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Fabrication and Testing of Fiber-Reinforced Plastic (FRP)

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ABSTRACT

The present study deals and analysis for different FRCSP has higher strength to weight ratio and exceptional buckling resistance. In addition, these structures have effective heat insulation. In this context, FRCSP i.e., fiber reinforced composite sandwich panels fabrication is taken up for aerospace applications. Significant advances in the manufacturing of the FRCSP structures themselves have given greater flexibility in various operating conditions.

The various types of composites materials are Matrices

- ***Organic Matrix Composites (OMCs)***
- ***Polymer Matrix Composites (PMCs)***
- ***Carbon-carbon composites***
- ***Metal Matrix Composites (MMCs)***
- ***Ceramic Matrix Composites (CMCs)***

Reinforcements:

- ***Fibres reinforced composites***
- ***Laminar composites***
- ***Particulate composites***

Finally the project is concluded by The FRCSP can be fabricated by selecting the aluminum and glass fibre to overcome FMLs by improving bonding strengths and easy method of manufacturing along with better strengths which often requires the aerospace industry for its light weight parts.

The maximum impact strength is obtained for the fiber composite and has the value of 12 joules.

The occurred result is comapred with other metals the values are as below.FRP has much strength when compared with other individual metal.

INTRODUCTION

In fiber reinforced composites, addition of glass fibers improves the bending load carrying capacity. Glass fibers are cheaper compared to other reinforcements like carbon fibers; moreover they are used in roofing panels of electrical and electronic devices. Due to their exceptional mechanical characteristics, glass fibers have become the predominant reinforcements in fabrication of high performance composites along with the matrix which plays a vital role in the strength threshold of the composite.

It is observed that glass fibre reinforced plastic panels that are designed for the same ballistic protection as corresponding steel panels show considerable higher post-impact load carrying capacity than the steel counterpart. The sandwich panels having truss core structure is showing good mechanical properties and domination in buckling along with improved debonding of facesheets .The CFRP with honeycombs structures used in aerospace applications and the structures having pyramidal cores are having similar mechanical performance. Thus, for any functional applications that require an open-celled architecture where cooling fluid can pass through a sandwich core, the CFRP complex cores offer a best substitution to honeycombs. Compared to traditional structures in composites hybrid core and truss topology improve specific strength, lightweight, energy absorbing and moduli when composite sandwich panels along with hybrid foam filled lattice cores of CFRP having pyramidal structure which assembled from a carbon fiber.

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In view of transportation reduction in fuel consumption and improvement of safety in vehicle crashes are increasingly important along with the use of lightweight structural materials which offer appropriate impact behavior constitutes one of the alternatives. Fibre metal laminates (FMLs) are multilayered structures consisting of stacked metal sheets and composite thin plates, in which each constituent material is responsible for providing its best so that jointly a laminate with a good specific mechanical properties in 2024-T3 aluminium-based FML with more specific resistance and energy dissipation capacity under impact. By using filament winding machine continuous fibers can be oriented to match the direction and magnitude of stresses in a laminated structure, allowing optimal reinforcement loading.

Generally the mechanical properties of sandwich composites vary depending on the direction of the fiber arrangement; it is required to analyze them by use of an anisotropic theory. These composite materials are also usually constructed of thin layers, which may have different thickness and different +cross-ply angles. The cross-ply angle is the angle between major elastic axis of the material and reference axis. The variation in properties in the direction of the thickness implies non-homogeneity of the material and composite structures must thus be analyzed according to theories, which allow for non-homogeneous anisotropic material behavior. Some of the research work was done to evaluate the buckling load of thin FRP symmetric cross ply rectangular laminates with different orientations, which is subjected to uniaxial compression using finite-element method. The buckling load was evaluated by changing the parameters such as hole orientation, aspect ratio, thickness ratio, number of layers and boundary conditions. The effects of these five parameters are studied on buckling load. The results observed that the buckling load is more at hole orientation as 60 degrees and minimum at hole orientation as 30 degrees, decreases with the increase in an aspect ratio, decreases with an increase in the thickness ratio, increases from number of layer 4 to 12 and remains constant up to 20 . Application of lightweight materials is widely increased in aeronautical structures. Among these materials, foams with a significant weight saving have an important role, but their applications are limited by their low strength and modulus. The application of random-chopped sprayed FRP composites is impeded by the presence of voids, which are primarily formed by entrapped air in the composites and various volatile substances dissolved in the resin matrix which increases the mechanical characteristics and strengthening effectiveness.

