, or desired properties of the matrix, which are important for a composite structure are

reduced moisture absorption, Low shrinkage, Low coefficient of thermal expansion, Good flow characteristics so that it penetrates the fibre bundles completely and eliminates voids during the compacting/curing process, Reasonable strength, modulus and elongation, Must be elastic to transfer load to fibres, Strength at elevated temperature (depending on application), Low temperature capability (depending on application), Excellent chemical resistance (depending on application) , Should be easily process able into the final composite shape, Dimensional stability (maintains its shape).

1.4 FABRICATION METHODS:

There are numerous methods for fabricating composite components. Some methods have been borrowed (injection molding, for example), but many were developed to meet specific design or manufacturing challenges. Selection of a method for a particular part, therefore, will depend on the materials, the part design and end-use or application. There are various fabrication methods some of them are hand layup process, open molding, Vaccum assisted resin transfer molding(VARTM). Some of the high volume molding methods are Compression molding, Injection molding, Filament molding, Pultrusion. In the present work the hand layup process is followed for fabricating the required fibre reinforced plates.

II. LITERATURE REVIEW:

With a knowledge of the various types of composites, as well as an understanding of the dependence of their behaviors on the characteristics, relative amounts, geometry/distribution, and properties of the constituent phases, it is possible to design materials having property combinations that are better than those found in the metal alloys, ceramics, and polymeric materials.[1]. Suarez et al.[2,3] developed the impulse method to test the specimen. The test specimen was supported as a flat cantilever beam in a clamping block and impulse excitation was applied using an electromagnetic hammer. The transverse displacement of the beam was measured over time by means of non-contact eddy current probe positioned near tip of beam and Fourier transform was performed to obtain the frequency response function. Curve fitting to fourier transform was used by Suarez et al. to yield the complex modulus. One of the major environmental challenges facing municipalities around the world is the disposal of worn out automobile tires. To address this global problem, several studies have been conducted to examine various applications of recycled tire rubber (fine crumb rubber and coarse tire chips). Examples include the reuse of ground tire rubber in a variety of rubber and plastic products, thermal incineration of waste tires for the production of electricity or as fuel for cement kilns, and use of recycled rubber chips in asphalt concrete. Unfortunately, generation of waste tires far exceeds these uses.[4]

The addition of rubber particles increased the epoxy fatigue life by a factor of about three to four times. The rubber particle cavitation and plastic deformation of the surrounding material was observed to contribute to the enhanced fatigue life of the epoxy polymer. Then, the neat and the rubber-modified epoxy resins were infused into a quasi-isotropic, lay-up E-glass fiber, non-crimp fabric in a RIFT set -up to fabricate GFRP composite panels. Further, the stress-controlled CA tensile fatigue tests at stress ratio, R = 0.1 were performed on both of these GFRP composites. Matrix cracking and stiffness degradation was continuously monitored during the fatigue tests. Similar to bulk epoxy fatigue behavior, the fatigue life of GFRP composites increased by a factor of about three times due to the presence of rubber particles in the epoxy matrix. The suppressed matrix cracking and the reduced crack propagation rates in the rubber-modified matrix contribute towards the enhanced fatigue life of GFRP composites employing a rubber-modified epoxy matrix.[5]

In the present work, glass fibre composite is fabricated with rubber particles of different sizes as inclusions. Regression analysis is evaluated experimentally.

III. PREPROCESS

3.1 Materials used:

- Glass fibre of 5 mil and 8 mil mat.
- Epoxy resin Lapox 12 with hardener k6.
- Natural rubber powder of different particle sizes.
- Silicone spray as releasing agent.
- Aluminium plate.

3.2 Equipment used:

- Sieve shaker.
- Digital weight balance.
- Mechanical stirrer.
- Universal testing machine.
- Lathe machine.
- Drilling machine.

3.3 **Resins**:

The use of epoxy resin with lapox l-12 shown in fig.2 is that they bond practically to any material when inner support structures for additional tool stiffness are required. They are durable and won't rust and won't warp. They provide quick, easy and inexpensive modification for repair of valuable tools. These are low temperature curing resins, normally between 20 to 90°C, but some formulations are made for high temp curing. They are advantage of being used without solvent and curing without creating volatile by products and have low volume shrinkage. It's a thermosetting plastic and get hardened with the help of hardener k-6.This hardener is room temperature curing having low viscosity and commonly used for hand layup technique application. It gives rapid cure at normal ambient temperatures.

