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Experimental Study on the Tension-Tension Fatigue Behaviour of Glass/Flax Quasi Isotropic Composites

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Abstract
Fiber reinforced polymer are being used extensively in areospace , automobile applications, fatigue loading materials are subjected to cyclic stresses below the ultimate tensile strength application of repeated cyclic stresses will develop micro crack in the material, resulting in degradation of the mechanical properties, fatigue failure phenomenon in homogeneous materials initiates from single micro crack and propagates perpendicular to the direction of loading. Fatigue damage developed during the fatigue test is loading cycle dependent and during each cycle damage accumulates in the form of micro cracks in different planes. This study investigates tension to tension fatigue behavior of glass /flax quasi isotropic laminates, the constant amplitude tension-tension fatigue test were performed in different loads, with stress ratio R=0.025 and at a frequency of 3Hz, fatigue life of the material is presented using S-N curve and damage accumulated in the laminates is predicted by monitoring stiffness loss of the material. The damage growth in the material was characterized by evaluating the degradation in stiffness, it was observed that in the initial fatigue loading cycle the material exhibit rapid reduction in stiffness and maintained a constant rate of degradation until failure. In this work investigates the fatigue behavior of quasi isotropic glassflax composite laminates fabricated with a different sequence of 0/90°/0/90°/±45°/0/90°/0/90°.
Keywords: *Bi-directional Glassfibre, Bi-directional Flaxfibre, Epoxy, Quasi-Static Method.*

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I. INTRODUCTION

A composite is a combination of at least two materials, each of which maintains its identify in the combination. A mixture of clay and rocks could therefore be considered a composite, but ordinarily, our minds turn to more exotic system. Combinations of synthetic polymers with advanced engineering fibers, or plant fibers as amalgamations of the natural polymers, cellulose, hemicellulose, and lignin, provide example of sophisticated composites.

According to jartiz "composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structure made by physically combining two or more compatible materials, different incomposition and characteristics and sometimes in form". The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its 4 specificity or the laws which should give it which distinguishes it from other very banal, meaningless mixtures.

II. MATERIALS AND METHODS

The materials which are used for our project are,

S.NO	COMPOSITE \MATERIAL	MATERIAL SELECTION
I	Matrix material	Epoxy(LY556)+Hardener (HY951)
2	Fibre material	Bi-directional Glass fibre and Bi-directional Flax fibre

Table 2.1 material and method

2.1.1 Material used

The reinforcement materials including, Bi-directional Glass fibre and Bi-directional Flax fibreand matrix material including epoxy resin and hardener are shown in Table 2.1

2.1.2 Bi-directional fibre

E-Glass Fiberglass cloth is a light weight woven composite material that is commonly used in industrial, marine, and aerospace applications. Fibreglass E-glass cloth is considered the industry standard and provides an excellent balance between cost and performance. The bidirectional fabrics are made by stitching two layers in 0° & 90° directions. They are Non crimp fabric and provide excellent fatigue resistance.

2.1.3 Bi-directional Flaxfibre

Flax fiber is obtained from the inner bark of the stem of a plant grown in temperate and subtropical regions of the world. It is a natural, cellulosic, multi-cellular bast fiber. Flax fiber is 10–100 cm in length. Its diameter varies from 40 to 80 µm. Flax is much stronger than cotton fiber, however less flexible. The best grades are utilized to make cloth textures, such as lace, damasks, and sheeting.

2.2 Hand layup method

The method implemented in the fabrication of chicken feather and carbon fibre hybrid composite is hand layup procedure and is a closed molding technique. The process flow chart of hand layup is shown in Figure.2.1. In this method, chicken feather and carbon fibre are mixed with epoxy resin for uniform dispersion. Chicken feather of varying sizes are randomly oriented in the mould cavity. Epoxy resin mixed with carbon and chicken feather for proper wetting. A roller is used to compact the layer.

