ANALYSING THE FATIGUE LIFE ON WOVEN GLASS FIBER / EPOXY POLYMER COMPOSITE LAMINATE

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ABSTRACT:

The impact damage and fatigue life is inter-linked in this work. The laminates were prepared by hand layup process having two different thicknesses; 2 and 4 mm. The specimens were subject to low-velocity impact at different energy levels (7.85, 15.7 and 23.54 Joules). The 2 mm thick laminates experienced higher deflection and the absorbed energy was low, when compared to 4 mm thick laminates. The fatigue test was conducted for both impacted and non-impacted laminates, by keeping the stress ratio, R value at 0.1 and frequency at 3 Hz. The results indicate that the impact velocity is very much influential on the fatigue life of composite laminate. Further the results indicate that the fatigue life of the 2 mm thick impacted laminates was drastically reduced. A comparative study is also attempted to understand the behaviour of impacted laminates subjected to fatigue loading.

KEYWORDS: *Composites, Fatigue life, Epoxy polymer, Woven glass.*

1. INTRODUCTION:

The use of composites has evolved to commonly incorporate a structural fiber and plastic, this is known as Fiber Reinforced Plastics (FRP). Fibers provide structure and strength to the composite, while a plastic polymers holds the fiber together, common types of fibers used in FRP composite includes: Glass fiber, Aramid fiber, Carbon fiber, Boron fiber, Basalt fiber, Natural fiber(wood, flax, hemp..) etc. In case of fiber glass, thousands of tiny glass fibers are compiled together and held rigidly in place by plastic polymer resin. Common plastic resins used in composites includes: Epoxy, Polyester, Vinyl ester, Polyurethane and Polypropylene etc.

There are different types of manufacturing of composite laminates like Hand layup technique, Vacuum bag process, Compression molding, Filament winding etc. Composite materials however have some limitations like tensile & compression properties, fatigue behavior, impact response etc. Perhaps the most significant among these is the behavior of impact loading and fatigue after impact loading of the laminates. The impact damage may occur accidently at the time of manufacturing, fall of tools on its life time, from flying debris etc. from past decades several work is going on the impact related to the residual strength, tensile and compressive properties etc. The parameters like height of fall, impact mass, impact velocity, type of impactor etc. and also number of impact failure properties like, matrix and fibre damage, inter cracking, laminate splitting, deboning, delamination, pullout of fiber etc. In practical impact damaged components are can't see with our naked eyes, but there is some effect on the structure for after some long time. So it is very important to predict the life of damaged material. Investigations have been going on the fatigue life of the laminates after impact loading. Low velocity impact will influence much on the fatigue life and consequent reliability of the affected structure. Post impact fatigue behavior is still unlikely to be fully understood even for a material for which the fatigue response in undamaged laminates is known. For such conductions fatigue life prediction at different loading conductions is necessary. Fatigue is nothing but applying the cyclic load on the work.

Aim of the current work is to predict the fatigue life of woven glass fiber epoxy resin polymer composite laminates with impact damage it include the delamination and crack growth due to the combined effect of impact and fatigue.

2. LITERATURE SURVEY:

A. Bernasconi, et.al. [12] The effect of fibre orientation on the fatigue strength of a short glass fibre reinforced polyamide-6 has been investigated. Tension–Tension axial fatigue tests were conducted with specimens extracted from injection molded plates. Specimens were cut out of plates with different orientations with respect to the longitudinal axis of plates, and therefore displayed different orientations of the reinforcing fibers. Results are presented in the form of S–N curves, showing the variation of the fatigue strength as a function of the specimen orientation. The experimental data, both tensile and fatigue tests have been compared with values predicted by a failure criterion derived from the Tsai–Hill formula. The influence on the fatigue lives of the fiber orientation distribution in the thickness of the specimen is discussed.

S. Liuand J & A. Nairn, [13] the analysis has been done for providing fracture mechanics interpretation of matrix micro cracking in cross-ply laminates. The new energy release rate analysis for a fracture mechanics based interpretation of micro crack formation during fatigue loading. Fatigue experiments were run of three layups of AvimidandK Polymer/IM6 laminates and on four layups of Fiber lite 934/T300 laminates. A modified Paris-law was used and the data from all layups of a single material system were found to fall on a single master Paris-law plot. They claim that the master Paris-law plot gives a complete characterization of a given material system's resistance to micro crack formation during fatigue loading.

