Fabrication of E-Glass Fibre Based Composite Material with Induced Particulate Additives

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IN
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CANDIDATE'S DECLARATION

I am, B. Seshavenkat Naidu, Roll No. 2K18/CDN/02 student of M.Tech (COMPUTATIONAL DESIGN), hereby declare that the project Dissertation titled "**Fabrication of E-Glass Fibre Based Composite Material with Induced Particulate Additives**" which is submitted by me to the Department of Mechanical Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of and Degree, Diploma Associate ship, fellowship or other similar title or recognition.

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Abstract

A composite material based on E-glass fibre is fabricated with added additives. This fabrication process deals with following aspects, which are preparing the mould, cutting the fibre, preparing the resin and hardener mixture, adding the additives and final layup for compression. By changing the additive combination, different specimens are made. These specimens are inspected for their heat dispersion quality at high temperatures and durability after the exposure to high temperature. The final result showed the fabrication process was successful as all the fibre layers of the specimens were intact throughout the testing process. The samples with additives graphite, alumina trihydrate and fumed silica showed better structural rigidity even after the exposure to high temperatures. Then another set of specimen sample made of fibre and resin combination only evaluated for it physical properties and analysed virtually on a software for tensile loading and bending conditions.

Key words: Composite, fibre, additives, fabrication, layers, specimens.

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Chapter-1

1.1 Introduction

The composite material preparation began in earlier days with creating a mixture of mud and straw to create strong and durable bricks for their constructions, in the present days these composites have advanced into way more than mud straw, comprising of various reinforcing elements and additive chemicals. The composite materials play major role in replacing the metals and a substitute for the alloys at various occasions of use. When compared with the alloys composites are easy to prepare, the preparation of the alloys deals with heating the different metals to an elevated temperatures and then mixing them in proper proportions, this involves a complex stoichiometric process. When it comes to composites the individual materials neither need to be heated to high temperatures nor to be blended into one another to form a new material. The general ingredients required for the preparation of a composite material can be stated as, re-enforcement material, adhesive matrix and chemical additives, the different combinations of these ingredients results in different composites each with their own distinctive properties. The classification of each of these ingredients is discussed in detail, in the later part.

1.2 Classification of Composite Materials

The composite material construction comprises of two main components they are adhesive matrix and the reinforcement material. Based on these the composites can be classified into further sub categories. These classifications are discussed in the following sections.

1.2.1 Classification Based on Matrix material

The matrix material is the adhesive component used to bind the reinforcements together in the composites. These matrix materials are of three types they are as follows

a) MMC - Metal Matrix Composites
b) CMC - Ceramic Matrix Composites
c) PMC - Polymer Matrix Composites

a. Metal Matrix Composites [MMC]

The composite basically comprises at least two individual components, when one of the component is metal and the other is a different material like ceramic or organic system, the composite is called Metal Matrix Composite. MMC have many advantages like higher specific modulus, low density, stiffness but ductile in nature, greater specific strength and shows better sustainability at elevated temperatures than polymer matrix composites these are also good at thermal conductivity and lower coefficient of thermal expansion, because of these properties metal matrix composites are considered for various different range of applications like burning chamber nozzles in rocket, space shuttle, IC engine pistons, house construction, tube, cables, heat exchangers, aircraft parts and structural members etc. These MMC contains continuous or discontinuous reinforcement materials based shape of the object they are intended for.

b. Ceramic Matrix Composites [CMC]

Ceramic matrix composites are made up of ceramic strand fibres bonded into ceramic composites and these have same material in both reinforcement and matrix, one of the examples for this is carbon and carbon fibre matrix composite. The major quality of ceramic material is that it can withstand at higher temperatures, fire and electrical resistance, ceramic materials are also having light weight, Non corrosive and high strength than metals and polymers. These ceramic materials are processed by sintering process.

c. Polymer Matrix Composites [PMC]

Polymeric matrix composite materials are most commonly used composite materials. Polymer is a substance which consisting of inter linked molecules are also called Monomers, each molecule made up of identical units interlinked together, in these the matrix material is polymers like polyester, epoxy, polycarbonate, polysterene etc. The polymer matrix composites use materials like glass, steel, carbon or Kevlar fibres as their reinforcement materials. The material required for production or processing of polymer matrix composites are simple as compared to the metallic and ceramic materials. These polymer matrix composites can be biodegradable in nature based on the combination of matrix and reinforcement.

1.2.2 Classification Based on Reinforcement

The reinforcement materials are the major ingredients that provide strength to the composite. The types and the arrangements of these reinforcements cause major difference in the physical properties of the composite. The different types of reinforcement can be stated as fallows.

a) Particulate Reinforcement
b) Fibre Reinforcement
c) Laminate Reinforcement

a. Particulate Reinforcement

The composite with the reinforcement material in the form of particulates are called as Particulate reinforcement composites. The dimension of these particulates have a pivotal role in shaping the properties of the composite material and also the arrangement of these particulates i.e random arrangement or parallel arrangement also causes difference in the properties of the composites. These particles usually improve the composite's rigidity to a limited degree, but these are weak in improving the resistance to fractures. Particulate fillers that are individually used to enhance the properties of matrix materials, such as adjusting the thermal and electrical conductivity, enhancing material resilience at high temperatures, fire resistance, flammability, thermal stability, reducing thermal deterioration, reducing friction, increasing wear and abrasion resistance, enhancing machinability, reducing shrinkage and increases.

b. Fibre Reinforcement

The fibre can stated as fine threads extracted out of materials, these are easy to mould into any required shape because of their flexibility. These fibres as reinforcement materials bring optimum efficiency to the composites. The length of these fibres also plays major role in characterising the composite strength, the fibres can be stated as continues fibres or discontinues fibres.

Continuous fibres means, the fibres which have longer aspect ratios or it has long length, continuous fibre exhibits good mechanical properties than other fibres like Discontinuous fibres. The continuous fibres are mainly unidirectional and bidirectional, in the unidirectional type of arrangement all fibres in the composite material are arranged in one direction only and all fibres in composite material are parallel to each other and in the bidirectional fibre type of arrangement all fibres in the composite material are arranged in mutual perpendicular to each other. These types of bidirectional composite materials have high strength and stiffness. Discontinuous fibres means, the fibres which have small aspect ratio or the length of the fibre is less than the 3 centimetres. Discontinuous fibres are also called as short fibres. Fibres are highly helpful in the betterment of the fracture resistance of the matrix. In case of Discontinuous fibres type of composite materials the fibres are randomly distributed and the orientation is cannot be controlled.

c. Laminate Reinforcement

The composite with different layers of fibre reinforcement and all of them are joined together by matrix material the composite is called multi-layered composite since each layer has different reinforcement. They type of reinforcement is called laminate reinforcement. These type of composites provide maximum stiffness and rigidity, because of this they are hard to mould into complex shapes and designs.

1.3 Reinforcement

There are various types of reinforcement materials used in the composites, these are particulates, flakes, fillers, laminates and fibres. Among these reinforcement materials the laminates are difficult to mould into complex shapes and fillers add the least amount of the strength in comparison to others. The most optimum reinforcement material is fibre and this is used in fabrication process which is discussed in further chapters. The classification of the fibres is discussed in the following paragraph.

Fibres are the reinforcement material used in the composites, these provide strength and rigidity to the composite. The fibres are usually of two type’s natural and synthetic, fibres that are derived from natural origin are called as natural fibres.

1.3.1 Natural Fibres

These are obtained from tress, agricultural and plant wastage, but in general the extraction process fallows with immersion of plant stem in water for a time period of 21 days then stripping the fibres from stem and drying them to remove water content, upon drying these are treated with various chemicals for required characteristics [1.5]. Natural fibres apart from stem can also be obtained from bast, leaf, seed, fruit, wood, grasses [1.14]. Natural fibres have considerable mechanical properties but they also are lighter than glass fibre reinforced composite materials. The properties of natural fibres can be increased by the application of treatments like acid and alkali treatments. Plant fibres are completely recyclable by combustion, as well as being completely bio disposable, because they have organic matter like lignocelluloses or lignin content in them, but the same cannot be supposed for the remaining synthetic fibres and chemical additives like acid treatments. In present days natural fibres are used in making the ropes, canvas, papers and in textile industries also, with these advancements the natural fibres, such as flax, sisal, or kenaf are used to reinforce plastic body panels for automotive applications.

1.3.2 Synthetic fibres

Synthetic fibres are the products which are created according to the requirement of the application. These fibres have their characteristic features varied across different like physical strength, chemical resistance, thermal and electrical conductivity. Glass fibres which are synthetically produced each are named after their respective properties. These names range come as E-Glass which refers to fibres with low electrical conductivity, S-Glass which refers to fibres with high strength, C-Glass which refers to fibres with high chemical resistance, M-Glass which refers to fibres with high elasticity, A-Glass which refers to fibres with high content of alkali metals, D-Glass which refers to fibres with low electric constant, AR-Glass which refers to fibres with high alkali resistance [1.11]. While considering the glass fibres based on their weight, most of them are spun from silicate glasses with at least 50% of silicon dioxide in the molar basis [1.10]. Fibreglass is made of natural minerals and some manufactured chemicals, the basic raw materials are silica sand, limestone and soda ash. Fibreglass reinforcements are classified according to their internal properties, based on those properties the classifications are as follows.

a) E-glass is the most common type of reinforcement used in the present world. The word 'E' implies that it is an electrically resistant. It is cheap and most appropriate for general purposes applications.

b) S-glass, S2-glass, the word 'S' refers to Strength, it is about 20% stronger than E-glass and has higher modulus of rigidity, improved mechanical strength and is considerably expensive than E-glass.
c) C-glass or T-glass is the fibre with corrosive resistance quality.
d) A-glass is a high-alkali glass and It also offers good chemical resistance.
e) D-glass is used in circuit boards.
f) AR-glass is resistant to alkali chemicals.

The added strength and the distinctive chemical properties of the synthetic fibres makes them a preferable choice for the most of the composites. Among the different kinds of synthetic fibres we have chosen E-glass fibre for the fabrication process, the physical properties, chemical properties and the types of arrangement of the fibre in the mould are discussed in detail in upcoming chapters of this work.

1.4 Resin Mixture

The reinforcement material used are bind together using an adhesive system called matrix which comprises of a mixture of resin and hardener. These resins are of two types Thermoset and Thermoplastic which are differentiated according to their behaviour when subjected to heat.

a) Thermoset Polymers:

These polymers cannot be remoulded into new shapes by applying heat and pressure. These polymers are permanently hardened by heating process. These polymers are very flexible over long periods, it has low molecular weight. Thermoset goods can survive higher temperatures without loss of their structural integrity. The thermoset resins require accelerators or catalysts to speed up their reaction and mix with the hardener for the production of resin matrix. The exothermic reaction when the catalyst is added to the resin is very high in thermoset resins. Examples of Thermoset polymer resins are Polyesters, Polyamides, vinyl esters, Phenolics, Epoxies and other resins.

b) Thermoplastic polymers:

These polymers can be remoulded into new shapes by applying heat and pressure. Thermoplastics can be reheated, re-formed, and cooled as necessary without causing any internal chemical changes. Thermoplastic materials have low melting points as a result of these physical and chemical properties while manufacturing the thermoplastic resins doesn’t need any external catalysts to speed up the reaction with the hardeners, because of the catalyst less reaction the heat form the exothermic process in thermoplastics is negligible. Best examples of Thermoplastic resins are Acrylics, Fluorocarbons (Teflon), Polyamides (Nylons, Kevlar), Polycarbonates (Lexan), Polyesters, Polyvinyl chloride (PVC) and Polyethylene.

1.4.1 Types of Resins

The resin system apart from acting as binding material in the composite also improves the strength of the composite by absorbing the impact received by the composite. Considering all the additional qualities other than binding the material only a few resin systems are considered, they are as follows.

a. Polyesters

The cheapest, simplest resin systems are unsaturated resins made of polyester which are easier to produce and give good output. Vast amounts of this commodity are used annually around the globe. Those are formed by the polymerization of condensation of different diols and dibasic acids to give esters, a very viscous material that is then dissolved in a reactive monomer called styrene. Styrene decreases viscosity to a reasonable laminating degree. Polyesters usually possess relatively limited thermal stability, chemical tolerance, and ease of use. Applications involve in industries for shipping, industrial, building, appliances etc.

b. Orthophthalic

It is also called as the original polyester as ortho, or General Purpose Polyester (GP), was made. It is the cheapest, typically applied in the FRP market. This is mostly used in applications at which great mechanical properties, corrosion resistance, and thermal stability are not needed. It is achieved in water and sea water to a sufficient degree.

c. Isophthalic

It is also called to as Iso and polyester enhanced. It is expensive and has good strength, thermal stability at temperatures 55 ^{0}C and low resistance to corrosion. The increased resistance to water adhesion has encouraged its use as a silicone barrier-coat in various marine applications. Increased resistance to the chemical reactions in the system has led to widespread use with strong service life in underground oil tanks.

d. Phenolic

Phenolic resin is an output of phenol and formaldehyde reaction. This is one of the earliest thermosetting resins that can be cured without any catalyst, these are also fire resistant with the addition of additives like minerals and these are also cheap when compared to other resins. These resins have limitations like high settling temperatures while settling and greater pressures, longer settling times than polyesters, and restricted colour selection. The application of phenolic resins in composites is increasing rapidly, largely because of regulatory restrictions on spreading fires, producing smoke, and toxicity of smoke. This is commonly implemented in applications at varying temperatures in vehicles, equipment, telecommunications and as an automotive adhesive.

e. Epoxy

Epoxy resins belong to a large group of substances. The most of these are prepared from the reaction of bis-phenol A and epichlorohydrin. Epoxy resin systems exhibit exceptionally high crosslink density in three dimensions resulting in the improved mechanical efficiency qualities than rest of the resins. This has outstanding strength and hardness, exceptionally strong chemical, temperature and tolerance to electricity. Disadvantages include high pricing and complexity of manufacturing. Epoxy solutions are used in industries such as aircraft, defence, automotive, sporting gear, adhesives, sealants, coatings, construction, flooring and many other uses.

f. Gel Coat

Gel coats are made of resin and additives from the base. Polyester, vinyl ester, phenolic, or epoxy may be the basis resin. Additives are thixotropic agents, fillers, and other pigments. As the name suggests, the gel coat has the texture of a gel. This makes the gel coat capable of remaining without draping on vertical mold surfaces. It is first placed in the mold, so it becomes the building's exterior surface. It is used for paint replacement, cosmetic purposes, and environmental protection.

