Analysis of Strength in Unidirectional GRPF Based Fiber Orientations under Static Loading Using ANSYS

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ABSTRACT

The Composite materials have found widespread applications in various fields of engineering such as aerospace, marine, automobile and mechanical applications. The strength of the composites are depends on two factors which are fiber orientation and length. In our project we are analyzing the effect of fiber orientation in a rectangular composite lamina under transverse static loading by using the finite element method. The results are obtained with the help of five different angle of orientation of GRPF/epoxy. For analysis ANSYS software were used. By comparing the results of five different orientations finally conclude the better one which will utilize full strength of the fiber composite. It is observed that the stress value is maximum of 14384 N/mm^2 while considered the boundary condition 2 at 30^0. Also the stress value is minimum of 412 N/mm^2 while considered boundary condition 4 at 45^0. It is also observed that displacement value is maximum of 125.409 mm while considered boundary condition 2 at 60^0. From the result it is observed that the orientation at 30^0 with boundary condition 2 is safe while comparing other boundary conditions.

Keywords: Glass reinforced plastic fiber, Epoxy, Stress, ANSYS.

1. INTRODUCTION

1.1 Composite Material and Its Constituents

Composites are a combination of two or more constituent materials with significantly different physical or chemical properties. The performance of composites is superior to their constituent materials acting alone. The characteristics of resultant composite material are totally different from the individual constituents and unique. Within the composite, the different materials are apart and they do not dissolve or blend into each other.

In composites a distinct reinforcement is distributed in a matrix or binder or resin. The matrix material surrounds the reinforcement materials. Here the strength and stiffness of load bearing fibers are imparted to matrices to provide a good combination of strength and toughness of the resultant composite material. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation, and protects them from In this chapter the composite materials, history of composites and its constituents were discussed.

environmental damages due to elevated temperatures and humidity.

Fillers are added to reduce the cost and increase the modulus. They also reduce the mould shrinkage and control viscosity. They provide smooth surface to composite produced. Also toughness, colorants, flame retardants, ultraviolet absorbers, coupling agents, lubricants, heat stabilizers, and forming agents may also be added to the matrices..

1.1.1 Fillers and other additives

Fillers are added to a polymer matrix to reduce the cost (as fillers are less expensive than most of the resins) and to increase the modulus. They produce smooth surface. They control viscosity and reduce mould shrinkage during fabrication. But the problem is they tend to reduce its strength and impact resistance. The most common filler for polyester and vinyl ester resins is calcium carbonate ($CaCO_3$), which is used to reduce cost as well as mold shrinkage. Examples of other fillers are clay, mica, and glass micro spheres (solid as well as hollow).

Also toughness, colorants, flame retardants, ultraviolet absorbers, coupling agents, lubricants, heat stabilizers, and forming agents may also be added to the matrices. Coupling agents act as compatibilizers between the hydrophilic fibers and the hydrophobic polymers and improve the bond between materials by different ways; that is by eliminating weak boundary layers, by producing tough, deformable layers, by developing a highly cross-linked interphone region with an intermediate modulus, by improving the wettability (critical surface tension factor), by forming covalent bonds with both materials, and by altering surface acidity.

1.1.2 Matrix and its types

The high strength of composites is largely due to the fiber reinforcement. But the importance of matrix material cannot be underestimated. Matrix provides support for the fibers and assists the fibers in carrying the loads. It also provides stability to the composite material.

It keeps the fibers in place. It transfers stresses between the fibers. It protects the surface of the fibers from mechanical degradation (e.g. by abrasion). It acts as a barrier against adverse environments, such as chemicals and moisture.

The matrix plays a minor role in the tensile load carrying capacity of a composite structure. However, selection of a matrix has a major influence on the compressive, inter laminar shear as well as in-plan e shear properties of the composite material. It also improves the impact and fracture resistance of a component.

It distributes the loads evenly between fibers so that all fibers are subjected to the same amount of strain. It carries interlinear shear. It helps to avoid propagation of crack growth through the fibers by providing alternate failure path along the interface between the fibers and the matrix.

The major types of matrix are metal matrix, ceramic matrix and polymer matrix. Accordingly composites are classified into metal matrix composite (MMC), ceramic matrix composite (CMC) and polymer matrix composite (PMC). Table 1.1 gives the applications of composites classified on the basis of the matrix used.

