IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DESIGN AND FABRICATION OF FATIGUE ANALYSIS TEST SETUP FOR COMPOSITE MATERIAL TESTING

K.Praveen Kumar*, Dr.M.Manzoor Hussain, Dr.D.V Ravishankar
* Assistant Professor, Mech.Dept, St.Peter's Engineering College, Maisammaguda.
Professor In Mechanical Engineering Department, JNTU Hyderabad.
principal & Professor In Mechanical Engineering Departmen,TKR College Of Engineering & Technology,Meerpet.

ABSTRACT

Lot of research work is published on various aspects of fatigue failure behavior of laminated composite materials. There is no standard method followed by researchers since these research works published in this area are based on specific case studies. The methodology followed and presented in the literature is based on case studies of actual components to be manufactured with laminated composites. In this connection the present project work is aimed at establishing the laboratory scale model flexural fatigue test rig to understand the failure behavior of laminated composites, subjected to flexing cyclically. In the present project work is aimed to Design and fabrication of flexural fatigue analysis test setup for composite material testing laboratory scale model to log the data generated by the test rig. The data logged is further analyzed to understand the fatigue failure behavior of laminated composites of research work titled critical analysis of utilization of composite materials with a basic objective of reducing the complexity of existing design to reduce the cost of machine which could be easily established in any engineering mechanics of solids laboratories. This work consist of the experimental work and test results and suggests better flexural fatigue test results with comparison of heavy duty fatigue test rig.

KEYWORDS: Fatigue Failure, Material Testing, Test Rig, Fabrication.

INTRODUCTION

The present research work mainly is focusing on development of low cost flexural fatigue test rig could be fabricated in the work shop which could be able to perform and generate useful data to understand fatigue failure behavior of laminated composites. This work establishes critical test procedures for the polymer reinforced composite materials to be used in certain engineering applications to perform flexural fatigue analysis the test sample have to be moulded in the laboratory. In this regard the following sections would also deal with Polymer matrix composites and manufacturing processes in general. The following sections also provide the information related to the development of experimental setup and testing procedure adopted.

Flexural Fatigue

The present research work considers flexural fatigue is a critical property to be understood, while designing laminated composite components. In this connection efforts are made in designing and development of computer interfaced flexural fatigue test rig which is capable of storing the data related to the dynamic response of the laminate subjected to flexural fatigue.

Polymeric and composites materials are used increasingly as structural parts in industry and therefore many information on mechanical properties (creep, relaxation, fatigue life) are necessary. Composite materials behavior subjected to fatigue load is very complex due to non homogeneous and anisotropic properties, and it has been studied for a long time; however, composite materials design is still based on very long fatigue tests and high safety factors are used. Composites industry uses various types of resin (usually epoxy or polyester resin) and reinforced fibers (usually fiberglass). Many industrial components and consumer goods are made in this way, such as parts for boats, car components, etc. Composite materials are used primarily in aerospace, military and automotive industries, however, are also utilized in sports such as golf, fishing, skiing (and snowboarding) and in the naval industry These

materials have very high mechanical properties such as low weight, high strength and stiffness, good formability and high design flexibility. Many theoretical studies are dedicated to the study of crack propagation, applying the concepts of fracture mechanics. Fatigue failure can be described as a sequence of two phases:
1. Crack formation.
2. Crack propagation.

The crack propagation has been studied carefully, ignoring the formation crack, and precracked specimens are used for this purpose; the study requires the development of equipping, methodologies and specialist analysis. Fatigue studies usually require several days (sometimes weeks) of load cycles to obtain an appreciable damage. The tests show inhomogeneous results, so it is necessary to do many repetitions to get a more accurate .

To estimate of fatigue life. In this case it is very important to develop a specific approach to fatigue tests based on the use of materials testing machines (FTM) to avoid the utilization of expensive hydraulic machines. Some ideal characteristics of FTM machines are:
1. Adaptability to different geometries and rigidities of the specimens.
2. Facility to perform various conditions of load.
3. possibility to develop fatigue studies by recording the obtained data from different.
   tested materials, which can be applied any criterion to predict the fatigue life.
4. possibility to measure strains.
5. low cost of instrumentation to perform several tests simultaneously.
6. adaptability of load frequency.

Flexure Test
The flexure test method measures behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Maximum fiber stress and maximum strain are calculated for increments of load. Results are plotted in a stress-strain diagram. Flexural strength is defined as" the maximum stress in the outermost fiber". This is calculated at the surface of the specimen on the convex or tension side. Flexural modulus is calculated from the slope of the stress vs. deflection curve. If the curve has no linear region, a secant line is fitted to the curve to determine slope.

Need of a Flexure Test
A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. To ensure the primary failure comes from tensile or compression stress the shear stress must be minimized. This is done by controlling the span to depth ratio, the length of the outer span divided by the height (depth) of the specimen. For most materials S/d=16 is acceptable. Some materials require S/d=32 to 64 to keep the shear stress low enough.

