FATIGUE ANALYSIS OF COMPOSITE LAMINATES

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ABSTRACT

Aircraft today contains high percentages of advanced composite material in flight critical primary structures . Fatigue cracking is by far the most common of failure for aircraft components When it is exposed to number of cycles of loads, so it is important to analyse the fatigue behaviour of the composite for compact design of aircraft components. Our project deals with Analysing the fatigue behaviour of composite laminates . For this Unidirectional fibres (glass fibre, Carbon fibre, Kevlar fibre) at three different angle orientation as ANGLE PLY , CROSS PLY and UNIDIRECTIONAL are designed and analysed in ANSYS workbench . In the result we are going to compare the fatigue behaviours of these different types of composite laminates by plotting SN-curve.

Key Words: Composites, fatigue, ANSYS, fibres, equivalent stress, SN- curve.

1.INTRODUCTION

A composite material (also called a composition material or shortened to composite, which is the common name) is a material which is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements.

Material fatigue is a phenomenon where structures fail when subjected to a cyclic load. This type of structural damage occurs even when the experienced stress range is far below the static material strength. Fatigue is the most common source behind failures of mechanical structures.

There are three stages of fatigue fracture:

1. Initiation
2. Propagation
3. Final rupture.

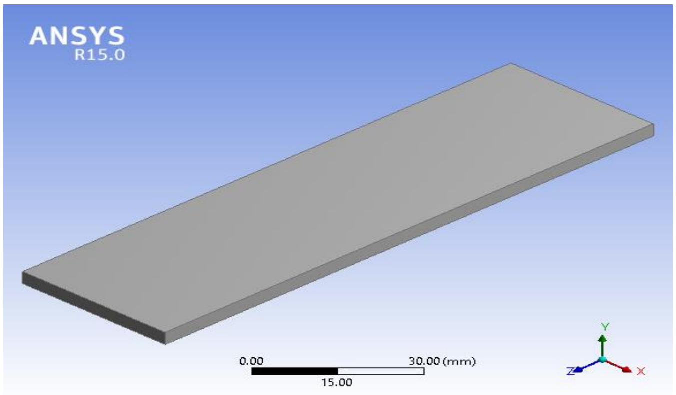
When the geometry and especially the loading are straightforward, simple hand calculations often suffice to determine the fatigue life of a component. The expected life of that component at a given stress level is then estimated from an S-N curve.

In a general sense, Fatigue Analysis has three main methods, Strain Life, Stress Life, and Fracture Mechanics; the first two being available within the ANSYS Fatigue Module.

2.OBSERVATION:

2.1. DESIGN:

The first process of the methodology is creating the three dimensional model of the epoxy glass, epoxy carbon and Kevlar composites. Each composites have three different ply orientation or cross ply, angle ply, and unidirectional.



(Fig.2.1.1). 3D Modelling of composite laminates

	GLASS	CARBON	KEVLAR
DENSITY (kg/m^3)	2500	1800	1400
YOUNG`S MODULUS X DIRECTION (MPA)	45000	12334	75000
YOUNG`S MODULUS Y DIRECTION (MPA)	10000	7780	6000
YOUNG`S MODULUS Z DIRECTION (MPA)	10000	7780	6000
POISSON`S RATIO XY	0.3	0.27	0.35
POISSON`S RATIO YZ	0.4	0.42	0.20
POISSON`S RATIO XZ	0.3	0.27	0.35
SHEAR MODULUS XY (MPA)	5000	5000	2300
SHEAR MODULUS YZ (MPA)	3846.2	3080	2000
SHEAR MODULUS XZ (MPA)	5000	5000	2300

(Table.2.1.1) Material properties.