Material Selection

The FRCSP is made as 90 degree orientation with 11 glass fibre layers and 2 aluminum layers to form sandwich panel. Initial and final layer is taken up as Al alloy. First Al sheet is placed and then the E-glass fibre is layed up as first level glass and then followed by unidirectional (UD), roven and Chopped strand mat (CSM). The aluminum used as Al6063-T6.

The properties of E-glass fibre are listed as tensile strength 2050MPa, Poisson ratio 0.23, Youngs Moduls 85GPa, Shear Modulus 36GPa and density 2.6 mg/m3. The chemical composition of E-glass fibre used is 54% SiO_2, 15%Al_2O_3 and 12% CaO.

The properties of Al6063-T6 are listed as tensile strength 241MPa, Poisson ratio 0.3, Youngs Moduls 68.9GPa, Shear Modulus 25.8GPa and density 2.7 mg/m3.

Fabrication Process

In the fabrication process the layers of FRP is layed as Al sheet is taken up and on one of its side resin is applied then glass fibre is layed on it then applied resign again on other surface of the glass fibre layed up by roven then unidirectional fibre and then chopped strand fibre followed by Al sheet. The total number of layers layed up are 13. The first and last layers were Al alloy and in

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between the fibres were layed up. Then it is pressed and allowed for curing. The thicknesses followed for the materials used in the fabrication process are as follows: Aluminium-1.2, Glass-0.3, Roven-0.4, UD-1.1, CSM-0.75, Roven-0.4, UD-1.1, CSM-0.75, Roven-0.4, UD-1.1, CSM-0.75, Roven-0.4, Glass-0.3, Aluminium-1.2.
The fabrication process steps were shown in the following figure:
(a) Sizing of aluminum sheet
(b) Epoxy mixing i.e., LY556=L12
(c) Hardener: HY951
(d) Mixture of Epoxy and Hardener
(e) Resin Applying on Al
(f) Layup process
(g) Last Layer of AL
(h) Cutting of Specimen
(i) Final Speciman.

Figure 1: Fabrication process of FRCSP

INTRODUCTION TO COMPOSITES

Mankind has been aware composite materials since several hundred years before Christ and applied innovation to improve the quality of life. Although it is not clear has to how Man understood the fact that mud bricks made sturdier houses if lined with straw, he used them to make buildings that lasted. Ancient Pharaohs made their slaves use bricks with to straw to enhance the structural integrity of their buildings, some of which testify to wisdom of the dead civilization even today.

Contemporary composites results from research and innovation from past few decades have progressed from glass fiber for automobile bodies to particulate composites for aerospace and a range other applications.

Ironically, despite the growing familiarity with composite materials and ever-increasing range of applications, the term defines a clear definition. Loose terms like “materials composed of two or more distinctly identifiable constituents” are used to describe natural composites like timber, organic materials, like tissue surrounding the skeletal system, soil aggregates, minerals and rock.

Composites that forms heterogeneous structures which meet the requirements of specific design and function, imbued with desired properties which limit the scope for classification. However, this lapse is made up for, by the fact new types of composites are being innovated all the time, each with their own specific purpose like the filled, flake, particulate and laminar composites.

Fibers or particles embedded in matrix of another material would be the best example of modern-day composite materials, which are mostly structural.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. Fabrics have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. Reinforcing materials generally withstand maximum load and serve the desirable properties.

In matrix-based structural composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and deforming to distribute the stresses among the constituent reinforcement materials under an applied force.

The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have moisture sensitivity etc. This may offer weight advantages, ease of handling and other merits which may also become applicable depending on the purpose for which matrices are chosen.

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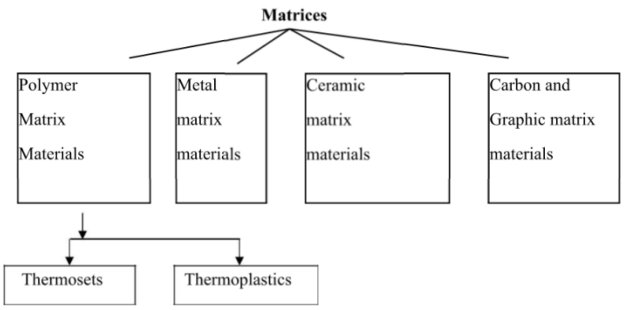

Polymer Matrix Materials

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications.

