FATIGUE FAILURE CHARACTERISTICS OF A FIBRE REINFORCED PLASTIC

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Abstracts This study describes the fatigue performance of pultruded Glass Fibre Reinforced Plastic (GFRP). A number of tests were conducted under static and cyclic axial loading to monitor static and fatigue performance. In this research a set up was designed and fabricated for determining the fatigue life of GFRP. Various samples with different ratio of fibre to resin were made and tested under static and dynamic condition . It was observed that the optimum ratio of fibre to resin to resist the static and dynamic load is same as per stress concern

Keyword: Pultruded GFRP, Dynamic load, Fatigue life

INTRODUCTION

The development of composite structures that we see today can be traced back to the 1940's with the construction of ply wood fuselage of the spitfire and mosquito fighter aircraft. Early 1950's a rapid increase in the wet lay up polyester fibreglass system were used to build all types of recreational boats. Some of the aspects like strength to weight ratio and durability of fibreglass constructions became apparent to designers of commercial aircraft. Some companies started the use of a few fibreglass reinforced to plastic composite parts such as wing tips, radom and tail cone. On the early Boeing 747 has over 10,000 square feet surface area of fibre glass composite structure. Fibre reinforce gives high ultimate tensile strength, high modulus of elasticity, and excellent dimensional stability to many components. FRPs are composed of continuous fibre/short fibres embedded in a plastic matrix . Matrix and fibre acts together to provide the reinforced fibres provide the rigidity of the component but main strength. So, the maximization of the mass fractions of the fibre content in the resin (matrix) is desired to maximize tensile strength, modulus of elasticity and other mechanical properties. However, there are limitations to the amount of fibre that can be embedded in a resin (matrix) . Recent study (1,2) has shown that large fibre mass fraction can result in a 30% to 40% decrease in static tensile strength. The optimum mass fraction of a fibre is also influenced by properties of the fibre and the type of matrix. Now a days the FRP are used not only in static condition. . But it is used in different dynamic loading conditions. Therefore, the dynamic behaviour of the FRPs are to be carried out extensively. Therefore, this research intends to concentrate its attention to find out relation between optimum mass fractions of fibre in a resin matrix under the dynamic loading conditions.

EXPERIMENTAL SET UP & TEST PROCEDURE

It was evident that the tensile strength of glass fibre reinforced sample depends not only on its resin matrix type and characteristics but also on the type of samples, its internal defects, grips etc. Therefore, special cares were taken to reduce voids. Modified grippers were also designed in such a way that test sample will not fail in the grip section.

At room temperature the resin is in a liquid form. The two halves of a cylindrical hollow tube were taken for preparing the samples. Initially the resin is mixed with chemical i.e. Methyl Ethyl Ketone (MEK) peroxide and a little amount of Cobalt as a catalyst and curing agent. The first layer of short chopped strand fibres was laid up in the two halves of cylindrical tubes. Then the fibres were wetted with uncured resin. The second layer of short chopped strand fibres was laid up on the previous layer and the fibres were wetted with uncured resin. Similarly operations were made until the two halves were full. Then the two halves were put together with the help of a no. of **'C'** clamps . Approximately 45 minutes time required for full curing of each casting. After curing the samples were machined to remove extra resin and fibre elements from the surface of the sample. Finally, the cylindrical rods were made for testing. About 500 mm long samples were taken for test.

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A set of gripping device were designed and constructed (figure 1) such that no failure will occur within the gripping area of the sample. The idea was that when sample were fitted and loaded the radial load which grips the test sample will vary with maximum gripping force at the end, (3,4). To achieve the internal surface of the gripper was tapered by 2%.

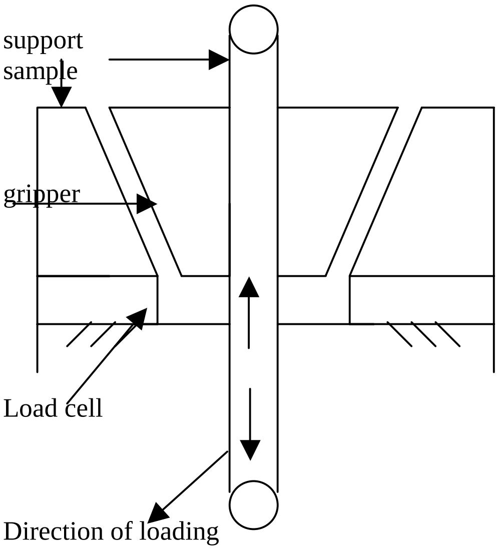

Fig. 1 Gripping device

The dynamic load system and the arrangement are shown in figure 1. In this loading arrangement the load arm is a hollow beam of rectangular section hinged at one end with the structure of the set up. At the mid position of the beam a connection were made with the test sample gripping attachment. The position of connection with the beam can be changed along the length of the loading beam. The other end of this arm there is a shaft welded to the beam. A pulley was fitted with the shaft through an extended bush. A rotating mass is fitted with the extended bush such that the amount of mass and the distance from the axis of rotation can be changed as desired. When the pulley and the bush rotate, rotating mass-produces a centrifugal force. A pair of roller bearing restricts the sidewise movement of this loading beam. Therefore the centrifugal force only results upward and downward motion of this end of the arm. Near to the free end of this beam provision was made for hanging dead weight. By changing the mass of the deed weight the required initial static tension can be applied. During the rotation of the centrifugal mass upward and downward force along with the static load cause fluctuating load at the beam supports. By lever action of this arrangement the applied load can be magnified and transmitted to the gripping attachment and thus to the testing specimen which is fixed with the supporting to structure. By shifting the position of the gripping attachment with the load beam the lever action can be varied. An a.c. motor is installed at the base of the set up structure for rotating the centrifugal mass.