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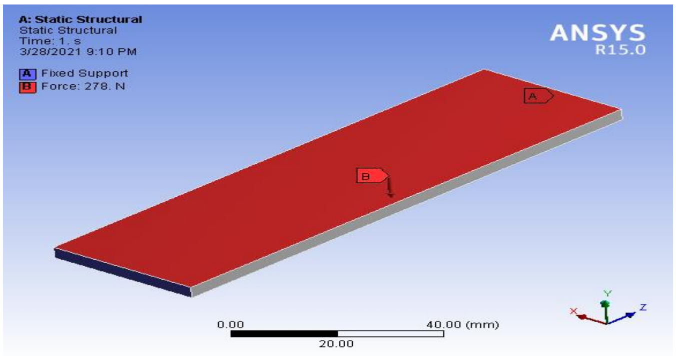
DIMENSIONS
Length : 120mm
Breadth : 35mm
Thickness: 3.6mm

PLY ORIENTATION
Cross ply : 0,90,0,90….(symmetrical orientation)
Angle ply: +45,-45…...(symmetrical orientation)
UD : 0



(Fig.2.1.2) Boundary conditions

The Boundary conditions for the composite laminates are both the ends of the model is fixed and applying load at the centre of the model. The loads are tabulated below.

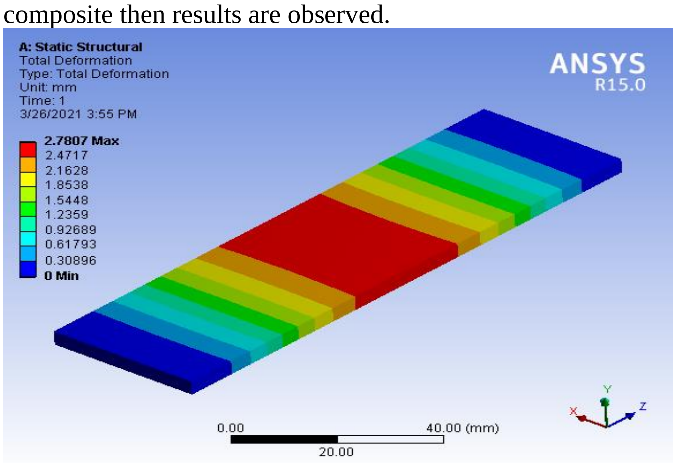
	Cross ply	Angle ply	UD
Load	610N	278N	768N

(Table.2.1.2) . Loads

2.2. ANALYSIS:

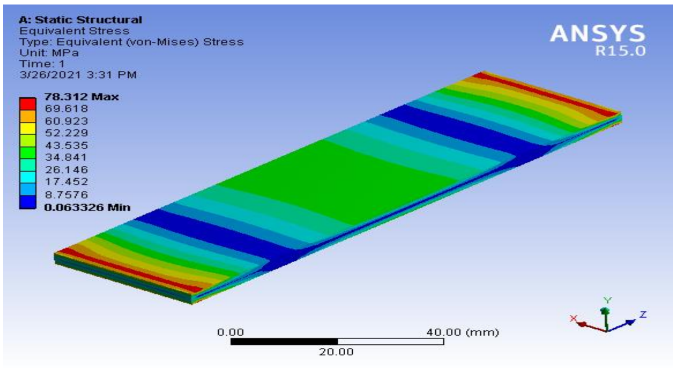
The structural analysis has been performed to identify the total deformation, equivalent(von mises) stress and equivalent elastic strain that was employed to study the fatigue behaviour of the composites. They are observed using contours and graphical representation of the data obtained.

The fatigue analysis for the cross ply, angle ply and unidirectional lamina is performed for three different composites as glass epoxy, carbon epoxy, and Kevlar composite then results are observed.