Fig2: Epoxy resin and Hardner

3.4 FOLLOWING PROCESS:

A release agent, usually in either wax or liquid form, is applied to the chosen mold. This will allow the finished product to be removed cleanly from the mold. Resin – typically a 2-part polyester, vinyl or epoxy – is mixed with its hardener and applied to the surface. Sheets of fibre glass matting are laid into the mould, then more resin mixture is added using a brush or roller. The material must conform to the mould, and air must not be trapped between the fiberglass and the mold. Additional resin is applied and possibly additional sheets of fiberglass. Hand pressure, vacuum or rollers are used to make sure the resin saturates and fully wets all layers, and any air pockets are removed. The work must be done quickly enough to complete the job before the resin starts to cure, unless high temperature resins are used which will not cure until the part is warmed in an oven.[6] In some cases, the work is covered with plastic sheets and vacuum is drawn on the work to remove air bubbles and press the fiberglass to the shape of the mold.[7]

3.4.1 Hand lay up Process:

In this process resins are impregnated by hand into fibres which are in the form of woven, knitted, stitched or bonded fabrics. Hand layup process usually accomplished by rollers or brushes. An increasing use of nip-roller type impregnators for forcing resin into the fabrics by means of rotating rollers and a bath of resin. Laminates then are left to cure under standard atmospheric conditions as shown in fig.3 below.

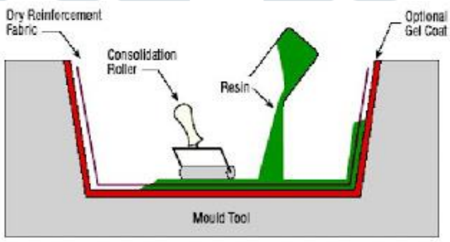


Fig3: Hand lay-up process

3.4.2 Fabrication

As shown in fig.4 8mil and 5 mil of glass fiber mat is taken and marked according to the dimensions 180*300mm by giving tolerance 210*330mm to the given dimensions (fig.6). The plate dimensions are given according to the ASTM standards. Rubber particles are segregated in three different particle sizes using sieve shaker. The segregated particles are 90, 225, 425Microns in size based on nominal diameter of pore size of sieves as shown in the fig.5.

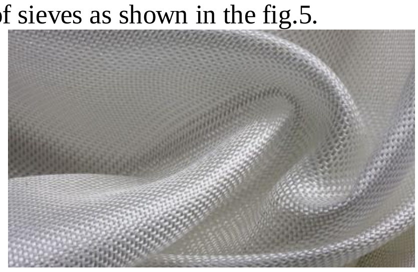


Fig.4: Glass Fibre Mat

The segregated 10% weight in rubber particles each in size of sieves mechanically mixed in Lapox 12 epoxy resin followed by sonication for an hour. Before applying the rubber particle filled epoxy resin to the pre-heated and pre-weighted glass fabric mat hardener K6 is mixed. During sonication the particle included resin hardener mix is added to glass fiber fabric sheet. 8 layers are laid up to achieve 3mm thick composite plates. The dimensions of the fabricated plate are 180mm * 300mm.These plates are processed in press at room temperature under a pressure of 200Kpa for 24 hrs. The edges of the produced composite plates are sanded for pleasing appearance. The weight of the particle rubber inclusions is 10% of the total weight of the composite (inclusions + resin + fiber).

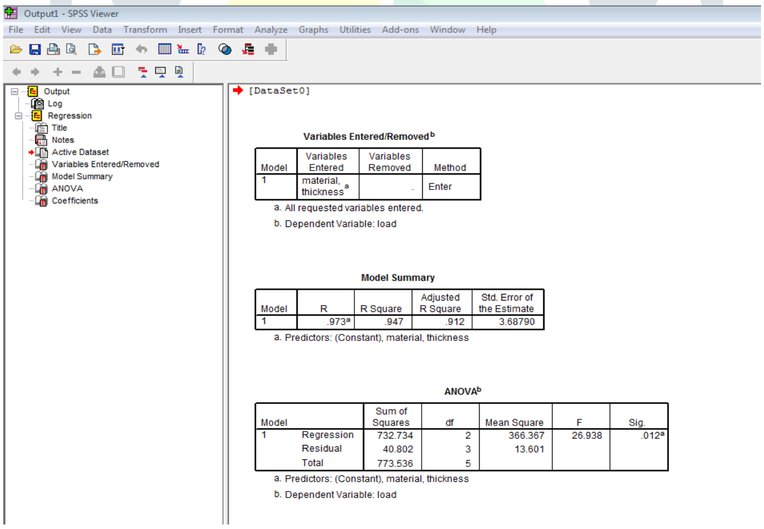
Fig.5: Sieves of (a) 225,(b) 425,(c) 90 microns

For both types of the specimen the nominal content of glass fiber in composite is set at 40% by weight and remaining 60% is resin, which is evaluated by burn out test (ASTM). Silicon grease gel as mould releasing agent is applied to the mould before the laying up process. Serrated rollers are used to compact the material against the mould and to remove any entrapped air. Along with these specimens a neat composite in which no rubber particles inclusion was also fabricated as shown in fig.6.