Following are the requirements of a good matrix material.

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

1.2 History of Composites

Throughout history, humans have used composite type materials. One of the earliest uses of composite material was by the ancient Mesopotamians around 3400 B.C., when they glued wood strips at different angles to create plywood.

Egyptians used of Car tonnage, layers of linen or papyrus soaked in plaster, for death masks dates to the 2181-2055 BC. Archeologists have found that natural composite building materials were in used in Egypt and Mesopotamia, since ancient builders and artisans used straw to reinforce mud bricks, pottery, and boats around 1500 BC.

Around 25 BC, “The Ten Books on Architecture” described concrete and distinguished various types of lime and mortars. Researchers have demonstrated that the cement described in the books is similar, and in some ways superior to the Portland cement used today.

Later, in 1200 AD, in Mongolia, using a combination of wood, bone, and “animal glue,” bows were pressed and wrapped with birch bark. These bows were extremely powerful and extremely accurate. Composite Mongolian bows provided Genghis Khan with military dominance, and because of the composite technology, this weapon was the most powerful weapon on earth until the invention of gunpowder.

From the 1870’s through the 1890’s, a reVolution was occurring in chemistry. Polymerization allowed new synthetic resins to be transformed from a liquid to solid state in a cross-linked molecular structure. Early synthetic resins included celluloid, melamine and Bakelite. Laminated composites were developed in 1920 from cellulose paper or fabric. They were being impregnated with phenol and were available for machining into cams and gears and bearings.

Engineered composites were reported to be introduced in 1940's where glass fiber was used as reinforcement of polymers.

During that period, majority of resins used include epoxy and polyester. components, glass fiber reinforced polyester composites were developed by Owen-Corning.

In 1960's , carbon fiber was used as a reinforcement material for making components used in aero space materials and for making sport goods. Here performance was given more priority than the cost. This was the beginning of the development of advanced composite materials.

1.3 Superior Characteristics of Composite Materials Over Other Materials

Majority of the composite materials provide a combination of strength and modulus that are either comparable to or better than many traditional metallic counterparts. Owing to their low density, the strength–weight ratios and modulus– weight ratios of these composite materials are superior to most of the other known metals. Fatigue strength as well as fatigue damage tolerance of many composite laminates are extremely good and because of this reason there are emerged as an important class of structural materials and found applications in aerospace, military, marine automotive industry. They are useful for making sporting goods and even have bio-medical applications.

Fiber-reinforced composites are not isotropic in nature. This non isotropic nature of a fiber -reinforced composite material creates a unique opportunity of tailoring its properties according to the design requirements. This design flexibility can be used to selectively reinforce a structure in the directions of major stresses, increase its stiffness in a preferred direction, and fabricate curved panels.

The use of fiber -reinforced polymer as the skin material and a light weight core, provides another degree of design flexibility that is not easily achievable with metals. Most fiber-reinforced composites are elastic in their tensile stress–strain characteristics. Most of the composite structures may exhibit a better dimensional stability over a wide temperature range as their coefficient of thermal expansion is much lower than that for metals.

High internal damping is another desirable advantage of composites. This leads to better vibrational energy absorption within the material and results in reduced transmission of noise and vibrations to neighboring structures. High damping capacity of composite materials is beneficial in many automotive applications as noise, vibration, and harshness are key issues for passenger comfort in automobiles. High damping capacity is also useful in many sporting goods applications.

The conventional manufacturing processes used for other materials like metals can't be used for the fabrication of composite materials. They require significantly less energy and lower pressure or force than the manufacturing processes used for metals. Parts integration and net-shape or near net-shape manufacturing processes are also great advantages of using fiber-reinforced polymers.

1.4 Major Applications of Composite Materials

Composite materials have been accepted as structural, semi and non-structural applications in many industries and they still have bright future in more demanding applications. A brief review of applications follows.

1.4.1 Marine applications

Glass fiber-reinforced polyesters have been used in different types of boats. All recreational boats are constructed of either glass fiber-reinforced polyester or glass fiber-reinforced vinyl ester resin. The use of composites in naval ships started in the 1950's and has grown steadily They are used in hulls, decks, bulkheads, masts, propulsion shafts, rudders and others of mine hunters, frigates, destroyers and aircraft carriers.

