Determination of Mechanical Characteristics of a Hybrid Composite Material

[1]ShoaibSadik, [1]Mohammed Jafer Kounain , [2]Syed Saleem

[1]Under graduate student, [2]Associate Professor,

Mechanical Engineering,

Ghousia College Of Engineering,

Ramanagaram-562159,

ABSTRACT

An important problem facing design engineers in the aerospace industry is how to achieve better design concepts by considering structure performance and manufacturing cost in the early stages of product development. One of the most important considerations in designing a space craft is weight. By reducing the weight of a spacecraft, it is easy to increase the pay load, which improves agility and reduces the launch cost. The structural and mechanical parts of a spacecraft generally represent a large percentage of its weight and, therefore, it is important to choose the proper material and structural configurations to minimize the weight. In many industrial applications reducing the weight of a structure without compromising its strength and stiffness is considered to be one of the most important design criteria. Today, the search of the best performance, quality and cost for space vehicles becomes a complex process. The purpose of this work is to perform a tensile test on honeycomb panels used in the satellites structural design. To fabricate the sandwich honey comb panel, Jute fibre sandwiched between the Glass fibres are used as face sheets and Glass fibre as core material, Epoxy as a bonding agent. The developed honeycomb panel is subjected to mechanical investigations as per ASTM standards to determine the tensile strength which is essential for structural design. The obtained results show a good experimental test results.

KEYWORDS: Honeycomb structure, American Society for Testing and Materials (ASTM).

1. INTRODUCTION

Composite material is a combination of two or more materials in which one of the materials is called the reinforcing phase which is in the form of fibres, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fibre or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibres, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fibre axis. The matrix is more ductile than the fibres and thus acts as a source of composite toughness. The matrix also serves to protect the fibres from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

II.METHODOLOGY AND SPECIMEN PREPARATIONS

Present work is focused on fabrication of honeycomb sandwich structure for various mechanical properties. Initially the honeycomb is fabricated as core for sandwich structure then GFRP face sheets were fabricated as per ASTM standard. The following procedure was followed for fabrication of sandwich structures, the face sheets of the sandwich panel were Jute fibre sandwiched between the Glass fibres are used as face sheets and Glass fibre as core material, Epoxy as a bonding agent. The face sheets with a thickness of 1 mm and a fibre volume ratio of 60%. The core used for the sandwich panel was glass fibre/epoxy and it was 4 mm thick. The sandwich panel was fabricated by bonding the cured face sheets to the core material with epoxy and polyester resin as adhesive at room temperature, the face sheets and core were bonded together. The final sandwich panel is a square plate of 300 x 300 mm dimensions with an overall thickness of 6 mm and a mass of 0.525 kg.

2.1 Material Selection

In the present work face sheets and honeycomb core are made up of glass fibre andepoxy.

Table 2.1 Properties of Glass Fibre and Epoxy

Material	**Density (ρ) kg/m3**	**Poisson's ratio (μ)**	**Youngs modulus (E) Gpa**	**Shear modulus (G) Gpa**	**Volume fraction (%)**
Glass fibre (200gsm)	2500	0.29	24.69	11.33	60
Epoxy/Resin	1250	0.35	2.75	1.5	40

2.2 Measurement of Fibre Volume Fraction

The burn-out test method is adopted to determine the fibre volume fraction of the E glass fibre / epoxy face sheets. In this method, sample of about 0.1 to 0.5 grams of face sheet was burned off in a high temperature oven at about 750°C for about an hour. Then, the remaining fibre mass is weighed and the volume of the fibre was calculated by dividing the mass of the fibre by the density of the fibre material. The fibre volume fraction (V_f) has been calculated by using below equation.

$$V_f = \frac{v_f}{v_f + v_m} 100 = \frac{\frac{m_f}{\rho_f}}{\frac{m_f}{\rho_f} + \frac{m_m}{\rho_m}} 100$$

Where,

v_f and v_m are the volume of fibre and matrix respectively.

m_f and m_m are the mass of fibre and matrix respectively.

$\rho_f$and $\rho_m$are the density of fibre and matrix respectively.

2.3 Fabrication of Glass Fibre Factsheets for Sandwich Structure

Glass fibre of 200gsm is cut in to dimension of 300 × 300 mm and calculating number of ply required for 1 mm thickness. Volume fraction for fibre/resin of 60:40 was taken for GFRP preparation.

2.4 Preparations of Glass Fibre Face sheet

1. As per calculation, Glass fibre mats of area 300 x 300mm were prepared for face sheet**.**
2. Epoxy/resin of LY556 type and HY951 type of hardener with 10:1 ratio were used.
3. Resin and hardener were stirred for five minutes for uniform mixing.
4. Mixture of resin-hardener (adhesive) was applied to the Mylar sheet using a spreader on a ceramic tile.
5. The glass fibre mat is placed on the Mylar sheet and mixture is applied on the ply until the entire ply gets uniformly wetted.
6. This procedure continues until to get 1 mm thickness of the face sheet.
7. After this and before it is kept for curing at room temperature, initially for 10min air is sucked by vacuum bagging in order to remove the entrapped air in the set up. After10 min suction of air is stopped.
8. Then Mylar sheet is covered and ceramic tile (weight) was placed over this Mylar sheet and the specimen was allowed to cure for 24hrs at room temperature.
9. Finally, once the specimen is cured, and then post curing is done for 2 hours at 100ºC.

