DEVELOPMENT OF CARBON FIBER REINFORCED POLYMER COMPOSITE AND TO INVESTIGATE ITS MECHANICAL PROPERTIES

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CERTIFICATE

I, hereby certify that the work being presented in the dissertation entitled " **Development Of Carbon Fiber Reinforced Polymer Composites And To Investigate Its Mechanical Properties**" in partial fulfilment of the requirement of the award of the degree of Master of Technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Sushil Kumar, Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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The external viva-voce examination of the student was held on successfully ________________

Signature of Examiner

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"You cannot teach a man anything:

you can only help him discover it in himself"

-Galileo

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ABSTRACT

Now-a-days application of composite materials are continuously increasing from traditional application areas such as military aircraft, commercial aircraft to various engineering fields including automobiles, robotics arms and even architecture. Due to their light weight, high tensile strength and corrosion resistance and easy to implementation makes the carbon fiber reinforced polymer composites in demands. The depletion of fossil fuels is an alarming for the automobile industry and due to this the automobile industries started making of composites material parts to reduce the vehicle weight to increase the fuel efficiency. Carbon fiber reinforced epoxy resins composites were use more in the automobile industries. A unidirectional carbon fiber use as reinforcement and the matrix use as Bisphenol-A. The purpose of my thesis work was to analyse the influence of the fiber orientation and the loading axis of the composites material. Two different proportion of the fiber and the matrix were taken into consideration to enhancing the mechanical properties. The sample were made according to ASTM d3309 for tensile test and ASTM d790 for flexural test through hand lay-up process. The specimens were subjected to tensile and flexural test on UTM. The effect of the fiber orientation changes the mechanical properties of the composites. As the orientation of the fiber increased the tensile strength of the composite were going to decrease. For tensile test of carbon/epoxy composite of $0°$ shows greater strength as compared to$30°,45°,60°\&90°$. For flexural test $30°$ shows good strength when three point bending were done. Three point bend method has been adopted to find out the flexural strength and flexural modulus. The comparison of the single layer and double layer of carbon fiber show and investigated the tensile strength, young’s modulus, elongation percentage, maximum load to break the composite, peak load and flexural strength.

CHAPTER – I

INTRODUCTION

Weight reduction of vehicle become the primary concerned to enhance the efficiency of fuel performance in automobile and aerospace. To reduced vehicle weight about 6-8% means to increases the fuel efficiency of 10% and this will also reduce the emission of the vehicle. Transportation sector shows that they are responsible for 70% of fuel consumption in The United State in 2008. Energy consumption is directly related to the vehicle weight. Many automobile industries were searching to develop new technology and designing strategies to increase the automobile performance while reducing the fuel consumptions. But the consumption of fuel is directly proportional to the vehicle weight. By reducing the vehicle weight is also became the primary factor for enhancing the efficiency of the vehicle. Some of the components of vehicle made up of metal in aerospace field or in automobile field would be replaced by reinforced composites material of same tensile strength to reduced small amount of weight give rise to increase 10% of efficiency. These steps were taken because of the rapid depletion of fossil fuels. The use of Carbon Fiber reinforced material is one of the practical solution to reduced vehicle weight. Since excellent mechanical and thermal properties lead the CF polymer composites used in automobile and aerospace field. These reinforce composites materials mechanical property were enhanced depend on the application. Due to their enhancing mechanical properties the research in these field became more prominent. For advanced fibre reinforced composites advanced structural fibres were used. CF came out to be an important advanced composites fiber because of their advantages like high strength, stiffness, heat resistance and low weight.

A composites is a structural material which consist of two or more material that bounded together to form third material, shows in figure 1. First material act as reinforcement and the other material which bind together is called matrix. The reinforcing material were in the form of fiber. The matrix material are in solid and liquid form. Fiber reinforced composites material means containing of high strength and high modulus fiber which were bounded with matrix with different boundaries between them. Normally fiber behave as the load carrying medium and the matrix behave as surrounding material for the fiber known as load transfer medium between them. In these composition fibre act as reinforcement to the matrix and the

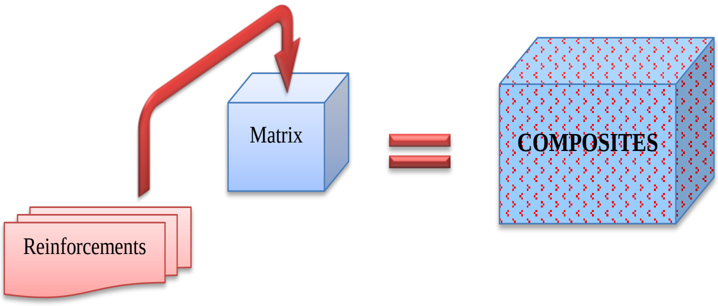

Figure 1 Definition of a composite.

matrix act as binder for the fiber. With these two some other constituents were also included to improve their binding properties of fiber reinforced composites material to form a third material of desired properties. These were coupling agent, coating and filler. Human being were not create the concept of matrix. The concept were existence in nature. One of the example were taken into consideration is wood. In this lignin acts as matrix which is reinforced with cellulous fibre. History also shows the example of composites when the people were build their houses with mixing husks or straw mixed with clay several hundred years ago.

1.1 Classification of composites material

The composites material were basically classified based on the fiber and the matrix, figure 2 shows the classification of composites material

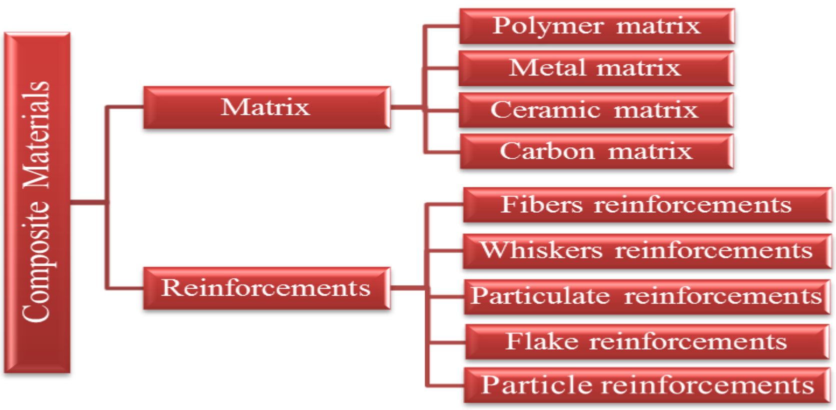

Figure 2 Classification of composites material

1.2 Composites material selection process

A composites material for making a new composites several consideration were brought into existence for the improvement of mechanical properties. The selection of material is done properly to reduce the poor performance of composites material. While selecting a material having a knowledge of about

i. Types of load applying on the composites.
ii. Modes of loading on the composites.
iii. Durability of the composites.
iv. Operating and environmental condition of composites.
v. Structure of the composites which is particularly design for consideration.
vi. Manufacturing process through which the composites are made.
vii. Cost which include both the material and the preparation of final product.

The selection of material depends on the mode of failure and the area of application. For the selection of material modulus, strength, fracture toughness, stiffness and material index were also responsible. To calculate the deformation, modulus is used. To calculate the load carrying capacity, strength is used. Yield strength is responsible when no permanent deformation takes place when the load is applied. Fracture toughness is consider for the brittle fracture. Stiffens means load per unit deformation. Stiffness differ from modulus because it influence on both the modulus as well as the design of material. Material selection not only consider the tensile modulus but also modulus–density ratio. The modulus-density ratio is also known as material index which is used when minimum mass and minimum cost is analysed. Weight reduction is also one of the important consideration for composites materials. Some other consideration for material selection like corrosion, higher damping and control of thermal expansion. Fiber or fibres is a long and hair like material which are in continuous form (filaments) or in discrete form similar to pieces of thread. Fiber are in thread or yarns form which is used to produces other material. Fibers are the main constituent in the reinforced composites material. It occupy a large volume fraction compared to matrix.

1.3 Selection of fiber

Properly selection of fiber should be consider by fiber volume fraction, fiber length and fiber orientation. This also includes the properties of fiber:

i. Compactness.
ii. Stretchable strength.
iii. Compressible strength.
iv. Fatigue strength.
v. Electrical & thermal characteristic.
vi. Costs.

1.4 Carbon Fiber

Carbon fibre are available in the market with different tensile modulus range. The high modulus fibre (30×10^6) have higher density, higher cost, lower stretchable and compressible strength and lower stretchable-strain-failure comparable to low modulus fibre and vice-versa. The benefits of CF like high tensile strength-weight ratio, high tensile modulus-weight ratio, low coefficient of thermal expansion, high fatigue strength and high thermal conductivity gives the use of CF. The disadvantage are low-strain-failure, low impact resistance and have electrical conductivity.

1.5 Structure of Carbon Fiber

The mixture of CF include amorphous carbon and graphitic carbon. The graphitic form results because of their high tensile modulus, due to which atoms of carbon were organized in crystallographic arrangement of similar planes. The Carbon atoms were organized at the corner of the inter-connecting regular hexagons. The distance between the two adjacent atoms is smaller than the distance between the planes which were inter-connected with each other. The distance between in each plane is 3.4 A^o in CF structure and the distance between each atom is 1.42 A^o. The carbon atoms were bonded together by covalent bonding and the planes were bonded together by wander-wall forces. The covalent bond shows stronger in nature but the wander wall forces are weak in nature. This gives anisotropic of physical and mechanical properties of carbon fiber, the structure of CF shows in figure 3.

The structure of the CF

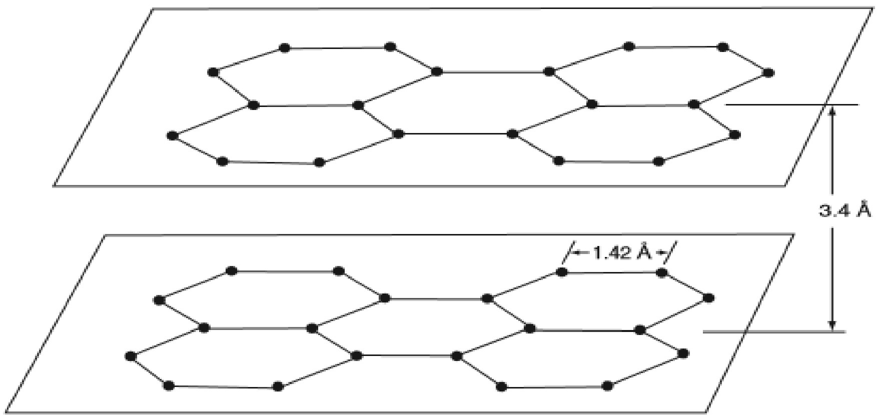

Figure 3 Structures of carbon fiber

1.6 Manufacturing process

Manufacturing of carbon fiber are based on two precursors, textile precursor and pitch precursor. The flow chart of manufacturing process were shown in figure 4.

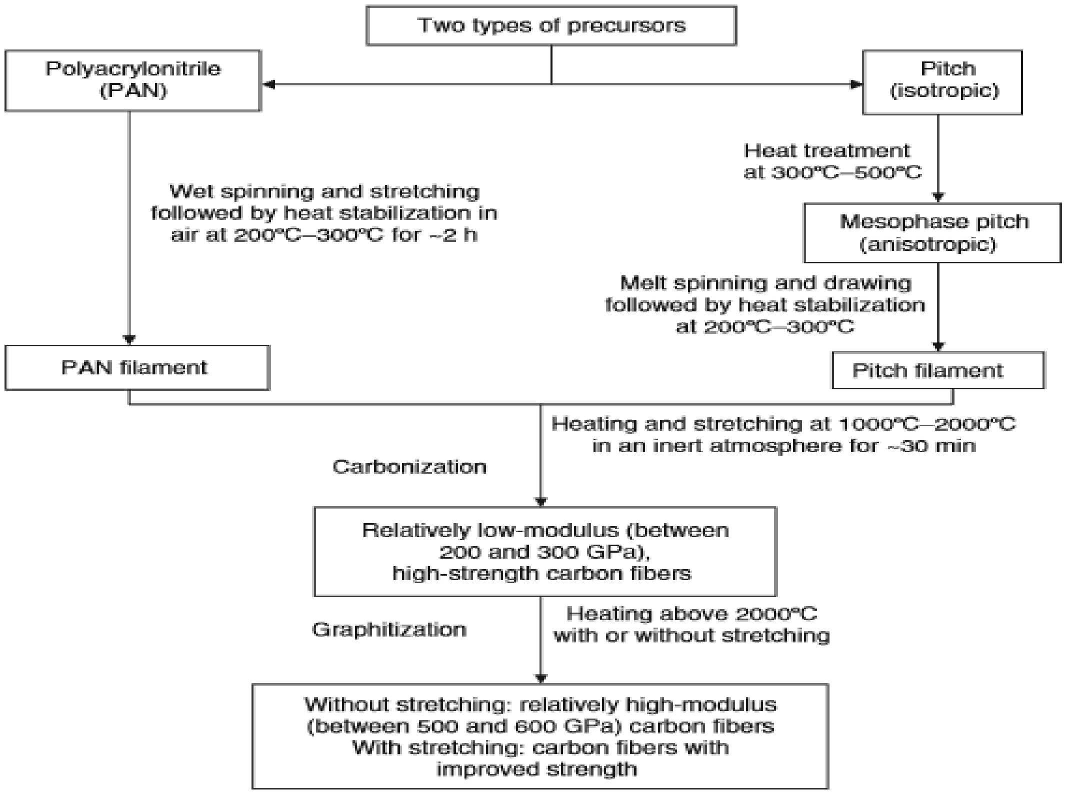

Figure 4 Precursor of carbon fiber

1.6.1 PAN based Carbon Fiber:

The common textile precursor is polyacrylonitrile (PAN). The highly polar CN group were organized on the molecular structure of PAN based CF fibre which were arranged on both side along the chain. Wet filaments were obtained from the PAN solution through spinning. At high temperature stretching takes which align the polymer chain in filament direction. Now in presence of air the stretched filament is heated at around 200º-300º C for some hours. A stable and rigid ladder structure were formed when the CN groups on identical side of the unique chain were combined and some CH_2 group oxidized. With increasing heating temperature to 1000º-2000º C in inert atmosphere the PAN filaments were carbonized. For resisting shrinkage and improving molecular structure tensile forced is applied on the filament. Within this, the elimination of nitrogen and hydrogen atom takes place and only the carbon atom is left on the filament. Now the carbon atom are organised in the aromatic ring pattern in similar planes. But the atoms of carbon were not perfectly organised in the plane which gives low tensile modulus. Again this carbonized filament were heated at or above 2000º C through which their structure become more order in this way it turns in the graphic form. This increase the tensile modulus. But the graphitic filament have low tensile strength. To improve the tensile strength again heat is applied to above 2000º C. Other properties of carbon fibre can also enhanced by improving the crystallinity structure and removing the defect which occurs due to missing of carbon atom and impurities.

