A REVIEW ON THE EFFECT OF FIBER ORIENTATION ON THE STRENGTH OF CARBON/EPOXY LAMINATES

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Abstract: Due to the properties like high strength high modulus and low density, the demand for composite material is increasing day by day. Carbon fiber and glass fibers have been able to satisfy the needs of wide varieties of application and hence are used on a large scale in the composite world. Early study has shown that many mechanical parameters such as the type of fiber, the orientation of fiber, stacking sequence of the laminate, thickness, number of layers, affect the strength of ply laminates. Different laminate combinations can be manufactured by altering the above parameters to obtain laminates with different characteristics. This paper deals with the study of the effect of fiber orientation as well as stacking sequence on the strength of laminates having 0^o, 45^o, -45^o, 90^o fiber orientation. The aim is to find out the best suitable stacking sequence which gives the good strength of the laminate. Finite element analysis will be done of the laminates and then it will be tested experimentally on a UTM machine.

Index Terms **- ASTM, Carbon fiber, FEA, Composite materials**

I. INTRODUCTION

Composite materials are multi-layered structures product which are made up of flat and curved panels/ply. They are built up from several layers of laminates which are bonded together with the combination of fibers and matrix. They possess good mechanical properties like high strength, low weight, and good fatigue characteristics and are corrosion resistant, hence they are widely used in many applications. For example, Engineering wood, it is manufactured by a wide range of wood by binding or fixing the strands, particles, fibers or boards of wood with the help of adhesives used to form a ply laminate. Engineering Woods are preferred in various applications due to their versatility, availability in a wide range of thicknesses, sizes, which makes them ideal for use in unlimited Industrial, and constructional and home project applications. Prior studies show that the strength of laminates depends on the factors such as the type of fiber, orientation of fiber, number of layers, thickness, and their stacking sequence. In recent years a wide range of materials are been used to form composite structures. Materials like metals ceramics or polymer binders are been reinforced with fibers or particles to form composite plates. For example, a carbon fiber surfboard is made of polyester resin reinforced with Carbon fiber particles. Composite such as concrete is known as hybrid composites as they are reinforced with one or more reinforcing material. Firstly, concrete is particle reinforced with particle composites then it is further reinforced with steel rods.

II. RELEVANCE

Laminated composite materials are generally used in aerospace, submarine, sports equipment, medical instrument, automobile, civil engineering, and many other industries. They are lighter and stronger than other structural materials. A laminated composite material consists of a number of layers of fiber and matrix which is bonded together. Each lamina is placed at the different orientation with different stacking sequence to form a laminate. Each layer of lamina has different properties because properties change with the change in orientation of fiber with different stacking sequence. Composite materials are produced in many combinations of fiber orientations. The main purpose of lamination is to know the characteristics of such structures subjected to different loads in different environmental conditions. It is necessary to find out the stress distribution in every layer of such structures under dynamic loading in complex environmental condition.

III. LITERATURE REVIEW

M. Tarfaoui et al. [1] studied the mechanical characteristics of composite structures evolving with strain rates. Strain rates effects were tested and calculated in particular on the mechanical behavior, damage and the strength of the composite laminates for 0^o, $\pm 20^o$, $\pm 30^o$, $\pm 45^o$, $\pm 60^o$, $\pm 70^o$ and 90^o fiber orientation in the direction of thickness. The split Hopkinson pressure bar technology was been used to test the specimen. Result showed that the strain rates were in the range of 1092 to 2425 s^{-1}. Quasi-static test was conducted on an Instron universal machine and the elastic properties and quasi-static response were evaluated. The research showed that the factors like modulus of elasticity, maximum failure stress, strain at maximum stress and the maximum strain are dependent on the fiber orientation and strain rates.

P. Naghipour et al. [2] focused on the effect of the fiber orientation and stacking sequence on the progressive mixed-mode delamination failure in composite laminates using fracture experiment and finite element simulations. The fracture surface of laminates with different stacking sequences was studied using Scan Electron Microscopy (SEM). The SEM micrographs provided detail information and the result gives the clarification about the effect of fiber orientation and stacking sequence on the fracture of the laminates.