PROBLEMFORMULATION
Basic Requirements and step by step approach in problem formulation are discussed below The paper aimed to Design and fabrication of flexutural fatigue analysis test setup for composite material testing (a laboratory scale model) for analyzing laminated composite materials subjected to flexural fatigue. The past research thesis of different authors were thoroughly studied in view of designing a low cost fatigue test rig that could be manufacture in the workshops of any engineering colleges. This work also establishes standardized specimen making procedures in order to have meaningful comparison of the experimental results.Basically the test rig consists of following components as furnished bellow

1. The gear box mechanism coupled to eccentric mechanism
2. The structure comprising of specimen fixture
3. The sensors designed to measure dynamic load applied on the specimens
4. The data log in system comprising signal conditioning system and A to D convertor to feed the data continuously for storing and further analysis
5. The power supply from three phase induction motor through v- belt transmission

The laboratory scale model consists of five components in which the structural part of the test rig and the power transmission system coupled to fatigue test rig have considerable scope for redesigning for reduction in cost, by designing considering dynamic forces acting on the sample

1. Design and development of low cost flexural fatigue test rig set up
2. Preparation of laminates by using Resin Transfer moulding (RTM)

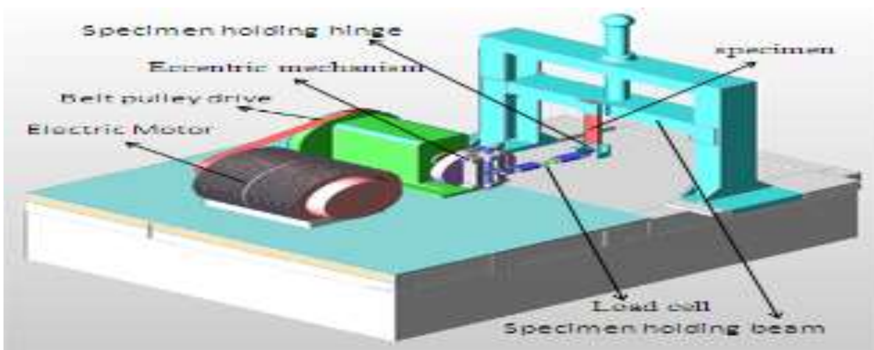
EXPERIMENTAL SET-UP DESIGN AND DEVELOPMENT

The flexural fatigue failure in laminated composite materials is a very common failure mode in most of the FRP components. As reinforced polymers used in weight critical applications, often over designed to compensate fatigue failure lead to the increase in weight which in turn hampers the objective of designer. In this connection the investigation on flexural fatigue failure behavior of laminate to be used in the component is very important. As standard equipment and test procedures are not available the need for custom built flexural fatigue testing equipment arises. The design of flexural fatigue test rig is discussed in detail in the following sections.

Flexural fatigue Test-Rig design and development

FRP components like windmill blades, leaf spring and most of the components used in automobile industry are generally subjected to flexural fatigue. The present research work considers flexural fatigue is a critical property to be understood, while designing laminated composite components. In this connection efforts are made in designing and development of computer interfaced flexural fatigue test rig which is capable of strong enough to generate the data related to the dynamic response of the laminate subjected to flexural fatigue. The test rig used in the present experimentation is shown in figure 3.1 and the schematic diagram furnished in figure 3.2.

This indigenous design consists of few important components developed to test the composite laminates made as per the NASA contractor's specifications [94]. These specifications of the laminate are also made as per the same aspect ratio reported in the above mentioned reference



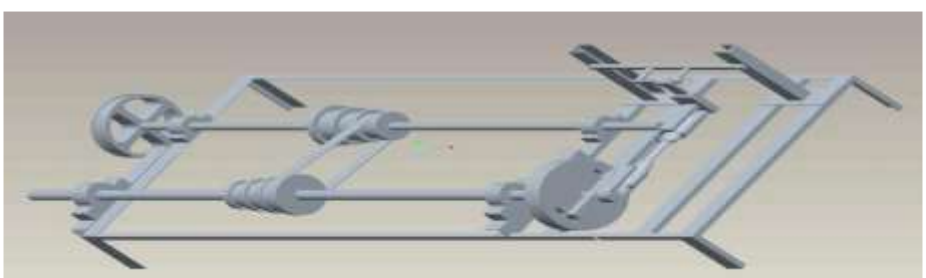


Figure 3.1: The typical Flexural Fatigue test rig proposed model

Working principle of Test Rig: The schematic diagram of test rig (shown in figure 3.1) is furnished in figure 3.2. The eccentric mechanism used is shown in the figure 3.6 and 3.6 (a).The eccentric mechanism is driven by an independent drive at speeds varying from 94RPM to 600RPM. The hinge eccentricity from the center of the crank is equivalent to the deflection induced in the composite specimen. This deflection resisting force is experienced by the linkage which is the dynamic load sensing sensor (strain gauge based load cell). The strain gauge bonded to the linkage (load cell) elongates and contracts along with the load cell which in turn imbalances the balanced bridge circuit connected to the strain gauge.

The output voltage of the bridge circuit is directly proportional to the deflecting load of the composite specimen. As eccentric mechanism rotates with the constant speed of 94 RPM, the strain measuring system develops voltage proportional to the degree of deflection. The voltage is in sinusoidal wave form. The cyclic load applied to the composite specimen generates a fatigue crack at the fixed end, which in turn reduces the stiffness of the composite specimen and that is been clearly reflected on the voltage output from the strain measuring bridge circuit. The amplitude of wave form decreases as the damage progresses, in due course as the cyclic loading proceeds from 0 cycles to n number of cycles. This diminishing wave form reveals the health of the laminate as the time progresses. The recorded data is analyzed to understand the fatigue failure behaviour of the laminate.