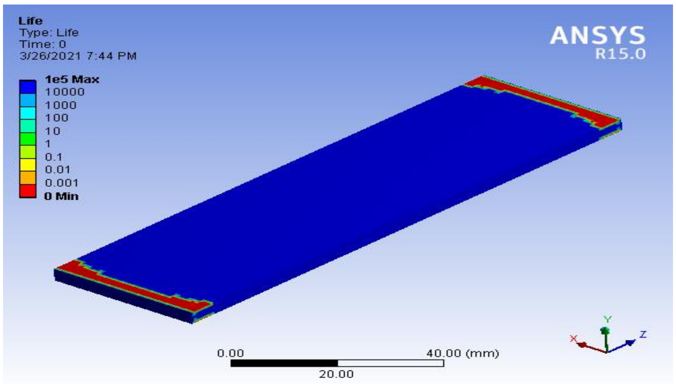
(Fig.2.2.1).Total deformation contours.

From this contours it is seen that the deformation is maximum at centre of the model due to load acting at that point and deformation is minimum at both the ends because both ends fixed.



(Fig.2.2.2). Equivalent stress contour.

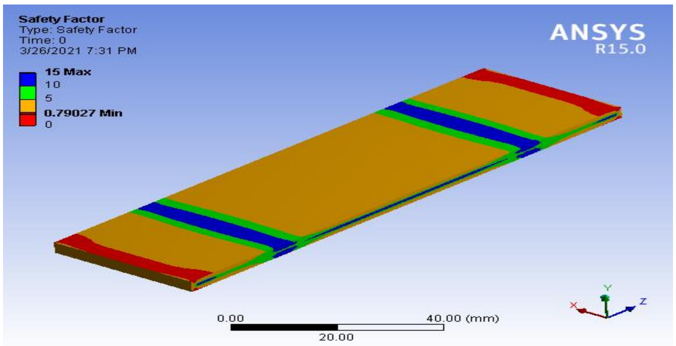
The stress contour shows the stress variations attained during the loading that is distributed over the model. The stress value is maximum at both the ends of the model due to fixed ends and the stress is minimum.



(Fig.2.2.3). fatigue life contour

Fatigue life is a mechanical and scientific term that relates to how long an object or material will last before completely failing because of concentrated stresses. In most cases, fatigue life is calculated as the number of stress cycles that an object or material can handle before the failure.

The blue contour indicate the maximum life and the red contour which is observed at the ends of the model indicates the minimum life.



(Fig.2.2.4) safety factor contour

The safety factor contours gives a safety factor with respect to 'infinite life'. In calculating this safety factor, the assumption is that there is no damage summation of stress history constituent cycles. An SF is calculated for all cycles individually, and the worst safety factor is reported. This report assumes that if the material/component can give infinite life when subjected to the worst cycle, then any subsequent cycles within the stress history do not have any further effect. This assumption is reasonable for ferrous materials that show a distinct endurance limit.

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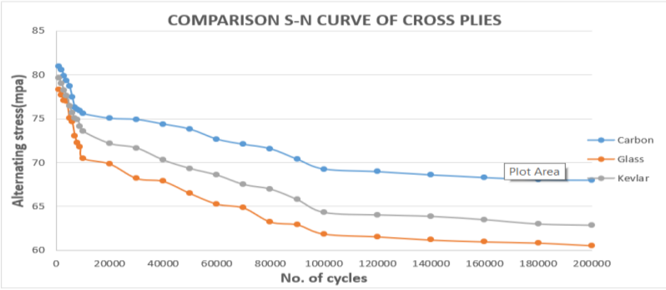
3.RESULTS:

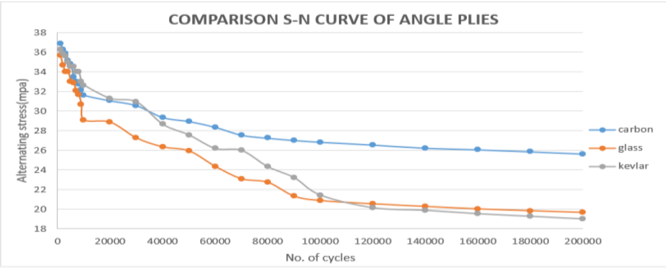


	Glass	carbon	kevlar
Endurance limit	60.570	67.987	62.857

endurance limits for cross plies

(Fig.3.1). Comparison SN-curve and endurance limit for cross ply

The above Fig.3.1 shows that the endurance limit of cross ply of each composite materials under cyclic loading upto 200000 cycles. The endurance limit is maximum for cross ply of carbon composites when compared to the glass and kevlar . so the cross ply of carbon composite will possess the higher fatigue strength and life compared to others.