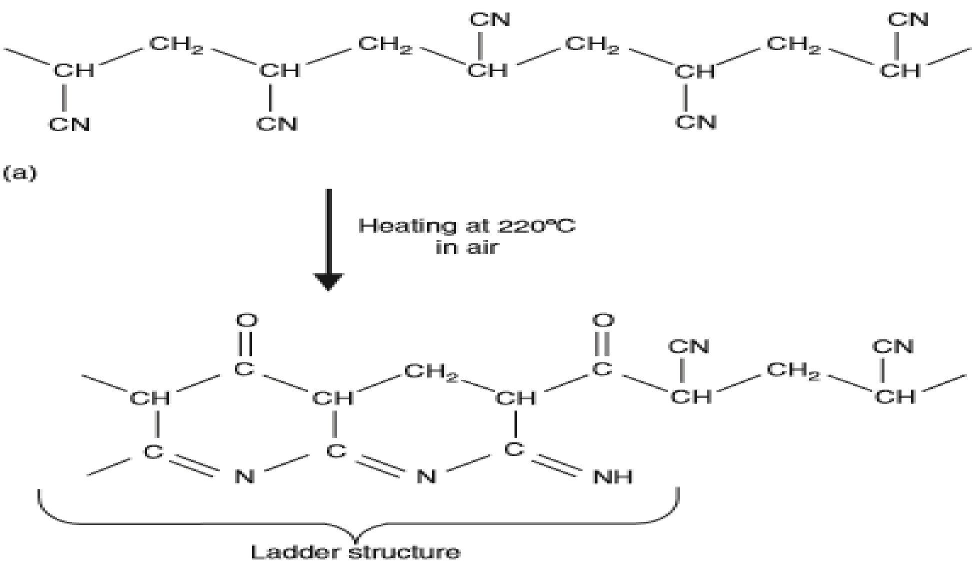

Figure 5 ladder structure of CN group.

1.6.2 Pitch based Carbon Fibre:

Pitch is the left product of petroleum. PAN based CF is costlier than Pitch based. The Carbon atoms organized in aromatic ring patterns in pitch have low molecular weight. To joins these molecules into long and two dimensional sheets like structure heating is increased to above 300º C. Highly viscous state is obtained at this state which is known as mesosphere. By melt spinning through spinneret mesophase pitch are produced through and this mesophase pitch molecules are aligned into the filament direction. Then this filament allowed to cool to form molecular orientation and then again heating between 200º-300º C in oxygen containing environment to stabilize the molecular orientation. The next steps is that filament are carbonized at 2000º C. The next step is same as PAN based CF for achieving GF.

1.7 PAN based Benefits of Carbon Fibre

CF have good tensile strength and high modulus. The good tensile PAN based carbon fibre have low modulus. But pitch based carbon fibre have high modulus but low tensile strength and strain-to failure compared to PAN based fibre. The axial compressive strength is lower than tensile strength in carbon fibre. PAN based carbon fibre has high compressive strength compared to pitch based carbon fibre. This indicates that the higher the tensile modulus the lower the compressive strength. PAN based carbon fibre has low electrical and thermal conductivity than Pitch based carbon fibre. Carbon fibre is available in the forms such as tow, woven, chopped and milled form.

1.8 Matrix

The important of matrix in the composites material are: the fibres should be reserved in specific region, (2) the stress transmission between the fibres (3) it acts as a resistance to the adverse environments like chemicals and moistures, and (4) acts as protection on the surface of fibres due to mechanical degradation. Tensile load carrying capacity of the composites does not include the role of matrix. The selection of matrix depends on compressible strength, inter-laminar shear and in plane shear properties of the composites. Under compressive loading the matrix provide supports against the fibre buckling, under bending loads inter-laminar shear strength is consider and under torsional loads in-plane shear strength is consider. To design damage tolerant structure matrix and fibre interaction is consider. The characteristic of the matrix is responsible for the defects in composites structures. A number of matrix materials are available for the use of commercial and research work. Some of them are polymer matrix, metal matrix etc.

The matrix can be further divided into:

i. Polymer Matrix
ii. Ceramic Matrix
iii. Metal Matrix

1.9 Polymer Matrix

A polymer is known as long chain molecules containing one or more repeating units of atom joined together by strong covalent bonds. Similar chemical structure of large polymer molecules is collected together is called polymeric material. The molecules are frozen together to form solid states. Polymer matrix are divided into two parts (1) thermosets polymers and (2) thermoplastic polymers.

1.10 Classification of Polymer Matrix

The classification of the polymer matrix were based on the types of plastic. The classification of polymer were show in figure 6.

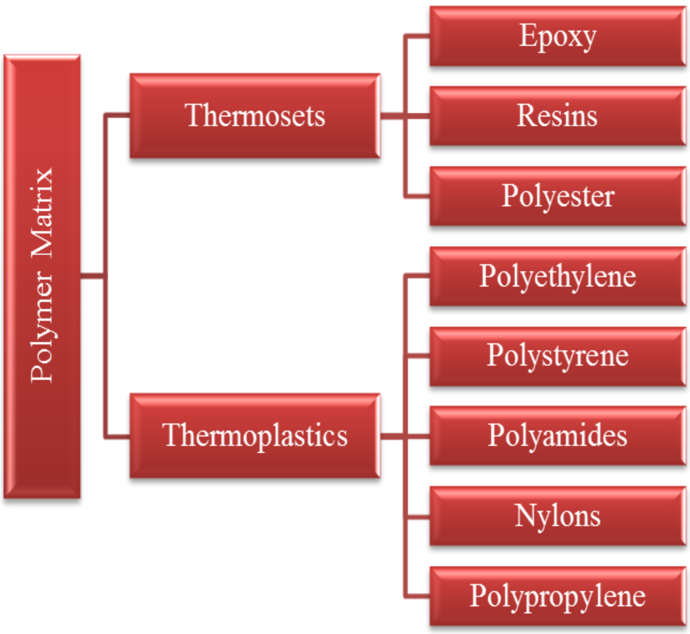

Figure 6 Classification of polymer

1.10.1 Thermoplastic polymers

The molecules were not joined chemically in thermoplastic polymers. The intermolecular forces between the molecules are weak such as van der walls bond and hydrogen bonds. The structure of thermoplastics polymer were shown in figure 7. These temporarily bonds are broken with the application of heats and the molecules which were arranged moves relative to each other to form new configuration when pressure applied. The molecules can be frozen by cooling and the new configuration get the desired shape. The thermoplastic material can be reshaped again and again.

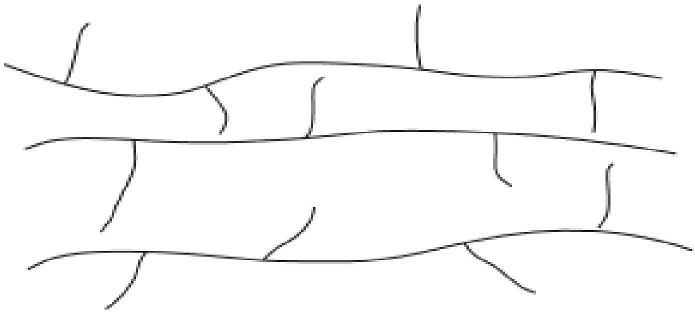

Figure 7 Structure of thermoplastic polymer

1.10.2 Thermoset polymers

On the other hand the molecules of the thermoset polymers are chemically joined together by cross-links. The structure of thermosets polymer were shown in figure 8. A three dimensional networks can be formed by this. During the polymerisation reaction cross-links were formed. Due to this the cross linked were not be melted by application of heats. In this way it can be formed permanent shaped.

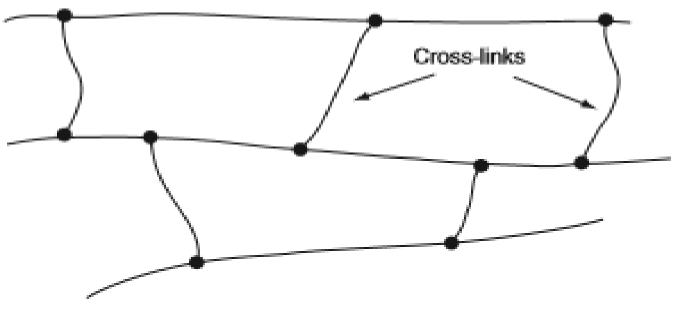

Figure 8 Structure of thermosets polymer

1.11 Selection of thermosets matrix

The selection of thermosets matrix is consider by looking its mechanical properties. The desirable mechanical properties of matrix for high performance of composites materials are

i. During curing low shrinkage takes place.
ii. During curing volatile matters were absent.
iii. The resistance were good enough to chemical and solution.
iv. The adhesion were well enough for the fiber, filler and other substrate.

1.12 Benefits of thermoset polymers

The thermosets polymer were also known as resins it also acts as matrix materials which was use fiber reinforced composites. The lower-molecular-weight liquid chemical having very low viscosity were used as a beginner material in the polymerization of thermosets polymer. Before the polymerization reaction started the fibers were immersed or pulled through inside the chemical. When the time of fiber incorporation takes place the polymer viscosity was low due to this reason a good wettability between the fiber and the matrix were achieved without the need of high temperature and pressure. The wettability between the fiber and the matrix were very important to acquire a good mechanical properties. The other advantages of the thermoset polymer were there because of thermal stability and chemical resistance.

1.13 Epoxy

Beginners material of the epoxy matrix were low-molecular-weight chemical liquid resins which carries an epoxied group, having three member group of two carbon atom and one oxygen atom. The beginner structure of the epoxy were shows in figure 9.

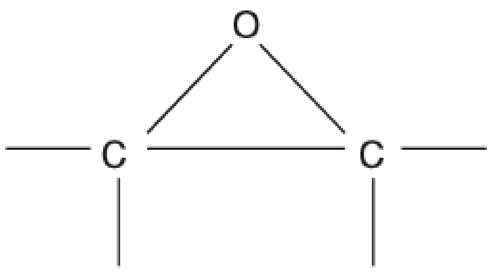

Figure 9 Beginner epoxy structure

A well-known beginner material was Diglycidyle ether of Bisphenol-A (DGEBA), which carries two epoxide group having both end of the molecules. A molecule of DGEBA were show in figure 10.

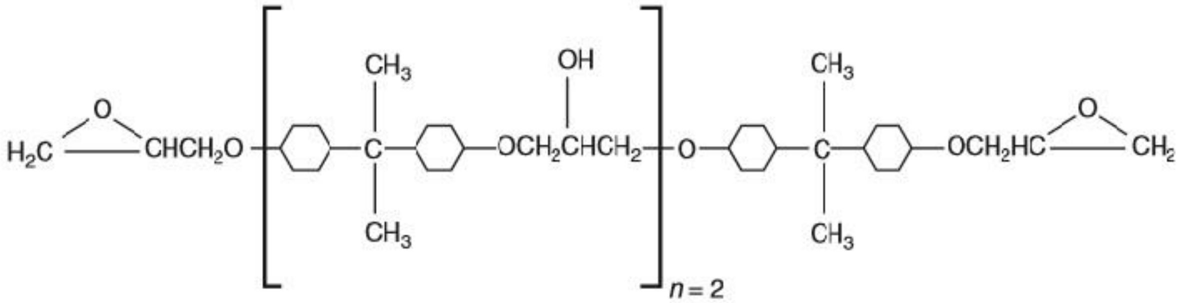

Figure 10 Molecule of DGEBA

The ingredients which are going to mix with this liquid were the diluents who's going to reduce it viscosity and flexibilizers to enhance the impact strength of the matrix. A molecule of DETA were show in Figure 11. Before the fiber were immersed in the matrix a small amount of reactive curing agent were added to transfer the liquid state to solid state. This curing agent is known as Diethylene triamine (DETA).

$$H_2N-(CH_2)_2-NH-(CH_2)_2-NH_2$$

Figure 11 Molecule of DETA

The amine group of DETA molecules of hydrogen atoms were going to react with the epoxide group of DGEBA molecules. The reaction of DETA and Epoxy were shows in figure 12.