Among all these types of resins discussed, we have used a combination of epoxy resin and an amine based hardener for the fabrication of the composite, their volumetric proportions in the mixture and the application process is discussed in detail in the later chapters.

1.5 Additives

The final component in the composite preparation process is filler material, these are added as per requirement. Filler materials are the chemical in the fine porous form for most of the composite applications they can be any chemicals like calcium carbonate, silica, graphite etc. Filler materials add qualities like electrical conductivity, thermal conductivity, fire resistance, improve strength, thickens the solution etc.

The different combinations, compositions and preparation methods of the above stated materials results in different types of composite materials each with their respective physical and chemical properties required of area of application. Here we intend to fabricate a composite with properties like heat resistance, better heat dispersion and high strength. To achieve these qualities we have used chemicals like alumina trihydrate, graphite, calcium carbonate and fumed silica. The different combinations and compositions of these chemicals as additives in the resin mixture is discussed in detail in the further chapters of this work.

1.6 Manufacturing Techniques Involved

There are different types of manufacturing techniques involved in manufacturing the composites. These techniques can be differentiated based on the type of reinforcement and matrix involved or the shape of final object intended to make. The different techniques are open moulding, closed moulding and polymer casting. These techniques further have their own sub classifications, all the classifications of the manufacturing techniques are discussed in detail in the following sections.

1.6.1 Open Moulding

The open the reinforcement and matrix material are left to cure themselves without any external forces involving mostly. The different types of open moulding techniques are as follows.

a) Hand Layup
b) Spray-up
c) Filament Winding

a. Hand Layup Technique

Hand layup is an open moulding process which is ideal for producing various types of composites from tiny scale to large scale products. The amount of output per mould is limited, but large production volumes may be created using several moulds. Hand layup is the easiest way of producing composites, providing relatively cheap hardware, easy handling and a wide range of component sizes. Alterations in design can be made instantly. The cost in machinery is small. High output levels and good efficiency can be achieved with the professional operators. Resin mix is initially applied to the mould using a pressure tool. Once the mix has hardened enough, reinforcement material is put on the mould by hand and pressurised with a roller. Then laminating resin is applied and this is done by pouring, brushing, spraying, or using a roller. For the settling of the laminate rollers are used to pressurise and wet the reinforcement also to remove trapped air. In order to increase laminate thickness consequent layers of fiberglass reinforcement were added.

b. Spray up Technique

This is a low cost moulding and has rough surface finish, because of this it is not best suitable where a good surface finish of the objects is required. In this the reinforcement material is chopped and mixed with resin, this mix is sprayed into the mould surface layer by layer. Then the mould is left to dry and because of the chopped reinforcement material used in the spray the resultant material does not have good quality finish. But this process is much quicker than hand layup and even cost efficient in many aspects of manufacturing.

C. Filament Winding

This process is being mainly used to produce medium to high volume of small and large diameter tubing and pressure tanks. This requires the winding of continuous, pre-saturated reinforcing filaments around a revolving spindle until the entire surface is filled at the desired level. The filaments become soaked only before they reach the spindle, as they pass into a resin trap. The winding can be done In multiple directions, depending on the size of the unit. Upon cure, the spindle has to be extracted at the final stage of development, typically with the help of a hydraulic extractor. The final goods are usually of very high quality, these products are of high resin content and lack longitudinal strength.

1.6.2 Closed Moulding Process

In this moulding process the resin matrix, reinforcement and rest of the raw materials will be cured inside a closed mould. Inside this mould there will be no air it will be completely vacuum region. The closed moulding processes are mostly automated and so they are not easily accessible. These setups are mainly situated in large industries for high amounts of production.

The different processes which operate with this technique are as follows.

a) Vacuum bag Moulding
b) Vacuum infusion Moulding
c) Resin Transfer Moulding
d) Compression Moulding
e) Pultrusion
f) Reinforced injection moulding
g) Centrifugal Casting
h) Continues Lamination

a. Vacuum Bag Moulding

This process has many similarities to hand layup method, but the only difference is the raw materials in the mould are sealed under a vacuum cover. The preparation comprises of adding initial resin coat, fibres and resin mixture into the mould. This mould will be covered with an airtight layer and all the air under this layer will be sucked out and thus creating a vacuum area. This leads to removal of any void spaces and excess resin in the system by creating a product with exact mould dimensions.

b. Vacuum Infusion Moulding

This process consist of three main stages, first an initial resin coat is applied on to the mould, second dry fibre is arranged on the initial coat and they are left to settle. Now the top region of the fibres is covered with an air tight cover that has one inlet and an out let. Through the inlet the resin mixture will be transferred into the system and air comes out of the outlet. This is continued till the resin fill the system without any air gaps. The finished products will have a fine surface finish.

c. Resin Transfer Moulding

This process is very much same as vacuum infusion moulding and major difference is the way mould is sealed. In the initial coat is applied and the fibres are arranged, then the mould will be sealed leaving just the space for required dimension of the material. Then the resin is forced into the cylinder with high pressure and the air inside the mould will be ejected out through the outlet ports. The sealed mould will not be opened till the curing time is completed.

d. Compression Moulding

In this process the mould is set up on hydraulic press with inner cavity and outer cavity on opposite sides of the press. Initially the mould will be heated for short period of time after that the first coat of resin is applied and dry fibre is arranged layer by layer consecutively with the resin mixture. This whole setup will be compressed under the hydraulic pressure forcing the air to leave from air outlets. This pressure forces the raw materials inside to compress uniformly along the mould region.

e. Pultrusion

This is a fully automated process, where the fibres are soaked with resin and later compressed step by step. The first step comprises of fibres taken out from the rollers, these fibres are passed through the resin mixture and thus soaking them in the resin. These fibres are then pulled into the die section with great force and heated to cure the resin rapidly. This die section as compressed using the rollers while the time it is being heated, this is a continues process of manufacturing.

f. Resin Injection Moulding

This is majorly involved automotive industry for the manufacturing of parts. In resin injection moulding multiple resins are heated separately and combined with reinforcement material. This mixing happens in high pressure chambers where each of different resins enter from different sides. Though the mixture is processed at high pressure state the end result will be viscous fluid which is easily injected into the mould with high pressure.

g. Centrifugal Casting

Centrifugal casting is mainly used to manufacture hallow pipes. In this method the resin and the fibre are added the mould simultaneously through separate outlets. The mould here will be rotating constantly and this pushes the resin and fibre to the walls of the mould. The rotation effect also helps to mix the resin and fibre together while occupying the mould region without any air gaps. After the curing period the outside part of the composite have good surface finish rather than the inner part.

h. Continues Lamination

Continue lamination process is used to produce flat composite sheets which are used as side walls. The process continues lamination is mainly automated, the fibres are used as reinforcement materials in this process. The fibre and the resin mixture added into one another on a plastic sheet and these raw materials are covered with another layer of plastic sheet. Now this sandwich structure is passed through the rollers for compression and the final output we receive is a flat sheet of composite which can chopped down to required length and width.

1.6.3 Cast polymer Moulding

Cast polymer moulding is process where the resin matrix and fillers are mixed together without any reinforcements and poured into the moulds. This mix is usually left to air for hardening. This process of making campsites without reinforcement leads to produce the output without material with predetermined qualities. This technique involves two moulding processes they are as follows.

a) Gel Coated Cultured Stone Moulding
b) Solid Surface Moulding

a. Gel Coated Cultured Stone Moulding

Gel coat is a special polyester resin mostly used for outer surface treatment, this is a mixture of base resin and additives. This done to protect the object from outer wear and exposure. The most common additives used are marble, onyx and granite stones. The processing for this technique happens in a way that first the resin is sprayed and let settle, after that fillers are added upon the resin. This way layers are laid and left to dry.

b. Solid Surface Moulding

The solid surface moulding deals with resin matrix and additives mixture without any reinforcement. This mix rather than poured onto the mould, where the mould is created in such a way that it is protruded outwards. After pouring the resin filler mix the mould will be compressed using hydraulic press thus eliminating the air spaces. This method is mostly implanted in producing kitchen items and the individual items produced can also be joined together.

Chapter-2

2.1 Literature review

A A R Amer et al [1] In this the study was aimed at the reinforcement of concrete using the glass fibre. The fibres of glass used here ranged from A, E, R are named for some each with different chemical and mechanical properties. Each showed different characteristic properties at different conditions, but on a whole note the main advantages are fire resistance, tension, integral mechanical properties in spite of humid conditions.

TP Sathishkumar et al [2] In this study the glass fibre composites made out of different combinations of glass fibre strands. One type was using glass strand and other using the mat type material. The different specimens were prepared using different type of preparation methods like hand layup, compression moulding, dry hand layup and h-type press. These different samples were tested for mechanical, tribological, thermal and water absorption. Thus finally flexural strength and ultimate tensile strength of the glass fibre polyester composite has raised with increase in the fibre glass by fibre weight fraction.

Alexandre Landesmann et al [3] In this the experimental procedure was aimed at finding the mechanical properties of Glass Fibre Reinforced Polymer (GFRP) element produced by a manufacturing industry to specify its structural applications. For this the specimens were made of GFRP these were moulded to the shape of H flange and different types of testing comprising of direct tension and compression, two-point flexural bending, pin-bearing pushed-out and interlaminar shear deformation are performed. The findings showed that there is a significant variance in the nonlinear behaviour of the stress-strain curves at the highest load, with respect to the direct tension and compression measurements and their interrelated sections. The resultant fibre contents show a significant and obvious effect on the mechanical behaviour and the final strengths of the samples are found to increase with the fibre content rise.

Venkatachalam N et al [4] In this study the scope of using natural fibres is discussed but due to their in activity in adhesive properties led them to reduced strength and modulus, increasing the volume fraction of the fibre. This inefficiency can be overthrown by pre-treatment process of mechanical and physical nature. Mechanical pre-treatment like heating and beating, chemical pre-treatments like alkalization, silane, acetylation and benzoylation. These results were then analysed.

Meng Zhang et al [5] In this the implementation was about replacing the metallic objects with fibre reinforced composites in the field of dentistry. This was done by using the fibre composites of e glass material composites because of their non-toxic nature. These are still at use of temporary state, given proper time for research these fall into the category of important biomaterials.

Mustafa Abu Ghalia et al [6] The work has been done to evaluate the compressive and fracture durability of natural and artificial synthetic fibre-reinforced polymer, and the performance has been confirmed that the hybrid composites are inexpensive, recyclable and biodegradable and can reduce the use of synthetic fibres in certain different applications. The fundamental structure of cellulosic fibres and their effect on the thermal, mechanical, electrical, and physical properties of hybrid composites must be understood. The effect of the hardness of fractures and the compressive reaction of natural and synthetic fibre-reinforced polymers was studied and relationship was developed.

Md S. Islam et al [7] In this paper the experimentation was done to introduce hybrid textile composites in the field of cryogenic application. The fibre for this process was prepared using Vacuum Assisted Resin Transfer Molding (VARTM) process. Samples cut off from source plates were then subjected to adverse temperatures followed by short beam shear (SBS), at room temperature tests to assess inter-laminar shear stresses (ILSS). The fabric used was Kevlar material. The manufactured material was first introduced to cryogenic temperatures and then carried for testing the strength, shear, elongation capabilities. The results obtained show least reduction of 16.8% in Kevlar material.

Frank R. Jones et al [8] In this the study was done to establish the structure and properties of the glass fibres. The glass fibres used were mostly of silicate based with at least 50% SiO_2. These fibre glasses are used for insulation, reinforcement and optical purposes. The properties of thermal, strength, fracture of composites based on different combinations of glass material are considered and named fibres such as A, E, R, S. Depending upon usage recyclability of these are discussed.

Elizaveta Martynova et al [9] In this presentation of the glass fibre the various factors of different fibre combinations were discussed. The fibre was divided among the range with properties ranging from resistance to alkaline, rust free, high strength and so on. These different fibres are named as E, S, AR, ECR, D and quartz. These are further classified into their respective raw material combinations, Fibre forming process, application areas and quality control.