Two main kinds of polymers are thermosets and thermoplastics. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the chopped fiber composites form particularly when a premixed or moulding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins. elevated temperatures can reversed to regain its properties during cooling, facilitating applications of conventional compress techniques to mould the compounds.

Resins reinforced with thermoplastics now comprised an emerging group of composites. The them of most experiments in this area to improve the base properties of the resins and extract the greatest functional advantages from them in new avenues, including attempts to replace metals in die-casting processes. In crystalline thermoplastics, the reinforcement affects the morphology to a considerable extent, prompting the reinforcement to empower nucleation. Whenever crystalline or amorphous, these resins possess the facility to alter their creep over an extensive range of temperature. But this range includes the point at which the usage of resins is constrained, and the reinforcement in such systems can increase the failure load as well as creep resistance.

Thermosets are the most popular of the fiber composite matrices without which, research and development in structural engineering field could get truncated. Aerospace components, automobile parts, defense systems etc., use a great deal of this type of fiber composites. Epoxy matrix materials are used in printed circuit boards and similar areas.

Kinds of thermosets:

- Thermoplastics
- Polyethylene
- Polystyrene
- Nylons
- Polyropylene

Polyamides Direct condensation polymerization followed by rearrangement reactions to form heterocyclic entities is the method generally used to produce thermoset resins. Water, a product of the reaction, in both methods, hinders production of void-free composites. These voids have a negative effect on properties of the composites in terms of strength and dielectric properties. Polyesters phenolic and Epoxies are the two important classes of thermoset resins.

Epoxy resins are widely used in filament-wound composites and are suitable for moulding prepress. They are reasonably stable to chemical attacks and are excellent adherents having slow shrinkage during curing and no emission of volatile gases. These advantages, however, make the use of epoxies rather expensive. Also, they cannot be expected beyond a temperature of 140ºC. Their use in high technology areas where service temperatures are higher, as a result, is ruled out.

Reinforcements

Reinforcements for the composites can be fibers, fabrics particles or whiskers. Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular. Particles have no preferred orientation and so does their shape. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers. A reinforcement that embellishes the matrix strength must be stronger and stiffer than the matrix and capable of changing failure mechanism to the advantage of the composite. This means that the ductility should be minimum or even nil the composite must behave as brittle as possible.

Fiber Reinforcement

Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired.

Glass fibers are the earliest known fibers used to reinforce materials. Ceramic and metal fibers were subsequently found out and put to extensive use, to render composites stiffer more resistant to heat. Fibers fall short of ideal performance due to several factors. The performance of a fiber composite is judged by its length, shape, orientation, composition of the fibers and the mechanical properties of the matrix.

The orientation of the fiber in the matrix is an indication of the strength of the composite and the strength is greatest along the longitudinal directional of fiber. This doesn't mean the longitudinal fibers can take the same quantum of load irrespective of the direction in which it is applied. Optimum performance from longitudinal fibers can be obtained if the load is applied along its direction. The slightest shift in the angle of loading may drastically reduce the strength of the composite.

Unidirectional loading is found in few structures and hence it is prudent to give a mix of orientations for fibers in composites particularly where the load is expected to be the heaviest.

CLASSIFICATION OF COMPOSITES

Classification

Composite materials are commonly classified at following two distinct levels:

- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.
- The second level of classification refers to the reinforcement form - fibre reinforced composites, laminar composites and particulate composites. Fibre reinforced composites can be further divided into those containing discontinuous or continuous fibres.

  Fibre Reinforced Composites are composed of fibres embedded in matrix material. Such a composite is considered to be a discontinuous fibre or short fibre composite if its properties vary with fibre length. On the other hand, when the length of the fibre is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fibre reinforced. Fibres are small in diameter and when pushed axially, they bend easily although they

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have very good tensile properties. These fibres must be supported to keep individual fibres from bending and buckling.

- Laminar Composites are composed of layers of materials held together by matrix. Sandwich structures fall under this category.
- Particulate Composites are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category.

ADVANTAGES AND DISADVANTAGE OF COMPOSITES

ADVANTAGES

Summary of the advantages exhibited by composite materials, which are of significant use in aerospace industry are as follows:

• High resistance to fatigue and corrosion degradation.