Fig.6: Final fabricated Plates

IV. Regression analysis

After conducting the tensile test regression analysis is carried out on SPSS-14.0 and the values obtained in tensile test are given as input by taking the variables as material 5mil or 8 mil, size i.e., thickness of the specimen and load carried by each specimen then by taking load as dependent variable where as material and size are taken as independent variable as shown in fig.7 a formula is obtained. Load(L) = 51.124 + 1.115(Size) - 5.856(material)



Variables Entered/Removed[b]

Model	Variables Entered	Variables Removed	Method
1	material, thickness[a]	.	Enter

a. All requested variables entered.
b. Dependent Variable: load

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.973[a]	.947	.912	3.68790

a. Predictors: (Constant), material, thickness

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	732.734	2	366.367	26.938	.012[a]
	Residual	40.802	3	13.601		
	Total	773.536	5			

a. Predictors: (Constant), material, thickness
b. Dependent Variable: load

Fig7: Output

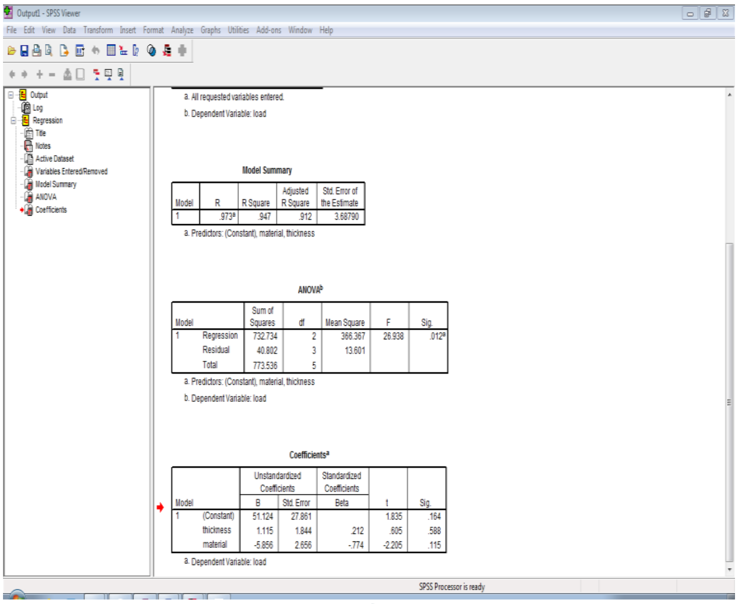


Fig.8: Obtained Equation

By using this obtained equation which is shown in fig.8 calculations are done and the theoretical values are acquired. From the obtained results, it is observed that theoretical values were somewhat close to that of the experimental (practical) values. A table is drawn i.e.tabel.1 showing the comparison of the experimental values to that of the theoretical values.

Type of Mat	Experimental Values			Theoritical Values		
	90 mic	225 mic	425mic	90 mic	225mic	425 mic
5 Mil	25.765	35.195	31.350	29.649	30.754	31.879
8 Mil	9.075	9.14	8.015	8.736	7.621	9.851

Table1: Comparision of experimental results with that of theoritical results

V. RESULTS AND CONCLUSIONS

- The composite plates fabricated are not delaminated after carrying out the tensile test.
- It is observed that the plates with rubber inclusions endured more load than the neat composites.
- It is also found that the plate made with 5mil glass fibre mat is showing high load carrying capability than the plate made with 8mil glass fibre.
- After the tensile test performed on all the fabricated plates it is observed from the results that the maximum load is recorded at 225microns rubber particles inclusion of 5 mil mat than that of all the plates.
- It is also observed that the plate with 225microns rubber particle inclusion of 8mil mat showed high load carrying capability than that of the 90mic and 425mic rubber particle inclusion plates of 8mil mat.
- From the results it is perceived that 225mic rubber particles have meshed well with both the 5mil and 8mil mats.
- From regression analysis using SPSS-14.0 formula is generated. Using this formula theoretical values are obtained and are compared with that of the practical values which are observed to be nearly equal.
- So, the present study conclude that the strength of the plates with rubber inclusions is more when compared to neat composite and the strength is not dependent on the thickness but, it is dependent on the way the rubber powder mould with the fibre.

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