Mohan Kumar S et al [10] In this the work was done to fabricate a composite material put of E-glass fibre and Polyester resin. This manufacturing was achieved with a settling time of 24 hours using the hand layup process. The final manufactured specimen was submitted to tensile test, hardness test, impact test and flexural tension test. Compared to the performance produced, the results of the testing showed that 70% of the volume fraction of the reinforcement yielded greater tensile properties, stiffness efficiency and flexural strength compared to others.

Rasheed Atif et al [11] In this study the properties of the epoxy composites is discussed when additive materials are added to it. If a monolithic epoxy is considered, it is vulnerable to fracture because of its brittleness. This can avoided by using the reinforcement of Nano fillers. One these fillers is graphene, to find the effectiveness of graphene a composite material is fabricated using epoxy as matrix. Then subjected to numerous tests which gave results as graphene can significantly enhance the fracture toughness of epoxy composites, graphene sheets with smaller dimensions are more efficient in betterment of fracture toughness than those with higher dimensional sizes, high crosslink density is favoured for advanced mechanical properties in thermosetting materials such as epoxy.

Sanjay M R et al [12] In this study the natural glass fibres were used to prepare the composite and analyse its properties. Natural fibres have higher properties such as high physical strength, lower weight, low density, relatively strong mechanical properties, non-abrasive, environmentally friendly and biodegradable properties. Natural fibres are usually extracted from leaf, bast, seed, fruit, wood, grasses and so on. Every fibre has unique characteristics that make it ideal for different application areas. The increase of environmental issues in the world's main industrial industries contributes to the use of natural fibres in polymer matrix reinforcements. A hybrid composite is a mixture of two or more distinct fibre types in which one fibre type addresses another fibre’s deficit. The hybridization of natural fibre composite with another natural fibre does not provide greater mechanical properties such as glass fibre hybridization and this form of hybrid composite is thus ideal for low-cost applications and is popular in engineering markets such as the automotive and construction industries.

D.R.Moore et al [13] The work was done to develop a method to cure the composites at lower temperatures than usual. This was achieved by using a special catalyst and a proper co-polymer. The process usually deals with the initial cure for 14hr at 85^0C and a further 2hr at 175^0C. The testing was done with different combinations of catalyst and comparing it with the high temperature curing process. In the final comparison a large composite spar structure has been prepared with the low temperature curing resin system. This resulted in spring back in the wall of spar which is related to lower residual stress. This is inferred by demonstrating that low temperature healing in an autoclave accompanied by a consequent quick healing at high temperatures will increase cost-effective processing.

Qing-Song Ma et al [14] The work was done to use silicone resin as a binder in fabrication of the composites. In this process silica powders with various mass ratios of acetone solvent are used, this was later heated to a temperatures ranging from 250 ^{0}C to 1000 ^{0}C. During the heat treatment process, silicone resin underwent organic – inorganic transformation and acted as the bonding agent between silica particles at a low temperature of 1000 ^{0}C. This resulting in increasing the flexural strength of binder with increase in mean size of silicone powders.

Ching-Chun Tseng et al [15] In this study a catalyst was developed to react with the bisphenol A as thermal latent catalyst. To achieve this the chemical chosen was a series of soluble PEG600 imidazole derivate. For this the chemical catalysts chosen were, PEG600-Imidazole, PEG600-4-methylimidazole, PEG600-1-(2-hydroxyethyl) imidazole, PEG600-5-(hydroxymethyl)-imidazole. The sample preparations were stated from ranging of 3% and above with 2hr time of titrations and that was used as catalyst. The final result was showing that novel PEG600-imidazole catalyst provided complete or near complete curing systems in the temperature range about 150–159 °C.

J.-C. Munoz et al [16] In this study the reactions of epoxy and phenoxy resins, to that of the reaction to catalyst and post curing conditions. The catalyst used was phencat 382 and urea hydrochloric acid in the ratios of 1:1. To compare this catalyst another catalyst used is epoxidized oil seeds with 58% of mixture. The post curing time for both the conditions was 4hr and results obtained showed that the Phencat 382 was the best catalyst. It was also found that ELO which can be used as plasticiser in the mixtures of epoxy and phenolic resins, improves the flexural resistance and other mechanical properties of pure simple resins.

Dipen KumarRajak et al [17] The study was done to review about the advancement of the reinforcement materials as the composites. This comprised of the classification of the composites on the basis of matrix material like polymer, ceramic and metal matrices. These were further classified based on the reinforcement material nature like fibre, particulate and sheet. The reinforcement material each used had different chemical and physical characteristics which gave each of the composite a different nature of its own in various combinations.

JIE CHEN et al [18] In this the composite was created using graphite and epoxy/phenoxy resins. The Diglycidylether of bisphenol A was used as the epoxy resin matrix in this study. The thermally latent activator *N*-benzylpyrazinium hexafluoroantimonate was used, the graphite used was 90% of the content. The composite was prepared by melt blending and compressive cooling and there by the mechanical properties were analysed by determining their elastic modulus and flexural strength. The composite with 55wt% graphite showed the maximum flexural modulus and flexural strength of the composites.

G. Devendhar Rao et al [19] The work was done to fabricate a composite with E-glass fibre and filler materials as SnO_2 and Poly Tetra Fluro Ethylene. The epoxy resin used is diglycidly ether of bi-phenol –A (DGEBA) based with a hardener tri-ethylene tetra amine (TETA) mixed in a ratio of 10:1. In the form of filler materials the chopped e glass fibres, SnO_2 and Poly Tetra Fluro Ethylene are used. The samples of two different kinds are prepared one which is doped with SnO_2 and other which is without SnO_2. Both the samples were tested for fracture tensile test and flexural test. It was found that the mechanical properties such as modulus elasticity i.e. 22 GPa to 25 GPa and flexural strength i.e. 18 GPa to 22 GPa was strengthened in E glass long fibre with SnO2 nano powder.

Bejoy Francis et al [20] in this paper the properties of diglycidyl ether of bisphenol-A epoxy resin improved with poly (ether sulfone ether ketone) and poly (ether sulfone) polymers were investigated. The poly ether sulfone ether ketone was processed using 4, 4'-difluorobenzophenone with dihydroxydiphenylsulfone as a solvent at 230 ° C using potassium carbonate as a catalyst. The blend was prepared by meting and mixing at an initial temperature of 180 ^{0}C for 3hr and later post cured at 200 ^{0}C for 2hr, after this the blend was cooled down to room temperature. Then the analysis for various properties was carried out. The tests of the study revealed that epoxy resin crack durability improved with 'poly-ether-sulfone-ether-ketone' and 'poly-ether-sulfone' when combined. The increased resilience of the fracture was attributed to the improvement in matrix ductility. The blend’s thermal stability was similar to that of the pure epoxy compound.

Haiming Chen et al [21] The work here was done to cure the diglycidyl ether of bisphenol-A using poly amide amidic acid and 4, 4_-diaminodiphenylsulfone. The samples were made using mixtures of stoichiometric amounts of the epoxy and the chemicals. Epoxy group and active-hydrogen molar ratios were 1:1:0, 1:0.75:0.25, 1:0.5:0.5, 1:0.25:0.75, and 1:0:1. After the mixture the epoxy was cure with the different combinations of poly amide amidic acid and 4, 4_-diaminodiphenylsulfone. The results obtained after the analysis were the processing temperature decreased when treated with amidic acid polyamide co-curing agents and 4, 4_-diaminodiphenylsulfone, compared with the samples processed with poly amide amidic acid and 4, 4_-diaminodiphenylsulfone individually. This is because the poly amide amidic acid in the

Co-curing agent can catalyse the reaction of poly amide amidic acid and 4, 4_-diaminodiphenylsulfone.

Md. Naimul Islam et al [22] The work here was done to fabricate the E-glass fibre reinforcement material based on the polyester resin. The resin used was Unsaturated polyester resin since resin was polyester the reaction times were slow. So the catalyst Methyl Ethyl Ketone Perroxide is used to accelerate the reaction. The fibre content was varied from 5% to 50% and the composite was fabricated. Then the specimen was subjected to analysis of the strength and bending, the results obtained showed that the increase in the fibre content has increased the tensile strength of the specimen with 50% of fibre having 72MPa.

Francois-Xavier Perrin et al [23] The work here was done to do fabricate a composite based on epoxy-amine resin with bisphenol a as an external catalyst. The specimen was prepared using epoxy resin and amine hardener, the catalyst used to accelerate the process was bisphenol a. This specimen was digitally analysed for thermal and physical changes in the structure. The study found that the thermodynamic data relating to the complex of epoxy-BPA was marginally less than anticipated. This can be concluded from BPA 's interaction with hydrogen-bonded acceptors other than epoxy (ether and amine) groups. This research indicates that the mechanical solution will provide useful knowledge on the epoxy-amine treatment of complex commercial structures.

Carola Esposito Corcione et al [24] The work was done to analyse the cold curing epoxy resins with respect to a relation of curing time and thickness. The epoxy resin used for this testing was a diglycidylether of bisphenol-A which was mixed with the hardener in the ratios of 4:1. The healing reaction of the cold-healed epoxy resin was measured at various healing times and thicknesses, each sample was heated to a temperatures of up to 250 ^{0}C. For the specimen subject to various conditions, a full calorimetric analysis was carried out, which revealed that a duration of roughly weekdays is adequate to complete much of the healing reaction at room temperature.

John D. McCoy et al [25] The work was done to find the curing mechanisms of diglycidyl ether of bisphenol A epoxy with diethanolamine. To find out curing reactions the specimen was prepared using the epoxy diglycidyl ether of bisphenol A and the hardener diethanolamine both of these are mixed in a stoichiometric mixture of 1:0.187 parts by weight. The resin and the hardener were heated to 70 ^{0}C for an hour before mixing, after the specimen preparation it was digitally analysed for the reactions in physical, thermal and chemical natures. The study found that a non-monotonic dependency of the average glass transmitting temperature attainable on healing temperature and amine concentration, a minimum gel time value at high healing temperature, complex reaction kinetics and a high stability rate. Those were the representations that were achieved through the research.

Istebreq A. Saeedi et al [26] The work is done to find the behaviour of amine- and anhydride-cured epoxy systems using multi terminal epoxy functional network modifier. The epoxy chosen for this process is diglycidyl ether of bisphenol-A based epoxy and the samples were prepared from using the amine or anhydride hardener. The samples prepared using above chemicals were tested on FTIR spectroscopy, Differential Scanning Calorimetry, Dielectric Spectroscopy and Electrical Conductivity the results then obtained showed that the progressive decrease in the glass transition temperature of the modified samples has been observed with raising TTE, this is described in terms of improvements in resin network architecture.

Guijun Yang et al [27] The work was done to examining the influence of calcium carbonate on the epoxy based composites. In this the epoxy used was bisphenol A diglycidyl ether and the hardener used is 4,4’-diaminodiphenylmethane. The sample was prepared by dispersing calcium carbonate in acetic acid of 100ml and agitating at 60 ^{0}C for 2hr. This calcium carbonate was added to the resin mixture at 60 ^{0}C and later cured at different temperatures ranging up to 170 ^{0}C. The specimen thus obtained was tested for toughness and thermal stability. The study indicates that the rigidity behaviour and thermal stability of calcium carbonate epoxy composites is comparatively higher than that of discrete epoxy resin.

ALLAN E et al [28] The work was done to find the effects of base catalysts to process epoxy resins. The catalysts used were tetramethylguanidine and heptamethylisobiguanide, both the components are liquids of very high strength and solvents for variety of materials. Upon the analysis with these chemicals as catalysts and curing agents it was found that these are most likely catalysts rather than curing agents for the epoxy polymerizations. When used in low concentrations reagents were successful. It is claimed that the reactivity of these chemicals is accessible to tertiary amine nitrogen atoms, strong base strength and good solvent capacity.

T. Ueki et al [29] The work here is done to design an epoxy resin system for the use at cryogenic temperatures. The epoxies considered for this are di-epoxy compounds, these were mixed with the hardeners like anhydride MNA, aromatic amine DETDA, amine DICY using these 3 samples were prepared. Thus prepared samples tested for mechanical properties by varying surrounding temperatures, taking them till cryogenic range. The data obtained showed that, since they displayed high fracture durability even at negative temperatures, it was found that the two-dimensional network organized epoxies (phenoxy) were stronger. The phenoxy may also be used as an epoxy additive, and could be used at negative temperatures.

Tong Wu et al [30] The work was done to find the mechanical properties of the epoxy resin strengthened by hydroxyl-terminated polyurethane at cryogenic temperatures. The epoxy resin used in this work is diglycidyl ether of bisphenol A, it is modified by using two kinds of hydroxyl-terminated polyurethanes for different samples. The mixtures were taken in the ratios of 1:4 compositions, upon specimen preparation it tested using impact testing machine and analysis is done for mechanical properties and phase separation, the outcomes of the impact and tensile tests indicate that the addition of hydroxyl-terminated polyurethane with sufficient content into the epoxy matrix could effectively boost mechanical properties.

Cheng-Fu Yang et al [31] The work here is done to enhance the compatibility of poly and phenoxy resins in blends. Samples of phenoxy mixtures were prepared using methylene chloride as a solvent by treatment. Polymer solutions were thoroughly agitated and then placed as layers on substrates at 40 ^{0}C, these additional heat annealed. The thermal behaviour of the blends were measured using differential scanning calorimeter , the phenoxy blends relationship parameter was calculated using the melting point depression test and was -0.336. After annealing, chemical exchange reactions between PBA and phenoxy can enhance the feasibility of phenoxy blends. The crystallinity of PBA decreased with an improved degree of trans-reaction in the blends.