1.4.2 Aerospace and military applications

The major structural applications for fiber-reinforced composites are in the field of military and commercial aircrafts. Weight reduction is very critical for higher speeds and at increased payloads and is accomplished by the usage of composite materials. With the introduction of carbon fibers in the 1970's, carbon fiber-reinforced epoxy has become the primary material in many wing, fuselage, and empennage components The structural integrity and durability of these early components have built up confidence in their performance and prompted developments of other structural aircraft components, resulting in an increasing amount of composites being used in military aircrafts.

1.4.3 Space applications

Weight reduction is the primary reason for using fiber-reinforced composites in many space vehicles. Among the various applications in the structure of space shuttles are the mid-fuselage truss structure, payload bay door (sandwich laminate of carbon fiber-reinforced epoxy face sheets and aluminum honeycomb core), remote manipulator arm (ultrahigh-modulus carbon fiber-reinforced epoxy tube), and pressure vessels (Kevlar 49 fiber-reinforced epoxy).

Fiber-reinforced polymers are used for support structures for many smaller components, such as solar arrays, antennas, optical platforms. Carbon fiber-reinforced epoxy tubes are used in building truss structures for low earth orbit (LEO) satellites and interplanetary satellite.

1.4.4 Automotive applications

Applications of fiber-reinforced composites in the automotive industry can be classified into three groups: body components, chassis components and engine components.

Exterior body components, such as the hood or door panels, require high stiffness and damage tolerance (dent resistance) as well as a ‘‘Class A’’ surface finish for appearance. The composite material used for these components is E-glass fiber-reinforced sheet molding compound (SMC) composites. Among the chassis components, the first major structural application of fiber-reinforced composites is the Corvette rear leaf spring, introduced first in 1981.

Uni-leaf E-glass fiber-reinforced epoxy springs have been used to replace multi-leaf steel springs with as much as 80% weight reduction. Other structural chassis components, such as drive shafts and road wheels, have been successfully tested in laboratories and proving grounds.

The application of fiber-reinforced composites in engine components has not been as successful as the body and chassis components. Fatigue loads at very high temperatures pose the greatest challenge in these applications. Development of high-temperature polymers as well as metal matrix or ceramic matrix composites would greatly enhance the potential for composite usage in this area.

1.4.5 Sporting goods applications

Fiber- reinforced polymers are extensively used in making sporting goods. Tennis rackets, racket ball rackets, golf club shafts, fishing rods, bicycle frames, snow and water skis, ski poles, pole vault poles, hockey sticks, baseball bats, sail boats, kayaks oars, paddles canoe hulls, surfboards, snow boards, arrows ,archery bows, javelins, helmets, exercise equipment’s, athletic shoe soles and heels are a very few examples.

1.5 Merits of Composite Materials

- Composites generally have good resistance to corrosion.
- They generally increase mechanical damping.
- Increase in toughness.
- They have excellent fatigue strength.
- They are of low cost.
- They have good tensile strength.
- They have good resistance to fire.

2. RESULTS AND DISCUSSIONS

In this chapter, the modeling of the layer using ANSYS and the steps used to solve them were discussed and the results of boundary conditions were analyzed.

2.1 Modeling of Structure

To study influences of fiber orientation upon deflection and for different stresses. A laminated composite plate of dimension 200mm×100mm×1mm with a unidirectional cross section using the finite element analysis software.

Using pre-processor element the modeling of rectangular lamina in shell element was created. After created circular area and subject in the rectangular lamina looks like the following figure. After applying load it can be solved by using solution command prompt. Results can be displayed by using post processor and von-mises stress is plotted to show the maximum stress obtained.

Maximum stress is easily found out by using the ansys solve command. But it is difficult to estimate the stress directly from the results. For that stress gradient graph is developed by means of path operations. By using the path operations the stress is easily calculated.

5.2 Meshing Model

In this method, a body or structure in which the analysis is carried out is subdivided in to smaller elements of finite dimensions called finite elements. Then the body is considered as an assemblage of these elements connected at finite number of joints called nodes or nodal point. The meshed view of lamina plate is as shown in fig 5.2.

