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DESIGN ANALYSIS AND EXPERIMENTAL EVALUATION OF SANDWICH COMPOSITES SUBJECTED TO FATIGUE

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Abstract— The fatigue response of sandwich composite panels with an improved structure and different orientations to increase their fatigue resistance is investigated herein. In order to compare the fatigue performance of sandwich structures, a specific and instrumented ball drop tester was designed and developed. Different sandwich structures are analyzed. Composite materials here compose of E-Glass fibre matrix composite skin and a foam core. Usually the foam core is Polyuretene (P.U) and Polyphenolic .The latter structure is specially designed to improve crashworthiness for transport applications, aeronautical and space structures.

The main results of this study are evaluation of the absorbing energy performance of the sandwich structures, subjected to a repeated impact of the sandwich panels up to fatigue, and the development of criteria useful for materials selection. These sandwich panels have shown a better performance in terms of impact energy absorbing properties and strength respect to traditional sandwich structures. The predicted fatigue behavior of sandwich panel compared fairly well with results from finite element analysis. Analytical predictions of these were also found to be in good agreement with experimental data. Specimen deformation behavior and fracture features are correlated to deformation curves obtained during the testing. Extensive experiments are carried out to characterize different oriented sandwich panels for the mechanical behavior as well.

KeyWords— composites, sandwich, fatigue, deformation.

I. Introduction

Increasing performance demands for modern technology applications make it necessary to look for new materials. It is difficult to achieve high and strict performance standards using any one material, hence new materials are fabricated by combining two or more conventional materials. These materials named as composite materials give unique combination of properties, which cannot be obtained from any single conventional material. A formal definition of composite materials give by ASM Handbook [4] is macroscopic combination of two or more distinct materials, having a recognizable interface between them.. Composites are normally made by incorporating some reinforcement such as fibres in a bulk material known as matrix. Some of the main advantages of composite materials are high strength, modulus, bending stiffness and chemical resistance. Properties of composites can also be tailored according to specific design requirements, directional and spatial properties.

Defining a composite material needs information on three aspects

- Matrix material: e.g. metal, polymer or ceramic
- Reinforcements: e.g. continuous or discontinuous fibres or particles
- Structure: e.g. laminated or sandwich

The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Matrix materials are usually some type of plastic, and these composites are often called reinforced plastics. There are other types of matrices, such as metal or ceramic, but plastics are by far the most common. There are also many types of plastics, but a discussion of them is beyond the scope of this week's column. Suffice it to say for now that the two most common plastic matrices are epoxy resins and polyester resins.

Metal Matrix Composites (MMCs) - mixtures of ceramics and metals, such as cemented carbides and other cermets

Polymer Matrix Composites (PMCs) - Thermosetting resins are widely used in PMCs

Examples: epoxy and polyester with fibre reinforcement, and phenolic with powders

Ceramic Matrix Composites (CMCs) - Al_2O_3 and SiC imbedded with fibres to improve properties, especially in high temperature applications

II. Literature Survey

A. Russo, B. Zuccarello worked on the analysis of the mechanical behaviour of a class of sandwich structures widely employed in marine constructions, constituted by fibre-glass laminate skins over PVC foam or polyester mat cores. In detail, a systematic experimental study and numerical simulations have shown that the theoretical prediction of the strength and the actual fatigue mechanism of these sandwich structures can be affected by significant errors, especially in the presence of prevalent shear loading. Moreover, because of the low shear stiffness and the elastic constants mismatch of the skins and core

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material, fatigue modes and strength are strongly influenced by eventual stresses orthogonal to the middle plane of the sandwich. In particular, for the sandwich structures with PVC foam core; such a stress interaction leads to early skin–core delimitation fatigue. By means of accurate non-linear simulations, accurate fatigue criteria, which can be used at the design stage in the presence of complex loading, have also been developed.

Kepler et al. describes a series of tests focused on the combination of structural loading (bending, shear) and simultaneous penetrating impact on sandwich panels with thin GFRP face-sheets, with emphasis on the specific damage morphologies and developments depending on the type and magnitude of structural loading. The test specimens were sandwich panels, length 250 mm and width 150 mm, with carbon fibre prepreg face-sheets ([0_/90_], thickness tf ffi 0.5 mm) bonded to the faces of a foam core (density 80 kg/m3, thickness H = 10 mm). The impact velocity was approximately 420 m/s, using a spherical steel impactor, diameter 10 mm, with a mass of 4.1 g. A high-speed camera was used for registration of panel response. It was demonstrated, that, at preload levels above a specific limit, the impact would cause catastrophic failure, i.e., complete or near-complete loss of structural load carrying capacity. Developments of failure morphology, consistent with the observed evidence, were derived and outlined.

III. Sample Preparation

The preparation of the sandwich panels, and it has been by compression moulding techniques.

Figure 3. unidirectional fibre

Figure 4. Epoxy resin (LAPOX)

Figure 5. polyurethane foam

Figure 6. polyphenolic foam

A. Design and Fabrication of Metallic Mould

The pressure to be applied to consolidate laminate after impregnating resign should be applied by compression as the required specimen are to be manufactured as per ASME specifications. The mould is made of MS material. To prevent the leakage of resin four dams were fixed through nuts and bolts on a 10mm thick MS plate which was having machined by facing operation on lathe machine. The detail of the mould is shown in fig.