• High 'strength or stiffness to weight' ratio. As enumerated above, weight savings are significant ranging from 25-45% of the weight of conventional metallic designs.

• Due to greater reliability, there are fewer inspections and structural repairs.

• Directional tailoring capabilities to meet the design requirements. The fibre pattern can be SZlaid in a manner that will tailor the structure to efficiently sustain the applied loads.

• Fibre to fibre redundant load path.

• Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.

• It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.

• Composites offer improved torsional stiffness. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.

• High resistance to impact damage.

• Thermoplastics have rapid process cycles, making them attractive for high volume commercial applications that traditionally have been the domain of sheet metals. Moreover, thermoplastics can also be reformed.

• Like metals, thermoplastics have indefinite shelf life.

• Composites are dimensionally stable i.e. they have low thermal conductivity and low coefficient of thermal expansion. Composite materials can be tailored to comply with a broad range of thermal expansion design requirements and to minimise thermal stresses.

• Manufacture and assembly are simplified because of part integration (joint/fastener reduction) thereby reducing cost.

• The improved weatherability of composites in a marine environment as well as their corrosion resistance and durability reduce the down time for maintenance.

• Close tolerances can be achieved without machining.

• Material is reduced because composite parts and structures are frequently built to shape rather than machined to the required configuration, as is common with metals.

• Excellent heat sink properties of composites, especially Carbon-Carbon, combined with their lightweight have extended their use for aircraft brakes.

• Improved friction and wear properties.

The ability to tailor the basic material properties of a Laminate has allowed new approaches to the design of aeroelastic flight structures. The above advantages translate not only into airplane,

DISADVANTAGES

Some of the associated disadvantages of advanced composites are as follows:

a). High cost of raw materials and fabrication.

b). Composites are more brittle than wrought metals and thus are more easily damaged.

c). Transverse properties may be weak.

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d). Matrix is weak, therefore, low toughness.
e). Reuse and disposal may be difficult.
f). Difficult to attach.
g). Repair introduces new problems, for the following reasons:
• Materials require refrigerated transport and storage and have limited shelf life.
• Hot curing is necessary in many cases requiring special tooling.
• Hot or cold curing takes time.
h). Analysis is difficult.
i). Matrix is subject to environmental degradation.

However, proper design and material selection can circumvent many of the above disadvantages.
New technology has provided a variety of reinforcing fibres and matrices those can be combined to form composites having a wide range of exceptional properties. Since the advanced composites are capable of providing structural efficiency at lower weights as compared to equivalent metallic structures, they have emerged as the primary materials for future use.

In aircraft application, advanced fibre reinforced composites are now being used in many structural applications, viz. floor beams, engine cowlings, flight control surfaces, landing gear doors, wing-to-body fairings, etc., and also major load carrying structures including the vertical and horizontal stabiliser main torque boxes.

Composites are also being considered for use in improvements to civil infrastructures, viz., earthquake proof highway supports, power generating wind mills, long span bridges, etc.

MANUFACTURING PROCESSES

Fabrication/Manufacturing Techniques

Tooling of Composites

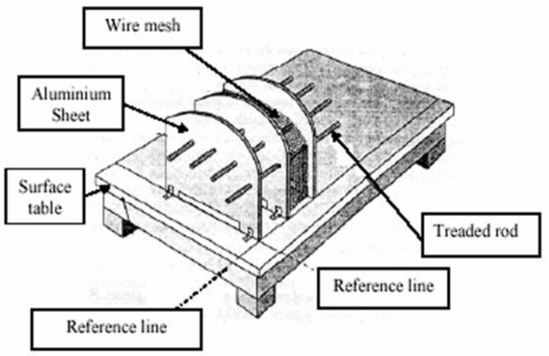
The manufacture of composite detailed parts and assemblies requires that some kind of accurate repeatable tool surface be provided, which is capable of withstanding repeated exposures to the cure cycle environment of high temperature sand pressures. Individual composite parts or details will require a variety of support tooling-beyond the initial cure tool, which are as follows:

- Master model reference patterns,
- Trim or router tools,
- Precision hole location drill tools,
- Assembly fixtures,
- Ply locating templates, and
- Associated shop aids.