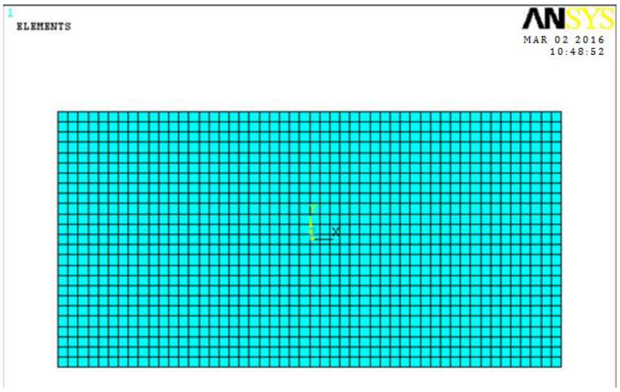

Fig 2.2 Meshed View of Lamina Plate

2.3 Solving Model

From fig 5.3 and 5.4 The properties of each type of finite element is obtained and assembled together and solved as whole to get solution.

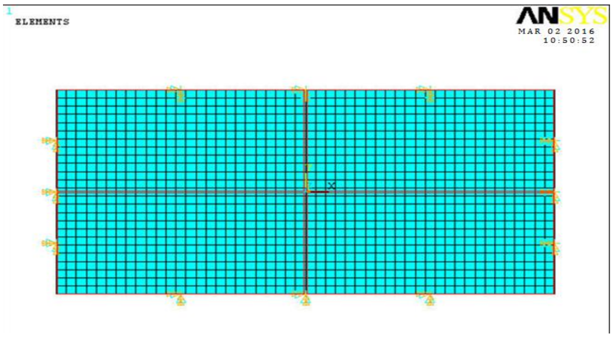

Fig 2.3 Solve the Lamina plate

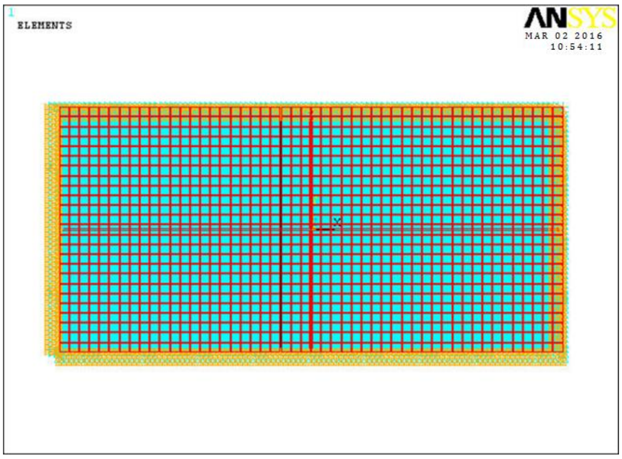

Fig 2.4 Solved Lamina Plate

The shear strength of the glass fibre/epoxy composite was quite sensitive to strain rate and the shear strength increased as strain rate increases.

a) GRPF /EPOXY STRESS RESULTS

The stress values of the lamina at different boundary conditions at different orientations are as shown in the Table 2.1.

BOUNDARY CONDITIONS	0 DEGREE	30 DEGREE	60 DEGREE	90 DEGREE
B1	624.372	679.378	677.546	628.382
B2	11874	14384	14284	11884
B3	692.412	623.521	625.521	698.842
B4	476.651	437.242	435.24	484.601

Table 5.1 Stress Result of GRPF/Epoxy

b) GRPF/EPOXY DISPLACEMENT RESULTS

The displacements values of the lamina at different boundary conditions at different orientations are shown in the Table 2.2.

Boundary Conditions	0 Degree	30 Degree	45 Degree	60 Degree	90 Degree
B1	0.469255	0.448734	0.438342	0.468734	0.475953
B2	79.751	115.409	120.875	125.409	81.851
B3	0.391136	0.37362	0.366702	0.35363	0.381146
B4	0.194586	0.117971	0.122807	0.11880	0.124586

Table 2.2 Displacement Result of GRPF/Epoxy

GRPF /EPOXY STRESS GRAPHS

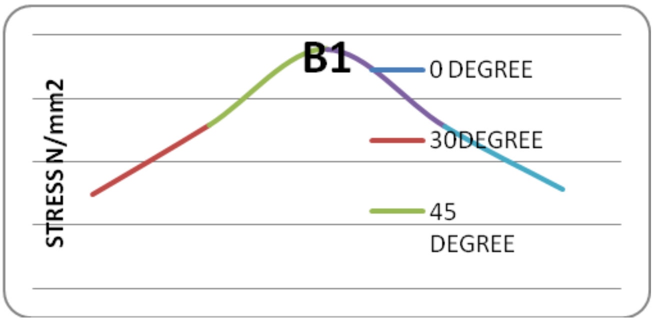

Fig 2.5 Stress graph for the Boundary Condition 1

The stress values of the composite at different orientation while considering the boundary condition 1 is shown in figure 2.5. It is observed that the while considering boundary condition 1 stress value is maximum at the fiber orientation of 45^0.