Figure 7. Representation of Mould

In this particular mould is designed and fabricated to achieve uniform thickness. The laminate surface finish is of the grounded surface finish of the mould surface, the uniform thickness is obtained by keeping spacers made out of MS flat with 10mm thickness.

B. Formation of classical Laminate Theory

From the laminate theory the estimation of young's modulus of the composite laminate in the direction of load application and in transverse direction can be done by solving the above mentioned equations. This process is comber some and laborious. To avoid the laborious processes laminate design software is developed as a first experimental work. The Laminate software sheet is shown below :

Figure 12. Laminate software front end generated using VB software

V. Experimental Results

In the above chapter analysis has been done with the help of the ANSYS software and the results obtained were furnished in the form of ANSYS results output screen shots and in the following sections the results were published by performing different tests by Universal Testing Machine with computer integration were performed in the CIPET Hyderabad are as follows.

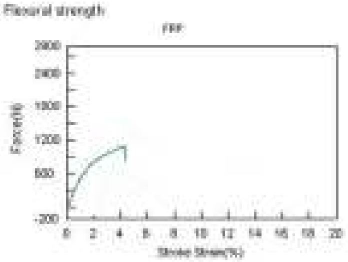

Figure 13. Graph obtained between force and strain for 0 degree orientation from the computer of UTM

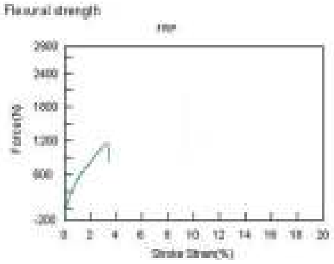

Figure 14. Graph obtained between force and strain for 10 degree orientation from the computer of UTM

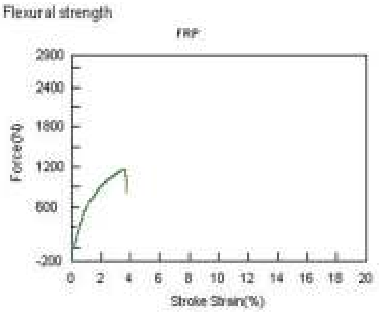

Figure 15. Graph obtained between force and strain for 20 degree orientation from the computer of UT

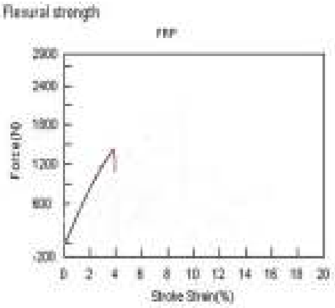

Figure 16. Graph obtained between force and strain for 45 degree orientation from the computer of UTM

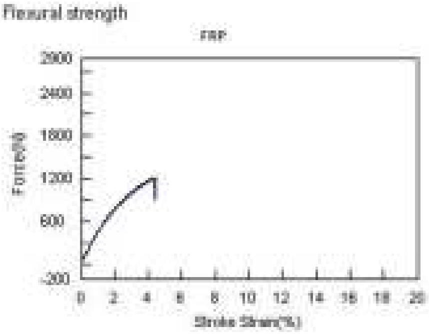

Figure 17. Graph obtained between force and strain for58 degree orientation from the computer of UTM

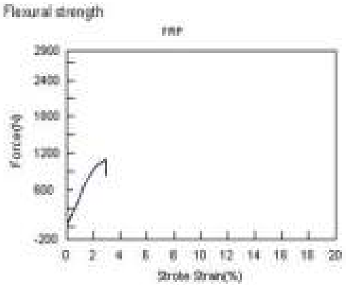

Figure 18. Graph obtained between force and strain for 0-90 degree orientation from the computer of UTM

In the following sections comparative statements of analytical test results with FEA analysis are furnished for further investigation to arrive at meaningful conclusions.

Table:1

Load in N	orientation	Bending Stress N/mm2	
		FEA	experiment
1124.76	0^0	99.603	86.5359
1186.85	10^0	81.565	117.478
1194.75	20^0	112.278	107.254
1452.28	45^0	102.845	98.758
1258.9	58^0	102.201	97.586
1086.26	0^0-90^0	99.89	104.89

Table:2

Load in N	Orientation sequences of stacking	Strain	
		FEA	experimentation
1442	0^0	4.19E-04	0.008954
1357	10^0	1.65E-03	0.002579
674.313	20^0	2.80E-03	0.00194
901.438	45^0	8.00E-03	0.00775
604.188	58^0	6.55E-03	0.00665
174.828	0^0-90^0	0.00182	0.001774

Table:3

Load in N	Orientation	Deflection in mm FEA	Deflection in experimental
1442	0^{0}	0.51	0.82
1357	10^0	0.21	0.4
674.313	20^0	0.281	0.48
901.438	45^0	21	17.5
604.188	58^0	7.9	8.6
174.828	0^0-90^0	4.084	5.25

VI. Conclusion

- The experimental results furnished in **table no:1**, regarding bending stress corresponding to the bending load applied is very close to the analytical binding stresses. The small variation about 10% is may be due to small defects, generally appears due to the poor workman ship, during the preparation of the samples.
- The experimental results furnished in **table no:2**, regarding the binding strain is also appeared very close i.e.,7% to the analytical bending strain, when compared to the FEA.
- The experimental results furnished in **table no..3**, regarding the deflection for the given load is also very close to the analytically appeared deflection compared to the FEA. i.e., 8% deviation.
- The FEA was implemented and the deflection was observed to be 0.04mm.

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