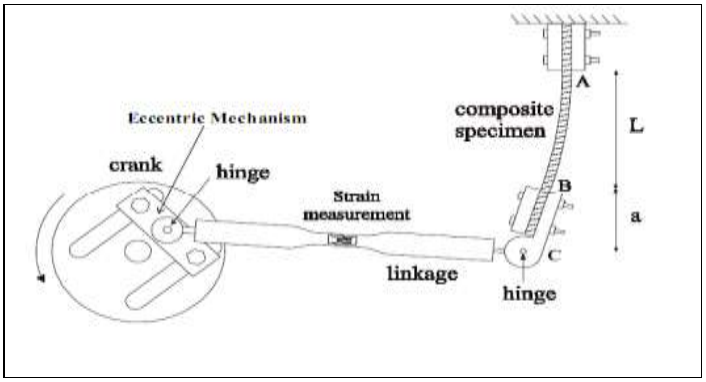


Figure 3.2: Schematic diagram of Test Rig

Specifications of the Test-Rig:

Bending load capacity	0 to 1000 N
Frequency	1.57 to 10 RPS
Specimen specifications	
Length of Specimen	100 to 500 mm
Width of Specimen	30 to 50 mm
Thickness of Specimen	2.5 to 10 mm

Structure of Test Rig:

The structure of test rig is fabricated by using 100mm standard U- channels of M.S. used to fabricate the basic platform of test rig, which provides a platform to install power transmission system which consists four bearing blocks, out of which one set of bearing blocks consists to provide rotation to eccentric mechanism. The basic platform is made of 1.2 m long and 1.2 m wide as shown in figures below 4.3 and 4.4. And the legs were provided with same U-channels is to obtain 1 m height from the ground. A provision is also incorporated to fix this total structure on foundation bolts. The steps involved in fabrication are shown in the fallowing figures

Fig.3.3 U-Channels

Fig.3.4 Base frame

Power Transmission System:
A 3 HP motor is selected to provide rotary motion to eccentric motion mechanism. The power is transmitted from stepped V- pulley blocks capable of providing varying rotary speeds from 3 cycles per sec. to 10 cycles per sec. in three steps. The induction motor rated rpm is about 1450 rpm with three phase power motor is installed on basic frame with a reverse rotation switch. The power is transmitted from motor to eccentric mechanism by stepping down the rpm from 1450 rpm to 180 rpm in two stages, by virtue of that sufficient torque is developed in the eccentric mechanism which is directly connected to flexural fatigue test specimen through an arm (load cell) by converting the rotary motion to oscillatory motion. The total assembly is shown in fig.4.5 below.

Fig.3.5 power transmission system mounted on base frame

The Eccentric Mechanism:
The eccentric mechanism is a 20 mm thick MS round disk of diameter is 300mm.The two vertical slots are provided in the round disk, which is assembled to rotating shaft by a flange coupling and a suitable locking mechanism is also incorporated to avoid an accidents through a bolt tightened from outside to center of shaft by machining internal threads in the shaft center.

The details are furnished in following fig.3.6

Fig.3.6 Eccentric mechanism and the total Test Rig assembly made in this project work

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

3.6 (a). Eccentric mechanism of the referred test rig design

Basic Components of Test Rig:

Important components of the test rig are given below:

1. Load cell
2. Specimen holding beam
3. assembly(refered test rig) replaced with eccentric mechanism
4. Induction motor
5. Adjustable columns (sliding)
6. Electronic circuit (signal conditioning system)
7. Data acquisition system

EXPERIMENTATION

The specimen making for the conducting flexural fatigue experiments with specific standards with repeatable quality is essential to perform meaningful experiments. In The referred research work samples are prepared with compressed moulding technique. The volume fraction of reinforcement obtained by compression moulding technique varies from batch by batch since there no qualitative method followed in applying the pressure on the pressure plate. Because of that, in the present work RTM method is considered to make these specimens as per standards with repeatable volume fraction of reinforcement. In this direction the specimen making mould which is comparable with RTM injection system is designed and fabricated. A closed mould is designed with 5.5 mm depth mould cavity and 300mm x 300mm laminate size. The details of specimen preparation and testing schedule are furnished in the following sections.

The testing schedule of the laminates:

4.1.1 Specimen preparation

4.1.2 Tensile testing

Specimen preparation:

Specimens were moulded by RTM technique. As per ASTM D 638 specifications, 5.5 mm (average) thickness laminates of desired orientation sequences are molded. Each laminate (240mmX240mm) consists of $[\pm 0^0]_4$and $[\pm 45^0]_{4,}$ orientation are made of unidirectional glass fabric were prepared. The tensile specimens with a width of 30 mm and 200mm long were cut by diamond disc saw. Similarly specimens with 5.5 mm thickness with four layers were also prepared for deflection test in cantilever mode. The specimens were of 30mm width and 140mm long were cut from the big laminate of 240X240mm. The matrix material used is general purpose polyester resin.

Details of RTM:

Fig.4.1 Representation of RTM

4.1.2.(a). Mould: A closed mould with made of mild steel which is machined from 15mm thick plate and a mould cavity of 5mm depth is machined by milling operation to mould the laminate with top cover made of 10mm thick MS plate. The details are furnished in the following figure.

Figure 4.2. Representation of Mould

b) Top covers plate:

The purpose of top cover plate is to apply uniform pressure on the laminates through this arrangement as shown in figure 3.5. As there is no control over the applied pressure, the spacer plates of desired thickness of 2.5 mm, 5.5 mm (depending on the requirement) and width 25mm are placed at the edges of four dams which restricts the movement of the pressure plate which ensures a uniform thickness which is equal to the thickness of spacer plate.

Polyester Resin:

Polyester resins are unsaturated resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Polyester resins are used in sheet molding compound, bulk molding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass so-called fiberglass reinforced plastic (FRP) are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls.

Unsaturated polyesters are condensation polymers formed by the reaction of polyols,organic compounds with multiple alcohol or hydroxy functional groups, with saturated or unsaturated dibasic acids. Typical polyols used are glycols such as ethylene glycol; acids used are phthalic acid and maleic acid. Water, a by-product of esterification reactions, is continuously removed, driving the reaction to completion. The use of unsaturated polyesters and additives such as styrene lowers the viscosity of the resin. The initially liquid resin is converted to a solid by cross-linking chains. This is done by creating free radicals at unsaturated bonds, which propagate in a chain reaction to other unsaturated bonds in adjacent molecules, linking them in the process. The initial free radicals are induced by adding a compound that easily decomposes into free radicals. This compound is usually and incorrectly known as the catalyst. Substances used are generally organic peroxides such as benzoyl peroxide.