2.5 Fabrication of Honeycomb Core for Sandwich Structure

Glass fibre of 200gsm is prepared like face sheets (Jute fibre sandwiched between the Glass fibres) with **1 mm** thickness and volume fraction for fibre/resin of 60:40 was taken for FRP preparation.

2.6 Preparation of HoneycombCore for Sandwich Structure

1. As per calculation and using above glass fibre face sheet preparation procedure, 0.2 mm thick Glass fibre sheet (wet condition) is prepared for Honeycomb core**.**

2. Then it is placed on honeycomb (half hexagonal shape) structured pattern with required dimensions (we must take more dimensions than the required final dimensions).

3. The hexagonal rods are placed on that sheet and matched the three sides of hexagonal rods with three sides of hexagonal structured pattern to all the slots.

4. The specimen was allowed to cure for 24hrs, then the three sides of hexagonal shape sheet are ready to use for preparation of full hexagonal honeycomb.

5. This procedure continues until to get required number of sheets (9 sheets).

6. Cut the 110mm width core sheets to the required dimensions of core height 10mm (110mm width sheet cut to 10 numbers of each 10 mm height).

Fig 2.1 Prepared Glass Fibre Honeycomb Core

7. Then spreading the adhesive (mentioned above) to the one extreme faces of cut honeycomb core and placed the core sheets side by side on ceramic tile.

8. Then joining the two core sheets of extreme faces of honeycomb core to get honeycomb structure over the entire length (290mm).

9. This process is repeated until to get required dimension (85 to 90 sheets), then allowed to cure for 24hrs at room temperature.

10. Finally, once the specimen is cured and then post curing is done for 2 hours at 100^{o}C.

2.7Honeycomb Sandwich Structure Preparation

For the production of honeycomb sandwich structure, 1mm thick two glass fibre sheets and 10 mm thick one glass fibre honeycomb core are used of more than final required dimensions (300 × 300 mm). The components required for preparation of honeycomb sandwich structure is shown in below fig.2.2

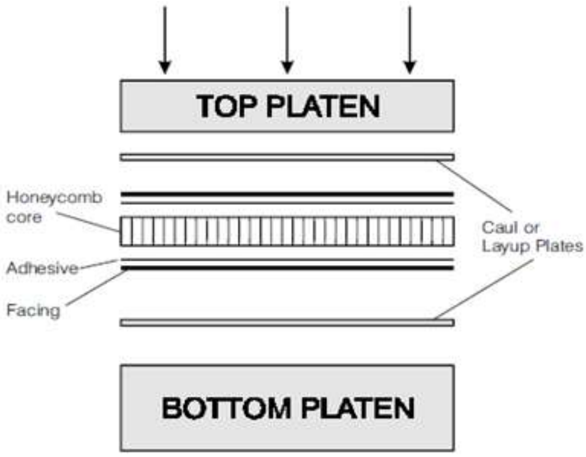

Fig.2.2 Components used for Preparation of Honeycomb Sandwich Structure

2.8 Procedure for Preparation of Honeycomb Sandwich Structure

1. Placed the prepared polyester/epoxy face sheet during preparation of sandwich on ceramictile.
2. Prepare Epoxy/resin of LY556 type and hardener of HY951 type mixture as adhesive with 10:1 ratio.
3. Resin and hardener were stirred for five minutes for uniform mixing.
4. Applied the require amount of adhesive (resin + hardener) and spread on a bottom face sheet and to one side of honeycomb core material using spreader.
5. Then placed the honeycomb (adhesive coated side) core on bottom face sheet and align in proper position.
6. Again applied the require amount of adhesive to top of honeycomb core and to the other face sheet.
7. Then placed the face sheet with adhesive downside on top side of honeycomb core and covered with two tile blocks for 24 hours.
8. Cut the sides of prepared sandwich shown in fig.2.3 to the required Standard dimensions of 300 × 300 mm with overall thickness of 6 mm.
9. Finally, the sharp edges are removed by using emery sheet in the honeycomb sandwich structure

Fig.2.3 Prepared Honeycomb Sandwich (Honeycomb Core between 2 Face sheets

2.9 Tensile Test Specimen

According to ASTM D 3039M, the specimen was cut into required dimension (250×25×12) mm using diamond wheel saw and is finished using emery paper. End tabs are mounted at the both ends (40 mm) of the specimen for the purpose of gripping and the ASTM standard dimensions are shown in below table 3.1

Table 3.1 ASTM D 3039M Tensile Test Dimensions

Total length in mm	Span length (L) in mm	Width (b) in mm	Thickness (t) in mm
250	170	25	6

According to the above standard, prepared tensile test specimen (along the width and thickness) is shown in below fig 2.4