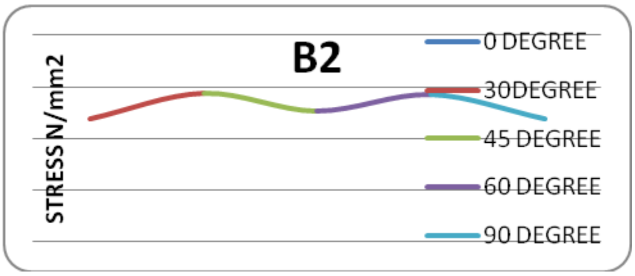

Fig 5.6 Stress graph for the Boundary Condition 2

The stress values of the composite at different orientation while considering the boundary condition 2 is shown in figure 5.6. It is observed that the while considering boundary condition 2 stress value is maximum at the fiber orientation of 30^0 and 60^0.

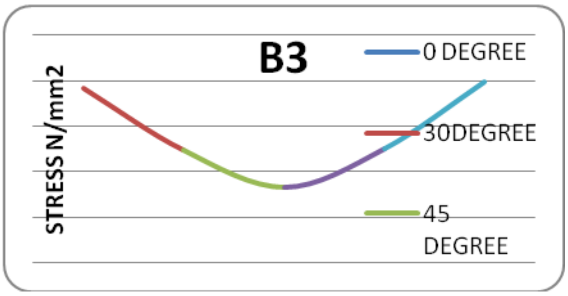

Fig 5.7 Stress graph for the Boundary Condition 3

The stress values of the composite at different orientation while considering the boundary condition 3 is shown in figure 5.7. It is observed that the while considering boundary condition 3 stress value is maximum at the fiber orientation of 0^0 and 90^0 and is very low at 45^0 orientation.

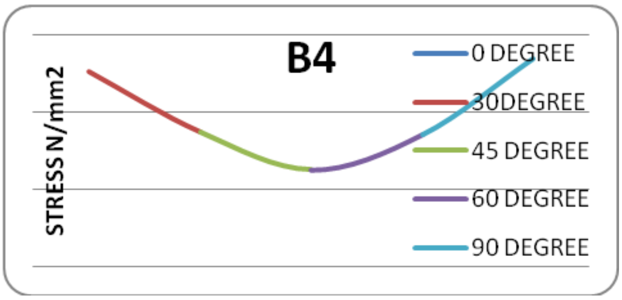

Fig 5.8 Stress graph for the Boundary Condition 4

The stress values of the composite at different orientation while considering the boundary condition 4 is shown in figure 5.8. It is observed that the while considering boundary condition 4 stress value is maximum at the fiber orientation of 0^0 and 90^0 and is very low at 45^0 orientation but gradually increase in 60 degree orientation lamina.

GRPF/EPOXY DISPLACEMENT GRAPHS

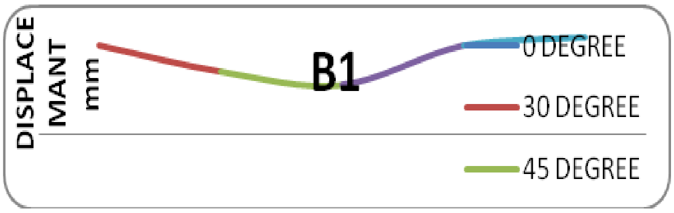

Fig 5.9 Displacement graph for the Boundary Condition 1

The displacement values of the composite at different orientation while considering te boundary condition 1 is shown in figure 5.9.

It is observed that the while considering boundary condition 1 displacement value is maximum at the fiber orientation of 0^0 and 90^0 and is very low at 45^0 orientation. It is observed that the lamina which is have 90^0 orientation have more displacement and it able to withstand more time compared to other orientations.

The displacement values of the composite at different orientation while considering te boundary condition 2 is shown in figure 5.10. It is observed that the while considering boundary condition 2 displacement value is maximum at the fiber orientation of 60^0 and is very low at 90^0 and 0^0 orientations. It is observed that the lamina which is have 60^0 orientation have more displacement and it able to withstand more time compared to other orientations.