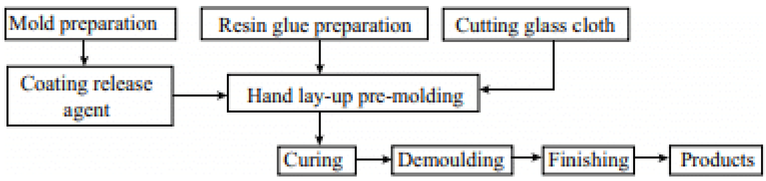

Figure 2.1 Hand layup process flow chart

2.3 Overview of Quasi-Static Method

A quasi-static test is described as energy absorption capability of the composite when they are crushed under axial loads. The quasi-static tests are performed using a hydraulic press where the specimen is crushed at a very low crosshead speed between two parallel steel platens. Static fatigue or creep rupture, which refers to the time-dependent failure of a material when subjected to a constant load, is used as a measure of gauging the relative resistance of a material. The importance of quasi static processes is precisely that they can be considered to involve a system that is permanently in equilibrium, both within itself and with its surroundings. When the gas system is isolated, the weights on piston are removed one by one slowly, at any instant of upward travel of the piston. So every state passes through by the system will be in an equilibrium state. Thus the system passes through the locus of all equilibrium points.

III. EXPERIMENTATION

Two types of plate were manufactured. For the first specimen the orientation is 90°/90°/±45°/90°/90°, and for the second specimen the orientation is 90°/90°/±45°/90°/90° respectively. The specimens used in the fatigue tests were prepared from these thin plates. The geometry and dimensions of the fatigue specimens are shown. Two types of test were performed. One series of fatigue tests were carried out in an electromechanical machine where frequency and stress ratio can be changed and the load is controlled by a load cell. The tests were performed in constant amplitude displacement mode (the load wave was sinusoidal constant amplitude). Other series of tests were carried out in an servo-hydraulic Instron machine in constant amplitude load. All the tests were performed in tension with stress ratio R=0.025 and frequency 3 Hz at ambient temperature. The displacement in constant amplitude displacement mode was imposed by the eccentricity of one piston rod and crank system and measured using a dynamic axial extensometer fixed in the specimen. Periodically the procedures were stopped and a static loading test carried out.

Table 3.1 COMPOSITION OF COMPOSITES

	Layer 1	Layer2	Layer3	Layer4	Layer5
Fibre sequence with orientation	0/90° Glass	0/90°Flax	±45° Glass	0/90° Flax	0/90° Glass
Fibre sequence with orientation	0/90° Flax	0/90° Glass	±45°Flax	0/90° Glass	0/90° Flax

3.1 QUASI-ISOTROPIC LAMINATE

In the case of the quasi isotropic laminate for the 25mm and 3.5mm rectangular specimen the fracture toughness is in arrangement, within experimental error, of the value of given for a [90/90/±45/90/90] 5s flax and glass –epoxy laminated in the ASTM E1922 standards. A quasi isotropic laminated result when the individual lamina are laminated in such a manner as to produce an isotropic [A] matrix , this means that extension and shear are uncoupled. The conditions of isotropic response only apply to the [A] matrix. The [B] and [D] matrices may or may not be fully populated, and extension shear coupling is possible. Several rules are apply for a quasi isotropic laminate.

1.The total number of layers must be n ≥ 3.

2.All layers must have identical orthotropic elastic constants they must be the same material) and identical thickness.

3.The orientation of the kth layer of an n-layer laminate is

$$\boldsymbol{\theta} = \frac{\pi\,(k-1)}{n}$$

3.2 Processing:

Many techniques are available in industries for manufacturing of composites such as compression mouldings, vacuum moulding,pultruding, and resin transfer moulding are few examples. The hand layup process of manufacturing is one of the simplest andeasiest methods for manufacturing composites. A primary advantage of the hand layup technique is to fabricate very large,complex parts with reduced manufacturing times. Additional benefits are simple equipment and tooling that are relatively lessexpensivethanothermanufacturingprocesses.Thefiberswereaddedtotheresinmixedhardenerwithrequiredweight percentages. The fiber resin hardener mixture was poured in to the moulds for different testing prepared as per ASTM standards.Thesetting timetaken by thecompositeswasapproximately 24hours.Thepreparedcompositesweresubjectedtotensile,flexuralandimpacttests.