A dynamic load cell was used to measure the load to the test sample. This dynamic load cell connected to a computer was initially calibrated. All static tests were conducted by using Universal Testing Machine. Extensions during static test were measured by the extensometer using the Linear Variable Differential Transducer (**LVDT**).

Table –1 Static strength of GFRP at different ratio of fibre to resin

Obs. No.	**Ratio of fibre to resin**	**Mean dia, d mm**	**Gage Length, L_0 mm**	**Load at failure, Kg_f**	**% of elongation $(L_f - L_0)100/ L_0$**	**Tensile strength, MPa**
01.	1:1	20.2	103.2	735	0.75	22.56 *****
02.	1:2	22.55	105	2750	0.87	67.59
03.	1:2.5	22.39	105	2500	0.93	62.29
04.	1:3	20.47	103.5	1345	1.35	40.02
05.	1:3.5	20.14	102.5	1150	0.38	35.47
06.	1:4	19.7	104.5	1000	0.38	32.17
07.	1:4.5	19.38	103.85	870	1.1	28.94
07.	1:5	21.02	102.34	950	0.62	26.88
08.	1:5.5	19.52	100.1	710	1.02	23.25
09.	100% resin	19.9	105	550	0.714	17.27

***** Bonding between fibre and resin was not sufficient.

Table –2 Dynamic strength of GFRP at different ratio of fibre to resin (Static load 325 kg)

Obs. No.	Ratio of Fibre to Resin	Static Load, Kg	Mean stress, σ_m MPa	Cyclic Loading		Max stress, σ_{max} MPa	Cycles to Failure, N
				Min Load, Kg	Max Load, Kg		
1	1:1	325	10.07	175	483.33	14.8	1100
2	1:2	325	8.08	175	483.33	11.87	1,52,000
3	1:3	325	10	175	483.33	14.4	85,341
4	1:3.5	325	10.1	175	483.33	14.88	11,305
5	1:4	325	10.59	175	483.33	15.55	1800
6	1:4.5	325	10.88	175	483.33	16.07	689
7	1:5	325	9.31	175	483.33	13.66	1734
8	1:5.5	325	10.79	175	483.33	15.85	73

Table –3 Dynamic strength of GFRP at different ratio of fibre to resin (Static load 375 kg)

Obs No	Ratio of Fibre to Resin	Static Load, Kg	Mean stress, σ MPa	Cyclic Loading		Max stress, σ_{max} MPa	Cycles to Failure, N
				Min Load, Kg	Max Load, Kg		
1	1:1	375	11.72	225	541.17	16.57	180
2	1:2	375	9.4	225	541.17	13.29	1,43,223
3	1:3	375	11.41	225	541.17	16.13	1,21,157
4	1:3.5	375	11.79	225	541.17	16.66	204
5	1:4	375	12.33	225	541.17	17.41	135
6	1:4.5	375	12.74	225	541.17	18	100
7	1:5	375	10.88	225	541.17	15.3	58
8	1:5.5	375	12.56	225	541.17	17.75	16

Table –4 Dynamic strength of GFRP at different ratio of fibre to resin (Static load 475 kg)

Obs No	Ratio of Fibre to Resin	Static Load, Kg	Mean stress, σ MPa	Cyclic Loading		Max stress, σ_{max} MPa	Cycles to Failure, N
				Min Load, Kg	Max Load, Kg		
1	1:1	475	14.54	325	625	19.13	893
2	1:2	475	11.66	325	625	15.35	1,12,005
3	1:3	475	14.16	325	625	18.63	75,228
4	1:3.5	475	14.63	325	625	19.25	426
5	1:4	475	15.29	325	625	20.11	229
6	1:4.5	475	15.8	325	625	20.79	178
7	1:5	475	13.43	325	625	17.67	2621
8	1:5.5	475	15.58	325	625	20.5	92

RESULTS AND DISCUSSIONS

Table –1 presents that the static strength of the GFRP at different ratio of fibre to resin. From the table it is found that the strength of the composite varies 17.27 Mpa to 67.59 Mpa. The maximum strength observed for 1:2 ratio of GFRP. As the ratio of the resin increases, from 1:2 to 1:1 the strength of the composites decreases due to weak bonding between fibre to resin.

Table –2 shows that the dynamic strength of the GFRP at different fibre to resin ratio. During this test static load was 325 Kg and the alternating load was 150 Kg. In this case the fatigue life was maximum when the ratio of fibre to resin was 1: 2 as observed in static load condition. Table –3 and 4 present the fatigue life of GFRP subjected to same alternative stress with higher mean static load in the both the cases the fatigue life was higher for GFRP with fibre to resin ratio 1:2.

CONCLUSIONS

It was observed that the failure load of the GFRP under static condition was 67.59 MPa for fibre to resin ratio 1:2 which is maximum and hence may be concluded that the optimum ratio of fibre to resin is 1:2 for the used resin and fibre combination. For dynamic condition the failure stress is much lower for the same above ratio and this value varies from 11.87 to 15.35 MPa. Under this dynamic loading the fatigue life varies from 0.15 million to 0.11 million cycles. However in all types of loading conditions the optimum ratio of fibre to resin is 1:2 for the used resin – fibre.

It will be worth while to mention that minor defects like voids and other imperfections were observed at the failure surface of the sample. This may leads to some error to the test result. So, further study is required for final conclusion.

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