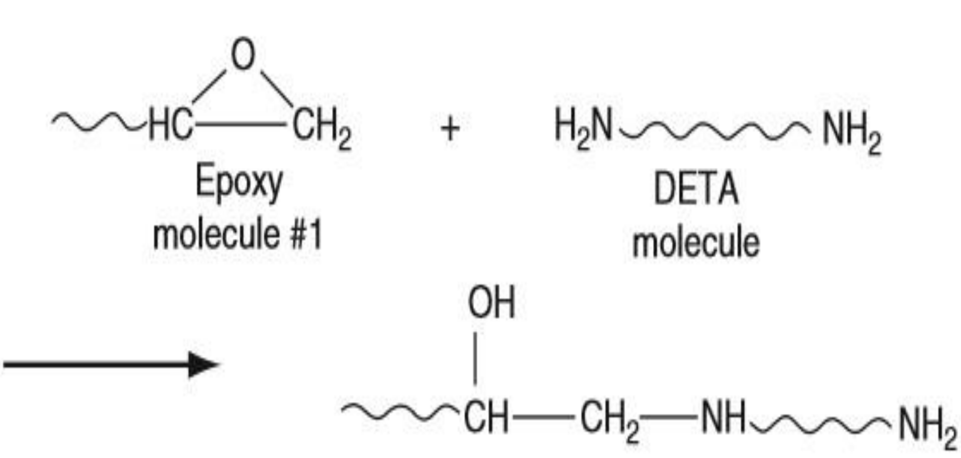

Figure 12 Reaction of DETA and epoxy

When the reaction were going to continue the molecules were formed a cross link with each other. The formation of cross link between molecule were shown in figure 13

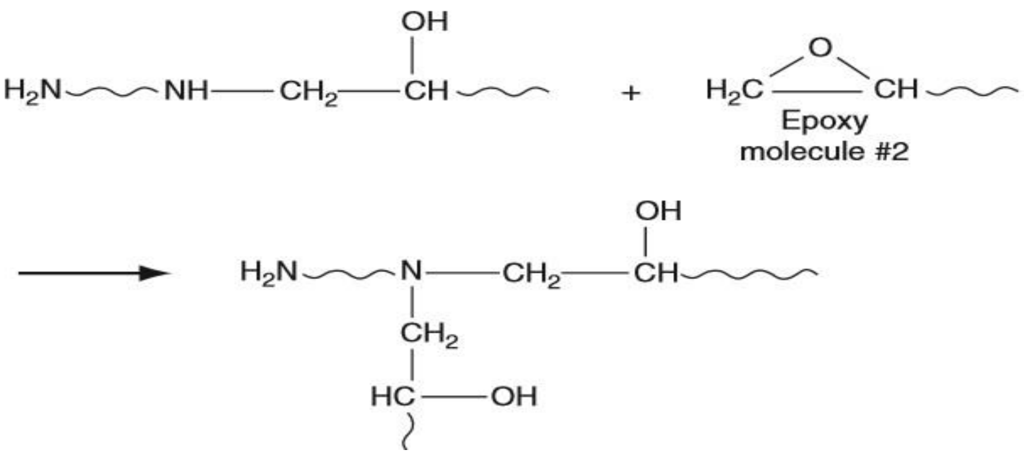

Figure 13 Crosslink formation

Finally the structure of the solid epoxy polymers were formed. The structure of solid epoxy polymer were shown in figure 14.

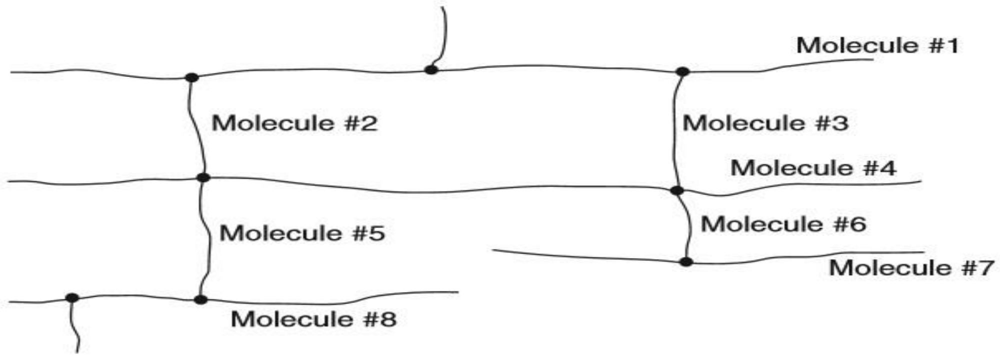

Figure 14 Structure of solid epoxy

There are many other epoxy resins with having different curing agent were also going to use in the industries. When the chemistry of the resins were going to change we get an advanced epoxy which reduce the moisture absorption problem. We can also reduce the curing time by adding the catalyst on the matrix which act as an accelerator of the reaction. As the addition of the accelerator done on the matrix, the bonding between the fiber and the matrix rapidly occur. The use of epoxy resin as matrix for making the composites through Hand lay-up were easy in the research field.

CHAPTER- II

SCOPE OF THE STUDY

The scope of the present work were derived from the literature survey

i. To reduce the vehicle weight slightly by replacing some parts of metal components with carbon fiber reinforce polymer composites material for increase the fuel efficiency.
ii. The rapid depletion of fossil fuel pull the whole attention of the researcher towards the advanced composites material.
iii. According to the application, the property of the composites material can be enhanced by combining two or more material.
iv. In the present technological century the use of iron ore, steel etc. going to decrease because of the limited properties found in it.
v. The technological development can take place only by the modification of material property.
vi. The orientation of the fiber also plays an important in the mechanical properties of the composites material.
vii. Tensile strength and flexural strength were observed by changing the orientation of fiber.
viii. Hand lay-up process were carried out for making the composites of desired shape and size.
ix. According to ASTM D3039 and ASTM D790 the sample were prepared.
x. Firstly the tensile strength and flexural strength of the single layer of the carbon fiber reinforced polymer composites were investigate with orientation of the fiber (0°,30°,45°,60°&90°).
xi. Then increasing the volume fraction of the fiber means doubling the layer of the carbon fiber were observed.
xii. The comparison of the mechanical properties were shown by the help of graph between the orientation of the fiber as well as fiber volume fraction (V_f).
xiii. The stress-strain curve were drawn to investigate the mechanical properties by the help of these relation.
xiv. Finally which orientation has the maximum tensile strength that is maximum load can be bare from the composite were going to analyse.

CHAPTER -III

OBJECTIVES OF THE STUDY

Objective of my present work have been derived on the basis of comprehensive literature survey:

i. The main aim of my research work is to make an advanced composite material which has the high tensile strength and high flexural strength.

ii. These objectives has drawn an attention to choose the fiber and the matrix in such a way that, it has a good thermal resistance and also water resistance when exposed to environment.

iii. The study of natural fiber and thermoplastic polymer limits the opportunity because of hygroscopic in nature and huge amount of cost is involved.

iv. Carbon fiber were chosen as a fiber because of their good strength & thermal resistance and the matrix were epoxies which resist to water absorption come under thermosets polymer.

v. A lot of research has taken place on the carbon fiber by combining with polymer matrix to improve the mechanical property till now.

vi. While doing the literature survey the point strikes that the orientation of the fiber also effect the mechanical properties.

vii. Next objective was to prepare a sample (specimen) with three different orientation to analyse the mechanical properties.

viii. The layer of the fiber were also play an important role for the strength of the material.

ix. The comparison of mechanical properties of the composite were done and investigate which orientation is having high strength.

x. The composites material properties show vice-versa in nature which means increase one property lead to decrease the other property.

xi. Experimental work were performed to make a carbon fiber reinforced polymer composites.

xii. The results of the experimental work were going to compare with the other research paper for the evaluation.

CHAPTER- IV

SURVEY OF LITERATURE

[Patel and Patel](1993), the researcher detailed about the effect of tetrafunctional epoxy resins on the mechanical properties of the carbon fiber reinforced polymer. Two epoxy resins were going to use for the fabrication of carbon fiber epoxy composites and the comparison takes place. The specimen were made according to ASTM d standard. The mechanical properties were going to be investigated based on the different epoxy resins. The result shows that the tetra functional epoxy resins have a good impact on the flexural and inter laminar shear strength of the composites.

[Mujika et al](2002)**,** the research explained about the woven carbon fiber epoxy composites demands were increased in the research areas and the industries because of ease of manufacturing. Two different epoxy were used with the filler known as polysulfone. The sample were made according to ASTM d standard through vacuum technique. The effect of polysulfone were going to analyse when the mechanical properties were investigated. Flexural test and fracture toughness of mode-I and mode-II were going to be tested. Both the matrix use for making the woven carbon fiber were going to compare them with itself.

[Giovedi et al] (2005), the literature survey of the paper inform that the adhesion between the fiber and the matrix play an important role for the mechanical properties of the composites. In this paper two different types of carbon fiber were taken to observe the adhesion parameter. The effect of the EB irradiation were analyse on the specimen. The fiber were previously irradiated for resins impregnated specimens. The sample were made according to ASTM D4018 and ASTM E83 for testing specimen. The tensile strength and surface of the fiber were going to analyse. The observation shows that the effect of the EB irradiation modified the surface finishing or to improve the adhesion between the fiber and the matrix.

[Han-ki yoon](2007)**,** the researcher explained about the effect of the fiber orientation and the volume fraction for hybrid composites. The combination of the two reinforcement was Carbon Fiber Reinforced Polymer (CFRP) and the metal. Three orientation of the fiber were taken based on the experiment0°,45°&90°. The sample were made according to ASTM d standard. Two important mechanical were going to be investigated. Tensile strength and Fatigue life of the composites. The results shows that the tensile strength were decreases on 0°-90°

combination when CFRP ratio increased. But not in case of45°. Fatigue life was less as compared to both the cases when the ratio of CFRP was more.

[Naito et al](2008), a comparative study of the ultrahigh tensile strength PAN based, ultrahigh modulus pitch based and high ductility pitch based carbon fiber were done to investigate its mechanical properties like tensile strength and fracture toughness. The sample were prepared with specific dimension according to ASTM D3379. The tensile strength of the sample were done through UTM and the fracture strength were taken place by SEM. The stress-train relation were shown and the curves were drawn by comparing it. The Weibull statistical distribution were compared with itself and the result were shown that ultrahigh modulus pitch based carbon fiber has the lowest Weibull modulus than high ductility pitch based carbon fiber.

[F.H. et al](2008), the aim of the research paper was to find out the volume fraction of the fiber form the composites material. Two different types of fiber were chosen to find out the separate volume fraction. One was the glass fiber and the other was carbon fiber and compare them itself. The sample were made according to ASTM d standard with filament winding method. The physical properties and the volume fraction were going to find separately for each fiber. Because the volume fraction was also one of the important parameter for enhancing the mechanical properties. Filler were not used in this composites because it reduce the mechanical properties but increase the fir resistance. The result shows that the volume fraction of the glass fiber was less as compared to carbon fiber.

[Okabe et al](2010), explained his work how the numerical simulation and the sizing of the fiber effect the tensile strength of the unidirectional CFRP composites. The carbon fiber used as reinforcement was T300 and the epoxy was Bisphenol-A Epoxy resins having a curing agent. The sample were prepared with the desired shape and size with different orientation of the fiber (0°, 30°, 45°, 60° & 90°) for testing the mechanical properties. The sample were made according to ASTM d standard. The Weibull of Weibull model consider for the data which comes through experimental work. The constitutive law of the epoxy were also going to be calculated.

[Coban et al](2010), the researcher explained about the use of carbon fiber reinforced polymer because of their important mechanical properties. In this research paper one of the important parameter were going to evaluate was viscoelastic properties which were going to be effected by the orientation of the fiber on thermal cycles. The sample were made according to ASTM d standard while maintaining the orientation of the fiber. The changes of the temperature from middle range to transition were going to absorb the effect of thermal cycles. DMA results were gave a detailed description about the viscoelastic properties how the thermal cycles were effected when the temperature changes based on the orientation of the fiber.

[Marinucci et al] (2010), the researcher inform how the orientation of the fiber effect the mechanical properties of the composites. The composites manufactured here was angle ply composites by filament winding. The fiber used here was T300 and the matrix were epoxy resins. The specimens were made according to specific dimension of ASTM D3039. Testing of the sample informed that the slight changes of the orientation having low angle shows a good tensile strength then the orientation having high angle. Tensile test were going to investigate in which stress-strain curve, modulus of elasticity, poison ratio and tensile strength were observed. As the orientation of the fiber increase to high angle60°,70° and 80° the tensile strength were going to decrease.

[Banakar and shivananda] (2012), the effect of the orientation of the fiber were going to analyse by the researcher into his work. Three different orientation of the fiber were going to come under his work that was,30°,45°&90°. The laminated carbon fiber reinforced polymer composites were obtained. Epoxy resins of standard brand were going to take as matrix. The sample were made according to ASTM d standard through Hand lay-up. The mechanical properties were going to analyse by observing the orientation of the fiber. Tensile test and flexural test were done on UTM and the graphs were drawn to identify the other properties based on this test.

[Gururaja and Harirao](2013), the benefits of the hybrid composites drawn a researcher attraction to combine the advanced composites material such as carbon fiber and the glass fiber with three different orientation to obtain the required properties of the composites. The sample were made according to ASTM d standard through vacuum bagging technique. The specimen were made with three different orientation combination0°/90°, 45°/45° & 30°/60° having two combination of fiber into epoxy resins. Mechanical properties were going to investigate and compare them. Fracture surface of the fiber were also going to analyse. The result shows that in the combination of 0°/90° the carbon fiber were arranged as 0° and the glass fiber arranged as 90° because glass fiber has brittle in nature in this orientation and the mechanical strength were better as compare to other combination.

[Duleba et al](2014), the study of this research paper conclude the carbon fiber as reinforcement play an important role in the automobile industries with the matrix Bisphenol-A epoxy resins as fillers. Because of wrap and weave different types of bond were created and this different types of fabrics bonds were also compared with each other. The sample were prepared with three layer of carbon fiber orientation as (0°-45°-0°). With including this carbon nanotube were added to improve the mechanical strength of the composites. The simulation were also done for the composites to analyse the difference between experimental and simulation results. To simulate the composites in orthotropic material three properties were known: Young's Modulus, Poisson ratio and shear modulus in (x, y and z) axis.