Manoharan. R. et al. [3] Has studied stress-strain and displacement analysis for compressive load on the fiber-reinforced composite laminates fiber orientation play an important role in the load-bearing capacity of the composite to justify this the different fiber orientation like (0^o, 90^o, 0^o), (0^o, 60^o, 30^o) and (90^o, 45^o, 0^o) were analyzed under different compressive loading conditions with and without circular cut-outs the results showed that (0^o, 90^o, 0^o) configuration was the best and have maximum load bearing capacity and greater strength than other orientations. Cross-plies have the maximum load carrying capacity as compared to angular plies. The test also showed that as the diameter of the cut hole is increased, the strength of the plate decreases.

Ban. Bakir. et al. [4] presented in his study the effect of composite laminates orientation of grain reinforced composite material on the mechanical properties such as tensile strength, hardness, toughness also the microstructures were tested. The study was used to compare the effect of direction of fiber in order to improve the strength and toughness of the laminates the study showed that the best strength was found when the fiber is perpendicular with tensile force with angle 45^o, then parallel strength increased when fiber volume fraction increases unless exceeds 30% composite material. Best results were found when the hardness test, impact test, tensile stress were carried out on laminate with (0^o, -90^o, -45^o) fiber orientation.

M. R. Hossain et al. [5] presented in his study the strength of laminates made with vacuum-assisted resign infiltration (VARI) technique. The test was conducted on laminates having (0^o, 0^o, 0^o, 0^o), ((0^o, $+45^o$, -45^o, 0^o), (0^o, 90^o, 90^o, 0^o) orientations. The test was conducted by taking 25% volume fraction, during the test higher longitudinal tensile strength was found at (0^o, 0^o, 0^o, 0^o) and (0^o, $+45^o$, -45^o, 0^o). The (0^o, 90^o, 90^o, 0^o) laminar composites did not show any directional differences in tensile strength of the laminate in the test. The pattern of failure of composites was matrix cracking, partial fiber breaking, fiber splicing.

Hossein Rahmani et al. [6] Studied to gain a better understanding of Mechanical properties of epoxy resin composite reinforced with Carbon fiber. For this purpose, the effects of fiber orientation resin types and number of laminates on mechanical properties of laminated composites were been investigated. In the sample preparation, composites were manufactured by hand lay-up process using fiber orientation with an angles of 0^o, 35^o, 45^o and 90^o. The result showed that mechanical properties like tensile flexural and impact strength are mainly dependent on fiber orientation followed by the number of laminates. At similar fiber orientation composite made with EM 500 epoxy resin showed highest mechanical properties compared to other composites. It can be concluded that the order of the parameters affecting the mechanical properties of composite fiber is fiber > number of laminates > resin type. Specimen sustains superior load at 35^o orientations compared to other orientations.

Santhosh Kumar M. et al. [7] presented the study of tensile, flexural and moisture absorption properties of composites made from carbon fiber. The specimens were prepared as per ASTM standards for different thickness like 2 mm and 3 mm with the fiber orientation of 30^o, 45^o, and 60^o. This research indicates the tensile strength is mainly dependent on the fiber orientation and thickness of laminated composites. Increase in the thickness of laminates tends to increase the tensile strength. The load required to fracture the specimen depends on the thickness. The test showed that if the thickness is increased by 1 mm then 40% to 50% more load is required for failure of the laminate. While the tensile test was being carried out it showed that the tensile strength is superior in 30^o orientation, the percentage of elongation and Young's modulus increases with the increase in thickness. The flexural stress and Young's modulus increases with the decrease in the thickness. For the fracture of the laminate in case of 90 ^{o} orientation more loads are required. More elongation is observed in 45 ^{o} and elongation is minimum in case of 30^o orientation.

Sandeep M. et al. [8] studied the mechanical properties of composite materials for different orientations. In this research, the effect of fiber orientation on the flexural strength of the composite material was determined. The experimental results indicated the difference in flexural strengths in bidirectional fibers at 0^o, 90^o and $+45^o$, -45^o orientations. The results show the difference in flexural strength for 0^o, 90^o, $+45^o$ and -45^o orientation fiber for 4 mm thick sample is 16.36 and for 6 mm thick sample is 3.2.

