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DESIGN AND DEVELOPMENT OF GLASS FIBER REINFORCED POLYMER MATRIX COMPOSITES FOR ENGINEERING APPLICATION

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ABSTRACT

An experimental investigation has been carried out to develop new PMC using commercially available Epoxy and Polyurethane resin systems. These resin systems would be reinforced with glass fibers, filler materials and aluminium foils. Laminates are prepared by using the hand lay-up techniques of eight layers and mechanical test such as tensile test and compression test have been conducted. This work has been carried out to identify the appropriate resin systems, filler materials and glass fiber reinforcement to estimate the strength of the composite. Two types of glass fiber (chopped mat & woven mat) with reinforcement of filler material and aluminium foil used to estimate the strength of composite.

As per the results from the present experimental study, reinforcing aluminium foil and graphite filler in the chopped mat with Epoxy resin has high tensile strength compared to woven mat reinforcement. By reinforcing filler material has high tensile and compressive strength, the properties of the laminate is increased due to the filler material reinforcement in Epoxy resin as well as in Polyurethane resin. The properties of the laminate are increased due to the filler material reinforcement in both resin systems. From this investigation we conclude that filler material plays very important role in composite system. In both epoxy and polyurethane resin system by reinforcing filler material the mechanical properties and strength of the laminate under tensile and compression are increased. By comparing two resin systems Polyurethane resin has high strength in tensile and compressive loads.

Key words: *Composite, Epoxy, Polyurethane, Fiber, Filler, Reinforcing, Tensile strength, Compression strength.*

1. INTRODUCTION

Composite materials are not new inventions. In fact, composite materials existed in nature itself [1]. Thus nature is the origin of these materials. We need to develop glass fiber composites because of its Structural Performance, Cost Safety, low Strength to Weight ratio, Multifunctional Design, Superior fatigue Properties, low response of thermal variation and many more. Composite materials are basically heterogeneous materials, having two or more physically distinct components, when combined together they become stronger and stiffer and perform superior to each of the distinct components [2]. In general, a composite material consists of a matrix (the continuous phase) and a reinforcement (the intermittent phase). Out of these two, the matrix is the weakest part, while reinforcement is the strongest part, but as a composite system, the material will attain a high strength[3]. Reinforcing or additive constituents used for structural materials usually carry most of the load, or furnish the dominant properties. Among the polymer composites, the glass fiber, carbon fiber, and aramid fiber reinforced with thermoset resins like epoxy and polyurethane are well known [3]. These materials contribute to high performance due to their basic structure and also due to the strong bond formed at the fiber/matrix interface. Thus, their properties and strength can be attributed to these factors. Because of their strong structural characteristics and combined with their low specific gravities (of the order of 1.5 to 2.5), they have very high specific strengths as compared to conventional structural materials like wood, steel, and aluminum[6].

A composite material is defined as a structural material created synthetically or artificially by combining two or more materials having dissimilar characteristics. One constituent is called as matrix phase and the other is called reinforcement phase [3]. The main advantage of a composite material over the conventional material is like a metal is the combination of different properties which are seldom found in the conventional materials. The unusual combination properties include high strength to weight ratio, higher stiffness, improved fatigue resistance and corrosion resistance [5]. Epoxy-based film adhesives are being used increasingly for the fabrication and joining of aluminum and polymeric composite parts in the aircraft industry because of problems associated with conventional fasteners. While these materials must be stable in high service temperature environments, they must also be resistant to failure resulting from vibration and fatigue loading. This typically requires the addition of modifiers to base epoxy formulations to increase the adhesion, toughness, and peel strength of the materials. Previous research has been performed investigating epoxy modifiers that promote increased fracture toughness and provide better adhesive characteristics.

The scope of present investigation encompasses the preparation and properly evaluation of a new particulate reinforced polymer matrix composite with epoxy and polyurethane as the matrix material and glass fiber, filler material and aluminium foil as reinforcement to estimate which resign system have high strength. The aluminium foil used very sparingly as a reinforcing material has very good strength. The results of previous works have shown that through the addition of glass reinforcement to epoxy, the hardness, tensile strength and young's modulus were improved, and the properties increased with the addition of particulate volume fraction. The mechanical properties are evaluated and compared with the matrix, since these properties are very much desired in the structural materials.

2. LITERATURE

The literature gives a brief about the present research work on evaluation of mechanical properties.
The mechanical strength of an anhydride-cured epoxy resin was studied by means of tensile tests as a function of particle size and volume fraction of an alumina trihydrate particulate-dispersed phase[4]. The effect of milled carbon fibers of two types (differing in length) on the properties of rigid polyurethane foams in the density range from 50 to 90 kg/m^3 is investigated[10]. The detailed literature survey is given by reference journals.