Preparation of composite laminate:

The preparation of laminates consists of following process:

1) Coating.(releasing agent)
2) Stacking of fibers.
3) Fixing of mould.
4) Filling of resin in cylinder.

5) Building up pressure in the cylinder.
6) Injection of resin in mould.

4.3.1 Releasing agent: First wax polish is applied to the mould surface to improve the surface finish of mould and then poly vinyl alcohol (PVA) is sprayed to form an invisible layer which prevents sticking of laminate to the mould then the mould is left for 15 min to dry.

Fig. 4.3 Applying Silicon Spray

4.3.2 Stacking of fibers: Stacking of fiber consists of the cutting of fiber mats according to the required dimension and keeping them in the mould as per the pre-defined stacking sequence. (i.e.) $\pm 0^0$ and $\pm$ 45^0 orientations.

Fig.4.4 Stacking of Fiber Mats

4.3.3 Fixing of mould: After stacking the glass fiber mat, the upper plate of the mould is kept slowly on the bottom plate of mould by matching the bolted holes and tightens the bolts.

Fig.4.5 Fixing of Mould

4.3.4 Filling of resin in cylinder: Before filling the polyester resin in the cylinder, 200ml polyester resin and 2ml (i.e. 2percent of 200 ml) cobalt nopthalate accelerator are taken in one jar and 200ml polyester resin and 4ml (i.e.2 % of 200 ml) catalyst in another jar and mixed gently. In one cylinder pourthe resin which is been mixed with accelerator and in the second cylinder pour the resin mixed with catalyst with the help of the funnels.

Fig.4.6 filling the cylinders with resin mixed with catalyst and accelerator up to the required level

4.3.5 Building up Pressure in the Cylinder: After filling the cylinder with accelerated and catalyzed polyester resign , the pressure vessel is closed then the inlet valves and out let valves are closed to build up required pressure ie., about 2atms.,. Then the out let valve is opened to inject the resign in to the mould as shown in Fig.

Fig.4.7 Building up Pressure in the Cylinder

4.3.6 Injection of resin in mould: Resin is injected slowly in to the mould by opening the outlet valves of the cylinder after building up the required pressure in the cylinder. When resin is coming out from pressure vessel air in the mould is pushed out through the vent. then close the outlet valves and leave for curing the resin. After closing the outlet valves the remaining resin inside the cylinder must be removed as the pressure inside cylinder becomes atmospheric pressure, then close the outlet valve and open the inlet valve for pouring the thinner to flush out the inside resin. After curing the resin, laminate is removed from mould. These two varieties of laminates are prepared for further analysis to proceed with fatigue experimentation.

Fig.4.8 Injection of Resin

4.3.7 Removal of Laminate from the mold:
After filling the mold containing fiber mats with resin, leave it for 24 hrs. for the resin to get spread throughout all parts of the fiber mats. After 24 hrs. Remove the upper plate of the mold and then the laminate from the mold.

Fig 5.9 Removal of Laminate

4.4. A Trail Flexural Fatigue Test conducted on $(\pm 0^o)_4$ Test Rig :
The objective of the test rig is simulating desired reversed cyclic bending load application on the composite laminate which is fixed vertically as shown in figure 5.10. The bending load is measured from the signals of load cell. The eccentric mechanism is rotated through the head stock–pulley system by 3 horse power induction motor. Through this pulley system the rotating speed is obtained 1.57 RPS. The signal continuously coming from load cell is fed to signal conditioning system to amplify the signal to a readable extent. The signal conditioning system is capable of amplifying and conditioning the signal precisely. This analog signal is proportional to the load applied on the composite specimen. The signal is fed to the NI 6009, data logger with 8 channels. The data generated and logged is very huge, the LAB VIEW software continuously logs the data and stores the data in hard disk. The LAB VIEW software provides a facility to capture the data in the form of "snap shots". The data logging system has the capability of sampling

frequency of 48 kilo samples per second. As the frequency of loading cycles is 1.57 RPS, a 3.33 seconds snap shot could not be plotted as a complete cycle of loading, the sampling frequency has been reduced to 300 samples per second. The snap shot data can be exported to excel format. The typical sample in excel format is furnished below in the table 4.1. The sample front end of the LAB VIEW soft ware during experiment is furnished in the figure 4.11 and the snap shot data exported to excel could be plotted as shown in the figure 4.12. The data represented in this figure has to be further processed i.e. conversion from time vs. voltage data should be converted into load in Newton vs. number of cycles of load application.

Figure 4.10. Flexural fatigue test rig.

The NI 6009 data logger stores the data in the system hard disk in the 'LAB-VIEW' format. By converting this data into compatible excel format will provide the excel graph sheets which can be read to understand the failure behaviour of the specimen. From these graphs failure behaviors' can be modeled, as shown in table 4.1. There is a facility in the system that enables review of the logged data. In case the data generated is of large size then the data can be picked as per the programmed schedule in order to handle the data easily.