Wan-PingYen et al [32] The study was done to find the potential of soluble PEG-imidazole as the thermal latency catalyst for epoxy/phenoxy resins. The resin considered for this study is diglycidyl ether of bisphenol A, its two phase system and the catalyst of different combinations of PEG-imidazole were added to the systems the soluble PEG-imidazole to analyse their thermal latency and storage stability, homogeneous catalysts were used to cure the epoxy resin system. The final results after comparison showed that the PEG 200-imidazole catalyst has better latency than other catalyst combinations.

P. Coronado et al [33] The work here to done analyse carbon fibre epoxy subjected to mode-I delamination. The specimen chosen is carbon fibre composite with symmetrical laminate configuration. This specimen was carried in to a MTS testing machine with 1KN load cell, the testing was carried over a range of temperatures beginning from 90^0C to low as 60^0C. The analysis indicated that the material displayed improved mechanical properties in the tests conducted at 90 ^{0}C during the static initiation process, when fatigue delamination was initiated, it was observed that the overall delamination energy required to activate the crack increased with increased test temperature.

J.M.Q. Oliveira et al [34] The work here is carried out to find the effect of mixed mode bending test on wood through numerical analysis. The wood considered here is clear wood from maritime pine, on this mixed mode bending test is performed and analysed through cohesive damage model, model description and mixed mode ratio. The experimental findings revealed that the distribution of strain energy release rate components along the propagation of crack is nearly uniform, with the exception of placed peaks at the edge of the samples. Simulations of crack development however revealed that the crack propagation is linear and no variation was observed between the crack length at the edges and the middle of the sample.

Xin Zhang et al [35] The work here is done to find the fracture strength of the ceramic composites at high temperatures. In this work the ceramics considered were of different compositions of zinc and silica, the usual temperatures for crack propagation in ceramics is from 1400^0C to 1600^0C in the medium of air, but the ceramics chosen are tested for very high temperatures. The study reveals that the quantitative influence of the crack size on the strength of the fracture is evaluated at different ambient temperatures and it is concluded that the reduction in the crack size is very significant in increasing the performance of the composites at low temperatures.

Mahmoud S. Soliman et al [36] The work here is done to find the fracture of rolled Al-15 vol% B4C composite on high temperature application. The composite used for this process is 14 wt% (15 vol%) B4C, 0.48 wt% Ti and 0.25 wt% Zr, the product was homogenized for 16 h at 540^0C before being hot rolled at 500 ^{0}C. Then the product is carried for tensile testing at temperatures ranging from 300 ^{0}C to 500 ^{0}C and analysed for various chemical and physical properties, the analysis showed the presence of threshold stress that its value raises with decline in the testing temperature, elongation showed a maximum value at 500 ^{0}C.

Guozheng Chen et al [37] The work here is done to analyse the fatigue fracture of the aluminium matrix composites. The composite used for this process is the mix of Al-12Si-Cu-Ni alloy and the composite, the alloy was preheated to 750^0C and then poured into a piston die at 350^0C with a pressure of 8MPa. The specimen formed is a bond of aluminium alloy and a composite of its matrix, which was processed for fatigue fracture testing under various mechanisms. The results showed that the properties of fatigue fracture change from brittle to ductile with the temperature increase from 25 ^{0}C to 350 ^{0}C. 3 Standard fracture models are defined by the properties of fatigue fracture surfaces where the amplitudes of the cyclic strain are less than 0.3%. It showed the essence of the alloy bond fatigue.

James R. Reeder et al [38] The work here is carried out to summarise the testing methods available for the analysis of fracture and the strength the composite materials. The testing procedures talked about here are multi-mode bending test, double cantilever bending test, end notch flexural test these test each signify different properties such as the multi-mode bending test has been presented for a split unidirectional laminate, double cantilever bending test and end notch flexural test together are called as multi-mode bending test. These tests all together determine the flexural rigidity and tensile strength of the composite.

O. Adekomaya et al [39] The work here is done to find the effect of fibre orientation and fibre loading on the impact and tensile strength. Composite chosen for this work is made of E-glass fibre and epoxy resin, the resin and the hardener were mixed in a ratio of 100:33 and application was done through hand layup method. The glass fibres were oriented at different angles of 30^0 and 60^0 each were considered as different samples and the testing for tensile and impact were performed. The results showed that glass fibre-reinforced epoxy composites could be manufactured by hand lay-up technique with varying degrees of fibre loading and fibre orientation, while composite specimens displayed an increased strength relative to other composite materials independent of fibre loading or fibre orientation.

Danish Ahmad Reshi et al [40] The work her is done to analyse the mechanical properties of the e glass fibre composite with epoxy resin matrix system. The specimen prepared is of the composition made of fibre and resin with 50% of each, where the resin and the hardener were at a ratio of 1:0.5, process involved was hand lay-up method. The specimen thus obtained was carried out for tensile test, bending test, impact test and compression test, the results obtained showed that the material had tensile 28.223 N/mm^2 , compressive strength 46.221 N/mm^2 and flexural strength 28.12 MPa.

L.E.Asp et al [41] The work here is done to find the effects of moisture and temperature on the interlaminar delamination of the composite. The composite chosen here is carbon epoxy composite its code is HTA/6376C, this composite is subjected through delamination of mode-I, mode-II and mixed mode bending test. The test specimens which are dry are taken as one set and that are moist as another set, these test are conducted at a range of temperatures from -50 ^{0}C to 100 ^{0}C. The result analysis of these tests shows that the critical strain energy release rate reduces with moisture content and increases in temperature in pure mode II. However, the effect of moisture on the rate of release of strain energy at -50 ^{0}C in pure mode II is not definitive. The critical strain energy release rate decreases with humidity content even in mixed mode. No dependency is found on temperature. The rate of release of strain energy in pure mode I is not influenced by changes in moisture content but increases slightly at high temperatures.

L.A. Carlsson et al [41] The work here is done to design the end notch flexural test for mode II testing. In this a specimen is considered and the analysis is done determine how well the flexural rigidity of the specimen holds, based on these analysis values the design proceeds further to improve the qualities. The work done in this paper shows that the deformation of the interlaminar shear may influence the calculation of the toughness of the interlaminar Mode II fracture. But, when using beams of a high thickness to crack length ratio, the effect can be minimised. In the other hand, the structural review proposed in order to scale the ENF specimen shows that a minimum thickness must be used to preserve linear behaviour.

Georgia Charalambous et al [43] The work here is done to analyse the effect of temperature on the mixed mode testing of the carbon epoxy composite. The specimen used this process is carbon epoxy named IM7/8552, this specimen is processed through quasi static test for fatigue and fracture analysis and these tests are performed at different range of temperatures varying from -50 ^{0}C, 20 ^{0}C, 50 ^{0}C, 80 ^{0}C. The results of these experiments are analysed revealing a substantial improvement in the hardness of the interlaminar fracture at 80 ^{0}C in the range of 38% with respect to the conditions of room temperature. At the other hand, sensitivity to a temperature range of -50 ^{0}C to 50 ^{0}C did not produce any statistically important difference in the material's fracture toughness. The improved interlaminar crack resilience at 80 ^{0}C is largely due to the matrix’s increased ductility at high temperatures. Simultaneously under the loading of fatigue, delamination rose gradually with temperature increases. The delamination crack will advance two magnitude orders at 80 ^{0}C faster than at room temperature for a set normalized energy release value.

James Thomason et al [44] The study done her deals with the generation of the fibre composites from the waste materials and regarding their strength. The production of the glass fibres from the manufacturing waste and potentially worn out composites are very cost efficient and environmental friendly. There are various process in involved in such production but all lack in the strength of the fibre, this loss in strength varies from fibre to fibre like E glass 40-65% loss, Basalt 80-97% loss, Alkaline 70% loss. Thus the study depicts the loss in strength of the glass fibre from recycled or wastage products.

J. H. HWANG et al [45] The work done here is to find the effect of directional crack propagation on composites regarding the interlaminar toughness. The composite taken for this work is carbon epoxy composite, this composite is subjected to width tapered double cantilever beam test and end notch flexural test. The samples are prepared with different interlaminar orientations with respective angles of 0^0, 45^0, 90^0. The crack propagation directions upon the force application are analysed the crack directions considered are 0^0, 15^0, 30^0, 45^0 twelve different samples were investigated for this purpose. The conclusion of study reveals that the implementation approach measured critical strain energy release rate is found to be higher than the outcome deduced from beam theory. The prominent discrepancy is due to fibre bridging for the mode I study by aggregation and crack edge splitting and fiber bridging by mode I impact for mode II fracture.

Kwang-HeeIm et al [46] The work done here is to study the affect of temperature damage on the composites fibre polymers. The composite used her is carbon fibre laminates combined with epoxy resin, specimens prepared were of two different resins each. These specimens are tested for impact and bending at different temperatures ranging from 25 ^{0}C to 300 ^{0}C these results were analysed on damage analysis software's. The findings obtained from the analysis demonstrate that as laminates temperature increases the impact-induced damage region of the delamination reduces. In the event of increased temperatures a linear relationship was found between the intensity of impact and the delamination areas.

R. Rikards et al [47] The work here is done to find the interlaminar fracture toughness of the glass fibre reinforced composites. The glass fibre used prepare the composite is of e-glass, it will be subjected to mode I and mode II testing. Tests performed will be double cantilever beam test, end notch flexural test, mixed mode bending test results obtained from these tests will be analysed through various analytical methods. These tests show that the development of the interlaminar fracture hardness for both composites in mode I delamination crack is almost of the same magnitude due to substantial fibre bridging in the case of composite. The mode I crack critical energy release thresholds for both composites are approximately the same.

YongjingWang et al [48] The work here is done to determine the healing ability of the self-healing composites at low temperatures. The self-healing composites are basically are of capsule type layers, when a crack originates these capsules break and fill the gap generated, but these occur efficiently at normal temperatures. If the crack propagation happens due to low temperature like at -60 ^{0}C for such conditions the work was carried out. This analysis was carried to through digital processing which gave the results to efficient healing at low temperatures this happened by adding vessels and an extra conductive layer into a composite material. Healing agents are continuously applied to the vessels and released after they have harmed the host. The conductive layer increased the temperature of the composites by means of electrical heating to help the healing agents circulate and cure.

Yasuhide Shindo et al [49] The work here is done to analyse the mode I fatigue delamination in the composite materials at low temperature. The composite used in this process is made up of plain weave fabric of E-glass and the epoxy resin used is a bisphenol-A, the specimen samples were cut out of the composite and were subjected to double cantilever test with an axial loading of 30 KN. The tests were performed at different range of temperatures from -196 ^{0}C to -269 ^{0}C. The results were analysed by analysing the finite elements, showing that the growth rates of the composite woven laminates at low temperatures were much less than at room temperature. The dominant growth mechanisms for delamination by fatigue were different at room temperature and low temperatures. The key mechanisms of fracturing were fibre – matrix de-bonding at room temperature. Nevertheless, at low temperatures, the dominant fatigue-delamination growth mechanisms were both fibre-de-bonding matrix and fragile matrix fracture.

Hiroshi Yoshihara et al [50] The work here is done to find the fracture toughness of wood by end notch flexural test. The material considered for this process has a density of 0.48gm/cm^3 and these were conditioned at 20^{0}C and 65% relative humidity, material is cut into a beam of 20mmX20mmX500mm. The testing was carried out by fixing the ends and placing the load in the centre, the analysis of the test result reveals that the durability of the fracture at the start of the crack progression improved as the initial length increased. So, the dependency of the fracture toughness on the initial crack duration should be considered.

T. D. Hapuarachchi [51] The work here is done to use aluminium trihydroxide as additive material into the composite. The chemical acts as a flame retardant on exposure to extreme heat conditions. To find out this effect different samples of the specimen are created with weight% of aluminium trihydroxide ranging from 30% to 50% and these samples are subjected to high temperatures like 200-600 ^{0}C. The analysis after the testing shows 50wt% sample has the high time to ignition of 24sec, specific extinction area with peak of 680sec. This shows the addition of aluminium trihydroxide will improve delay of ignition time and peak temperature.

J. Tarrio-Saavedra et al [52] The work here is done to add fumed silica as an additive to the resin mixture and analyse the composite formed under various temperature conditions. The samples were prepared with different wt% of fumed silica ranging from 5wt% to 60wt%. These samples are tested for various physical properties under the temperature ranging up to 600 ^{0}C. The result analysed showed that the sample with 30wt% of silica has given the best results of all the specimens.

M. Y. A. Fuad et al [53] The work here is done to use calcium carbonate as an additive to improve the impact strength of the composites. To analyse this various specimen samples of the composite are prepared with the calcium carbonate weight% ranging from 1wt% to 20wt%. The specimens thus prepared were tested for impact strength and other physical properties at different temperatures using DSC method of analysis. The results obtained showed that the samples with the chemical content ranging from 5wt% to 10wt% had better impact strength resistance.

