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Flexural Fatigue Failure Behavior Of Angle Ply Hybrid Composite Laminates

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Abstract:- *Hybrid Composites Are Usually Used When A Combination Of Properties Of Different Types Of Fibres Have To Be Achieved, Or When Longitudinal As Well As Lateral Mechanical Performances Are Required. In This Work Unidirectional Carbon And Woven Glass Fabric Used As Fibres To Form A Hybrid Composite Laminate. Whereas Epoxy And Polyester Resins Used Individually In Different Laminates As Matrix. These Laminates Were Made In 0-90,+-45,And +-55 Degree Orientations. These Specimens Are Prepared In The Laboratory Using Compression Moulding Technique. Tensile Test Is Performed On The Above Laminates To Estimate Ultimate Tensile Stress And Later These Specimens Are Undergone To Cyclic Loading On Fatigue Testing Equipment To Study The Fatiigue Failure Behaviuor Of Composite Laminates*

I. Introduction

Hybrid Composites Most Frequently Relates To The Kinds Of Fibre-Reinforced Materials, Usually Resin-Based, In Which Two Types Of Fibres Are Incorporated Into A Single Matrix. The Concept Is A Simple Extension Of The Composites Principle Of Combining Two Or More Materials So As To Optimize Their Value To The Engineer, Permitting The Exploitation Of Their Better Qualities While Lessening The Effects Of Their Less Desirable Properties. As Such, The Definition Is Much More Restrictive Than The Reality. Any Combination Of Dissimilar Materials Could In Fact Be Thought Of As A Hybrid. A Classic Example Is The Type Of Structural Material In Which A Metal Or Paper Honeycomb Or A Rigid Plastic Foam Is Bonded To Thin Skins Of Some High-Performance Frps, The Skins Carrying The High Surface Tensile And Compressive Loads And The Core Providing Lightweight (And Cheap) Structural Stability.

The combination of sheets of aluminium alloy with laminates of fibre-reinforced resin, as in the commercial product ARALL (aramid-reinforced aluminium, Davis, 1985) is a related variety of layered hybrid, and the mixing of fibrous and particulate fillers in a single resin or metal matrix produces another species of hybrid composite.

A hybrid laminate includes plies of different materials within its lay-up. In this case every ply is identified by its fibre orientation angle and a subscript on the angle identified the type or material.

Laminate Lay-up	Code
0^o_B	$[0_B/\pm45_{GR}/90_{GR}]_S$
45^o_{GR}	
-45^o_{GR}	
90^o_{GR}	
90^o_{GR}	
-45^o_{GR}	
-45^o_{GR}	
0^o_B	

Angle ply laminates: an angle ply laminate has a lay-up where successive plies alternate between +θ and – θ in fibre orientation. Based on this definition, angle ply laminates with an odd number of plies are mid plane symmetric but are not balanced and angle ply laminates with an even number of alternating + θ and – θ plies above the mid plane. A $[\pm45]_s$ lay-up is an example. The mechanical response of angle ply laminates provides an explanation for the use of $\pm45^0$ plies at structural locations that require large shear stiffness. A set of $\pm45^0$ plies increase the shear stiffness to a great extent. In the axial stiffness 90^0 plies are selected to maximize the transverse stiffness and 45^0 plies are selected to maximize the shear stiffness of the lamina

Influence of fibre orientation: strength and stiffness of a composite laminate depends on the orientation of the plies with reference to the load direction. Proper selection of ply orientation is necessary to provide a structurally efficient design. As stated above a composite part might require 0^0 plies to react to axial loads, $\pm 45^0$ to react the shear loads and 90^0 plies to react to the side loads. For example a lay-up of 50% of 0^0 plies and 50% of $\pm 45^0$ plies will have strength and stiffness equivalent to those of aluminium when loaded in the 0^0 direction.

NOMENCLATURE

Y is the instantaneous stiffness of the laminate

$\mathbf{Y_0}$ Represents the stiffness of the laminate (where further reduction in stiffness was not observed due to pivoting state occurrence in the specimen.)

$\mathbf{A_1}$ is the constant obtained by the software from regression analysis

X Represent number of fatigue cycles the specimen undergone

1/t Represents the stiffness decay constant

M= bending moment

I= Moment of inertia

FLEXURAL FATIGUE FAILURE ANALYSIS

1.preparation of laminate- manufacturing technique

2.preparation of carbon-glass-epoxy composite laminate by compression moulding technique

3.preparation of carbon-glass-polyster hybrid composite laminate

EVALUATION OF TENSILE PROPERTIES OF COMPOSITE LAMINATES

CARBON-GLASS-EPOXY At [± 0-90^0] ORIENTATION.