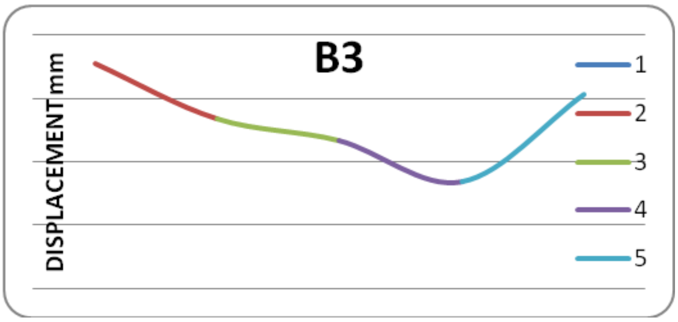

Fig 5.11 Displacement graph for the Boundary Condition 3

The displacement values of the composite at different orientation while considering te boundary condition 3 is shown in figure 5.11. It is observed that the while considering boundary condition 3 displacement value is maximum at the fiber orientation of 0^0 and 90^0 and is very low at 60^0 orientation. It is observed that the lamina which is have 0^0 orientation have more displacement and it able to withstand more time compared to other orientations.

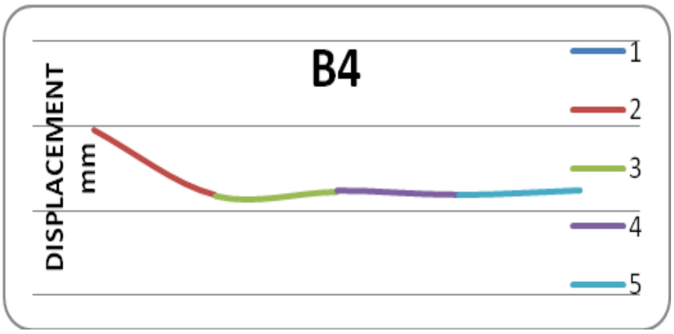

Fig 5.12 Displacement graph for the Boundary Condition 4

The displacement values of the composite at different orientation while considering te boundary condition 4 is shown in figure 5.12.

It is observed that the while considering boundary condition 4 displacement value is maximum at the fiber orientation of 0^0 and in other degree orientations it is almost same as shown above. It is observed that the lamina which is have 0^0 orientation have more displacement and it able to withstand more time compared to other orientations. The safe material tabulation for GRPF/epoxy composite is shown in table 5.3. And the analysis results are discussed below.

6. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

This experimental analysis of GRPF/epoxy based composites using ANSYS leads to the following conclusions

- Modeling of the composite lamina in ANSYS is possible.
- Analysis of the composite at different orientations is possible using ANSYS.
- The stress and displacement curves are obtained are analysed using ANSYS.
- It is observed that the stress value is maximum 14384 N/mm^2 while considered the boundary condition 2 at 30^0.
- Also the stress value is minimum 412 N/mm^2 while considered boundary condition 4 at 45^0.
- It is also observed that displacement value is maximum 125.409 mm while considered boundary condition 2 at 60^0.

From the result it is observed that the orientation at 30^0 with boundary condition 2 is safe while comparing other boundary conditions.

From this it is concluded that we can use the safe orientation for better performance. The default orientation of material is replaced by safe orientation are show above results.

6.2 Future Scope

- The influences of fiber-matrix interface debond on the behaviour of fiber reinforced composite lamina and considering the matrix material as elastoplastic, viscoplastic, elastoviscoplastic is the topic for future work.
- The composite is built ply's with different orientations are considered as future scope.
- The next step would be to study the interaction between two or more fibers, finding an expression for the optimal distance of the perturbed region that produces the bsest representation of the stress transfer between them. These topics will be discussed in future work.
- A major challenge relating to composite design is the availability of simulation tools and a lack of general composite material characterization, the commercial software developers have not yet solved this problem.
- Another issue is the computational time required to model composite structures and components. Current composite material models within commercial design software require very long solution times.
- The essential requirement is the development of the tools required for product design, simulation, manufacturing and regulation.
- Future scope of glass/epoxy and carbon/epoxy are mainly incorporating in specialized areas like aerospace, marine applications, space research etc.

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