3.3 Tensile tests:

An electronic tensometer used to find the tensile and flexural properties of the composite specimens. The tensile test specimenswere made in accordance with ASTM-A 370M to measure the tensile properties.

3.4 Fatigue tests:

Fatigue testing machines are used to determine the durability of a material, component or product, and are suitable for tensile, compression, and alternating load tests.Fatigue tests on coupons are typically conducted using servo hydraulic test machines which are capable of applying large variable amplitude cyclic loads. Fatigue testing is a specialised form of mechanical testing that is performed by applying cyclic loading to a coupon or structure.

IV. Results and Discussion

The measurement of stiffness changes that occur during fatigue loading of fiber composites has received considerable attention as a quantitative indicator of fatigue damage development because it is now generally accepted that strength degradation does not always reflect the progression of fatigue damage. Stiffness changes are directly related to internal stress redistributions in the composite and where strength reductions are large, the attending stiffness changes are also large.

The stiffness changes of the glass fiber composites in tension–tension (R=0.025) fatigue at various stress levels are shown . These composites showed negligible reduction in stiffness with increasing fatigue cycles at all stress levels. A similar pattern of negligible stiffness reduction (and indeed small increases) has been reported

Table4.1 Experimetal results of fatigue test

CYCLES	VARIENT 1		VARIENT 2	
Stage	**Specimen 1**	**Specimen 2**	**Specimen 1**	**Specimen 2**
Load stable Cycle	0	501	438	522
Half Life Cycle	200	4000	5000	6000
End Load Cycle	370	7964	10829	11510

4.2 Experimental results for tensile tests

Samples	Peak Load in N	Ultimate Tensile Strength in MPa
Sample 1a	16371.720	187.10
Sample 1b	14921.963	170.50
Sample 2a	14156.623	161.80
Sample 2b	13993.990	159.90

3.4 S-N CURVES

An S-N curve defines the number of cycles to failure, N(S), when a material is repeatedly cycled through a given stress range ,the S-N curve is used to calculate the damage in a fatigue analysis. If needed you can define a number of different S-N curves and use them at different arc lengths along a line.For the S-N curve, the endurance limit is the maximum magnitude of stress at which the specimen can withstand infinite numbers of the stress cycle.

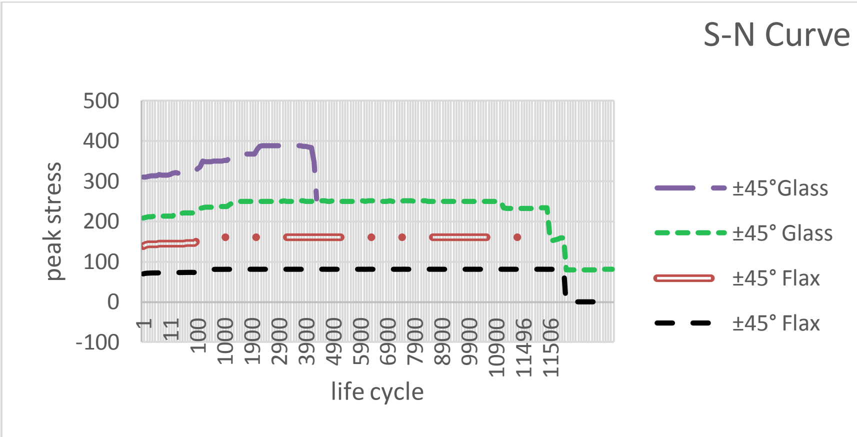

Fig.4.1 Comparison of Peak Stress and Life Cycle [S-N Curve] with Frequency of 3Hz and the value of R=0.02.