[Rahmani et al](2014), the aim of the researcher was to enhance a good strength composites materials by fixing a fiber & matrix ratio 40:60 with including the orientation of the fiber 0°, 35°, 45°, & 90° and the number of laminate. The binder of the fiber was Epoxy resins of araldite. The sample were made through hand layup according to ASTM D638, ASTM D790 & ASTM D256. The researcher were analyse the effect of mechanical properties by changing the orientation of the fiber. In this three mechanical properties were going to compare with the other composites was tensile strength, flexural strength and the impact strength. Through SEM fracture surface were also going to analyse according to number of fiber ply. One of the interesting things were come out that there is a slight difference between the five ply and three ply composite in tensile and flexural testing.

[Poyyathappan et al](2014), the researcher explained about the combining of two fiber for enhancing the mechanical properties. A use of single fiber have a specific properties which can be failure in some application but the hybrid composite give a good mechanical properties. A combination of glass fiber and carbon fiber into a one matrix were going to take place. The sample were made according to ASTM d standard through hand lay-up having the specific ratio of both the fiber and the matrix. The orientation of the fiber were also consider while making the specimen 0°&90°. The mechanical properties were going to investigate both the effect the orientation of the fiber and also the hybrid one. The results shows that the flexural strength of the hybrid composites were better as compared to GFRP composites but the cyclic loading seems to be less effected.

[Gunaslun et al](2014), the comparison of the fiber reinforced polymer were going to analyse in this research work. The research work said that the FRP has laminated strength in the field of concrete structure. The use of the FRP were also going to take place by replacing the concrete in construction area. The name of the fiber observed by seeing the strength like carbon fiber, glass fiber etc. the mechanical properties were going to compare with the other to replace them. The pull out test and the laminated strength were analysed by the laboratory to check the bonding strength and the load bearing capacity by using in the place of concrete.

[Kumar et al] (2014), one of the very important parameter were going to consider which effect the mechanical properties was the thickness of the composites with the variation of the orientation. In this research hybrid composite were going to analyse of two different glass fiber and the carbon fiber having a polymer epoxy resins. The sample were made according to the ASTM d standard through hand lay-up. The sample were made with two different thickness having the orientation of the fiber. The mechanical properties were going to investigate like tensile test and flexural test. The results shows that while increasing the thickness of the composites leads to increase the tensile strength, elongation percentage but decrease the flexural strength and flexural modulus.

[Agarwal et al](2014), the researcher explained his work based on the volume fraction of the fiber. In this paper bidirectional and short carbon fiber reinforced polymer composites were taken. Five different ratio of fiber were taken for their analysis. The sample were made according to ASTM d standard through hand lay-up. The mechanical and thermo-mechanical properties were going to be investigated based on the volume fraction of the fiber. The mechanical properties were going to increase with increasing the fiber ratio except inter laminar shear strength. A comparison were also done on long and short fiber.

[Senthil and Sountharararasu](2015), a comparative study would have taken place between the glass fiber and carbon fiber with and without the effect of orientation of the fiber. The polymer were taken as the epoxy resins. The sample were made according to ASTM d standard through hand lay-up. While making the specimen were made with two different fiber individually with without the orientation of the fiber. The mechanical properties were going to investigate separately to observe the effect. The results shows that the two different fiber has two different properties according to application. Firstly the comparison were consider between the orientations of the fiber, $90°$orientation were shown good strength as compared to$30°$ & $45°$. Secondly the $90°$orientation of the carbon fiber epoxy resins had good strength than $90°$ orientation of the glass fiber.

[Jagannatha and Harish](2015), the selection of the particular fiber having a specific properties were going to be enhanced by combining the two fiber into one matrix to get required properties known as hybrid composites. These conclusion come when the required properties were not going to match the application. The hybrid composites were made according to ASTM d standard through vacuum bagging technique having the different ratio of both the fiber and the matrix. The mechanical properties were going to investigate like tensile strength, hardness, tensile modulus & peak load and compare them. The objective of the research work was to show that as contain of the fiber increases into the composites the mechanical properties were going to enhanced.

[Vikram et al] (2015), the researcher explained his work that the carbon fiber reinforced polymer composites were majorly accepted in the field of automobile, aeronautical and the industries of sports and goods. The polymer used here was the epoxy resins of araldite. The sample were made according to ASTM d standard having three different ratio of fiber and matrix through vacuum bag technique. The mechanical as well as the thermal properties were going to be investigated. The result shows that the fiber contain up-to 5 % were going to enhance the mechanical properties. As the fiber contain going to increase to 7 % the mechanical properties were going to reduce as compared to 3% and 5%. The contained of fiber play an important role for the flexural test, tensile test and thermal analysis.

[Saravanan and vetrivel] (2016), in this research work the author combined the carbon fiber and the glass fiber with the epoxy resins as matrix to enhance the mechanical properties as hybrid composites. These two fiber has the different proportion of mixing one matrix. The sample were made according to ASTM D standard to analyse the mechanical properties. The sample were made through vacuum bagging technique with three laminates. The first sample has both the end as carbon fiber and the middle one as glass fiber, the second one has both the end as glass fiber and the middle one as carbon fiber and the third one was carbon fiber then glass and continued with the thickness of 5mm. The mechanical properties which were going to investigate was flexural strength, impact strength and ultimate tensile strength. The results shows that the mechanical properties increases with contain of carbon fiber increases.

[Jeoung et al](2016), in this paper a researcher wants to explain that carbon fiber reinforced polymer were going to replace by the metallic material. The binder of the fiber were going to used here was epoxy resins. The sample were prepared through Vacuum Assisted Resins Transfer Moulding (VARTM) to avoid the bubbles appear on the composites. The orientation of the fiber and the loading axis were observed in this research. The orientation of the fiber were going to change to get maximum strength of the composites.

Tensile strength and fracture shape were investigated based on the orientation of the fiber and the loading axis. By analysing the results CFRP engine hood were made and also drop test were done to show good energy absorption.

[Li et al](2016), the researcher drawn a conclusion that the use of carbon fiber were taken because of their high strength and good thermal & mechanical properties. The experimental as well as the simulation of the composites were conducted. The material used for the experiment was Carbon Fiber, Bisphenol-A Epoxy resins and Curing agent. The sample preparation were done by using Weibull of Weibull model. A hexagonal shaped of composites were made. The tensile testing were performed with different angle in the simulation. Numerical simulation were performed and then compare them with the FEM. The Tensile test and fracture were investigated based on Fiber volume fraction. The main aims of this research was to calculate the tensile strength of different angle with different epoxy and compare the result with each other and the simulation were also indicate the results.

[D.R and Y.S](2016), the researcher inform about the parameter of mechanical properties through which fiber reinforced polymer composites were depend. The parameters which effect the mechanical properties of the composite were fiber orientation, volume fraction of the fiber, type of the fiber, physical properties and the interfacial adhesion between the fiber and the matrix. Tensile strength were shown on the basis of this parameter. According to orientation of the fiber 0°shows the best strength, according to fiber content up-to certain range the strength was good if the fiber content increases the strength was decreases, according to physical properties means the standard specification of the sample were made and the last was interfacial adhesion which were depend the fiber and the matrix bond to improve the mechanical properties. These were analyse between the matrix Epoxy resins and the fiber contain glass.

[Shimamoto et al] (2016), the objective of the researcher was to enhance the mechanical properties of the short carbon fiber and to investigate its fiber orientation. The sample were prepared with two different ratio of the epoxy resins, curing agent and the carbon fiber. The first preparation were contain 20% of carbon fiber and the second one contain 40% of carbon fiber. The orientation of the short carbon fiber were preperg through extrusion technique. The comparison of the flexural strength were done between the oriented fiber and the random orientation of the fiber. The result shows that the orientation of the short fiber from 0° to 10° have double flexural strength than random fiber oriented. The orientation were indicated by plasticity of the composites and the elasticity of the composites indicate the random orientation.

[Wang et al](2016), the effect of the temperature and the orientation of the fiber were going to analyse the long carbon fiber reinforced polymer composites on the mechanical properties. Two different ratio of the carbon fiber were contained in the composites. The sample were made according to ASTM d standard through extrusion compression moulding having the orientation 0°and90°. Mechanical properties were going to investigates with the effect of two different temperature. The results shows that as the temperature increases from medium to glass transition the mechanical properties were going to reduce. While comparing with respect to the orientation, 90° orientation has the more effect of temperature than 0° orientation of the sample.

[Schoberl et al](2016), this research explained about how the slight changes in the orientation of the fiber effect the strength of the material. The role played by the orientation of the fiber for carbon fiber reinforced polymer according to application played an important part. To get the exact orientation of the fiber a polarization light was going to be used. The reflected polarization light were going to be connected by the camera which capture the reflection of light and indicate the orientation of the fiber. The reflection of the polarized light played an important role to inform the exact location of the orientation.

[Solomon et al] (2017), survey of the research paper explained about the mixing ratio of the fiber and the matrix contained in it. In this paper carbon fiber chosen as the fiber and the matrix was epoxy resins araldite. The sample were made according to ASTM d standard through vacuum bagging technique. The specimen were made with three different ratio of epoxy and carbon fiber for analysing the mechanical properties. Tensile strength, flexural strength and hardness of the composites were investigated.

[Ma et al](2017), this research include the comparison between the thermoplastic and thermosetting polymer composites. In this unidirectional (UD) carbon fiber were taken with two different types of matrix such as Polyamide (PA) and Epoxy resins. The sample were prepared according to ASTM d3039 tested on the Universal Testing Machine (UTM) with two different orientation 0˚ and 90˚ to analyse the tensile strength. Both transverse and longitudinal tensile strength were analysed. The mechanical properties were investigated according to fiber distribution, interfacial shear strength and impregnation condition. Through scanning electron microscopy (SEM) fracture surface were analysed. Single fiber pull out test and fiber volume fraction (V_f) by microscopic observation were also analysed. All the mechanical properties were investigated and compare them.

CHAPTER- V

MATERIALS AND METHODOLOGY

5.1 Equipment

Measuring Jar: In this jar epoxy resins and hardener were pour and mix so that the matrix were prepared well before making the specimen.

Stir: Stir are going to use for the mixing of epoxy resins and hardener properly, so that the mixture of hardener and epoxy resins will be uniform throughout the solution.

Weight Measuring Device: By using this devices the weight percent of epoxy resins and hardener were measured. According to the specific ratio, these two were taken.

Stick: Stick is going to use when the matrix were poured on the mould and the carbon fiber were compressed by it so that wettability of the matrix and the fiber get properly.

Scissor: Scissor is used to cut the Carbon Fiber with different orientation and according to the dimension of mould.

Mould: A mould were with frame board in the carpentry shop Block 55-A Room No-102 by using the equipment available in this shop. A mould has a specific dimension according to the ASTM D standard.

Brush: A brush is going to use for spreading the epoxy resins uniformly under the mould and over the fiber.

Universal Testing Machine (UTM): UTM is going to measure the mechanical properties of my composites material. This equipment were available in Block 55-A, Room No-102, Strength of Material (SOM) lab in Lovely Professional University. This is also known as universal tester. In this I am going to test tensile strength of my materials. To test in UTM we have to make the sample according to standard specification.

5.2 Material

The materials we are going to use for my research work is Carbon Fibre, Epoxies & Hardener and releasing agent.

Carbon Fiber

A long and continuous CF were obtained from Hindoostan composites solution Pvt Ltd. Having a brand name HinFab with the product code HCU302 which was Uni Directional Woven Carbon Fabric.

Figure 15 Image of Carbon Fibre Fabric

Specification of carbon fiber

The specification of the uni directional woven carbon fabric were shown in table 1. Based on the specification of the product were going to sell. To buy the carbon fabric we need to know the specification. It is the general term used in the market.

Table 1 Specification of carbon fiber

Characteristics	Specifications	Tolerance	Test Method
Areal weight (g/m^2)	300	3%	ASTM D3801
Width* (mm)	500	-0/+10mm	ASTM D3774
Dry fabric thickness(mm)	0.32	0.03mm	ASTM D1777

Properties of carbon fiber

The properties of the fiber means the characteristic of the fiber. It is important to know because by observing it we can clarify the physical properties. By using this properties we can calculate the mechanical properties. The mechanical properties were depend based on the fabric properties. The fabric properties were tabulated in table 2.

Table 2 Properties of carbon fiber

Density (g/cm^3)	1.8
Filament diameter (µm)	7
Tensile strength (MPa)	4000
Tensile modulus (GPa)	240
Elongation (%)	1.7
Sizing	Epoxy compatible

Epoxy and Hardener

A multi-purpose low shrinkage epoxy resins Araldite AW 106 contain Bisphenol-A Epoxy Resins which cure at room temperature with Hardener HV 953 were obtained from Huntsman Pvt Ltd. ARALDITE is the name of the brand and the product code is AW 106 & HV 935.

Figure 16 Image of Epoxy and Hardener

Data sheets of epoxy resins

The data provided for getting the information about the characteristic of epoxy resins and hardener. The data sheet were available on the net according to the product brand and code. These sheets were let us know about the individual and the combined information about the epoxy resins and the matrix. The explanation of data were tabulated on table 3

Table 3 Product Data of Araldite AW106 & Hardener HV 953

Characteristics	Araldite AW 106	Hardener HV 953	Mix
Colour (visual)	Neutral	pale yellow	pale yellow
Specific gravity	ca. 1.15	ca. 0.95	ca. 1.05
Viscosity at 25°C (Pas)	30-50	20-35	30-45
Shell life (2-40°C)	3 years	3 years	-

Properties of epoxy resins and hardener

The properties of the epoxy resins and hardener were give an information about the physical characteristics of the matrix. The properties were tabulated on table 4. According to the information provided we can calculate the mechanical properties of the composites material.

Table 4 Properties of Epoxy resins & Hardener

Boiling point	>200°C
Vapour pressure	<0.1 Pa at 20° C
Density	1.15g/cm^3
Miscibility with water	Immiscible at 20℃
Young's Modulous	1900 N/mm^2

Releasing agent

Heavy duty Silicone carbide spray was going to use as a releasing agent. It is mainly used for the purpose of not allowing to stick the mould and the samples. It act as a resisting agent for sticking any kinds of plastic material.