The primary objective of any tool for composite fabrication is to make an accurate repeatable part within the confines of the process parameters defined by the manufacturer/designer and the detail performance characteristics meeting the requirements of the end user. Design of the initial tool becomes the most pressing initial issue of tooling for composites.

Template Method

There are several techniques of building a plaster master determined by the shape of the part. If the part is not symmetrical and does not have a constant cross-section or the size is large, the master model is made from a series of templates secured to a flat base to form a 3D full-scale model of the part. Space between the templates is relative to the degree of abruptness of the contour. For normal gentle contours, a space of 15-20mm is common. Templates are usually made of aluminium to prevent corrosion. For temporary masters, steel is some times used, however, because of the amount of moisture present during mixing and application of the plaster, steel templates may rust. A schematic of typical template plaster master .



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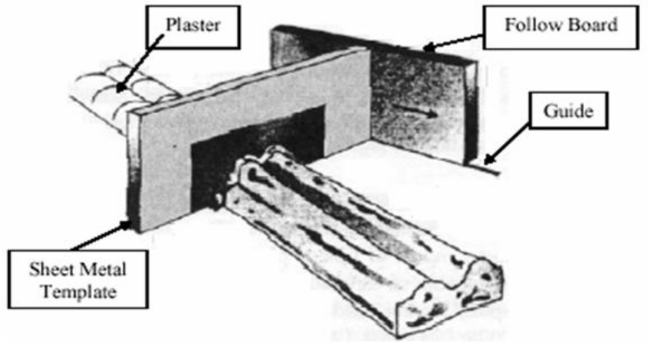
If electronic data is available, the templates can be NC-machined or cut with water or laser jet directly from the flat pattern generated by the data. Except for NC-method, deburring is generally required to remove spurs or sharp edges from the templates prior to use. Holes are drilled to the templates for threaded rod spacer sand screen support rods. For large models, air passages are cut into the bottom of the template to allow for even curing of the plaster. Once sufficient templates have been prepared, bluing is applied to a flat-ridged steel table and scribed with a pointed tool to denote the location of each template. Flatness of the table is critical and should be within0.127mm. Tooling balls, which indicate the x-, y- and z-direction are some times placed on the table corners as reference points for the system. Each template is attached 90° to the base table with angles. Threaded rods are secured with nuts on each side of the template to provide rigidity to the template face. Wire mesh is placed between the templates and secured to the threaded rod. This is used to hold plaster in place. Slurry of plaster is poured between the templates; surface is made even and left to dry to forma smooth and accurate surface. Because of the tendency of plaster to absorb moisture, it should be sealed after the surface has had adequate time to cure. Commercially available lacquers can be used to seal the surface and provide a suitable protection within the shop environment.

Follow Board Method

A method widely used when a constant cross-section is required to be built is the follow board. A flat surface is required with an accurate side surface to act as a guide rail. A template of the contour is prepared from sheet of aluminium or steel and attached to a wooden guide support. Plaster is mixed and built up on the surface to within 3mm of the final contour. Partial drying is recommended before the final plaster mix is applied. This will prevent shrinking and cracking of the plaster surface which otherwise would affect accuracy. Using the template and guide support, the plaster contour is formed by pushing the template evenly over the surface.



Prepreg Method

There is considerable number of prepregs available as epoxy 'B' staged glass or carbon reinforced cloth. The first step prior to prepreg application on the master surface is to ensure that the prepreg and the master surface are absolutely clean and free from debris and that the surface is smooth and without pin holes. A quick vacuum check is always a good idea at a minimum of 6.2 kPa. A loss of 500 Pa within 5 minutes with the pump non-operating is acceptable. Apply masking tape around the tool periphery for later application of the sealant tape. It is absolutely necessary that the, master surface can be released with a suitable hard wax or other release agents. After the cleaning and releasing processes have been completed, release coated tooling pins should be placed into the holes of the master. Series of steps followed after the above processes are:

- Carefully lay each ply onto the surface and work out wrinkles or air bubbles and maintain the warp direction of each ply in the 0ºdirection.
- An overlap between the plies should be preferably 3-6 mills.
- Debulking should be done to ensure that no air is entrapped at the interface and the smooth surface on the tool. It is accomplished by application of a peel ply net to the edge of the laminate and working out wrinkles and air bubbles.
- Sealant tape should be placed around the periphery to prevent resin flow. Adequate precautions should be taken to allow for resin bleed.