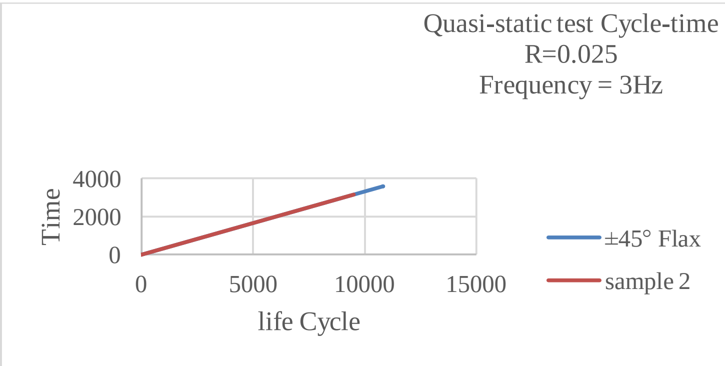

Fig.4.2 Comparison of Time Taken and Life cycles for Specimen ±45˚glass fiber and ±45˚ flax. [tension-tension] at various time levels.

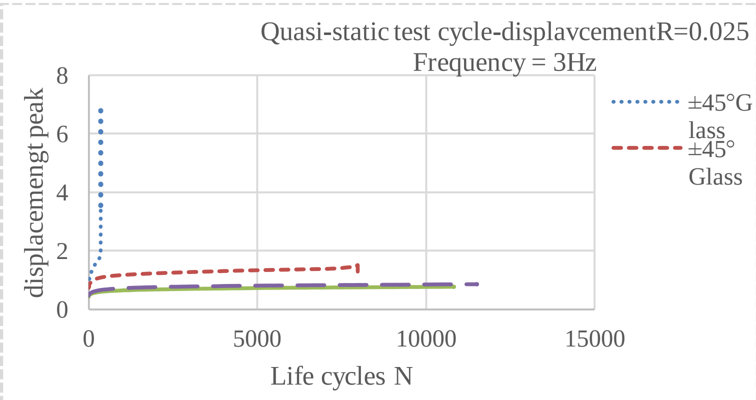

Fig.4.3 Comparison of peak displacement and life cycles of both the specimen 1 and 2 with the frequency of 3Hz and R=0.025.

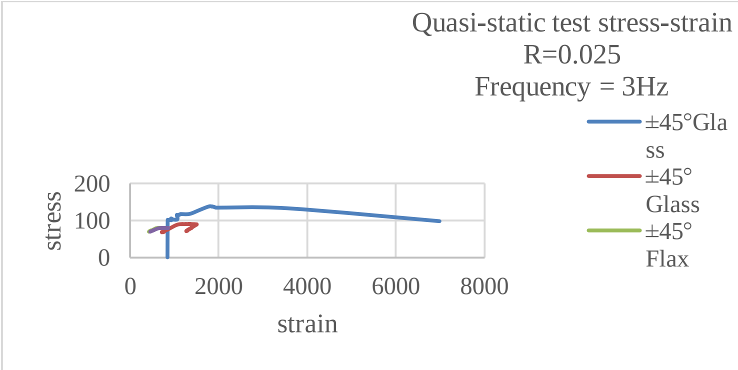

Fig.4.4 Comparison of stress and strain of both the specimen 1 and 2 with the frequency of 3Hz and R=0.025.

V. CONCLUSION

The fatigue characterization of quasi isotropic glass – flax laminates under on axis tension-tension fatigue test at a stress ratio of R=0.025 and frequency of 3Hz . The static tensile property of composite depended on the orientation of individual plies. The fatigue failure of glass fiber reinforced material withstands minimum loading with minimum number of life cycles. The fatigue failure of flax fiber reinforced material withstands maximum loading with maximum number of life cycles. Therefore the [0/90°flax/0/90° Glass/±45°flax/0/90°glass/0/90°flax] flax fiber variant results that higher fatigue strength than [0/90°glass/0/90° flax/±45°glass/0/90°flax/0/90°glass] glass fiber variant.

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