Y.Al-Assaf&H.ElKadi, [14] Fatigue behaviour of unidirectional glass fibre/epoxy composite laminates under tension-tension and tension-compression loading is predicted using artificial natural networks. Stress-life experimental data were obtained for fibre orientation angles of 0^0,19^0,45^0,71^0 and 90^0. These tests were performed under stress ratio 0.5,0 and -1. The feed forward network is used, provided accurate modelling between the input parameters and number of cycles to failure. Although a small number of experimental data points were used for training the natural network. The results obtained comparable to other current fatigue life prediction methods.

3. EXPERIMENTAL ANALYSIS:

In the first step, composite laminates are formed by placing woven glass fiber cloth is hand-laid up one ply at a time in the desired angles required. The desired composite thickness is built-up by placing successive layers of the fiber and resin mixture. The purpose of this step is to achieve the desired fiber architecture as dictated by the design requirements.

In the second step, fibers and resins were mixed together to form a lamina. In this, each fabric layer was wetted with resin mixture using a squeezing plate for proper impregnation. The squeezing plates were used to remove excess resin and air, which results in compaction of the plies.

The third step involves creating intimate contact between each layer of the lamina. This step ensures that all the entrapped air is removed between layers during processing. Consolidation is a very important step in obtaining a good quality part. Poorly consolidated parts will have voids and dry spots. The bagged part was then placed in an oven and cured under the specified time, temperature and pressure. The vacuum bag was evacuated to remove the air and the autoclave supplied gas pressure to the part. The vessel contains a heating system and a blower which circulate the hot gas.

The final step is solidification, which may take up to 120 min for thermo sets. Vacuum and pressure was maintained during this period. In thermoset composites, the rate of solidification depends on the resin formulation and cure kinetics.

4. EXPERIMENTAL INVESTIGATION:

The cyclically applying load on the work is nothing but fatigue. The fatigue test is conducted as per ASTM D3479 test STD it is shown in the fig 1. The schematic diagram for fatigue test specimen is shown in fig 1 for 4mm. At the ends of the laminates Aluminum is used as tabing for the purposes of holding the specimen to test machine. The servo hydraulic computer controlled Fatigue testing machine is used. The fig 2 shows the schematic diagram for fatigue machine fixtures. In this one is movable other one is fixed. The two jaws are operated by hydraulically because it holds the specimen very rigidly and handling is easy shown in fig 3

The input values given for the fatigue testing is as follows, the tests were conducted at stress ratio, ($R = \sigma_{min}/\sigma_{max}$) R=0.1, Frequency is 3Hz. The frequency is kept below 5Hz to avoid thermal effect on the specimen because it also reduces the fatigue life. The maximum load on the specimen is 40% to 70% of the ultimate tensile strength for the un impacted specimen (7.5KN).

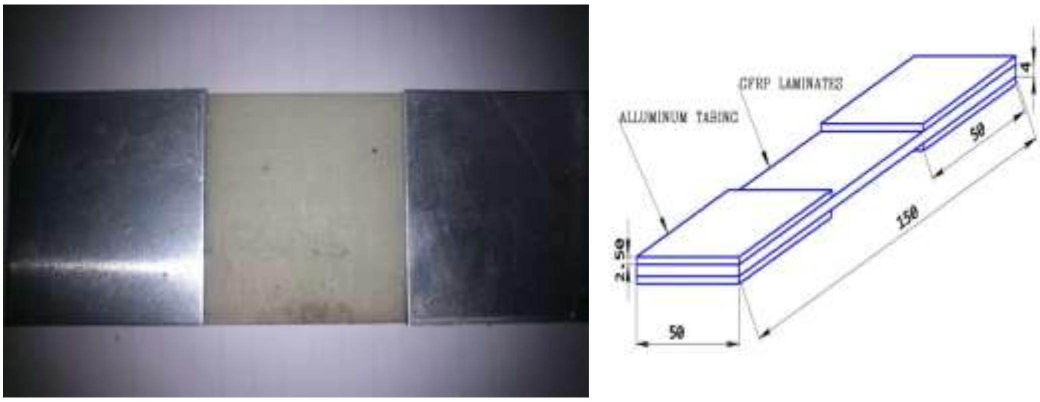

Figure 1. Fatigue Test Specimen as per ASTM standard.

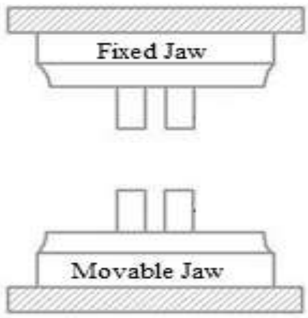

Figure 2. Schematic diagram showing the fatigue test machine fixtures.