5.3 Experimental setup

A hand lay-up process is used for making the sample of CFRP composites. The equipment and the material discussed above was act as the whole setup for my research work. The whole of the work were done inside the Lovely Campus under the guidance of my mentor.

5.4 Research Methodology

To prepare a composites material the following steps are considered

a) Mould
b) Hand lay-up process
c) Sample preparation
d) Testing

Mould:

i. To prepare a specimen of composites material for our research work we use to make a mold first.
ii. To make a mould we are going to use a wooden cardboard which is used for making a frame.
iii. For tensile testing mould are going to make according to ASTM d3039 standard.
iv. The mould have a specific dimension of 165 x 13 x 2 mm shows in figure 17.
v. For flexural testing mould are going to make according to ASTM d790 standard.
vi. The mould have a specific dimension of 127 x 13 x 4 mm shows in figure 18.

Figure 17 Mould for tensile test

Figure 18 Mould for flexural test

Hand layup process

i. Hand layup process is the simplest process to produce a composites of desired shape and size.
ii. To prepare a sample of desired sized we use a mold.
iii. The uni-directional Carbon Fibers cut with different orientation according to the specific size with respect to mould before performing the experiment.
iv. A releasing agent were going to spray on the mould properly so that the sample were not stick on the mould.
v. The Jar would kept clean and dry where the epoxy and hardener were pour in it.
vi. A weight measuring device is used for taking epoxy and hardener of ratio 80:20.
vii. A stir is used for mixing the epoxy and hardener uniformly.
viii. After mixing the matrix were poured inside the mould.
ix. Then the piece of Carbon Fiber were kept and with the help of stick the fiber were pressed for wettability.
x. The extra matrix were removed with the help of stick.
xi. Now leave the specimen of the room temperature for a week to solidify properly and the images were shown in the figure19.

Figure 19 Images of specimen with mould

Sample preparation:

i. After going for the hand layup process the sample were ready to take out from the mould.
ii. The sample were stick on the wood which create a problem for separating the specimen and the mould.
iii. To separate them a carpentry lab were used in 55A-302 for using the equipment available there.
iv. With the help of chisel, hammer, file and cutter the specimen were taken out properly.
v. A little careless would damage the sample and break it.
vi. At the end a cutter is used to cut the unwanted area of composites to get desired shape and the images of the sample were shown in figure 20.

Figure 20 Images of Specimen for test

Testing

i. The testing of the specimen after achieving the standard size and shape were done in Lovely Professional University.
ii. Universal Testing Machines (UTM) was going to use for testing the mechanical properties, tensile test with the images were shown in figure 21 and flexural test with the images were shown in figure 22.

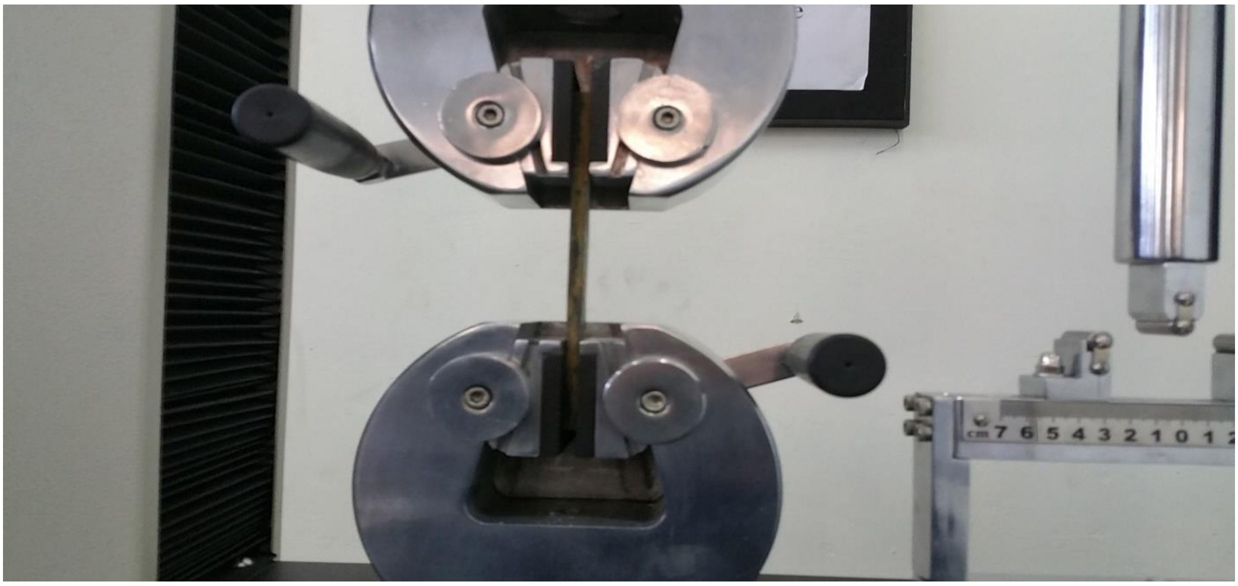

Figure 21 Images of Specimen Mounted for Tensile test

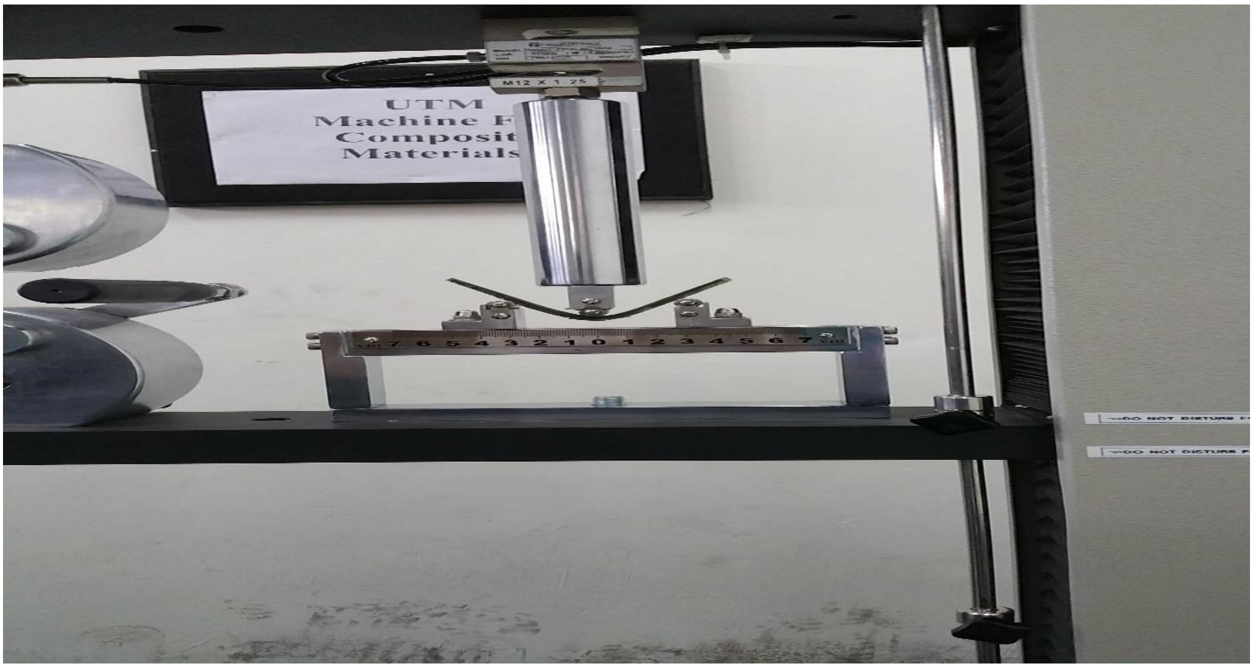

Figure 22 Images of Specimen Mounted for Flexural test

5.5 Proposed work plan with timelines

The thesis of my work would have been represented on the gantt chart. This chart contain the information of the task and at what time period the task would have been done. The representation of my work according to timeline have shown in the figure 23.

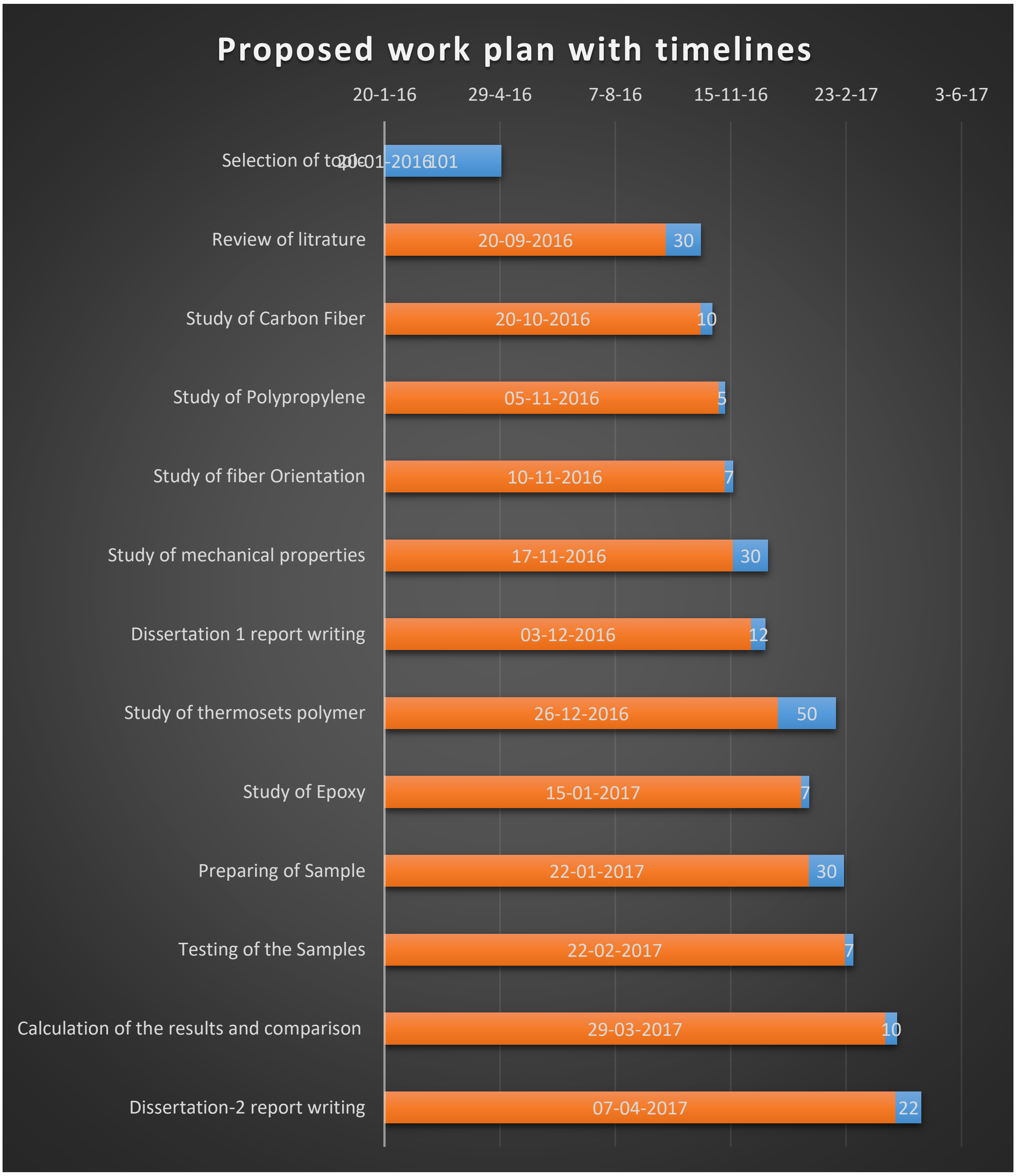

Figure 23 Proposed work plan with timeline

5.6 Experimental work

The experimental work were performed based on the literature survey because while doing the survey of the research paper information about the parameter would have come out which were going to effect the mechanical properties. Four parameter were going to consider in my thesis work. They are orientation of the fiber, choosing of the polymer, thickness of the sample and volume fraction of the fiber. The first parameter was the orientation of the fiber and the loading axis which really shows the variation of the mechanical properties based on the orientation of the fiber. The second parameter was to choose the polymer which were going to use as the matrix. Though it won't bear the load but it transfer the load to the reinforcement and act as the binding material for the reinforcement. Different polymer has the different binding strength which improve the mechanical properties. The third parameter was the thickness of the composites material because the mechanical properties were also depend on the thickness of the specimen. Tensile strength and the flexural strength of the sample were also depend on the thickness of the composites materials. Finally the volume fraction of the fiber were also played an important role to enhance the mechanical properties because content of fiber in the composites increase the mechanical properties.

The orientation of the fiber were going to maintain by cutting the unidirectional fiber with the different angle (0°,30°,45°,60°&90°). To choose the appropriate polymer was a difficult task. While choosing the polymer we are going to consider their characteristic which effect the mechanical properties. To maintain the thickness of the composites was also a difficult task because the thickness of the composites was depend on the depth of the mould. Within the fixed depth of the mould the fiber and the matrix were going to be mixed has difficult task. To maintain the volume fraction of the fiber some of the following steps were going to take

i. Make a neat sample means make a sample of epoxy resins only according to ASTM d standard.
ii. Weight the neat sample in the measuring device and note down the weight.
iii. Then make a sample by combining matrix and fiber which act as composites and measure the weight.
iv. The difference of the neat and the composites were going to be noted down.
v. This difference were going to tell us the weight of the fiber.
vi. OR cut the fiber according to the specific dimension of the mould and put it into the measuring device.
vii. This tell us the weight of the fiber directly.

viii. Then apply the volume fraction of the formulae to calculate the fiber volume of the composites.