T. Zhou, X. Wang et al [54] The work here is done to the carbon based nano fillers, graphite nano plates. These graphite additives were compared to the silicon carbide micro particles. The samples of the composite materials were manufactured using epoxy resin as matrix and the additive materials of the carbon and graphite with each respective wt% up to 90wt%. These prepared samples were analysed for electrical, thermal conductivity and impact strength at various temperatures. The final analysis show that by adding 12 wt% graphite or 71.7 wt% silicon to epoxy, the thermal conductivity was at its maximum that were respectively 6.3 and 20.7 times in the respect of epoxy.

A. Rucigaj et al [55] The work her is done to study the curing of bisphenol A-aniline based benzoxazine using different catalysts. The catalysts which were employed this this work were 4,4''-thiodiphenol, *o*-dianisidine, 2-mercaptobenzimidazole and 4-mercaptophenol. The curing action of these catalysts were obtained by the analysis through differential scanning calorimeter, these analysis was done see the catalytic ring opening of the benzoxazine. The results of application of catalysts showed that there was significant reduction of onset temperature and among the used catalysts, thiodiphenol showed the best curing efficiency.

2.2 Research Objective

In the above mentioned work of different authors there were various topics covered in the field of composites these can be summarised as following, "The composites are used in the field of construction to reinforce the concrete. The different forms of fibre arrangement resulted in increase of the material strength of the composite, this different forms of arrangement is using fibres strands and fibre mat. The composite are even considered as the replacement materials in the in the field of dentistry. The composite material made out of the natural fibres are the great examples of the biodegradable material. The different adhesive components like epoxy and polyester show different kinds of reactions while curing, even the catalysts used with these resins had prominent effect on the final composite manufactured. The different additive chemical used individually added their distinctive character to the composite".

All the work mentioned above was carried out each at an individual level, nothing was tried with a combination different arrangements. Since each individual work had a promising out put the objective of this research it take input from the each work and combine it to form a new composite material. The literature review of the work carried by different authors represented that the fibre mat provide more strength than fibre strand, epoxy resin doesn't need any accelerator with the hardener, rubber moulds allow better compression, graphite adds heat dispersion quality, silica raises the resin viscosity, alumina trihydrate adds fire retardant quality, calcium carbonate adds strength to the composite. But all these results are showed in different individual samples, so following research work is intendant to obtain all the above stated qualities into a single material. This is done by trying different compositions of more than one additive into the resin mixture and this process is continued till an optimum result of the material is achieved. This research even focuses on the simplest way to fabricate the composite, where the fabrication process does not involve any automated support at any point of the composite manufacture while making.

Chapter-3

3. Materials Involved in Fabrication

As discussed in the earlier chapters the intension here is to fabricate a composite with the qualities of heat dispersion, heat resistance and high strength. To achieve these qualities different material combinations are used for the fabrication process. These materials include fibre, resin matrix and additional additives, the following paragraphs elaborates the physical and chemical characteristics of the each individual item used in this particular fabrication of the composite material.

3.1 Fibre

The fibre used in this study is E-glass fibre, word 'E' stands for electrical resistivity and these fibres are widely used as insulation materials in electrical applications. Along with electric resistance this material also has properties such as resistance to heat and temperature, resistance to chemicals, resistance to moisture when compared to other fibres and maintains its strength over varied conditions. There are two broad classifications of the E-glass fibres based on the boron content, usually the temperature for obtaining the E-glass fibre with boron content is 1140 ^{0}C to 1185 ^{0}C and the melting point is ranged between 1050 ^{0}C to 1064 ^{0}C and the softening temperature is about 840 ^{0}C, whereas the softening temperatures of the E-glass free of boron content is 916 ^{0}C.

On a large scale to produce the E-fibreglass, boron oxide is applied to silica, lime, alumina and magnesia while alkaline oxides are excluded. This composition is then heated, and the molten paste begins to obtain a viscous consistency at around 800 ° C. This is almost homogeneous at 1400 ° C but the last bubbles and impurities only vanish at 1500 ° C from the bottle. The molten mass, when refined, is perfectly transparent when it leaves the furnace and the mass is passed through dies to produce a thread of glass. This thread is then made to scale, wrapped and dry.

Products made of e-glass fibres are particularly resistant to abrasion and vibration and have excellent flexibility. The glass thread has a higher specific resistance than that of alloys. This capability enables the development of glass threads that reinforce high-performance composites. The excellent electrical insulating properties, even at low thicknesses, combined with its mechanical strength and behaviour at various temperatures, formed the basis for the first glass thread applications. The thermal conductivity of e-glass fibres is low. The fibre is non - flammable and can withstand temperatures above 600 ° C.

Fig. 1 E-Glass Fibre Mat

The chemical composition of the E-glass comprises of different items such as silicon, aluminium, boron, calcium, magnesium in different quantities. The chemical composition of the E-glass with regarding to the weight% is as follows (SiO_2-55%)+(Al_2O_3-14%)+(TiO_2-0.2%)+(B_2O_3-7%)+(CaO-22%)+(MgO-1%)+(Na_2O-0.5%)+(K_2O-0.3%). In this chemical composition some impurities can be found based on the manufacturing process involved, these impurities can be of metallic chemicals like iron.

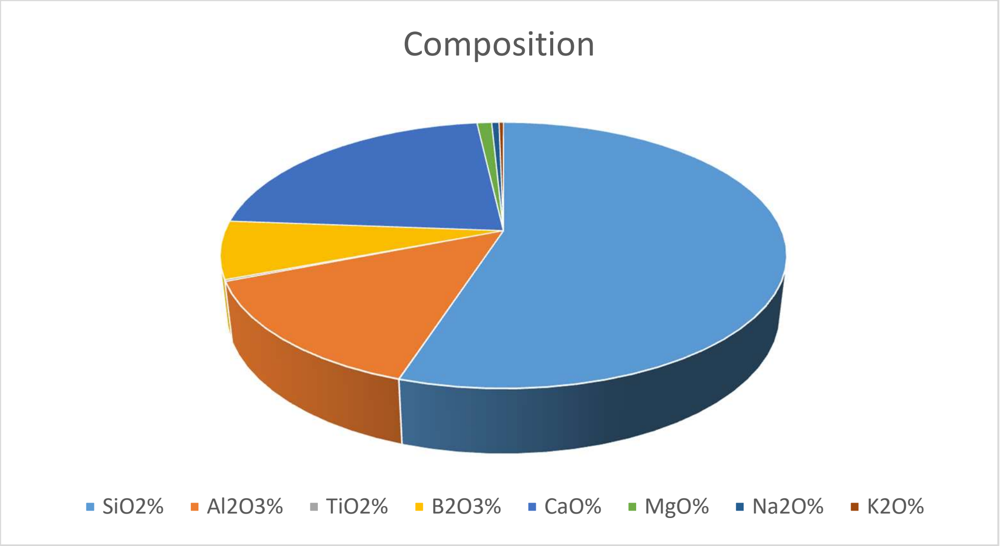


Fig. 2 Chemical Composition of E-Glass

The physical properties like density, young's modulus, strength and elongation etc of the E-glass fibre are as follows.

Properties	**Units**
Density	2.58 g/cm^3
Tensile Strength	3.44 GPa
Young's Modulus	72.3 GPa
Elongation	4.8%
Thermal Expansion Co-efficient	54x10^{-7} ^{0}C
Poisson's ratio	0.2

Table. 1 Properties of Fibre

The E-glass Fibre on commercial level is available in the form of woven mattress structure with required amount of grams per square meter, or it is also available in the form fibres strands for various applications of moulding into complex structural forms.

3.2 Resin Mixture

The resin mixture used is an epoxy blend of Bisphenol A [$C_{15}H_{16}O_2$] and amine hardener. The resin has its melting point ranged between 175 ^{0}C to 180 ^{0}C and density at room temperature is 1.38 g/cm^3, with a molecular weight of 228.29 gm/mol.

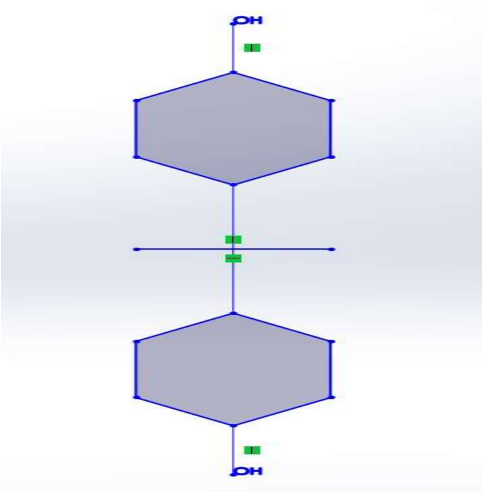


Fig. 3 Resin structure

Fig. 4 Resin

The resin physically appears as a clear solvent with viscosity higher than water and this can be altered based on the need of the user. This resin can be cured in different ways such as, using catalyst where it cures to itself and the catalyst used is anionic catalyst and the other way is using hardener. These hardeners can be anything among amines, anhydrides, phenols and thiols.

Hardener used here is an amine based hardener with a pot life of 30min and the curing period of 48hr at room temperature for the resin and hardener mixture. The exothermic reaction after the mix of resin and hardener can be easily contained at the room temperature. Only after the curing period of the resin and hardener the specimen will attain its complete strength and flexibility to be suitable for physical modification. This curing time can be altered with the change of temperature.

3.3 Additives

There are a total of four different additives used in this process these four were used in different combinations for different samples. The addition of each additive induces a new quality to the specimen, these qualities can be stated as adding thermal conductivity, improved impact strength and added density to the specimen. The additives used are Fumed silica, Calcium carbonate, Alumina Trihydrate and Graphite. All these additives were considered in the fine porous form, as it will be easy to mix with the resin.

Fig. 5 Additives

3.3.1 Fumed Silica

Fumed Silica is usually quoted as thixotropic agent, which are used to thicken the solution. The normal silica usually exists in a crystalline from, so for dissolution of the chemical in the solvent fumed silica is used which is of fine powdered state. The usage of silica elevates the viscosity of the resin mixture so that it can be easily applied on during the layup process.

Fumed silica is produced by a process called Pyrolysis. This is a thermochemical process which can be used to process any organic material. The process of pyrolysis is where the organic material is subjected to heat at elevated temperatures, at this stage the material separates into different chemical and physical molecules, all this process happens in the absence of oxygen. Because of the heat the material disintegrates, this integration leads to formation of new molecules, which form into different products than original material used. Fumed silica is produced through pyrolysis of either silicon tetrachloride or from quart at high temperatures which are greater than 1500 ^{0}C.

Fig. 6 Fumed Silica

Since fumed silica is obtained through the burning process, it exists in very fine particulate state because of this nature it should be handled with precaution, it should not be contacted with directly with hand, and there should be a protection layer in-between, while application as there is a chance of causing breathing issues if inhaled. The properties of the fumed silica are as follows.

Properties	**Units**
Molecular weight	60 gm/mol
Melting Point	1601 ^{0}C
Boiling Point	2231 ^{0}C
Density	2.3 - 4.5 g/cm^3
Size Range	7-14 nm
Specific Surface area	200-390 m^2/gm

Table. 2 Properties of Fumed Silica

3.3.2 Calcium Carbonate

Calcium carbonate is most commonly used additive in the composites, it is usually referred as an inorganic filler material in the area of composites. This is used for maintaining cost efficiency of the resin mixture and also to increase the density of the mixture.

Calcium Carbonate is available abundantly in nature. It’s produced by sedimentation process of fossils, corals, shell fish etc. These sources are taken and further processed into the materials or objects of daily needs. This is also mostly used in the production of chalk, separation walls of the house.

Fig. 7 Calcium Carbonate

Chemical formula of the calcium carbonate is $CaCO_3$, it is also obtained from lime stone and marble. The physical appearance of the chemical is of white powder material with poor solubility in water. The properties of calcium carbonate are as follows.

Properties	**Units**
Molecular weight	100.08 gm/mol
Melting Point	825 ^{0}C
Boiling Point	decomposes
Density	2.93 g/cm^3
Size Range	≤50µm
Specific Surface area	3 m^2/gm

Table. 3 Properties of Calcium Carbonate

3.3.3 Alumina Trihydrate

Alumina trihydrate is a filler that adds fire retarding feature to the composite. This filler material when exposed to extreme heat or temperature, releases water content. So the filler when added to composite, the composite reacts in a way that on exposure to extreme temperature white smoke is released from the composite, reducing the flame spread.

This additive is produced through Bayer process. In this first the bauxite ore is powdered and heated with sodium hydroxide at the temperatures around 200 ^{0}C. The next step involves in the removal of impurities in the processed bauxite. This process dissolves all the chemicals other than alumina and silica in the mix, these appear in the form of red mud. This mud is separated from the solution using rotary method. Now this mixture will be precipitated by subjecting to heat exchangers, because of this heating silica is separated out of the mix. The rest of the mix will be washed, dryed and heated in calciner at elevated temperatures of 1000 ^{0}C, to extract out alumina. In this process along with alumina other by products like silica and various iron oxides are also formed.

Fig. 8 Alumina Trihydrate

The physical appearance of the chemical is of white crystalline powder and the chemical formula is $Al_2O_3.3H_2O$. This chemical is usually obtained by dissolving aluminium ore in sodium hydroxide at elevated temperatures and aluminium trihydrate is separated from the solid that remain after the heating process. The properties of alumina trihydrate are as follows.