3. SELECTION OF THE MATERIAL

The selection of the material is made by taking into account the need to keep the following inherent properties at the given performance specifications, hardness and monolithic character, strength in respect of mechanical and thermal loading, elongation at a particular strain, outdoor stability and waterproofing.
It is evident that the role of filler materials in aircraft applications has not been carried out so far. To start with, we would like to carry out a general study of the mechanism of mechanical behaviour of Epoxy and Polyurethane based composites with & without filler materials and Aluminium foil try to process and correlate and compare the data to estimate the strength of a composite.

The materials to be used in this investigation are:

Polymers - Epoxy, polyurethane

Reinforcement -Glass fiber, Aluminum foils, Filler material

3.1 Processing of PMC's

There are so many processing methods, the method of production and PMC's selected by a manufacturer will depend on factors such as cost, shape of component, number of components and required performance. In this experimental investigation we used hand layup method to prepare laminates.

3.2 Hand lay-up methods

In hand lay-up the reinforcement is put down to line a mold previously treated with a release agent to prevent sticking and perhaps a gel coat to give a decorative and protective surface.The reinforcement can be in many forms including woven rovings and chopped strand mat. The liquid thermosetting resin is mixed with a curing agent and applied with a brush or roller taking care to work it into the reinforcement.

4. MATERIALS AND EXPERIMENTAL WORK

4.1 Materials

Materials which are used for producing PMC laminates with reinforcement are discussed in this part. PMC laminates are basically requires the matrix materials and reinforcement materials. Matrix materials are produced by using resin systems with accelerator and catalyst. In some cases it requires filler materials also with hardener material. Reinforcement materials are produced by using glass fibers.

4.1.1Epoxy

Epoxy systems are the major composite material for low-temperature application [usually under 200ºF (93ºC)] and generally provide outstanding chemicalresistance, superior adhesion to fibers, superior dimensional stability, good hot/wet performance, and high dielectric properties. Epoxy can be formulated to a wide range of viscosities for different fabrication processes and cure schedules. They are free from void-forming volatiles, have long shelf lives, provide relatively low cure shrinkage. They also have good chemical stability, flow properties, excellent adherence, water resistance, and low shrinkage during cure, freedom from gas formation, and stability under environmental extremes.

4.1.2 Polyurethane

Polyurethanes are one of the most versatile polymers known. They are synthesized by the reaction of a polyester polyol, or polyether polyol, with an aromatic or aliphatic isocyanate. The reagents often used for classroom demonstrations are polyester polyols and polyfunctionalisocyanates.

4.1.3 Filler materials

These are the materials most often added to polymers to improve tensile and compressive strengths, abrasion resistance, toughness, dimensional and thermal stability and other properties. Materials used as particulate fillers include wood flour (finely powdered saw dust), silica flour and sand, graphite, clay, talc, limestone.

4.2. Reinforcement

4.2.1 Woven mat

This is a bi-directional reinforcement, obtained by weaving or textile operations using strands running in both directions warp (longitudinal) and fill (transverse) and fibres remain parallel to each other. Woven roving may be specified by the end count (number of ends per centimeter in the warp and fill direction), thickness depends on the number of strands grouped to form one end.

4.2.2 Chopped strand mat

Chopped strand mat is probably the most widely used form of glass reinforcement. Strand of bonded filaments of about 50 mm long are themselves bound to one another in a random pattern to form a mat. Different binders are used to suit different applications, the main variable being the solubility of the binder

.

Figure 1-Woven mat

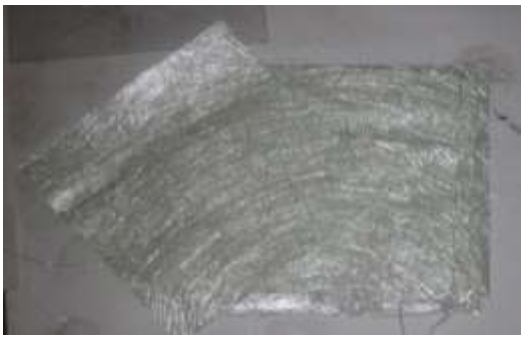

Figure 2- Chopped mat

4.3Mould used for preparing laminates

The mould used for the preparing laminates involves two mild steel plates, seven spacers and seven C- clamps. This mould is sufficient to carry out the fabrication process by using hand lay-up method and as well as by using compression molding method, figure 3 shows the mould assembly.

Figure 3-.Mould Assembly

Figure 4 -Spacers

Figure 5-Clamp

4.3.1 Mold plates

Two plates are having the dimensions of 250mm*250mm and 8mm thickness. These dimensions are selected according to the requirements of the fabrication process. The thickness of each plate is 8 mm, if it is less than 8mm then there may be chance of buckling of plates will takes place and laminates are not prepared well.

