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Investigation of Chopped Strand Mat-Woven Roving Characteristic in Durability Behaviour

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ABSTRACT

This paper investigates the durability behaviour of composite lamination structures using a combination of fibre glass and glass fabrics. The purpose of the study is to evaluate the behaviour characteristic of composite structures in terms of impact test, tensile test (monotonic test) and fatigue test (cyclic test) subjected to different fatigue loading. The materials selected for the studies were chopped strand mat (CSM) and woven roving (WR) fabric as reinforcement materials and produced by hand lay-up technique using epoxy resin. The orientation of lamination structures used in this research is $0^0/90^0$ and CSM as additional materials in composite structures. In this case, the investigation of durability behaviour of composite structures is on the lamination structures in 2 (two) symmetry of stacking sequence. five layers Based on the result it was found that the characteristic of composite lamination structures is dependent on the use and condition of its environment, especially under stress, strength and strain.

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INTRODUCTION

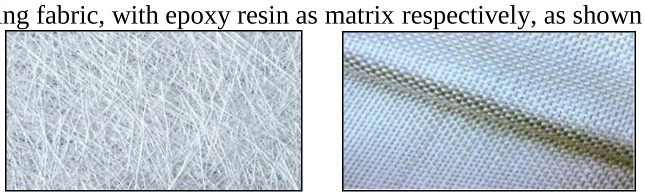
Polymer Matrix Composite is unique material and basically it has two constituents, which is a matrix and reinforcement. Matrix and reinforcement are combined together to produce other materials that produce a better properties than the individual materials used alone (Nazareth, D.S., 2001). The structures and components made by PMC (FRP) are being used for many structural applications, such as automotive, shipping and aerospace. Low velocity impact on composite materials is a very important factor which will affect the strength of materials, without any obvious damage at the impacted surface (Sutherland, L.S. and C.G. Soares, 2005).

In composite materials, the mechanical properties and the fatigue life of materials depends on a few types of factors, such as matrix and reinforcement materials, orientation, stacking sequence, volume fraction, porosity and moisture contents. The material selected for this study is one of the materials used in a maritime industry. Therefore, in order to understand the behaviour of this type of composite $[CSM/WR/CSM]_{2s}$, three types of experiments were carried out, which is a charpy impact test, tensile test and fatigue test.

MATERIALS AND METHODS

Specimen Fabrication:

The tested material chosen was chopped strand mat/woven roving, composite laminates. The composite has been made is composite lamination structures and were fabricated by hand lay-up technique. The composite specimen were cured at room temperature for 36 hours. The material used as a reinforcement were chopped strand mat and woven roving fabric, with epoxy resin as matrix respectively, as shown in Figure 1.



(a) (b)

Fig. 1: The materials used in composite lamination, (a) chopped strand mat (b) woven roving.

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Table 1: Characteristic of lamination structures.

	SPECIMEN
Chopped Strand Mat	3 Layers
Woven Roving	2 Layers
Stacking Sequence / Orientation	$[CSM/0/90/CSM]_{2s}$
Ply	5 Layers
Resin	Epoxy
Average Thickness	$\pm$ 4

Mechanical Testing:

Charpy Test:

The charpy test is a dynamic three point bending test, whereby the pendulum of charpy instrument falls in circular trajectory and hits the specimen in the middle of span length and transferring the kinetic energy to the specimen. The Zwick/Roell Charpy Test Rig Instrument was used for the investigations of impact damage resistance of composite lamination structures. The specimen length and width were [80 x 10] mm according to ISO-179 standard.

Monotonic Test:

The tensile test was performed using the Instron Machine Material Test System accordance with ASTM D-3039 standard and equipped with a load cell of 3 kN. The cross-head speed is 2 mm/min. The purpose of these tests is, to determine the mechanical properties which then will be used in a fatigue test. The dimension of the specimen is 250 mm in length, 25 mm in width and 4 mm in thickness according to ASTM D-3039 standard for the rectangular specimen size.

Cyclic Test:

Fatigue test has been carried out according to ASTM D-3479 for polymer matrix composites (PMC) using an Instron Machine Material Test System. The aim of this work is to investigate the basic characteristic of composite materials, $[CSM/WR/CSM]_{2s}$ as lamination structures, in term of life cycle and effect under different loading condition. In this test, five loading values have been considered, which is 50 %, 60 %, 70 %, 80 % and 90 % of ultimate tensile stress. The parameters chosen were based on a method to construct the S-N curve for composite materials. The fatigue tests were performed at constant load amplitude with a stress ratio R > 0, at low frequency of 5 Hz (Hansen, U., 1999).

RESULT AND DISCUSSION

In these works, three types of experiment have been performed, which are charpy test, tensile test and fatigue test. Different behaviour appears of each experiment. This is due to anisotropic behaviour of composite materials and which is more difficult to analyze, especially in the investigation of the strength and weaknesses of the materials (Huang, Z.M., 2004). Therefore, in order to know the general characteristic behaviour of composite materials, the $[CSM/0/90/CSM]_{2s}$ lamination has been used.

Figure 2 shows a peak force for five specimens of $[CSM/0/90/CSM]_{2s}$ in Charpy test condition. Based on this experiment, it shows the ability of composite materials to withstand the loads and its capability to absorb the energy from the impacted phenomenon. The highest load in this experiment is 350 N and the lowest load is 240 N. Each specimen has a difference of energy absorption behaviour, which is around 0.6-0.9 J. Although, it has a similar composite lamination structure, but it shows different of behavior. This is because the composite impact energy depends on the manufacturing process conditions and also fiber length, either continuous or short, as reported (Yu, S.B., 1999).