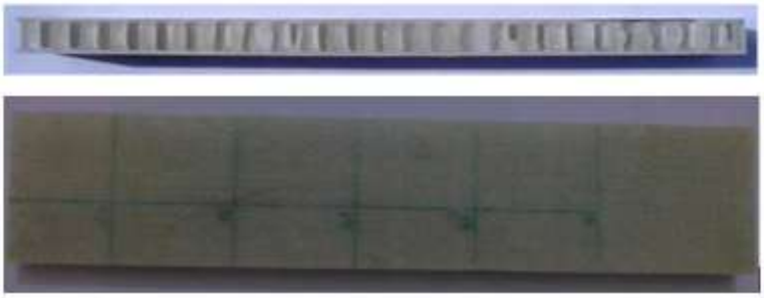

Figure 2.4 Tensile specimen

III. RESULTS & DISCUSSION

3.1 Tensile Test

Tensile testing, also known as tension testing, is a fundamental materials science testin which a sample is subjected to uniaxial tension until failure. The results from the test arecommonly used to select a material for an application, for quality control, and to predict howa material will react under other types of forces. Properties that are directly measured via atensile test are ultimate tensile strength, maximum elongation and reduction in area. Fromthese measurements the following properties can also be determined: Young's modulus,Poisson's ratio, yield strength, and strain-hardening characteristics.

Fig.3.1Universal Testing Machine (UTM) Setup& Tensile Test Specimen during the Test

The tensile test set up is shown in above fig.3.1. Tensile test technique, according toASTM D 3039M is used to determine the tensile strength of the composite sandwich. Testspecimens were sectioned from the sandwich panel with the width of 25 mm, thickness of 6 mm and length of 250 mm were prepared using a diamond saw along longitudinal direction.The specimens were tested using universal test machine at a cross head speed of 2 mm/min,then Stress-strain diagram and load v/s deflection diagram was recorded.

3.2 Tensile Test

According to the ASTM D 3039M standard (Table 3.1), tensile test on honeycomb sand wich composite specimen were carried out to determine the tensile strength (σ) anmodulus of elasticity (E) under load. The table 3.2 shows the test results.

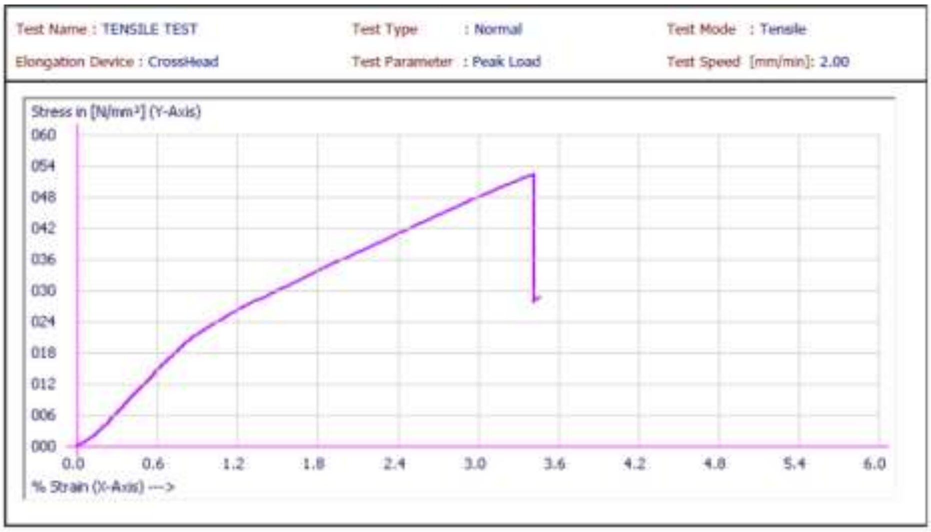

Fig.3.2 Stress-Strain Response of Sandwich Specimen in Tensile Test

Tensile stress-strain diagram of specimen tested for composite honeycomb sandwichin ribbon (L) direction shown in above Fig.3.2. A significant change in the slope of thestress–strain curve indicates non-linear curve up to 24 MPa (approximately) and then followsa linear path. Modulus of glass fibre as well as bonding strength between face sheets and coreand also fibres and matrix are the prime factors, which accounts for the tensile strength ofcomposite honeycomb sandwich.

Table3.2 Tensile Strength and Young's Modulus of the Specimen

Ultimate Load (P) in N	Cross Sectional Area (A) in mm2	Ultimate Tensile Strength (σ) in MPa	Youngs Modulus (E) in MP
15692	300	52.31	1511.85

The ultimate point (ultimate load 15692 N) in stress–strain curve represents thecomplete fracture of face sheets. The rest of the drops in the curve are indications ofprogressive failure of core as the applied load increases and the end of the curve representsthe pull out hexagonal core flies. However, the failure mode exhibits breakage and little pullout of hexagonal flies.

IV.CONCLUSION

In this study, the mechanical characterization of Glass fibre epoxy honeycombsandwich structure as per ASTM standards is discussed.The ultimate tensile strength and Youngs modulus of developed honeycomb panel is 52.31MPa and 1511.85MPa respectively and which as good agreement with theoretical results.

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