Figure 3. a) Fatigue machine b) Specimen arranged in Fatigue machine.

5. RESULTS AND DISCUSSION

Fatigue is nothing but applying the cyclic load on the work. There are different types of fatigue testes are there in that Tension- Tension fatigue is very important for laminates. In this each fatigue cycle the tensile fatigue load is applied, this causes the local buckling and displacement of the impact damage site. This is visible on front and back faces at the speed of fatigue cycling (3Hz). The amplitude of moment was in the range of 2mm but it was grater in those laminates with higher velocity impact.

In the tension phase of fatigue cycle the crack could be seen to open very slightly and after a few hundred cycles the 2 cracks would join across the impact indentation. In later stages of fatigue test some of surface plies would delaminate from the damage plies and buckle during the tension phase of the cyclic loading. This delimitations buckling would occur predominantly on the back face through occasional on the front face close to the impact damage site.

The crack is incremented throughout the width of composite laminate. The crack was elongated there is a reduction in the stiffness of laminate. It would appear that matrix and fiber failure increases gradually within the impact zone, it leads to the sufficient reduction in the stress and evenly final failure occurred in laminate perpendicular to the applied fatigue load it is as shown in Fig 5.5 to 5.9.

Below Fig shows Log of No. of cycle’s v/s Impact velocity (m/s) for fatigue life time curve, under Tension-Tension fatigue loading for 2 & 4mm thickness of woven glass fiber reinforced polymer composite laminates with and without impact loadings respectively. The impact damage decreases the fatigue life of the composite laminates. At the low velocity (3.132m/s) the impact damage has less effect on fatigue life compared to other velocities and so in the Log of No. of cycle’s v/s Impact velocity curve.

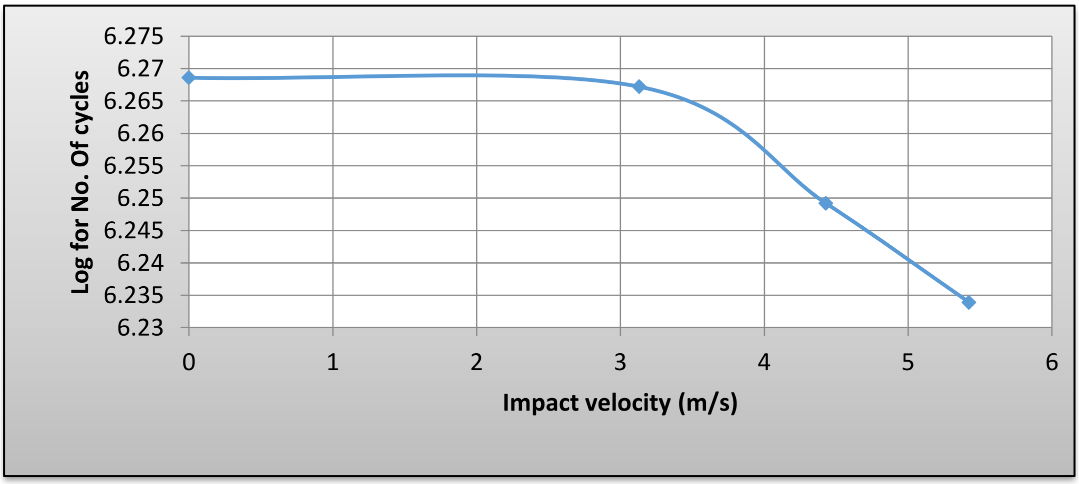

Figure 4. Fatigue life.

The fatigue life was determined for the laminates under impact velocities say 0, 3.132, 4.429&5.425 m/s. 4mm thickness of woven glass fiber reinforced polymer composite laminates low velocity impact of 3.132m/s, will not much effect on the fatigue life of the laminates at the impacted and un impacted, there is small variation on the fatigue life compared to the other velocity's 4.429&5.425 m/s. The fatigue life at these impact velocities is very small, because which cause the fiber damage in the laminates during impact loading.

6. CONCLUSIONS

The investigation of the effect of low velocity impact and tension-tension type fatigue on woven glass fiber/epoxy polymer composite laminate has led to the following conclusions:

1) The force versus displacement and the time versus force curves for each case have been drawn.
2) The impact damage has a significant effect on the subsequent fatigue life; it decreased the life of the component.
3) Increasing the amount of impact damage reduced the fatigue life of laminate.

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