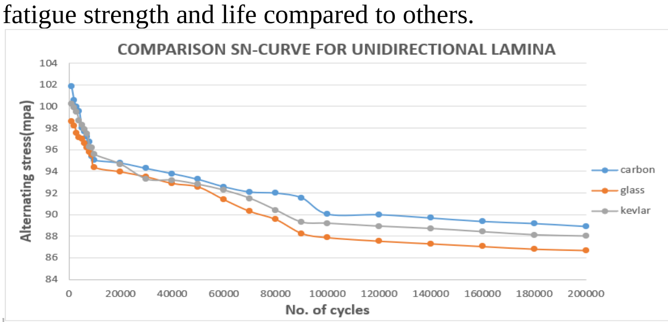


	Glass	carbon	kevlar
Endurance limit	19.674	25.654	19.054

endurance limits for angle plies

(Fig.3.2). Comparison SN-curve and endurance limit for angle ply

The above Fig.3.2 shows that the endurance limit of angle ply of each composite materials under cyclic loading upto 200000 cycles. The endurance limit is maximum for angle ply of carbon composites when compared to the glass and kevlar . so the angle ply of carbon composite will possess the higher fatigue strength and life compared to others.



	Glass	carbon	kevlar
Endurance limit	86.683	88.897	87.993

endurance limits for unidirectional lamina

(Fig.3.3). Comparison SN-curve and endurance limit for Unidirectional lamina

The above Fig.3.3 shows that the endurance limit of unidirectional lamina of each composite materials under cyclic loading upto 200000 cycles. The endurance limit is maximum for unidirectional lamina of carbon composites when compared to the glass and kevlar . so the unidirectional lamina of carbon composite will possess the higher fatigue strength and life compared to others.

At 200000 cycles	Glass	Carbon	Kevlar
Cross ply	0.7927	0.85593	0.8079
Angle ply	0.58524	0.72826	0.59114
UD	0.8912	0.88384	0.8897

Table.3.1. Safety factors of composites.