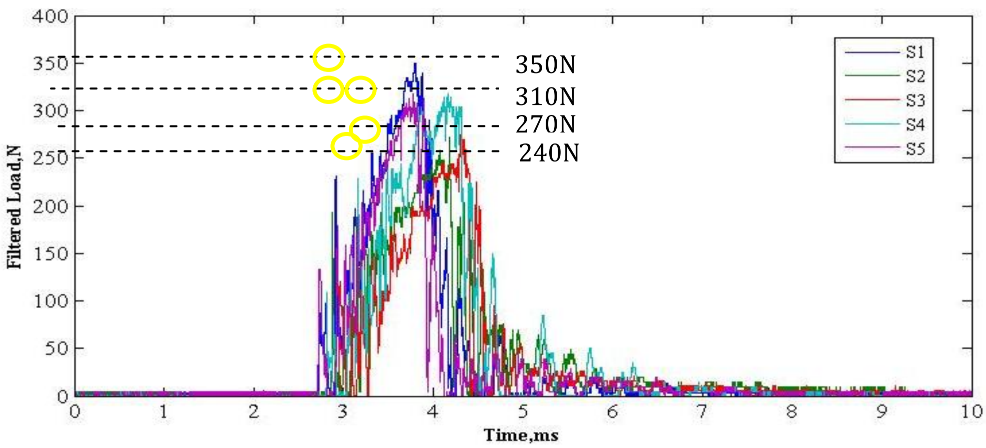

Fig. 2: Peak force behaviour of five specimens in Charpy test condition.

For tensile test, the stress and strain behaviour of $[CSM/0/90/CSM]_{2s}$ composite lamination structures has obtained, as shown in Figure 3. The average value of ultimate tensile stress (UTS) for five specimens that has been tested is 92 MPa, while the strain average is 0.044 mm. The interface between materials in composite lamination structures plays an important role in ensuring that the combination of materials is strong enough to withstand the load from other conditions. These factors also influence the differences that occur in strain behaviour. However, in general, the tensile properties of composites are markedly improved by adding fibres to polymer matrix since fibres have a much higher strength and stiffness values (Holbery, J. and D. Houston, 2006).

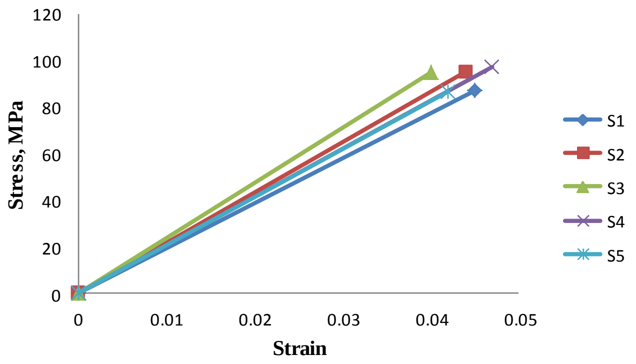

Fig. 3: $\sigma - \varepsilon$ curve of $[CSM/0/90/CSM]_{2s}$ composite lamination structures

In this experiment, it should be noted that the fatigue failure test is under the tension-tension (T-T) test condition with a load control circumstances, differences in percentage stress level of ultimate tensile stress. The ultimate tensile stress (UTS) values were obtained from the monotonic experimental that has been conducted before. Figure 4 shows the comparison graph of $[CSM/0/90/CSM]_{2s}$ composite lamination structures with a literature experimental. The purpose of this work is to know the difference of behaviour in composite lamination, in term of fatigue condition. The literature experimental used is Gi/Ep $[90]_7$ (Philippidis, T.P. and T.T. Assimakopoulou, 2008). Based on the graph, for both types of specimen, by increasing the maximum stress level, the number of cycles to failure is decreased. This is due to the number of stress level approaching the value of ultimate tensile stress (UTS). However, if the percentage of applied stress level is lower, the fatigue life will increase until it is approached the fatigue limit values.

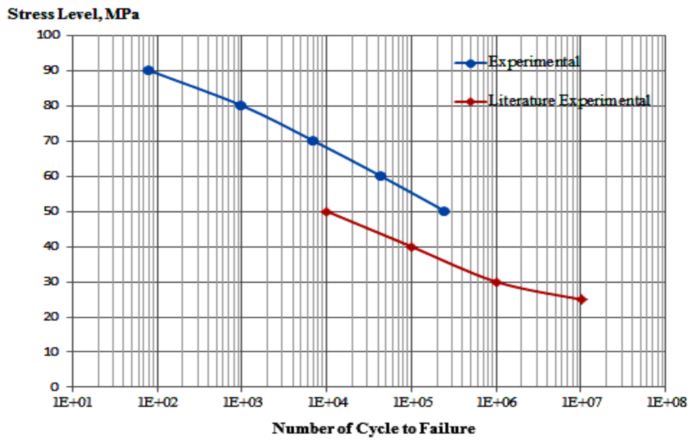

Fig. 4: S-N curves for $[CSM/0/90/CSM]_{2s}$ versus literature of experimental.

Conclusion:

The experiment was conducted in a Charpy test, tensile test (monotonic) and fatigue test (cyclic) for $[CSM/0/90/CSM]_{2s}$. Based on three types of experiments, the initial characteristic of composite materials, for this type of lamination structures is known. It also shows, with different type of composite structures, the behaviour of structural system is different. Furthermore, the characteristic of stress, strain, strength and impact phenomenon of this type of composite structures is identified.

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