CARBON-GLASS-EPOXY HYBRID COMPOSITE LAMINATE[$\pm 45^0$]

GLASS-POLYSTER HYBRID COMPOSITE[$\pm 45^0$]

CARBON-GLASS-POLYSTER HYBRID COMPOSITE[$\pm 55^0$

Estimation of bending load to be simulated for flexural fatigue analysis by Flexural fatigue Test-Rig The basic definition of high cycle fatigue , the stresses induced during cyclic loading should be well below the 50% of the ultimate tensile stress of the specimen subjected to fatigue loading. In view of simulating such stresses the following calculations provides the estimation of bending loads to be simulated on specimen.

M= W* L where W= bending load : L= effective length of the specimen.

Also I= Moment of inertia is equal to $bt^3/12$: where b= width of the specimen t= thickness of the specimen.

The load to be simulated to be estimated from bending equation $\mathbf{M / I = f_b / Y}$: f_b = bending stresses to be simulated, Y= half of the thickness of the specimen.

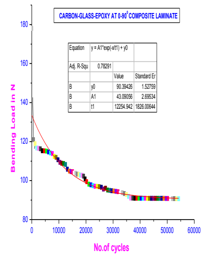
II. Resultsan Conclusions

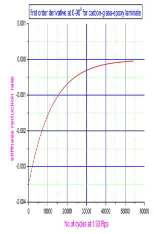
As the flexural fatigue failure behaviour of laminates are exhibiting pattern of continuous decay of stiffness with respect to number of cycles of load application. The pattern of the stiffness degradation curve analysed origin lab software.

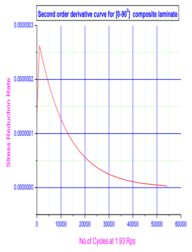
SNO	Degree of orientation	Material	Ultimate stress N/mm2	Breaking load N
1	[±0-90 º]	Carbon-glass-epoxy	427.2 MPa	178N
2	[±45 º]	Carbon-glass-epoxy	307.2 MPa	128 N
3	[± 55 º]	Carbon-glass-Epoxy	340.8 MPa	142 N
4	[±0-90 º]	Carbon-Glass-Polyester	202.9 MPa	84.56 N
5	[±45 º]	Carbon-Glass-Polyester	275.73MPa	114.89 N
6	[± 55 º]	Carbon-Glass-Polyester	314.08MPa	130.87 N

CARBON-GLASS-EPOXY HYBRID [±0-90 ^{o}]:

Stiffness degradation behaviour of carbon-glass-epoxy [±0-90^{0}]$_{10}$ orientation laminate with angle ply orientation sequence of stacking

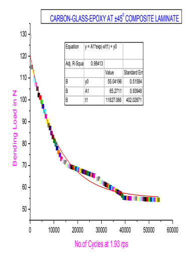


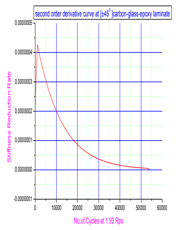


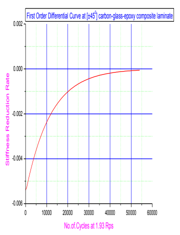


CARBON-GLASS-EPOXY HYBRID [±45 ^{O}]

STIFFNESS DEGRADATION BEHAVIOUR OF CARBON-GLASS-EPOXY [±0-45^{0}]$_{10}$ ORIENTATION LAMINATE WITH ANGLE PLY ORIENTATION SEQUENCE OF STACKING

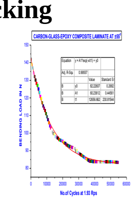


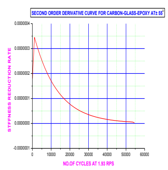


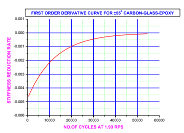


CARBON-GLASS-EPOXY [±55^{0}] COMPOSITE LAMINATE

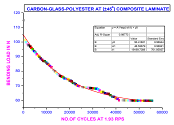
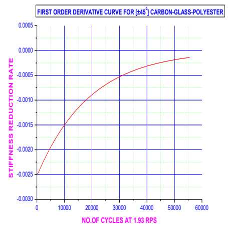
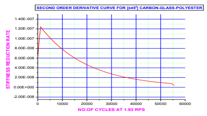
Stiffness degradation behaviour of carbon-glass-epoxy [±0-55^{0}]$_{10}$ orientation laminate with angle ply orientation sequence of stacking