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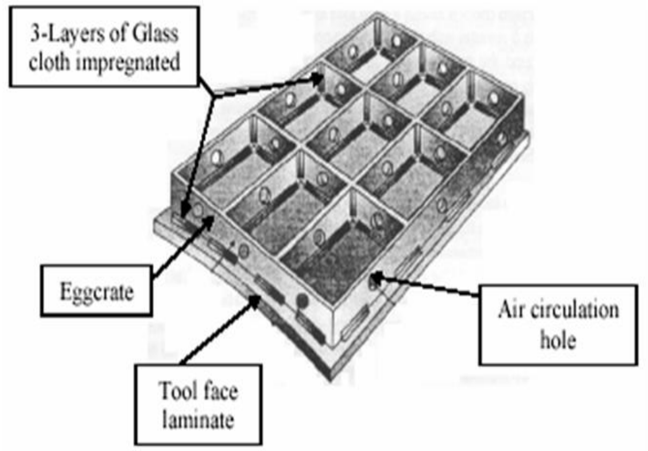
• The orientation for each ply should be such that a balanced system is maintained to minimise stress build up in the laminate.
• As a rule of thumb, debulking should be done after every 4-5 plies. Final build up of the laminate should be at least 9.5 mm.
• Final vacuum bagging is performed with a layer of peel ply, perforated Teflon, polyester breather and vacuum bag.
• Recommended heat up rate and cure temperature should be followed. Most systems can be initially cured at up to 63°C (145°F) and 586-689 kPa of pressure for 14 hours.
• After the autoclave cycle, carefully remove the bag and films .from the laminate to avoid lift up from the master surface. Attachment of support or back up structure (e.g. egg crate) to the laminate is very important to minimise any potential residual stresses built into the laminate. • Separation of the tool from the master should be done carefully to avoid damage to the master or the tool itself.

Tooling pins should be removed prior to separation. Once the tool is separated, the surface should be inspected for pin holes or -roughness. Pin holes can be filled with resin and the roughness can be smoothened with fine grit sandpaper. Care must be taken that no fibres are lifted by sanding along1he length of the fibres.



Another aspect considered important for composite fabrication is appropriate lay-up techniques along with composite cure control.

RESULT OF FRP

Thus the FRP composite samples are fabricated and tested. The composite are subjected to mechanical testing such as impact test. Based on the results, the following conclusions are drawn

The maximum impact strength is obtained for the fiber composite and has the value of 12 joules
The occurred result is comapred with other metals the values are as below.FRP has much strength when compared with other individual metal.

Aluminium

224-MPA	303-MPA	72-MPA
2289.00-kgf/sqcm	3099.56-kgf/sqcm	741.14-kgf/sqcm

FRP

241-MPA	434-MPA	152-MPA
2457.52-kgf/sqcm	4425.57-kgf/sqcm	1549.97-kgf/sqcm

Resin

TENSILE	FRACTURE	SHEAR
93-MPA	135-MPA	77-MPA
948.33-kgf/sqcm	1376.62-kgf/sqcm	785.18-kgf/sqcm

Average - (Composites)

TENSILE	FRACTURE	SHEAR
186-MPA	290-MPA	200-MPA
1898.28-kgf/sqcm	2967.25-kgf/sqcm	1025.43-kgf/sqcm

CONCLUSION

From the analytical and experimental investigation on glass fibers reinforced plastic composite the following conclusions have been arrived The maximum impact strength of 12 Joules is observed for sample S1 with an energy of 400 Newton's .Fiber reinforced plastics (FRP) have been widely accepted as materials for structural and non structural applications in recent years.Glass,carbon,Kevlar and boron fibres are commonly used for reinforcement Infact the uses of carbon and Kevlar is limited mainly to aerospace applications due to their very high costs This work has conclusively proven that the Glass fiber impact capability for FRP laminate to self-heal after low velocity impact damage.

Future Scope

The future scope of this paper is to test the FRCSP as per standards and comparing with other composite material categories. Also the best possible orientations can be evaluated by using the design of experiments in fabrication. Optimum process parameters can be suggested by considering the Taguchi techniques.the experimental data can be modelled and analyzed using other modelling techniques, such as fuzzy logic.

The other properties of composites such as moisture absorption, fatigue and tribological behaviour may be determined using extensive experimentation.

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