Milling and grinding process are carried out on the plates in order to get good surface finish.

4.3.2 Spacers

The spacers are made by using the mild steel material. It is having dimensions of 20mm*20mm with 2.5mm thickness. The dimensions are selected as per the fabrication process requirements. Thickness is selected in order to obtain the desire thickness of the laminates. Figure 4 shows the spacers.

4.3.3 C-Clamps

Clamps are used in the mold preparation is due to the load application process by using the screw threads. C-clamp means, it is having the C shape. It is having the dimensions of height 50mm and thickness 10mm. Milling and Grinding process are used to prepare the clamps. Figure 5 shows the C-Clamps.

4.4 Introduction of Mini- Universal Testing Machine

Materials testing systems are simple and effective. The designed tensile-compression testing equipment to be easy to learn, calibrate and operate. We offer a full range of digital indicators, materials testing equipments, grippers and fixtures for testing virtually any property from the compressive strength of concrete to the tensile strength of metal alloys, from the bending strength of finish hooks to the yield and foams, from the flexural strength of bone to the sliding friction of coatings and films, from the strength of drive belts to welds in torsion.

The parts in the UTM are Load cell, Strain gauge, Load Indicator, Grippers, Linear Measurement Instruments, Worm Gear, and Power Screw.

5. CONDUCTION OF EXPERIMENT

5.1 Preparation of laminates

The plates used for the fabrication process is cleaned with acetone in order to remove the dust particles. The woven roving mats (reinforcement) are cut for required dimension (230×230mm) and it is cleaned at top and bottom surface which would affect the properties of laminates. Resin system (matrix) is prepared by taking a epoxy resin of 200ml in the beaker and the filler material (graphite powder) is added into the resin slowly to avoid the air bubbles of 5%-10% of weight of resin and its is stirred well about 10 to 15 mins. After this process hardener, K-6 of 8ml (4% of weight of the resin) is added to the resin system in order to form chemical reaction and to give strength to the resin system and stirred well about 5 – 10 mins. For polyurethane laminate is prepared by taking 100ml of Polyols and 100ml of isocyanate in the beaker and the filler material (graphite powder) is added into the resin slowly to avoid the air bubbles of 5%-10% of weight of resin and stirred well about 2 to 3 mins.

Place the plate on the table and it is covered with a surface mat in order to remove the laminate easily. The resin system is coated on the mat by using brush and a woven mat is placed on it. Then again the procedure is repeated till 8 woven mats are placed between those mats where resin system is coated. The coated plies of glass fiber with the resign is placed one over the other are placed on one of the plates of the mould over which Teflon sheet coated with wax has been placed, The G.I sheet of gauge thickness also coated with wax is placed and finally the top plate of the mould is carefully located over the laminate and securely clamped using the clamps. After the curing process the mold is taken out from the compression molding press and the laminate is removed from the mold. The laminate, which is placed inside the mould, is allowed to cure at room temperature for 24 hours

Figure 6- Chopped mat Laminate

Figure 7-Woven mat Laminate

5.2 Test specimen preparation

Test specimens are prepared as follows, the specimen dimensions are marked on the laminate using a marker. The specimens are cut from each laminate for each test according to ASTM standards. The specimens are cut carefully according to the required dimensions using band saw machine. The specimens are trimmed to proper dimensions using emery paper.

Figure 8-Tensile test specimen

Figure 9-Compressive test specimen

The cut specimens are fixed to the mini UTM and load is applied slowly using Worm Gear, load cell indicates the load applied and the fracture load. The strain is measured in strain indicator which has been shown in below setup.

Figure 9-Tensile test specimen setup

Figure 10-Compressive test specimen setup

6. RESULTS AND DISCUSSION

6.1Tensile and Compressive properties of tested laminates

The Tensile & compressive test recorded values of Epoxy & Polyurethane laminates are as shown in Tables below. The comparative analysis of prepared laminates of specific grades is as shown.

6.1.1 Epoxy resin system

Table 1-Tensile test of Epoxy

Sl No	Laminate Code	Load Fractured in Kg
1	EPCM8	210
2	EPWM8	302
3	EPCMAL8	309
4	EPWMAL8	225
5	EPCMALGR8	349
6	EPWMALGR8	322

Table 2 - Compressive test of Epoxy

Sl No	Laminate Code	Load Fractured in Kg
1	EPCM8	180
2	EPWM8	223
3	EPCMAL8	112
4	EPWMAL8	139
5	EPCMALGR8	280
6	EPWMALGR8	262

6.1.2 Polyurethane resin system

Table 3- Tensile test of Polyurethane

Sl. No	Laminate Code	Load Fractured in Kg
1	PUCM8	229
2	PUWM8	187
3	PUCMAL8	380
4	PUWMAL8	302
5	PUCMALGR8	392
6	PUWMALGR8	265

Table 4- Compressive test of Polyurethane

Sl.No	Laminate Code	Load Fractured in Kg
1	PUCM8	207
2	PUWM8	199
3	PUCMAL8	153
4	PUWMAL8	172
5	PUCMALGR8	297
6	PUWMALGR8	221

EPCM8:- Epoxy (Resin), Chopped mat, 8 layers. AL- Aluminium (Reinforcement), GR- Graphite (Filler), WM (Woven mat). PUCM8:- Polyurethane (Resin), Chopped mat, 8 layers. AL- Aluminium (Reinforcement), GR- Graphite (Filler), WM (Woven mat).