After maintaining the four parameter the composites start making. The sample were prepared according to ASTM d standard through hand lay-up. Through hand layup the desired dimension of the specimen were going to obtain. A step down process were shown in the figure 24, for performing the experimental work.

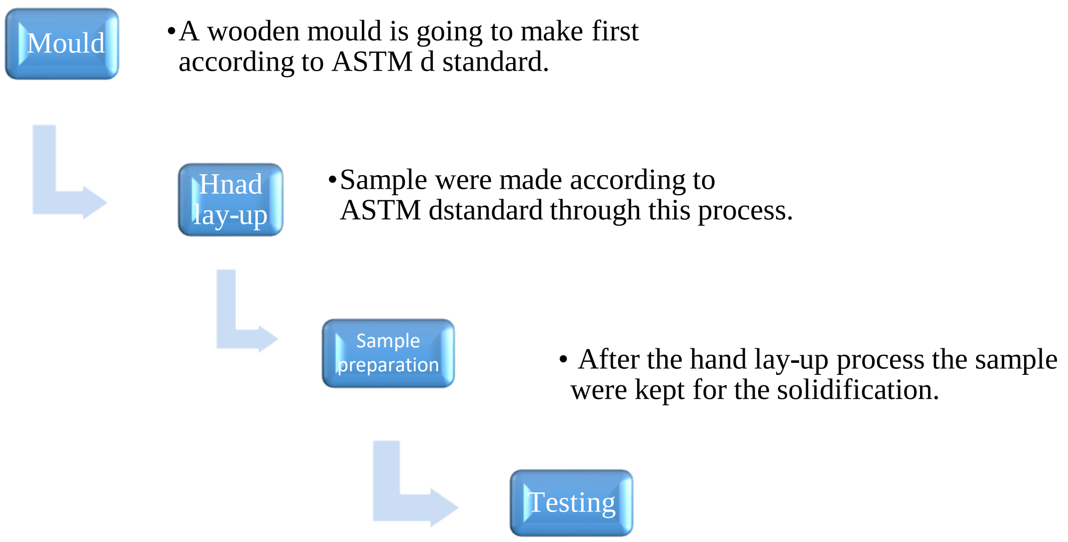

Figure 24 Step down process

The sample were prepared for tensile testing while maintaining the orientation of the fiber, thickness of the sample and the volume fraction of the fiber. There were five different orientation of the fiber (0°,30°,45°,60°&90°) were going to maintain. The thickness of the sample were 2 mm. Two different ways of the fiber and the matrix were taken single layer and double layer. The images of the sample were show in the figure 25.

Figure 25 Images of specimen before tensile test

The sample were going to mount on the UTM machines between the two clamps. One clamp is fixed and the other clamp is moveable. Then the tensile load was applied on the specimen. The breaking of the specimen were shown in the figure. The gauge length were maintained between the clamps by moving it and the data of the specimen were going to inter through the computer.

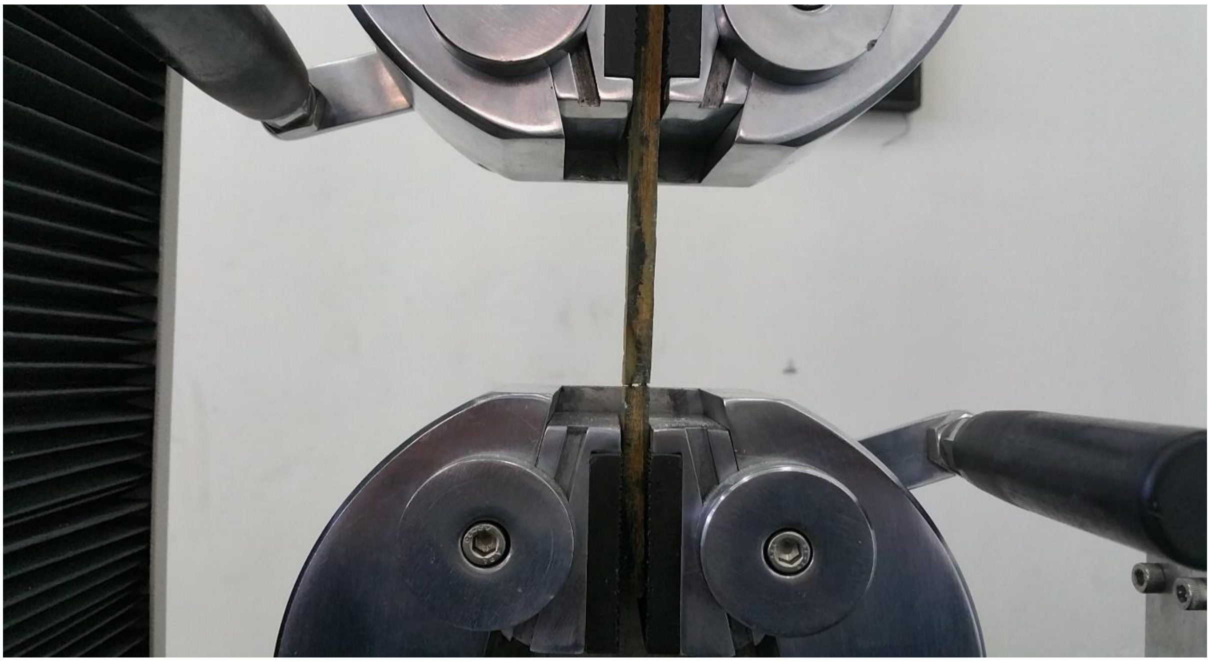

Figure 26 Images of specimen after tensile test on UTM

The single layer of carbon fiber tensile test were tested on the UTM machines according to ASTM d3309. The layer of the fiber and the matrix were single. The breakage of the specimen were shows in the figure. The orientation of the fiber were also going to maintain.

Figure 27 Images of specimen for single layer carbon fiber after tensile test

The double layer of carbon fiber tensile test were tested on the UTM machines according to ASTM d3309. The layer of the fiber were double. The breakage of the specimen were shows in the figure. The orientation of the fiber were also going to maintain.

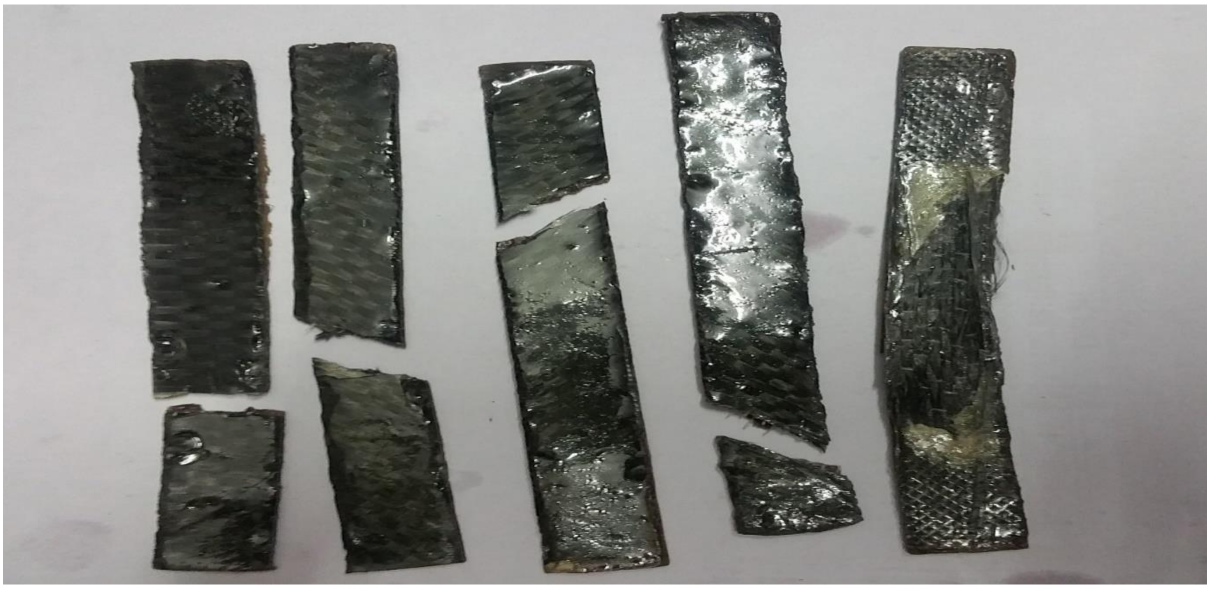

Figure 28 Images of specimen for double layer carbon fiber after tensile test

The sample were prepared for flexural testing according to ASTM d790 while maintaining the orientation of the fiber, thickness of the sample and the volume fraction of the fiber. There were five different orientation of the fiber (0°,30°,45°,60°&90°) were going to maintain. The thickness of the sample were 3 mm. Two different ways of the fiber and the matrix were taken single layer and double layer. The images of the sample were show in the figure 28.

Figure 29 Images of specimen before flexural test

The sample were going to keep on the UTM machines of the two points. The load was applied on the third point. The breaking of the specimen were shown in the figure. The length between the two point was fixed on which the specimen were placed. The data of the specimen were going to inter through the computer manually and the load speed were also inter.

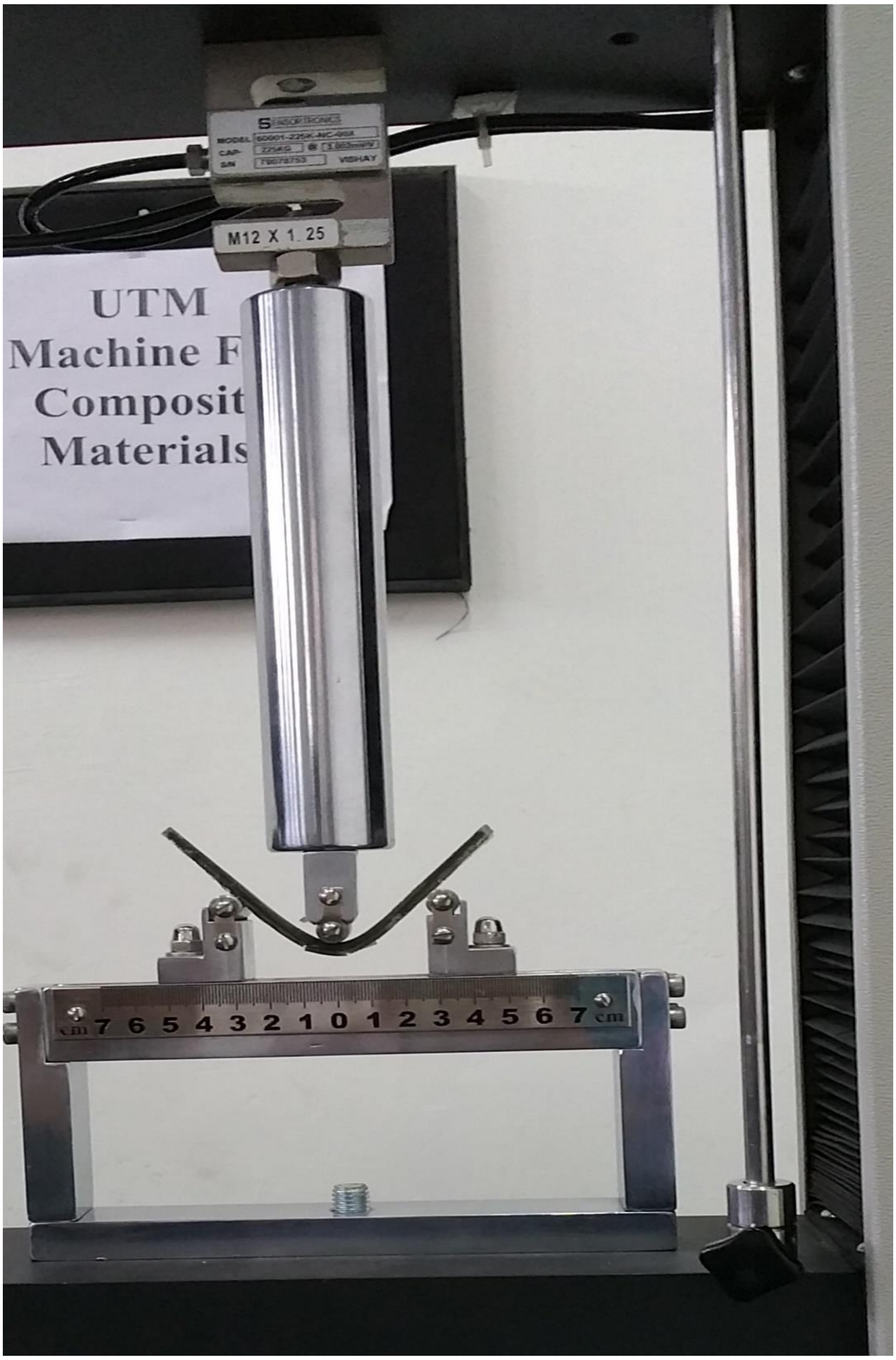

Figure 30 Images of specimen after flexural test on UTM

The single layer of carbon fiber flexural test were tested on the UTM machines according to ASTM d790. The layer of the fiber were double. The breakage of the specimen were shows in the figure. The orientation of the fiber were also going to maintain.