Properties	**Units**
Molecular weight	156.01 gm/mol
Melting Point	220 ^{0}C
Boiling Point	decomposes
Density	2.4 g/cm^3
Size Range	1-80μm
Specific Surface area	N/A

Table. 4 Properties of Alumina Trihydrate

3.3.4 Graphite

The additive graphite is used in the form of powder, this adds thermal and electrical conductive property to the composite. The physical appearance is of grey powder material which is not soluble in water.

Graphite powder is extracted from the natural sources of graphite which are fossils and other natural materials found underground. These are first pulverised in the mills and examined for particle size in the process. The pulverised material with required particle size are separated out and the rest is again sent back to the mills. This pulverised powder is mixed with the binder and tightly compacted under pressure. These compacted materials are heat treated without air at temperatures of 1000^0C. Thus formed final bricks are left alone or powdered based on the need and application.

Fig. 9 Graphite

Graphite is a crystalline carbon with hexagonal structure chemical formula can be stated as C, it is manufactured various forms from powder to crystalline based on the requirement. Graphite has a wide range of applications in spray painting, water treatment, fuel cells and solar applications. The properties of the graphite are as follows.

Properties	**Units**
Molecular weight	12.01 gm/mol
Melting Point	3651-3698 ^{0}C
Boiling Point	4201 ^{0}C
Density	1.8 g/cm^3
Size Range	≤ 1mm
Specific Surface area	0.6 m^2/gm

Table. 5 Properties of graphite

Chapter-4

4. Specimen Fabrication

All the components which are discussed in the previous chapter are taken in different combinations and used for fabrication of the composite. In the fallowing paragraphs the steps involved in the fabrication process are discussed in detail, the fabrication method fallowed here is hand layup method. The steps involved in the fabrication begin with mould preparation and deal with further details like fibre arrangement, resin mixing, fibre layup and final compression till the curing time is completed. All these steps are discussed below all with the dimensional qualities of each individual item used in fabrication.

4.1 Mould

The first step in the sample preparation involves in the making of the mould for the composite and the mould can be of any desired material. The mould should be designed based on the dimensions of the specimen, force application on the mould and ability to contain the overflow of the resin under compression. First a 3D design of the mould is made according to the requirements, so that its physical crafting can be done easily and material for the mould here will be rubber.

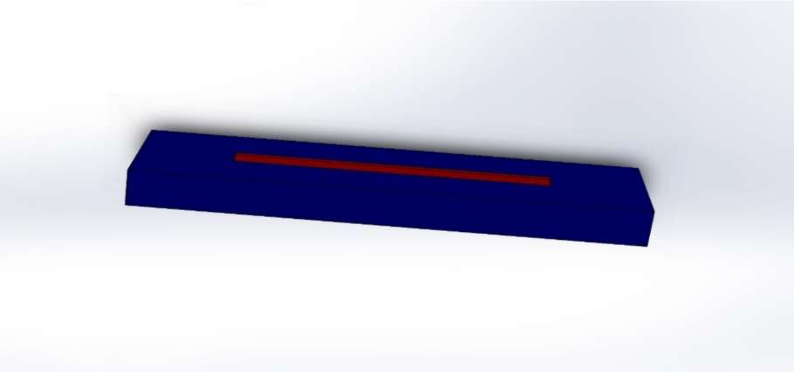


Fig. 10 Mould 3D Model

The intension is to use a rubber sheet of say 25mm thickness and cut out the middle portion so that a groove is made to accommodate the composite for compression. In the above picture, the blue coloured region is the whole mould and the red coloured region is the section removed for the composite. After the design of the mould is finished, the rubber sheet will be cut accordingly using a blade.

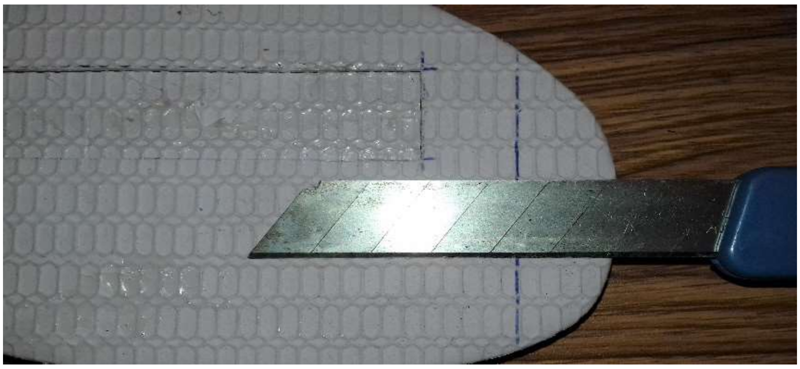


Fig. 11 Rubber Cutting

First, the markings are made according to the requirement of the specimen and the portion of the rubber is removed from the centre section. This section is removed such that groove in the middle is formed of dimensions 200x20x2mm and these would be dimensions of the specimen. The removed section will be in the cuboidal form with a volume of 8ml in total and so the volume of the specimen will be the same of the groove section.

Fig. 12 Rubber Mould

This groove shape is chosen as it does not have any cuttings in between, also the resin will be in a packed state when compressed and does not overflow out of the mould. This cutting of the mould can be observed even more clearly in the following wireframe design model.

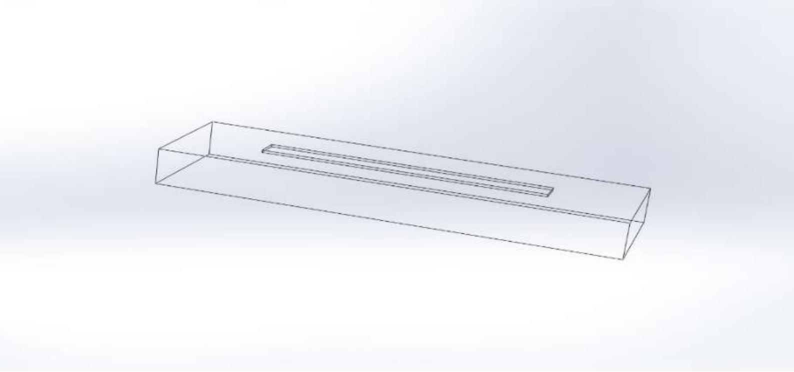


Fig. 13 Mould Wire Frame

4.2 Material

In this fabrication, we are intended to make a specimen of cuboidal structure having a volume of 8ml, so the dimensions chosen are 200x20x2mm and the mould is also made according to these dimensions. The intended structure of the specimen can be seen in the below 3D model which would be used in future references.

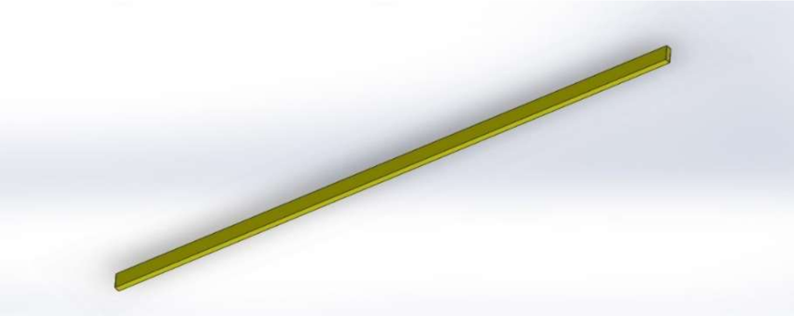


Fig. 14 Specimen 3D Model

To make a specimen of above mentioned dimensions, layers of fibre glass mat are used in the composites. The E-Glass fibre mat is taken and the markings are made with dimensions of 200mm length and 20mm breadth, these markings are made such that at least eight individual strips can be cut from a single sheet.

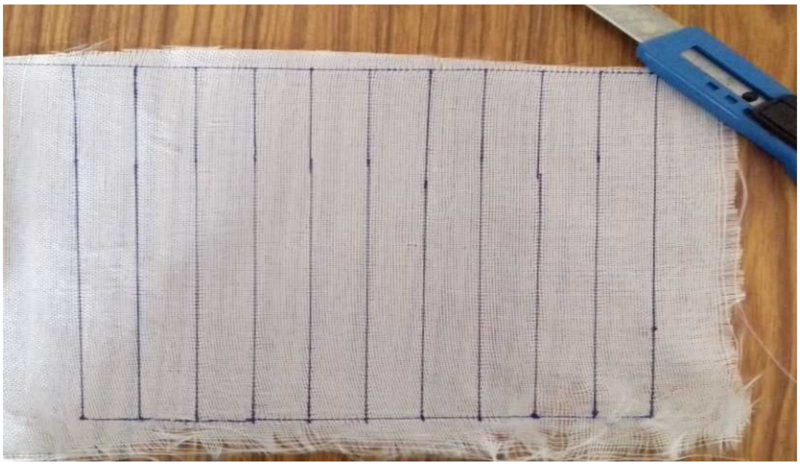


Fig. 15 Glass Fibre Mat with Markings

According to the markings made strips of fibre glass are cut such that each strip is 200mm long and 20mm wide. Here the intention is to fabricate each specimen as an eight layered structure, so eight strips are used in each individual specimen.

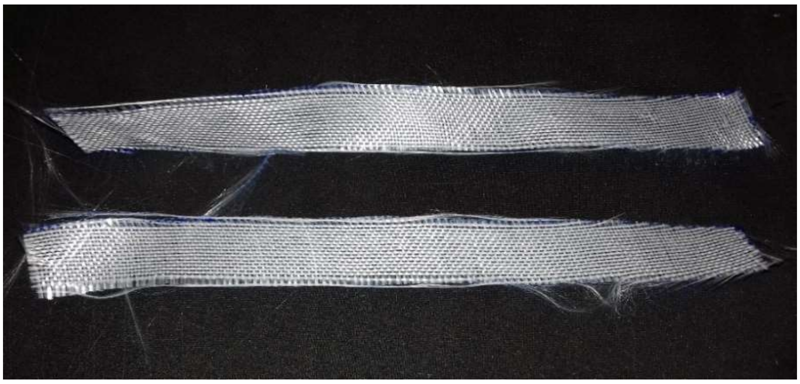


Fig. 16 Glass fibre strips

After the fibre strips are cut resin and hardener mixture with additives is prepared. First, the resin is taken in the measuring beaker and a volume of 9.2ml is taken into the mixing jar. In the mixing jar, the first additive to be added will be alumina trihydrate, as it is in the crystalline form and takes time to dissolve into the resin. This is stirred gently using a glass stirrer while adding the other additives graphite and calcium carbonate consecutively.

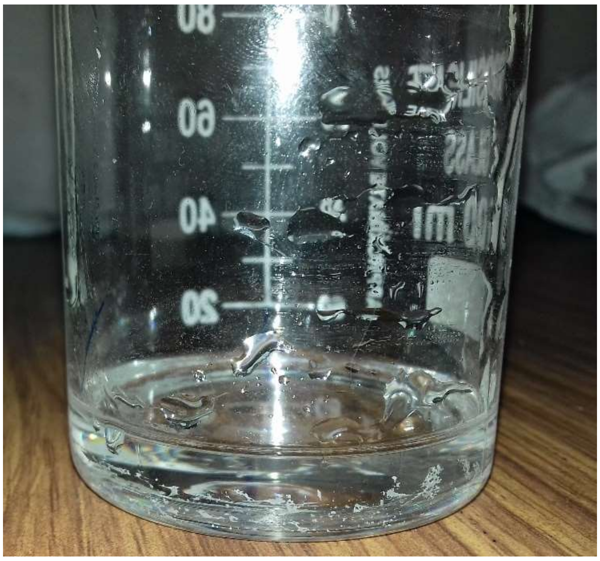


Fig. 17 Resin in Measuring Jar

To this mixture now, the hardener is added and this will be of the same volume as the resin i.e, 9.2ml and the stirring continues while adding the final additive fumed silica. This is added after the hardener as fumed silica helps to increase the viscosity of the mixture. The mixture is to be steadily stirred till the fumed silica is completely dissolved into the mixture. This completes the preparation of the resin mixture and the cutting of the fibre strips for the fabrication process.

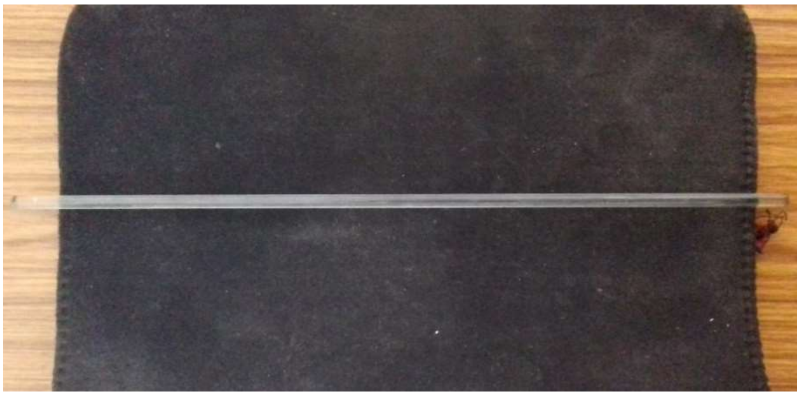


Fig. 18 Stirring rod

4.3 Arrangement of Materials

When all the materials required for the fabrication are prepared, then there involves the arrangement process as the final step in fabrication. Initially, a little amount of the resin mixture is applied to the base and walls of the mould, after that a single strip of the fibre is added by padding it all over to remove air underneath the strip. This way the consecutive layers of the fibre and resin are added, so that it forms an 8 layered sandwich structure inside the mould. This layering process must be completed within 20min from adding the hardener to resin, as the mixture will start hardening after 20min.