Date	########	
Time	12:07:42	
Y_Unit_Label	Voltage (V)	
X_Dimension	Time (s)	
X0	0.00E+00	
Delta_X	0.003333	
End_of_Header		
X_Value	12/8/2011 : 12:07:36 PM – Voltage - Dev1_ai0	
0	-0.97709	
0.003333	-0.99495	
0.006667	-1.02173	
0.01	-1.03958	
0.013333	-1.06254	
0.016667	-1.07146	
0.02	-1.08804	
0.023333	-1.09569	
0.026667	-1.11227	
0.03	-1.11865	
0.033333	-1.1314	
0.036667	-1.13395	
0.04	-1.1365	
0.043333	-1.13905	

Table 5.1: The sampled data in the form of time versus. Voltage

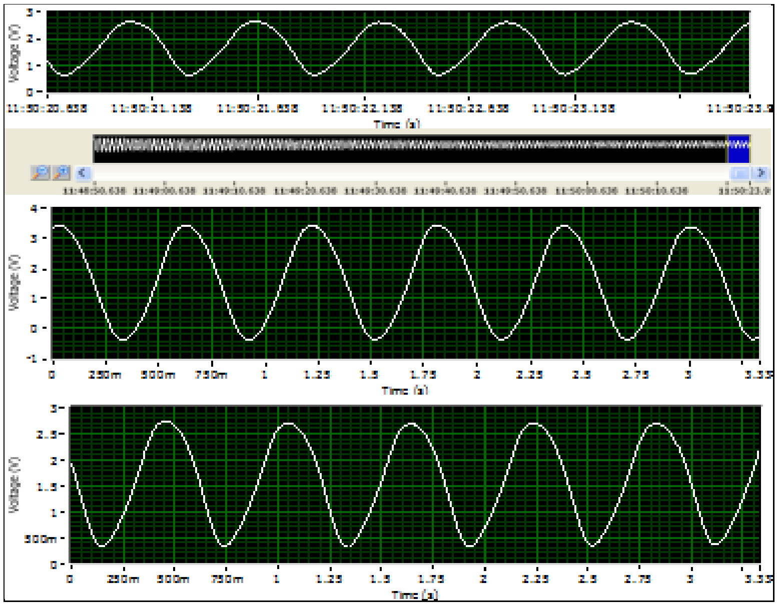


Figure 4.11: The front end of LAB VIEW software

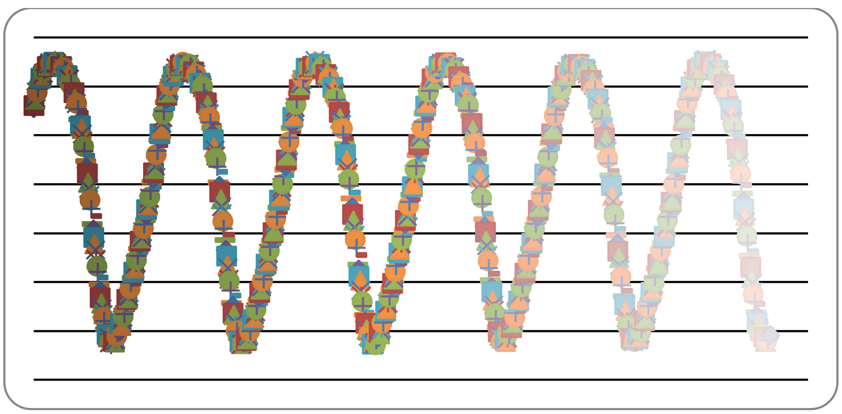


Figure 4.12: Excel plot of snap shot data voltage vs. time for 3.33 seconds

4.5. The flexural fatigue test conducted on specimens made by RTM Technique:
$(\pm 0^0)_4$ and $(\pm 45^0)_4$ specimen:

Before preceding the flexural fatigue test, the tensile tests have to be conducted to know the ultimate tensile stress and tensile modulus of the specimen. These tests are very important to start the flexural fatigue experiment. The maximum bending force to be applied on the specimen is calculated from bending moment equations. The bending force to be applied on the specimen is estimated from the bending stresses generated should be at least equivalent to the 50% of the ultimate tensile stress. These are the following typical equations involved to estimating the bending force to be applied while conducting the experiment to start with.

$M/I = f/Y = E/R$

Let M = Bending Moment = W*L (Where W is the bending load and L is the effective length of the specimen)

f = Bending Stresses = ultimate tensile strength $= \sigma_u / 2$

And **I** = Moment of Inertia of the specimen = $\mathbf{bt^3/12}$,

Where '**b**' is the width of the specimen and't' is the thickness of the specimen.

Y= t/2, t= thickness of specimen

E = Young's modulus (tensile modulus)

R= radius of curvature of bending

The load to be simulated is estimated from classical bending beam equation

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

i.e., **M/I = f/Y**, Where f is the bending stresses to be simulated as per the definitions of high cyclic fatigue loading.

The bending load could be estimated by the following formula, **W= f I /LY.**

$$W = \sigma_{u.} bt^2 /12L$$

For obtaining this bending force, tensile tests are conducted and the tests results are furnished in the following section

4.5.1 Tensile Tests:

Tensile tests are performed on the specimens made as per the ASTM D 638 specifications of (±0°). and ($\pm 45^0$) are tabulated in table 4.2. The specifications of the test specimen are 100 mm length, 5.5 mm thickness and 30mm width. Following figures related to tensile tests conducted on the above mentioned specimens. The figure 5.13. represents the tensile test set- up. The figure 5.13. furnished below are specimens subjected to tensile test.

Figure 4.13. tensile test on [$\pm 45^0$]$_4$ specimen is in progress

Sample orientation sequence in deg (CROSSPLY)	Max Tensile strength (MPa)	Modulus at 0.50% Strain(GPa)	Volume fraction Of fibres
[$\pm 0^0$]$_4$	269	39	0.55
[$\pm 45^0$]$_4$	49	8.9	0.55

Table 4.2. Tensile Test Results

4.6. Estimation of Bending Force to be applied on the Specimens to Conduct Flexural Fatigue Test:
From the content 5.5, the bending force equation is utilized to estimate the bending load to be applied is calculated and the results were furnished in following content.