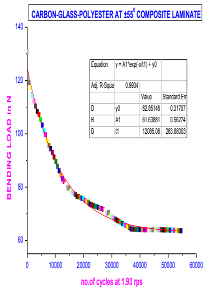
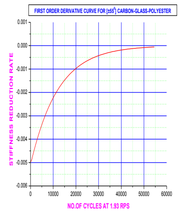
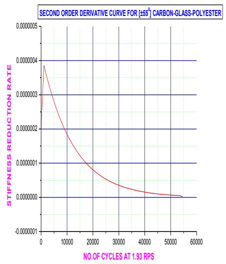




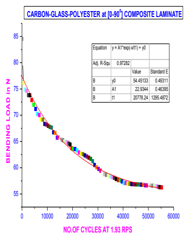
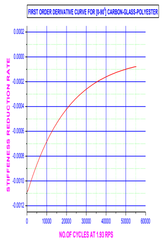
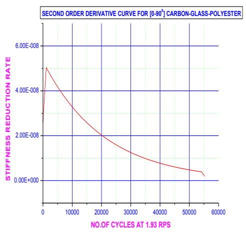
ARBON-GLASS-POLEYSTER HYBRID [±0-45 ^{o}**]**

STIFFNESS DEGRADATION BEHAVIOUR OF CARBON-GLASS-POLYESTER [±45^0]$_{10}$ ANGLE PLY ORIENTATION SEQUENCE OF STACKING 	 

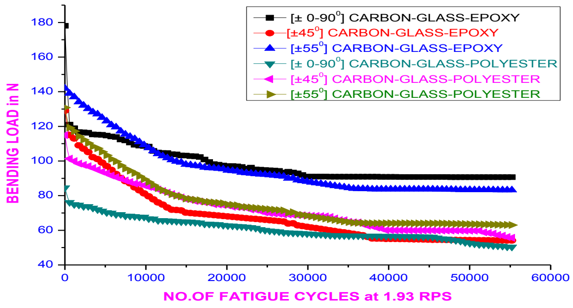
CARBON-GLASS-POLEYSTER HYBRID [±0-55 ^{o}]

Stiffness degradation behaviour of carbon-glass-polyester [±55^0]$_{10}$ angle ply orientation sequence of stacking 	 

CONSOLIDATED FLEXURAL FATIGUE TEST RESULTS OF [0^0.90^0], [±45^0], AND [±55^0] ANGLE PLY ORIENTATION SEQUENCE OF CARBON-GLASS-POLEYSTER HYBRID [±0-90^o]

Stiffness degradation behaviour of carbon-glass-polyester [±90^0]$_{10}$ angle ply orientation sequence of stacking 	 

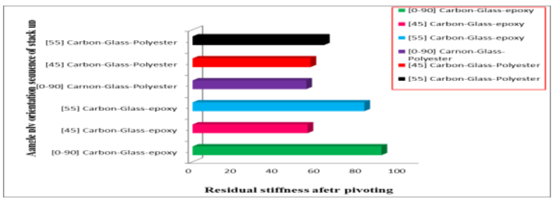
STACKING OF CARBON-GLASS-EPOXY & CARBON-GLASS-POLYESTER



*RESIDUAL STIFFNESS VALUES OF [0^0.90^0], [±45^0], AND [±55^0] ANGLE PLY ORIENTATION SEQUENCE OF STACKING OF CARBON-GLASS-EPOXY & CARBON-GLASS-POLYESTER

S N O	Material	Angleply orientation	Residual stiffness after pivoting
1	Carbon-glass-epoxy	[0-90^0]	90.39
2	Carbon-glass-epoxy	[45^0]	55.04
3	Carbon-glass-epoxy	[55^0]	82.22
4	Carbon-glass-polyester	[0-90^0]	54.55
5	Carbon-glass-polyester	[45^0]	56.41
6	Carbon-glass-polyester	[55^0]	62.85

ANGLE PLY ORIENTATION SEQUENCE OF STACK UP VS. RESIDUAL STIFFNESS AFTER PIVOTING



III. Conclusion:

1. **F**lexural fatigue failure behaviour of carbon-glass-epoxy and carbon-glass-polyester laminates at[± 0-90^0], [±45^0],[±55^0] orientations evaluated.
2. In carbon-glass-epoxy hybrid composite laminate the [0-90^0] orientation exhibits high stiffness reduction rate i.e 0.00000045 N/s^2 up to 250cycles and stiffness reduction rate is slow 0.0000001 N/s^2 up to35000 cycles.later no reduction in stiffness observed. This laminate has high bending load of 90.39 N.
3. For carbon-glass-polyester at [±55^0] orientation have high bending load of 62.85 N. stiffness reduction rate is high at 0.00000083 N/s^2 up to 200 cycles and reduction rate is low at 0.0000001 N/s^2 up to 40000 cycles.later no reduction in stiffness was observed.

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