Kumaresan M et al. [9] studied the effect of fiber orientation on mechanical properties of fiber reinforced epoxy composites. The work of this experimental study was been carried out to determine the effect of fiber orientation such as 0^o 90^o 90^o $+45^o$ -45^o orientations on the mechanical properties. The result showed that the 90° orientation shows better Mechanical properties as compared to 0 ^{o}/90 ^{o} and ±45^o. The 0 ^{o} orientation reacts to axial loads. The ± 45^o reacts to shear load and 90^o reacts to side loads. The mechanical properties such as tensile and flexural strength shows maximum value at 90^o.

S.S. Gunjate et al. [10] carried out a review on the strength of effect of different orientation and the stacking sequence of fiber. Test was done for 0^o 45^o -45^o 90^o orientation for glass epoxy laminates in finite element analysis and then it was validated experimentally on UTM machine. Most of the study was been conducted on 2 to 4 layers of composite laminate having 0^o 45^o and 90^o orientation.

IV. METHODOLOGY

The research consists of the following steps

Step 1: Finite Element Analysis

The finite element analysis (FEA) has been widely used by design engineers as a tool during the product development process. Engineers analyze their own design while they are still in the form of easily modifiable models to allow quick turnaround times and to ensure prompt implementation of analysis result in the design process. FEA is a tremendous productivity too, helping design engineers by reducing product development time and cost.

a) Modelling

Modelling of carbon epoxy or similar materials will be done by using suitable mechanical design software's for different ply orientations.

b) Analysis

Analysis of these models will be done by using ANSYS. Same not will be applied on every laminate plates.

Step 2: Fabricating of the laminates

From the results obtained from the finite element analysis some of the laminates will be manufactured by a suitable ply laminating method say hand layup.

Step 3: Experimental method

Universal Testing Machine will be used to test the bending strength of the composite laminate. The test specimen is to be made as per ASTM standards of the composite laminates. The specimen shall be then placed on the roller supports as shown in the figure below. The load is there been applied at the center of the laminate plate. The load is increase gradually until the failure of laminate occurs.

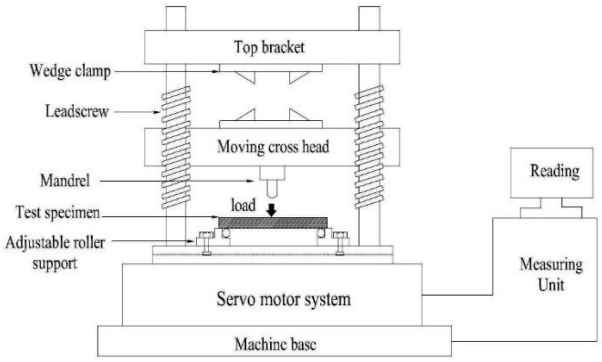

Figure 1. Experimental setup

The breaking load in the bending test is been found out on the Universal Testing Machine.

V. CONCLUSION

The report deals with different research studies based on the composite. A laminate is constructed by stacking a number of laminas in one direction. Laminate is consists of thin layers of fiber strands and may have different fiber orientation. The fiber orientation, stacking arrangements and material properties affect the response from the laminate. Here we have found that orientation of fibers changes the structural stability of laminates. Above studies are mostly conducted on 2 to 3 layers having 00 and 450 and 900 orientation of fiber elements of composite material. The factors affecting on strength of laminates are stacking sequence, fiber orientation, type of fiber, fiber material, type of matrix used, and manufacturing method. The most of studies in composite laminates dealing with fiber orientation and their stacking sequence. The finite analysis tool will be used for the analysis of various stacking sequences and fiber orientations to find the best suitable orientation. Result obtained from FEA will be used for further experimental study. For further work, a ply laminates will be manufactured with more layers and changing their orientation of fibers in each ply with different stacking with same material, in order to find out strength of the ply laminates. The laminates will be then tested and best orientation giving maximum strength will be found out.

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