$W = \sigma_u \, . \, \mathbf{bt^2} /$

Calculations of bending load for [±0^0]$_4$ orientation laminate

σ_u = Max Tensile strength =269 Mpa
b = width of the specimen =30mm
t = thickness of the specimen.=5.5 mm
L = effective length of the specimen =100 mm
Bending load $W = \sigma_u \, . \, \mathbf{bt^2} /12L$
$= 269x30x (5.5)^2 /12x100$
=203.4312 N

Calculations of bending load for [±45^0]$_4$ orientation laminate

σ_u = Max Tensile strength =49 Mpa
b = width of the specimen =30mm
t = thickness of the specimen.=5.5 mm
L = effective length of the specimen =100 mm
Bending load $W = \sigma_u \, . \, \mathbf{bt^2} /12L$
$= 49x30x (5.5)^2 /12x100$
= 37.056 N

The results are furnished in the following table

Sample orientation sequence in deg (CROSSPLY)	Max Tensile strength (MPa) σ_u	Modulus at 0.50% Strain(GPa)	$W = \sigma_u \, . \, \mathbf{bt^2} /12L$ Bending load in N
[±0^0]$_4$	269	39	203.433
[±45^0]$_4$	49	8.9	37.05

Table 5.3 Results of bending load of [±0^0]$_4$ and [±45^0]$_4$

RESULTS AND DISCUSSIONS

The present research work is aimed at to establishing the flexural fatigue test rig of laboratory scale model. The experimental tests (flexural fatigue tests) are conducted on glass polyester laminates made by resin transfer moulding system yielded results as follows: Before proceeding to flexural fatigue analysis tensile tests were conducted these are following results:

Sample orientation sequence in deg (CROSSPLY)	Max Tensile strength (MPa)	Modulus at 0.50% Strain(GPa)	Volume fraction Of fibres
[±0^0]$_4$	269	39	0.55
[±45^0]$_4$	49	8.9	0.55

Table 5.1.Tensile Test Results

The Tensile strength of laminates were noted for the maximum bending load to be applied is calculated.The maximum bending load is to be applied on flexural fatigue test for ±0º and ± 45^0 is 269N and 49 N, since the load is assessed in view of imparting bending stresses equivalent to 50% of the ultimate tensile strength of given laminate. For that the flexural fatigue test carried out while conducting the test from 0 time to about 4.5 hrs. the analog signals generated by load cell are captured periodically and data is exported to excel format in terms of time v_s voltage.

These are about 100 packets of data, the time vs. voltage which is in the sinusoidal wave form consisting of 1000 co-ordinates is once again plotted on excel sheet to identify the maximum voltage, which is corresponding to the maximum bending force. From these 100 packets of date maximum bending force is estimated form each packet of date from corresponding time and the number of cycles at which the maximum bending force applied is calculated since the rotational speed of eccentric mechanism is already known about 1.57 cycles/sec.From this the data is generated no. of cycles w.r.t. the maximum bending force from each packet of data corresponding to nth cycle of rotation.

Table 5.2: Stiffness degradation data of [±0^0] orientation with cross ply orientation sequence of stackin

Load in N	No.of.cycles
0	203.433
100.48	195.0901
219.8	174.7817
345.4	164.4822
405.06	161.7607
538.51	161.7837
591.89	153.7976
676.67	150.982
797.56	150.9805
904.32	148.3227
943.57	145.9081
1029.92	126.3948
1146.1	117.6701
1890.28	110.229
2138.34	109.1767
2474.32	107.4009
2701.97	105.3652
2739.65	102.7056
2797.74	89.8269
2824.43	85.7486
2964.16	81.7544
3058.36	78.933
3110.17	77.0881
3303.28	68.5054
3496.39	66.2801
4114.97	63.2782
4491.77	61.2136
4852.87	53.9836
5096.22	51.9006
5532.68	51.7336
4981.61	47.8545

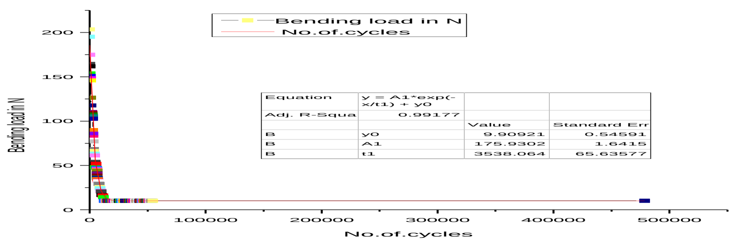
ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

6055.49	47.0603
6305.12	46.5053
6355.36	45.5965
6466.83	44.396
6531.2	43.9217
6590.86	40.8949
6626.97	40.5941
6653.66	38.3841
6686.63	36.1224
6714.89	36.0135
6749.43	35.5864
6772.98	34.369
6821.65	34.4097
7380.57	32.7602
7567.4	32.114
7892.39	29.3619
8262.91	29.1282
8700.94	25.6149
9132.69	24.2046
9679.05	21.4006
9964.79	20.6746
10489.17	16.6439
11366.8	16.0597
11999.51	14.1403
12767.24	10.0512
13547.53	10.0512
14057.78	10.0512
14894.59	10.0512
15305.93	10.0512
15769.08	10.0512
16552.51	10.0512
17397.17	10.0512
18012.61	10.0512
18552.69	10.0512
19196.39	10.0512
19915.45	10.0512
21078.82	10.0512
22000.41	10.0512
22564.04	10.0512