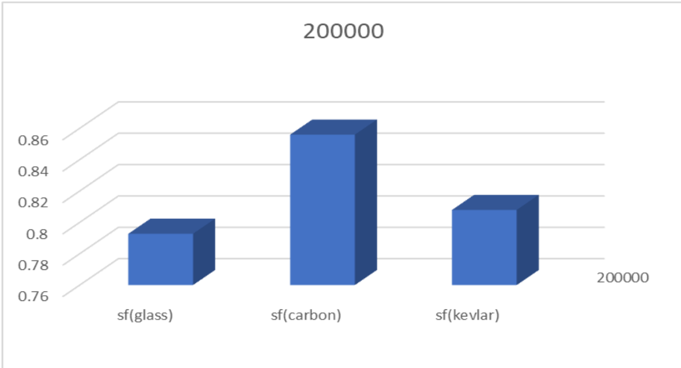


Fig.3.4. Safety factor comparison for Cross ply

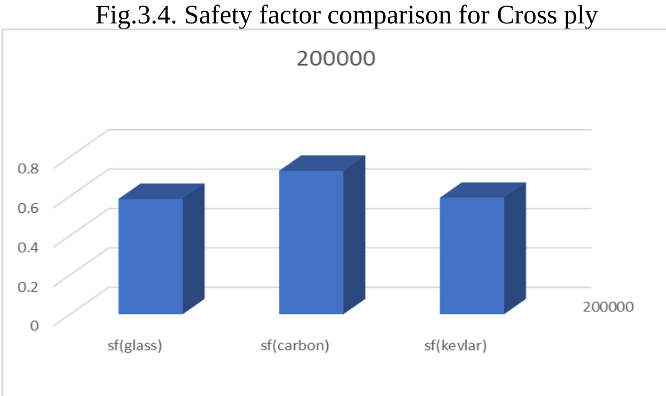


Fig.3.5. Safety factor comparison for Angle ply

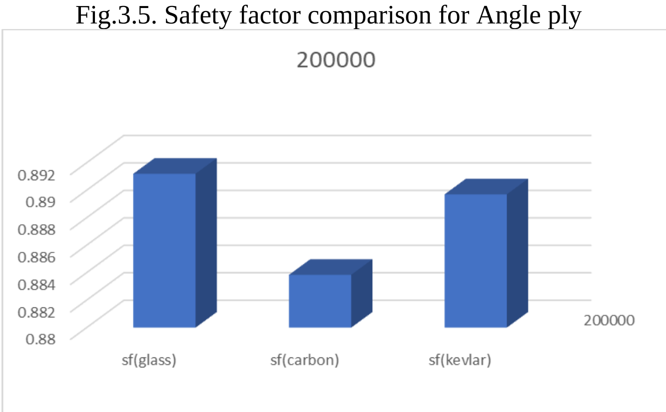


Fig.3.6. Safety factor comparison for UD

The safety factor for all the composites in unidirectional lamina shows the higher values when compared with each other. In that unidirectional lamina , glass composite gives the highest safety factor(0.8912).

4.CONCLUSION:

Generally composite materials possess more strength than the metal alloys In that composites made from unidirectional fiber is more stronger than the composites made from bidirectional fiber .As we design unidirectional fiber of Three different ply orientation as cross ply, angle ply and Unidirectional for glass ,carbon and Kevlar .

We conclude our discusion by determining which material and which ply orientation is the strongest among the others by comparing the results in percentage.

For the comparison we are taking ENDURANCE LIMIT, STRAIN, and FACTOR OF SAFETY.

The percentage difference between the two materials is determined by the difference between the two values is divided by the largest value between them.

1.ENDURANCE LIMIT:

CROSS PLY:

The endurance limit of the Epoxy carbon composite is 10.9% greater than the epoxy glass and 7.5% greater than the kevlar composite.

ANGLE PLY:

In angle ply also, the endurance limit of the epoxy carbon composite is greater than the other two composite. 23.3% greater than the epoxy glass and 25% greater than the kevlar composite.

UNIDIRECTIONAL LAMINA:

Like cross and angle ply the endurance limit of the unidirectional lamina of epoxy carbon composite is 2.5% greater than the glass composite and 1.02 % greater than the kevlar composite.

2.FACTOR OF SAFETY:

CROSS PLY:

The factor of safety of epoxy carbon composite is 7.3% greater than the epoxy glass and 5.6% greater the kevlar composite.

ANGLE PLY:

Epoxy carbon composite has the maximum factor of safety than the others. 19.6% greaterthan the glass and 18.8% greater than the kevlar composite.

UNIDIRECTIONAL LAMINA:

Unlike the before cases, epoxy carbon composite has the minimum factor of safety than the other two composites. Factor of safety of carbon composite is 0.8% lesser than the glass composite and 0.6% lesser than the kevlar composite.

From these observations we come to know that the endurance limit , strain and factor safety for epoxy carbon composite is greater than the other two composites.

So, the strongest and maximum life possessing material is **epoxy carbon composite.**

now we have to detemine the which type of ply orientation for epoxy carbon composite has the maximum endurance limit. The endurance limit of cross ply, angle ply and unidirectional lamina of carbon composite are 67.98, 25.654, 88.897 respectively. The unidirectional lamina of carbon composite has the maximum endurance limit.

In this project report , we analysed fatigue results for the three different ply orientation for the three materials . from the results given above we recommend the unidirectional lamina of epoxy carbon composite than the other orientations of materials.

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