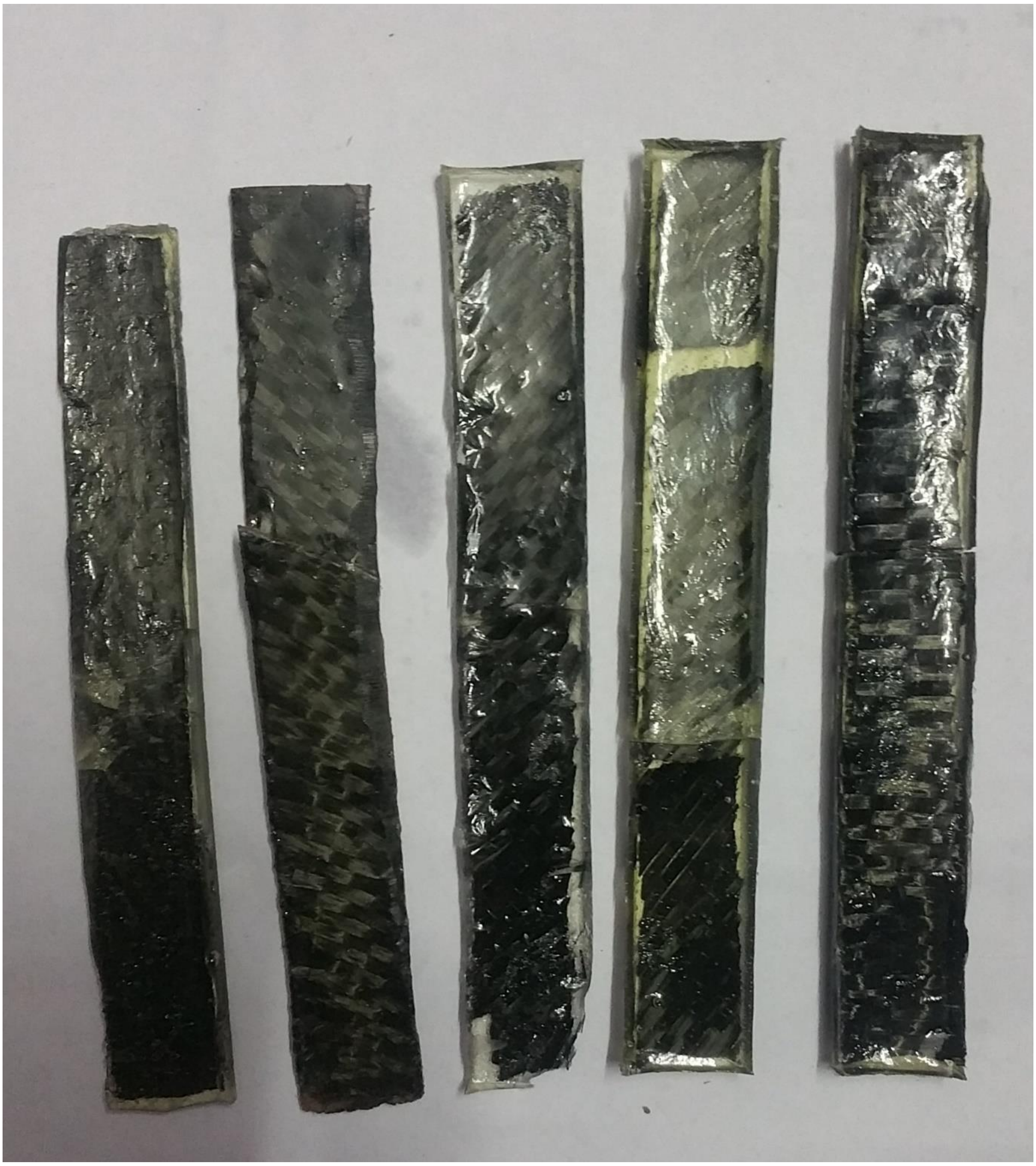

Figure 31 Image of specimen single layer carbon fiber after flexural test

The double layer of carbon fiber flexural test were tested on the UTM machines according to ASTM d790. The layer of the fiber were double. The breakage of the specimen were shows in the figure. The orientation of the fiber were also going to maintain.

Figure 32 Image of specimen double layer carbon fiber after flexural test

CHAPTER-VI

RESULTS AND DISCUSSION

The results of my research work were on the graph. The evaluation of the composites material tensile test and flexural test on the UTM machines were done inside the lovely Professional University campus itself. The stress-strain graph and the load-displacement graph were obtained from the UTM machine. The values of the strength, young's modulus, peak load, break load and the elongation were also obtained from the graph generated. The variation of the mechanical properties were shown based on the orientation of the fiber and the fiber content in it.

The comparison of the tensile test between the single layer of CFRP and double layer of CFRP were done based on the orientation of the fiber. The tensile strength results were compare between the single and double layer CFRP. In this tension load were applied on the specimen to evaluate the resistance of breaking material.

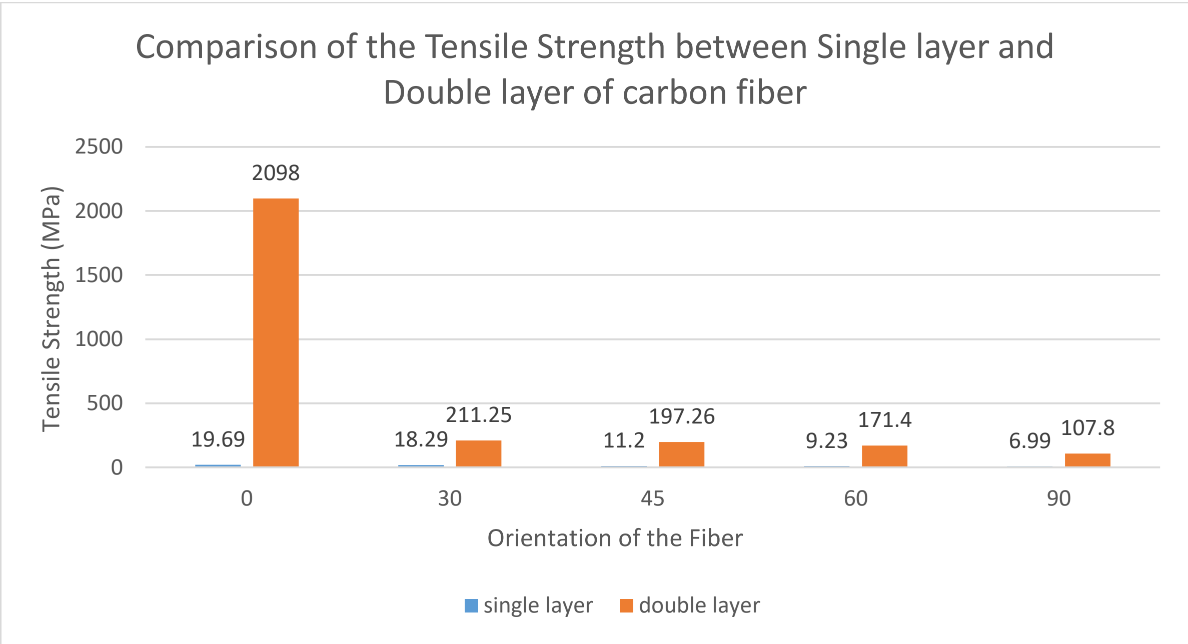

Figure 33 Comparison of composites tensile strength

The young's modulus results were compare between the single and double layer CFRP. The young's modulus of the composites material were calculated through the ratio of stress and strain. This property also deals with the stiffness of material.

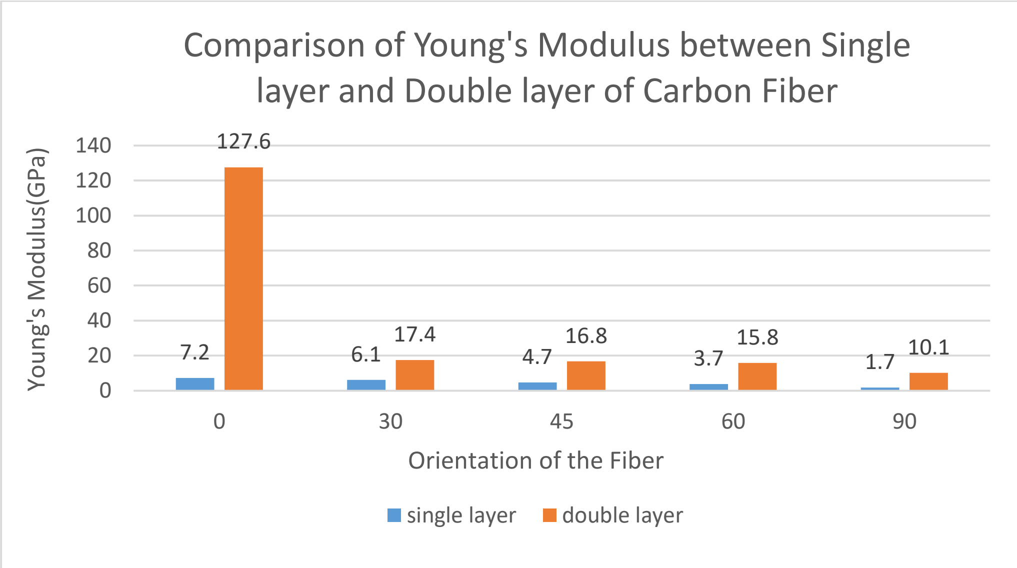

Figure 34 Comparison of composites young's modulus

The breaking load results were compare between the single and double layer CFRP. This properties tell us the maximum load to which a material is going to break.

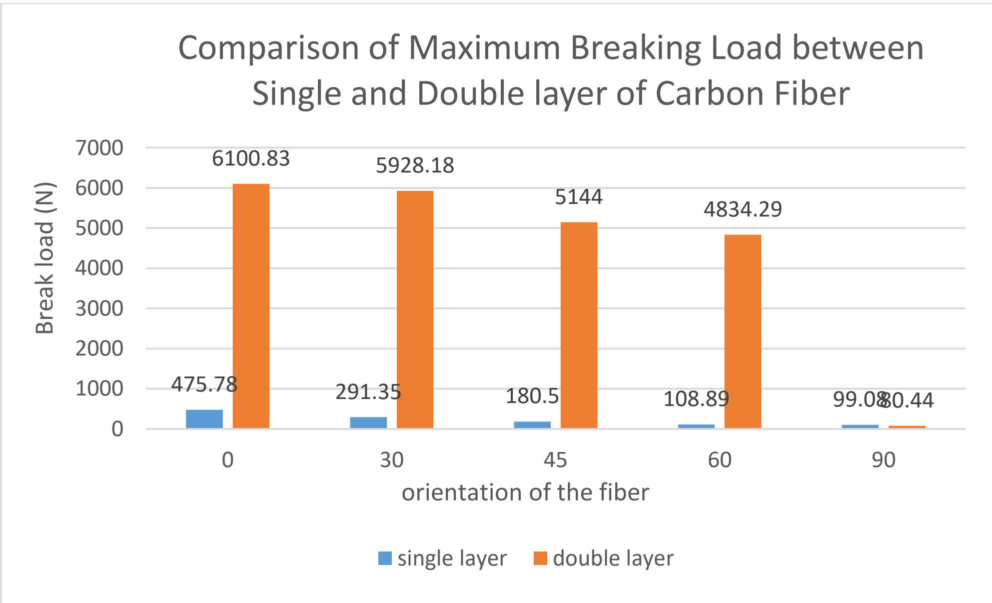

Figure 35 Comparison of composites maximum breaking load

The elongation results were compare between the single and double layer CFRP. This properties tell us the elongation of the material before necking.

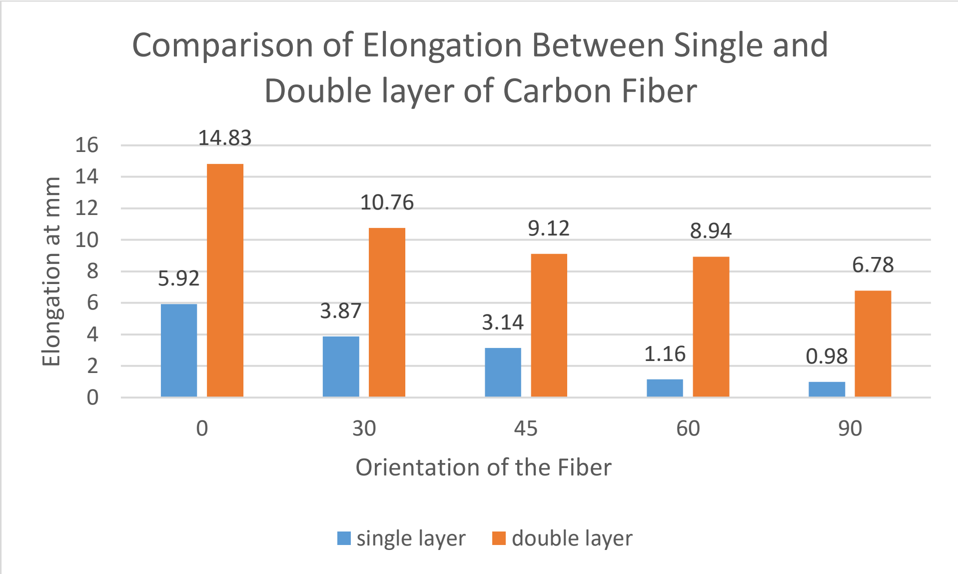

Figure 36 Comparison of composites elongation

The peak load results were compare between the single and double layer CFRP. This properties tell us the maximum load bear by the material at yield point.