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

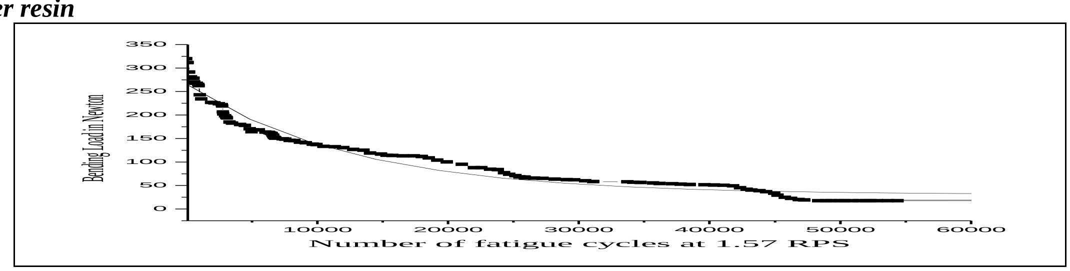
23242.28	10.0512
23831.03	10.0512
24287.9	10.0512
24689.82	10.0512
25170.24	10.0512
25481.1	10.0512
25865.75	10.0512
25906.57	10.0512
26602.08	10.0512
27245.78	10.0512
28164.23	10.0512
29088.96	10.0512
29665.15	10.0512
30506.67	10.0512
31128.39	10.0512
33731.45	10.0512
34169.48	10.0512
34748.81	10.0512
35693.95	10.0512
36191.64	10.0512
37158.76	10.0512
37794.61	10.0512
38502.68	10.0512
39607.96	10.0512
40356.85	10.0512
41085.33	10.0512
41805.96	10.0512
42351.01	10.0512
42837.63	10.0512
43218.32	10.0512
43834.83	10.0512
44342.76	10.0512
44954.73	10.0512
45214.65	10.0512
45761.9	10.0512
46254.75	10.0512
46832.34	10.0512
47267.73	10.0512
478727.1	10.0512

48331.89	10.0512
48929.47	10.0512
49293.66	10.0512
49992.45	10.0512
50320.86	10.0512
50934.13	10.0512
51434.78	10.0512
51992.24	10.0512
52312.65	10.0512
52854.37	10.0512
53652.83	10.0512
54394.73	10.0512



Graph of polyester resin

Figure 5.1: Stiffness degradation behaviour of [±0^0] orientation with cross ply orientation sequence of stacking of polyester resin



Referred graph of glass epoxy

Figure 5.1(a): Stiffness degradation behavior of [±0^0] orientation with cross ply orientation sequence of stacking

Table 5.3: Stiffness degradation Data of [± 45] orientation laminate with cross ply orientation sequence of stacking

Number of cycles	Bending Load in Newton's
0	37.07927
102.05	36.44253
246.49	31.78949
624.86	31.71039
920.02	30.82683
1343.92	30.29586

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

1507.2	29.21304
1843.18	29.05735
2362.85	28.99628
2719.24	28.60256
17.54	28.20315
4190.33	28.17902
4342.62	27.72439
4987.89	27.65098
5336.43	27.56625
5595.48	27.39245
5860.81	27.03623
6240.75	26.7588
6846.77	26.72898
6972.37	26.62883
7503.03	26.51816
7834.3	26.45851
8481.14	26.45163
8826.54	26.33383
9104.43	26.24492
9492.22	26.25694
10091.96	26.0549
10614.77	25.96836
11128.16	25.86947
11493.97	25.6717
12461.09	25.64718
13120.49	25.30512
13935.32	24.81283
14459.7	24.92263
14863.19	24.59489
15194.46	24.6278
15623.07	24.56174
15981.03	24.51689
16411.21	24.51365
16874.36	24.48691
17394.03	24.3862
17839.91	24.24246
18257.53	24.09588
18737.95	23.99248
19183.83	23.93822
19637.56	23.84962
20111.7	23.74891
20601.54	23.64979
22031.81	23.49339
22430.59	23.28977
23414.98	23.28582

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

24545.38	23.18393
24813.85	23.08876
25941.11	23.0621
26652.32	23.07824
27448.31	23.05585
28126.55	22.85579
28622.67	22.81244
29018.31	22.77067
29494.02	22.70422
29954.03	22.50225
30249.19	22.39269
30946.27	21.98054
31423.55	21.97825
31860.01	22.02437
32866.38	21.97255
33530.49	21.83498
34122.38	21.80634
34747.24	21.72834
35398.79	21.71909
35946.72	21.55447
36640.66	21.41413
37307.91	21.35638
38014.41	21.16913
38337.83	20.98956
38804.12	20.97935
38929.72	21.0091
39044.33	20.8815
40997.41	20.86496
41101.03	20.80033
41243.9	20.56752
41338.1	20.57242
41418.17	20.54853
41509.23	20.46737
41589.3	20.39554
41678.79	20.29151
43321.01	20.20062
44523.42	20.12626
45725.83	19.95254
46928.24	19.95023
48130.65	19.94792
49333.06	19.94561
50535.47	19.9433
51737.88	19.94099
52940.29	19.93868
54142.7	19.93637
55345.11	19.93406

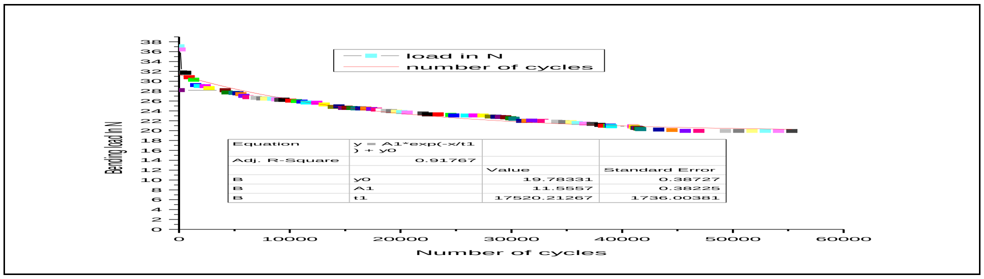
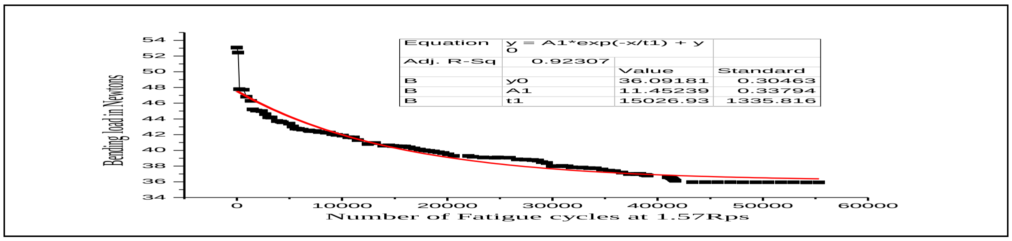