Fig. 19 First Layer of fibre

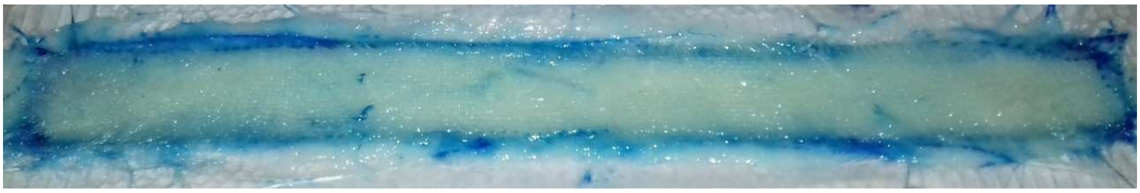


Fig. 20 After 8 Layers of fibre

After layering, the top surface will be covered with a thin film to avoid dust accumulation. Then the whole mould will be compressed by adding the force from the top of the mould. This force is created through weights and this weighing should not be extreme, as overweighing causes the resin mixture to flow out of the mould. An adequate amount of weight is used so that the layers of the fibre are well compressed together and in this fabrication, used weights are about 40kg, which must be equal to 392.28N.

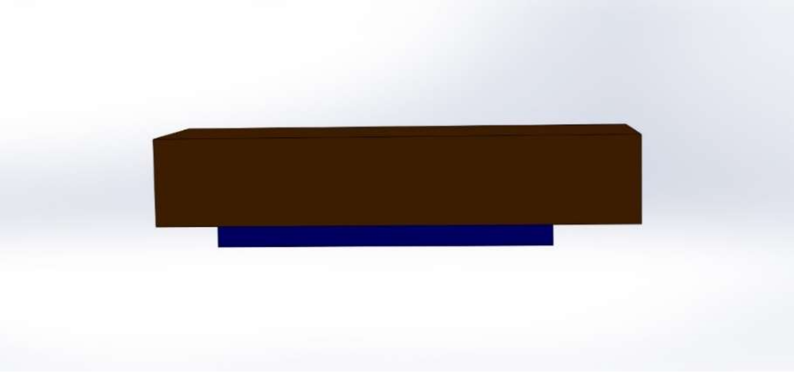


Fig. 21 3D model of the mould and weight

The brown object in the above figure is weight loaded and the blue object is the mould being compressed. Once the weight is added to the arrangement, the whole setup will be left aside, away from disturbances for a time period of 48hr. This is the time required for complete curing of the resin gardener mixture and any disturbances caused to the weights loaded will end up with improper compression of the specimen. The detailed view of the whole arrangement can be seen in the below wireframe model, where the yellow coloured object is the fibre layers being compressed.

Fig. 22 Wireframe model of the mould and weight

Chapter-5

5.1 Testing

The whole arrangement of the mould and the weight on it is set aside for 48hr for complete curing of the resin mixture, during this period it is considered that the loading is not disturbed and the whole setup is in a dry environment free form any kind of water or moist. After the curing period of 48hr, loading is removed and the specimen is taken out of the mould and thus, the fabrication of the composite material is completed.

The above discussed process is followed and a final of 7 different specimens were fabricated, each with different compositions of the additives, these are named from Sp-1 to Sp-7. The seven different specimens are made sure that they have the same physical dimension. The additive combinations of these specimens are as follows

Specimen	Fibre Layer	Fumed silica	Alumina Trihydrate	Graphite	Calcium carbonate
Sp-1	0	Yes	No	No	No
Sp-2	6	No	No	No	No
Sp-3	8	Yes	No	No	No
Sp-4	8	Yes	Yes	No	No
Sp-5	8	Yes	Yes	No	Yes
Sp-6	8	Yes	Yes	Yes	Yes
Sp-7	8	Yes	Yes	Yes	No

Table. 6 Combinations of the Specimens

The flexibility and the rigidity of each specimen were different from the other. The specimen without fibre was most flexible and considering the different number of layers, the eight layered specimen was most promising in terms of rigidity, so most of the specimens fabricated were eight layered.

Fig. 23 Final Specimens after 48hr curing period

The specimens fabricated were subjected to high temperatures to find their heat dispersion and withstanding capability. The specimens were subjected to heat till they reach a temperature high enough, where the behaviour of the specimen changes and at that pint they were inspected for their flexibility and rigidity compared to the initial post cured state. After the exposure to heat these samples were also compared to each other for flexibility and rigidity. The graph below show the time taken by the specimens to reach final temperature.

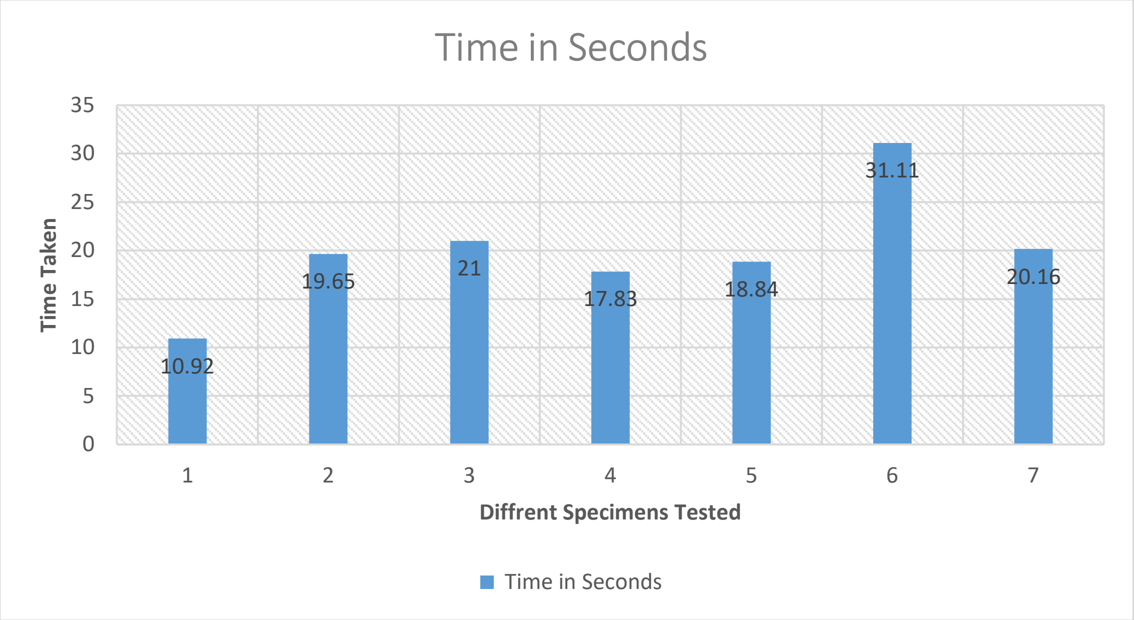


Fig. 24 (a) Time taken by samples to show reaction

The specimen with all the additives took the highest time of all and the specimen without fibre took the least time in the lot. After the exposure to heat the flexibility and rigidity of the samples was not the same as initial state, the specimen Sp-1 broke into pieces, Sp-2 got deformed from its original state, Sp-3 was deformed where the heat was concentrated, Sp-4 got heat spread mostly and was able to maintain its shape, Sp-5 was able to maintain its shape, Sp-6 got heat to spread all over efficiently and took longer to time reach high temperature and Sp-7 also got the heat spread efficiently and maintained its shape through the test.

Fig. 25 (b) Specimens after exposure to heat

5.2 Virtual Analysis

The testing procedure will involve on analysing the material in different loading conditions in a virtual mode. The results obtained will be compared to that of different other materials, all of this analysis will be done in abaqus software. The properties of the materials used are stated in the following table.

	Density-gm/cm^3	Young's Modulus-GPa	Poisson's Ratio
Mild Steel	7.85	205	0.29
Cast Iron	7.3	210	0.35
Aluminium	2.7	69	0.334
Copper	8.96	117	0.355
Composite	1.5955	0.028	0.225

Table. 7 Properties of samples Used

5.2.1 Tensile Test

The testing is done by creating a dog bone shaped testing sample and creating a tensile force in one direction and restricting the growth in other directions. The force applied is a pressure of 10.976K.Pa on the sample, in comparison to the composite the different materials are taken are Mild Steel, Cast Iron, Aluminium and Copper. In this test a random set of 28 nodes were selected from different points and variation of the direct stress at those points are plotted on a graph.

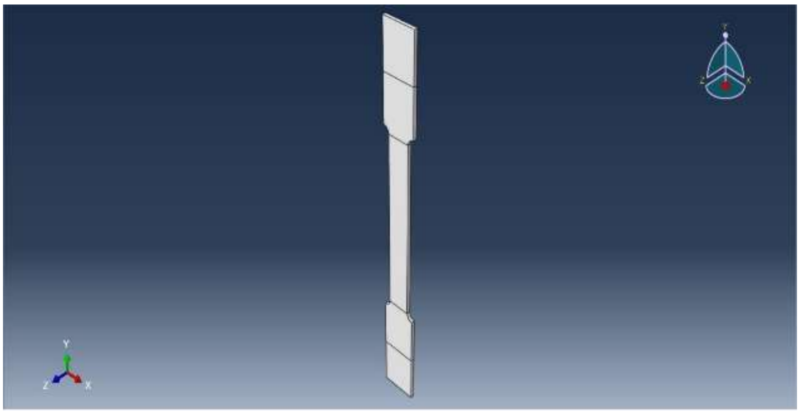
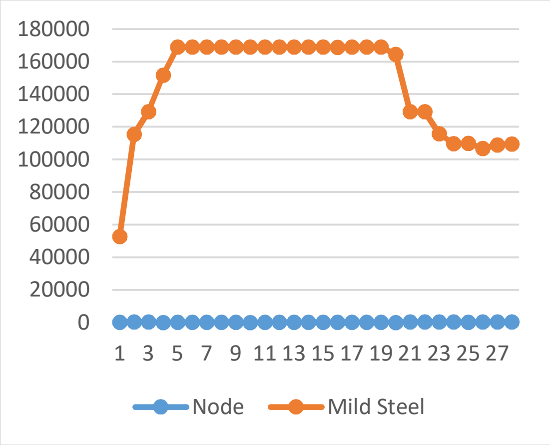


Fig. 26 Tensile Testing Sample



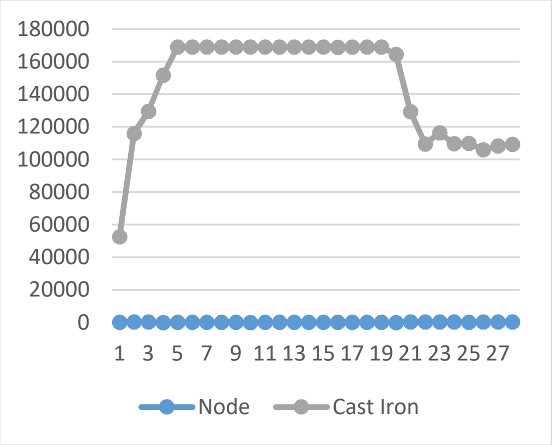


Fig. 27 Tensile Test of Mild Steel

Fig. 28 Tensile Test of Cast Iron

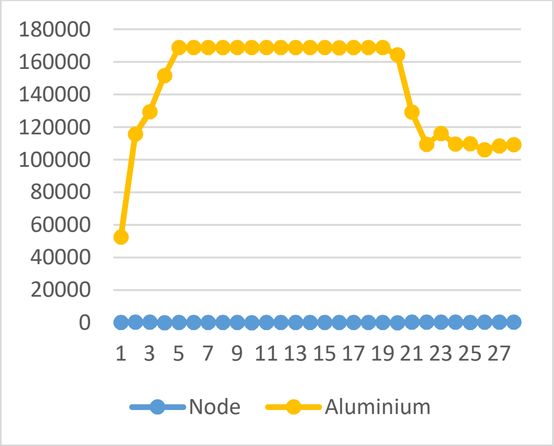


Fig. 29 Tensile Test of Aluminium

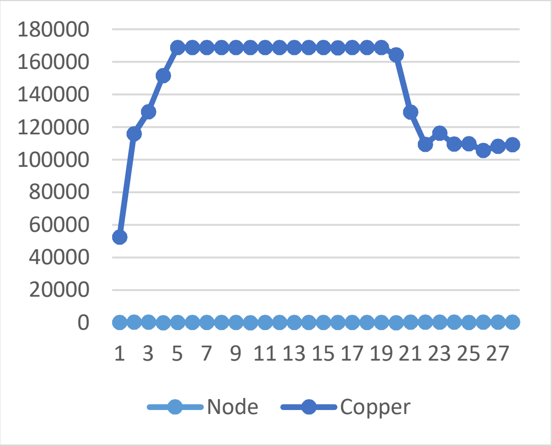


Fig. 30 Tensile Test of Copper

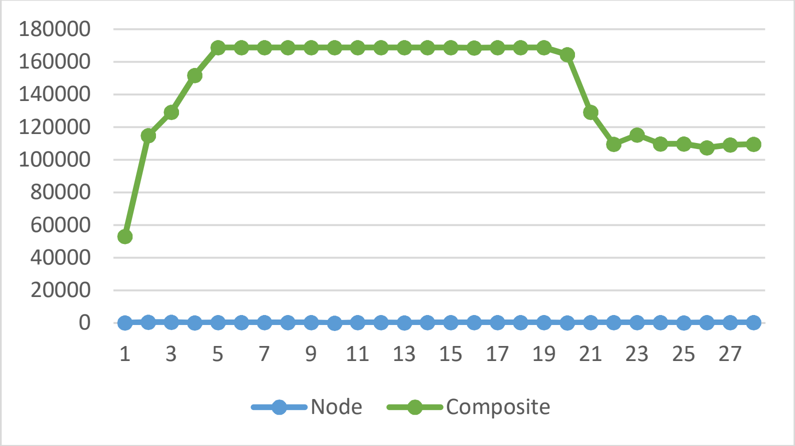


Fig. 31 Tensile Test of Composite

After the comparison it is observed that the maximum direct stress in the samples is observed to be 16.88kPa and this happened between the nodes 5 to 19. But the major difference is observed when the drop was seen in stress developed, this was different in each sample.