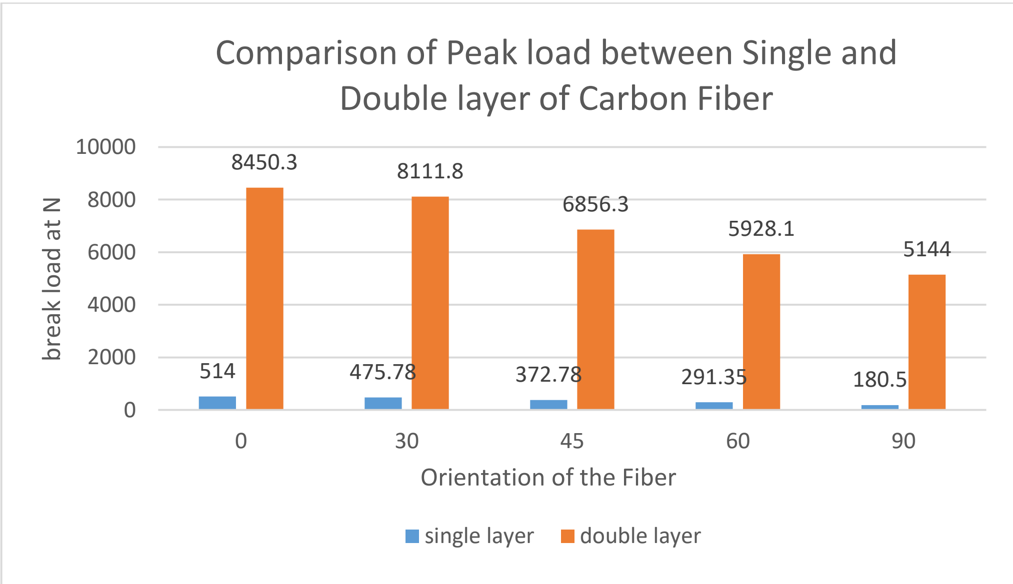

Figure 37 Comparison of composites peak load

The comparison of the flexural properties between the single layer of CFRP and double layer of CFRP were done based on the orientation of the fiber. The results of flexural strength were compare between the single and double layer of CFRP. In this the load were applied on the specimen to evaluate the resistance of bending properties.

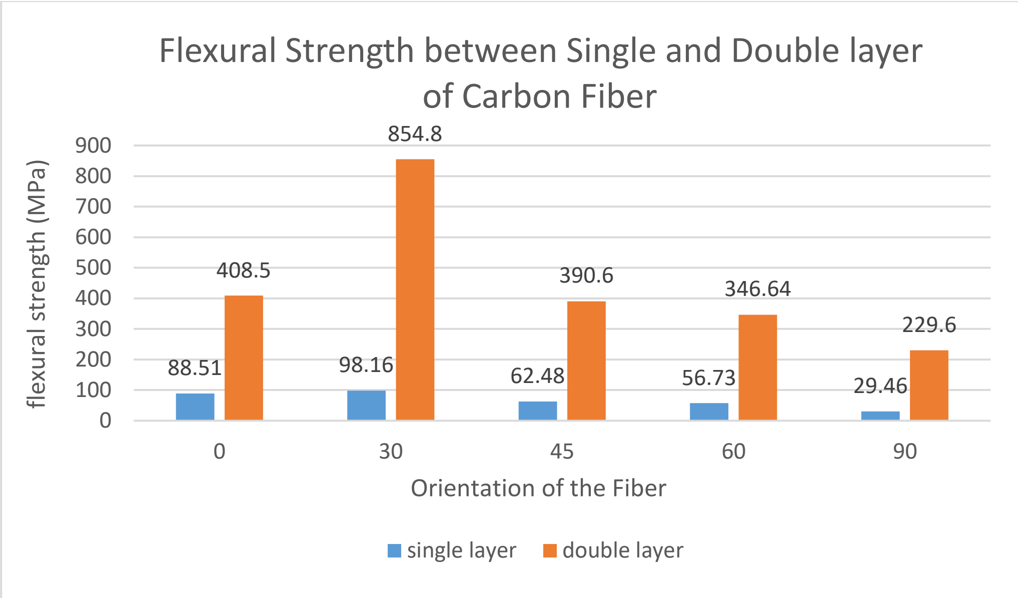

Figure 38 Comparison of composites flexural strength

The results of young’s modulus were compare between the single and double layer of CFRP. The young’s modulus of the composites material were calculated through the ratio of stress and strain. This property also deals with the stiffness of material.

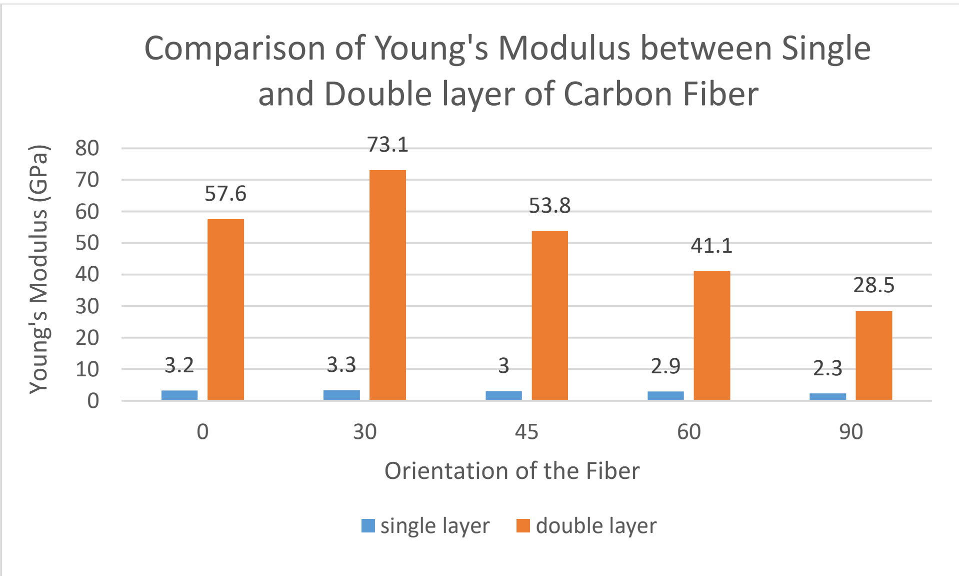

Figure 39 Comparison of composites flexural young’s modulus

The results of peak load were compare between the single and double layer of CFRP. This properties tell us the maximum load bear by the material at yield point.

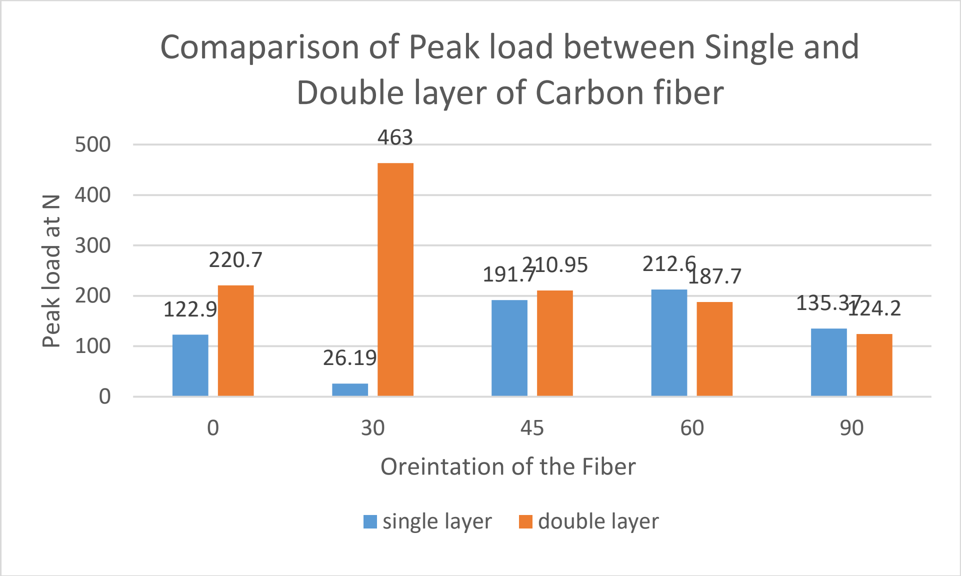

Figure 40 comparison of composites flexural peak load

The results of deflection at peak load were compare between the single and double layer of CFRP. This properties tell us the deflection of the at yield point.

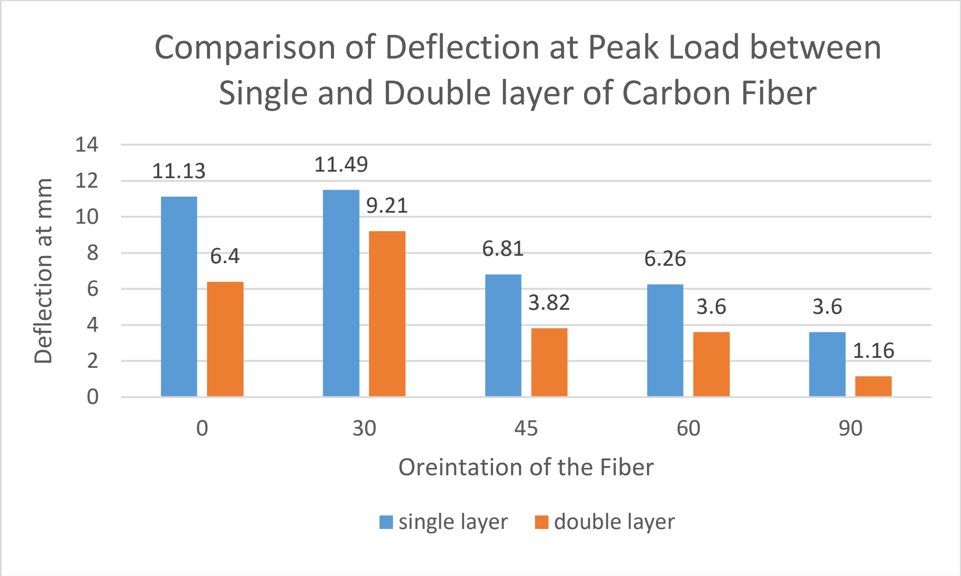

Figure 41 Comparisons of composites deflection at peak load

CHAPTER-VII

EXPECTED OUTCOME

The outcome of the research work shown in the tabulated form. The variation of the outcome were shows the effect of the fiber orientation and the fiber content in it.

The results of the mechanical properties for tensile test of single layer carbon fiber reinforced polymer composites were shown in table 5.

Table 5 Tabulated results for tensile test of single layer CFRP

Orientation (degree)	Break load (N)	Tensile strength (MPa)	Extension (mm)	Load at Yield Point (N)	Young's Modulus (GPa)
0	475.78	19.69	5.92	514	7.2
30	291.35	18.29	3.87	475.78	6.1
45	180.5	11.2	3.14	372.78	4.7
60	108.89	9.23	1.61	291.35	3.7
90	99.08	6.99	0.98	180.5	1.7

The results of the mechanical properties for tensile test of double layer of carbon fiber reinforced polymer composites were shown in table 6.

Table 6 Tabulated results for tensile test of double layer CFRP

Orientation (degree)	Break load (N)	Tensile strength (MPa)	Extension (mm)	Load at Yield Point (N)	Young's Modulus (GPa)
0	6100.83	2098	14.83	8450.3	127.6
30	5928.18	211.25	10.76	8111.8	17.4
45	5144	171.4	9.12	6856.2	16.8
60	4834.29	148.2	8.94	5928.18	15.8
90	80.44	107	6.78	5144	10.1

The results of the mechanical properties for flexural test of single layer of carbon fiber reinforced polymer composites were shown in table 7.

Table 7 Tabulated results for Flexural test of single layer CFRP

Orientation (Degree)	Deflection at peak (mm)	Flexural strength (MPa)	Peak load (N)	Young's Modulus (GPa)
0	11.13	88.51	191.7	3.2
30	11.49	98.16	212.6	3.3
45	6.81	62.48	135.37	3
60	6.26	56.73	122.91	2.9
90	3.6	29.46	26.19	2.3

The results of the mechanical properties for flexural test of double layer of carbon fiber reinforced polymer composites were shown in table 8.

Table 8 Tabulated results for Flexural test of double layer CFRP

Orientation (Degree)	Deflection at peak (mm)	Flexural strength (MPa)	Peak load (N)	Young's Modulus (GPa)
0	6.41	408.5	220.7	57.6
30	9.21	854.82	463	73.1
45	3.8	390.28	210.95	53.8
60	3.6	346.64	187.7	41.1
90	1.61	229.6	124.2	28.5

The comparison of the results from the experiment performed by us was done through the research paper Marinucci et al. The researcher calculated the tensile strength, young's modulus and poison ratio. Two of the properties, tensile strength and young's modulus were going to compare with my results. A little difference were shown when the comparison of both the results were taken place. To validate our results a previous research paper were consider.

Table 9 Comparisons of the mechanical properties

Orientation of the fiber (Degree)	Tensile strength Marinucci et al (2010) (MPa)	Young's modulus Marinucci et al (2010) (GPa)	Tensile strength of our results (MPa)	Young's Modulus of our results (GPa)
0	2509	153	2098	127
30	292	34	211	16.8
60	83	10.9	171.4	15.8
90	73	10.5	107.8	10.1

CHAPTER-VIII

SUMMARY AND CONCLUSION

i. The thesis work were performed based on the literature survey because while doing the survey of the research paper we get the information about the increasing demands of carbon fiber reinforced epoxy resins composites in automobile industries, aircrafts industries and sports good.

ii. The use of thermoset polymer as a matrix increased because of their mechanical and thermo-mechanical properties and to ease of making the composites through hand lay-up.

iii. The hand lay-up process was use in my research work which contain four steps to make a composites, first make a wooden mould then use the technique which can be easily make a composites which required a time for sample to preparation and finishing the sample according to the need.

iv. The specimen were made based on the orientation of the fiber and the ratio of fiber and matrix.

v. Two different test were done on the UTM that is tensile test and flexural test and the mechanical properties of both the testing were shown through this test.

vi. Tensile test shows the strength of the composites were going to decrease as the orientation of the fiber increased because the loading orientation was same but the fiber orientation were going to change.

vii. In case of flexural test results show the orientation of the fiber having $30°$ shows good strength as compared to other orientation of other the composites.

viii. By tensile testing of the results the orientation of the $0°$ double layer carbon fiber were preferred because of the good tensile strength and young' modulus of the composite.

ix. By flexural testing of the results the orientation of the $30°$ double layer of carbon fiber were preferred because of the good flexural strength and young's modulus of the composites.

x. The influence of orientation of the fiber and the loading axis plays an important role for tensile test and flexural test.

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