Figure 5.2: Stiffness degradation behavior of [± 45] orientation Laminate with cross ply orientation sequence of stacking



Referred graph of glass epoxy

Figure 5.2 (a): Stiffness degradation behavior of [± 45] orientation Laminate with cross ply orientation sequence of stacking

CONCLUSION

The flexural fatigue test rig fabricated in laboratory scale model performed similarly to the heavy duty. The specimen tested in referred test rig were made of compression moulding technique and the volume fraction is reinforcement achieved with compression mouldings in the order of 0.73 (73%) i.e. it 73% of glass fibre is incorporated by compression moulding technique.The pattern of stiffness degradation curve obtained with referred test rig test rig is very much similar to the stiffness degradation curve generated by the laboratory scale model test rig. The specimen made with the laboratory scale model are made of resign transfer moulding and the volume fraction of reinforcement is about 0.55 the difference in volume fraction of reinforcement when compared to compression moulded specimen is clearly reflected in stiffness degradation curve form both the testing equipment

The objective of fabricated laboratory scale model is to reduce the cost of machine to perform similar experiments at low cost. And with an objective of establishing the test procedure which can be easily carried out in abnormal engineering laboratory. To evaluate the flexural fatigue characteristics of all varieties of laminated composite materials with ease an authenticity. These experiments will provide a pathway to select better laminates pertaining the orientation sequence of stacking is possible for various engineering applications where in flexing are a critical functional requirement to be addressed while selecting suitable material.

SCOPE OF FUTURE WORK

The flexural fatigue machine can be utilized as a standards experimental set-up to conduct investigation on various laminated composite materials to meet various functional requirements. by adding additional features like including more number of operating speeds, investigations can be carried out to know the influence of fatigue loading cyclic frequency. by redesigning the load cell the operational loading fatigue can be varied for further investigations

REFERENCES

[1] Van Paepegem, W. and Degrieck, J. (2002). Coupled Residual Stiffness and Strength Model for Fatigue of Fibre-reinforced Composite Materials. Composites Science and Technology,62(5),687-696. SCI-IF: 2.171, SCI subject category Materials Science, Composites, rank: 1/21.

[2] Van Paepegem, W., Degrieck, J. (b) 2001. Experimental set-up for and numerical modelling of bending fatigue experiments on plain woven glass/epoxy composites. Composite Structures 51 (1), pp. 1-8

[3] Van Paepegem, W. and Degrieck, J. (2001). Experimental Setup for and Numerical Modeling of Bending Fatigue Experiments on Plain Woven Glass/epoxy Composites. Composite Structures, 51(1),1-8. SCI-IF: 1.116, SCI subject category Materials Science, Composites, rank: 4/21.
[4] Van Paepegem, (2006). Effect of friction on the hysteresis loops from three-point bending fatigue tests of fibre-reinforced composites. Composite Structures, 72(2), 212- 217. SCI-IF: 1.116, SCI subject category Materials Science, Composites, rank: 4/21.
[5] Van Hemelrijck, D., Ramault, C., Makris, A., Lamkanfi, E., Van Paepegem, W. and Lecompte, D. (2008). Biaxial testing of fibre reinforced composite laminates. Proceedings of the Institution of Mechanical Engineers Part L – Journal of Materials – Designandapplications,222(L4),231-239.SCI-IF: 0.244, SCI subject category Materials Science, Multidisciplinary, rank: 166/190.
[6] Makris, A., Ramault, C., Van Hemelrijck, D., Lamkanfi, E. and Van Paepegem, W. (2010). An investigation of the mechanical behaviour of carbon epoxy cross ply cruciformspecimensunderbiaxialloading.PolymerComposites,31(9),1554-1561. SCI-IF: 1.058, SCI subject category Materials Science, Composites, rank: 5/21. Times cited: 0
[7] Samyn, P., Quintelier, J., Van Paepegem, W. and De Waele, W. (2007). A relation between laboratory and full-scale testing of polyester/polyester composites under static and dynamic load. Proceedings of PRICM-6, 6th Pacific Rim International Conference on Advanced Materials and Processing, Jeju Island, Korea, 5-9 November 2007.
[8] Van den Abeele, F., Van Paepegem, W. and Degrieck, J. (2006). Experimental characterization and numerical modeling of impact damage in fibre-reinforced composites. Proceedings of the 12th European Conference on Composite Materials (ECCM-12). Biarritz, France, August 29 – September 1, 2006.
[9] Van den Abeele, F., Van Paepegem, W. and Degrieck, J. (2006). Experimental characterization and numerical modeling of impact damage in fibre-reinforced composites. Proceedings of the 12th European Conference on Composite Materials (ECCM-12). Biarritz, France, August 29 – September 1, 2006.
[10] Van den Abeele, F., Van Paepegem, W. and Degrieck, J. (2006). Experimental characterizations and numerical modeling of impact damage in fibre-reinforced composites. Proceedings of the 12th European Conference on Composite Materials (ECCM-12). Biarritz, France, August 29 – September 1, 2006.
[11] D.V.Ravishankar, K.Vasanth Kumar and P.Ram Reddy, Flexural Fatigue Analysis of Glass Epoxy Laminates by custom built computer Interfaced Flexural Fatigue test rig, International journal of emerging technologies and applications in Engineering Technology and Sciences,ISSN: 0974-3588| Volume 2 Issue 2| June '09- December '09.