6.2 Tensile strength Comparison Graph of Epoxy and Polyurethane resin

The figure 11 shows the comparison graph for the tensile strength of epoxy and polyurethane resin system. In the graph it is clearly shown that the Polyurethane resin system reinforcement (PUCMALGR8) is having high tensile strength of 392 kg compare to Epoxy resin reinforcement.

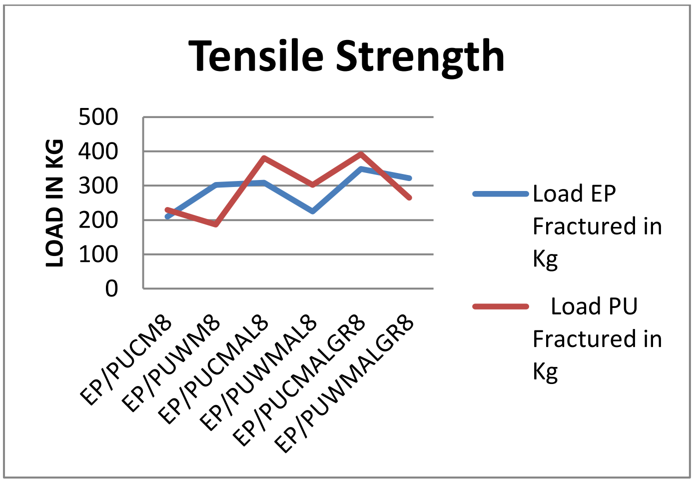

Figure 11: Tensile strength comparisoncurve

6.3 Compressive strength Comparison Graph of Epoxy and Polyurethane resin

The figure 12 shows the comparison graph for the compressive strength of epoxy and polyurethane resin system. In the graph it is clearly shown that the Polyurethane resin system reinforcement (PUCMALGR8) is having high compressive strength of 297 kg compare to Epoxy resin reinforcement.

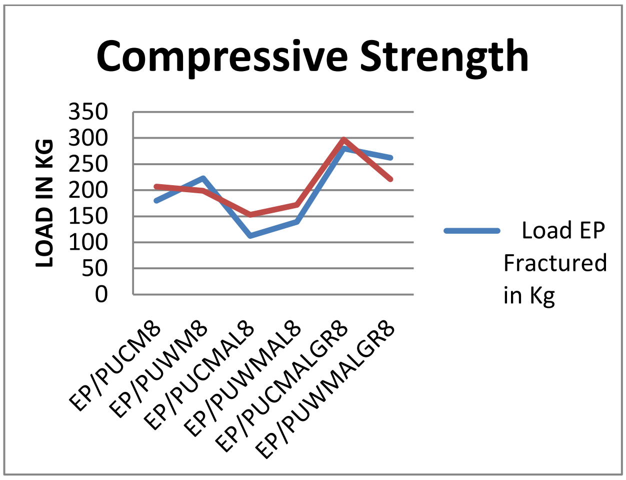

Figure 12: Compressive strength comparison curve.

7. CONCLUSION

As per the results from the present experimental study we can conclude that the properties of the laminate are increased due to the filler material reinforcement in Epoxy & Polyurethane resin with chopped mat. The results are compared without AL foil and Filler material,as per results of Table 1 the Tensile strength has increased 35% by the reinforcement of Chopped mat, AL foil and Graphite with Epoxy resin. As per results of Table 3 the Tensile strength has increased 41% by the reinforcement of Chopped mat, AL foil and Graphite with Polyurethane resin. As per results of Table 2 the Compressive strength has increased 36% by the reinforcement of Chopped mat, AL foil and Graphite with Epoxy resin. As per results of Table 4 the Compressive strength has increased 30% by the reinforcement of Chopped mat, AL foil and Graphite with Polyurethane resin.

From this investigation we conclude that filler material plays very important role in composite system. In both epoxy and polyurethane resin system by reinforcing filler material the mechanical properties and strength of the laminate under tensile and compression are increased. By comparing two resin systems Polyurethane resin has high strength in reinforcement of Chopped mat withFiller materials. Chopped mat with Filler materials plays very important role in this research investigation.

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