	Max Stress(kPa)	Dropped Down(kPa)	Difference(kPa)
Mild Steel	16.88	12.92	3.96
Cast Iron	16.88	10.94	5.94
Aluminium	16.88	10.94	5.94
Copper	16.88	10.94	5.94
Composite	16.88	10.95	5.93

Table. 8 Tensile Test Output

It is observed that all this variation had happened at the nodes 21 and 22 of the samples. The stresses developed at the different parts can be seen the following figure which depicts the different stress regions with distinctive colours.

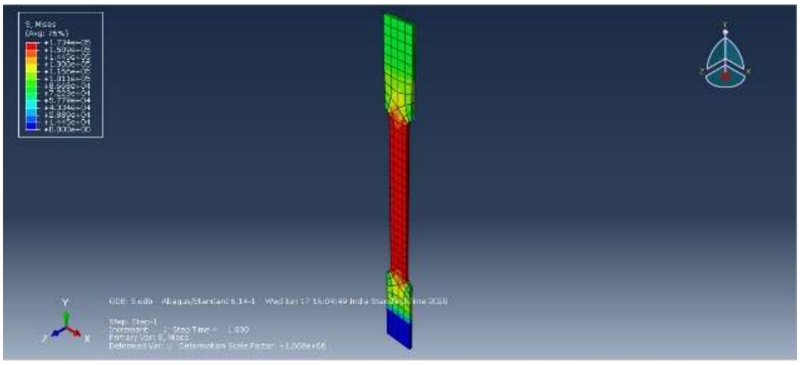


Fig. 32 Deformed Tensile test Sample

5.2.2. Bending Test

The bending test is performed on a flat bar design then a total of 40 elements are considered all the body and yield stresses are plotted to graph, force applied on the body will be of 687N and this is a concentrated force unlike the pressure applied in the tensile test. In this test the sample is arrested for its movement in all the directions except for y-axis where the loading is done. The sample is arrested by fixing its ends and force applied at the mid-section.

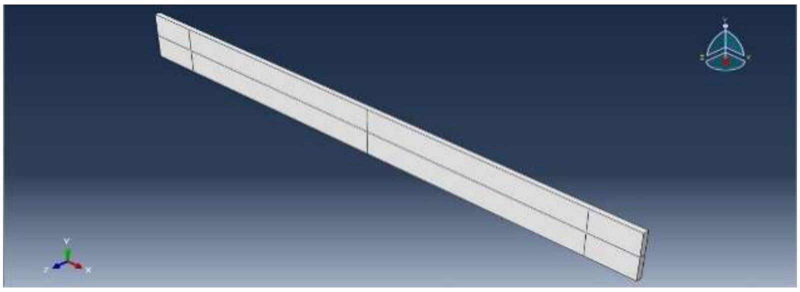


Fig. 33 Bending Test Sample

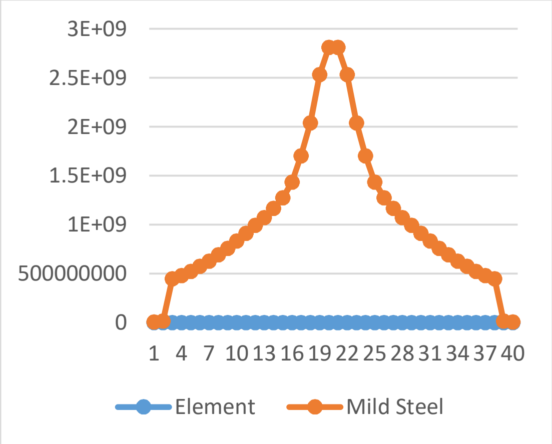


Fig. 34 Bending Test of Mild Steel

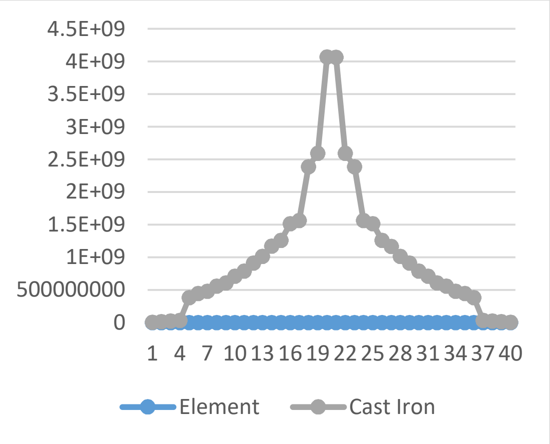


Fig. 35 Bending Test of Cast Iron

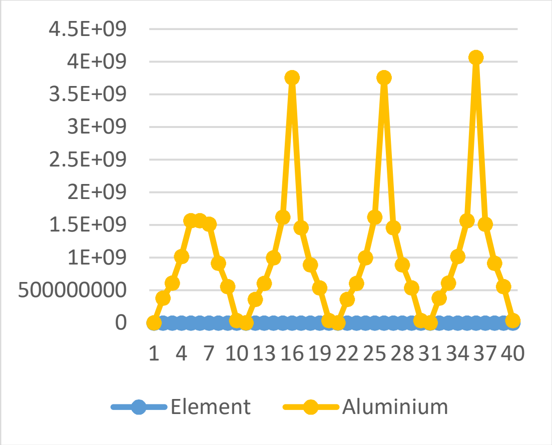


Fig. 36 Bending Test of Aluminium

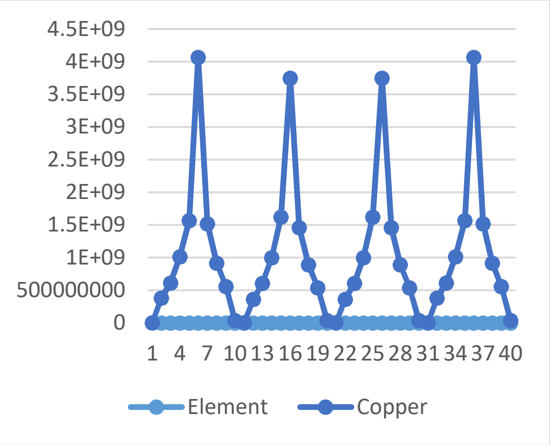


Fig. 37 Bending Test of Copper

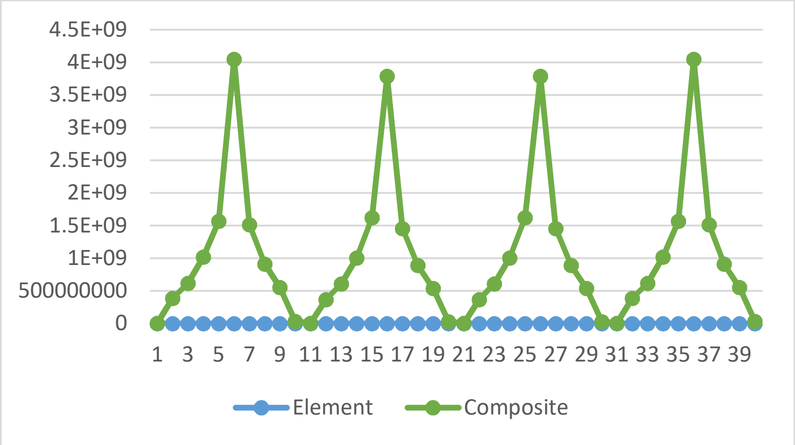


Fig. 38 Bending Test of Composite

It is observed that the mild steel and cast iron yielded out at one instance, whereas the rest of the samples had multiple yielding points. The yielding stress achieved in the different samples can be stated as fallows.

	Max Yield Stress(kPa)	No of Yielding Points
Mild Steel	281000	1
Cast Iron	407000	1
Aluminium	407000	4
Copper	407000	4
Composite	405000	4

Table. 9 Bending Test Output

Among all the material samples which had four yielding points it is observed that the aluminium had 3 yield points at with a yield stress of 407000kPa and on one point with a yield stress of 157000kPa. The deformation of the sample after the testing can be seen in the picture below with the different areas of deformation each depicted with distinct colours.

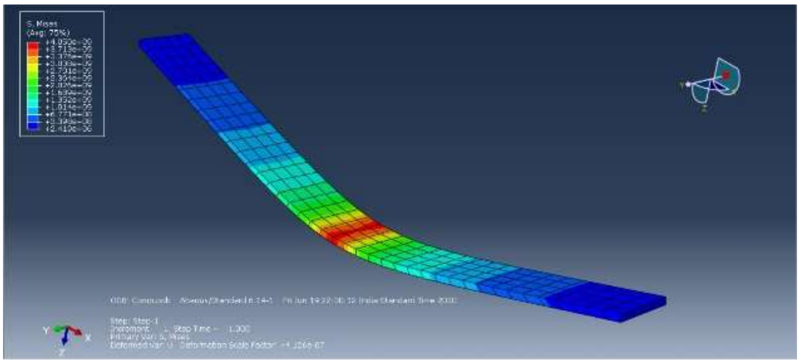


Fig. 39 Deformed Bending Test Sample

6.1 Results

The specimens after the exposure to heat shown change in their physical appearance, such as the breaking into pieces and permanent deformation in the shape. The specimens with the additives graphite and alumina trihydrate showed the better results in terms of heat dispersion along the body and maintaining the structural rigidity even after the prolonged exposure to heat. In all the specimens it was commonly observed that, all of the specimens with eight layered structure were intact throughout the process.

S.No	Specimen	Desity gm/cm^3	Youngs Modulus KPa	Time to Deformation in sec
1	Sp-1	6.095	487.52	10.92
2	Sp-2	5.62	684.67	19.65
3	Sp-3	7.455	205.36	21
4	Sp-4	7.455	209.26	17.83
5	Sp-5	7.455	213.15	18.84
6	Sp-6	7.455	217.04	31.11
7	Sp-7	7.455	213.15	20.16

Table. 10 Specimen Results when subjected to heat

This process had to deal with only heat application without any external forces acting on the body, if there were any external forces the specimens might have acted differently while testing.

The virtual testing process showed the stress output and the yield regions in the metals and the composite had same deformation regions, this shows that the resistive force generated in all the models is same.

S.No	Material	Max Stress in Tensile Testing. Kpa	Average Yield Stress in Bending Test KPa
1	Mild Steel	16.88 at node 20	281000
2	Cast Iron	16.88 at node 19	407000
3	Aluminium	16.88 at node 20	329000
4	Copper	16.88 at node 20	391000
5	Composite	16.88 at node 19	392000

Table. 11 Specimen Results for Virtual Analysis

The values of direct stress developed is 16.88kPa and the yield stress developed in the composite is 405000kPa. This has placed composite in a position to replace copper and aluminium but still not in place to replace mild steel and cast iron. The mild steel and cast iron still have better usable characteristics when compared to the composite. The composite analysed virtually is the combination of just fibre and the resin.

6.2 Conclusion

The fabrication process proved to be effective even without any artificial conditions to cure and mechanised loading to compress. The specimen samples fabricated were seen to have even surface thickness and had no air spaces in between, making sure it is at its best shape. The distinctive reactions of the each specimen when subjected to heat proved the effectiveness of the additive combination in each of the specimen, these reactions can be better heat dissipation, intact fibre layers and prolonged resistance to heat, this concluding the fabrication process was effective and reliable. The virtual analysis showed that maximum values a simple composite can sustain under the tensile forcing and the bending action applied to it, these stress values generated were compared with respect to the general metals like mild steel, cast iron, aluminium and copper.

6.3 Scope for Future Work

The composite made here was only in the shape of test specimens they further be moulded into the shape of any working component. The additives in the mixture are mixed all simultaneously in this setup, rather than this resin can be applied as individual layers each with different additive and applied after the earlier one is settled. This may create different layers on the composite with different characteristics, so that outer layers transfer the outer forces all along the body uniformly and inner layers absorb the forces received.

7. References

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8. Papers Published

1. Fabrication of E-Glass Fibre Based Composite Material with Induced Particulate Additives
   Conference: International Conference on Integrated Interdisciplinary Innovations in Engineering
   Journal: IOP Material Science Engineering

2. Virtual Analysis of E-glass Based Fibre Composite
   Journal: International Journal of Creative Research Thought's