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Mechanical Evaluation of Composite Sandwich Panel

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ABSTRACT

The objective of this study is to evaluate mechanical and physical properties of Carbon FRP composites including both laminates and sandwich panels. The combination of light carbon fiber reinforced polymer (CFRP) composite materials with structurally efficient sandwich panel designs offers novel opportunities for ultra light structures. The objective of this research is to develop a modeling approach to predict response of composite sandwich panels under static bending conditions.

INTRODUCTION

A carbon fiber composite refers to a composite in which at least one of the fillers is carbon fibers, short or continuous, unidirectional or multidirectional, woven or nonwoven. The matrix is usually a polymer, a metal, a carbon, a ceramic, or a combination of different materials. The matrix is three-dimensionally continuous, whereas the filler can be three-dimensionally discontinuous or continuous. Carbon fiber fillers are usually three-dimensionally discontinuous, unless the fibers are three-dimensionally interconnected by weaving or by the use of a binder such as carbon. Sandwich composed of two thin stiff face sheets and a thick lightweight core bonded between them. The objectives of this study is to understand the mechanical behavior of sandwich structures with Epoxy based honeycomb core and carbon fiber reinforced polymer (CFRP) face sheets fabricated by hand layup technique as a function of core thickness. Davies J.M et al studied the local buckling behavior of a compressed plate element supported by relatively weak isotropic core medium. When the sandwich panel is subjected to uniform compression the authors represented the panel as a simply supported plate resting on half space linear elastic foundation.

MANUFACTURING METHOD

Design of Carbon Fiber Reinforced Polymer Composites

The mechanical properties of composite is constituted by the individual properties of its constituents such as fibers, resin etc. Effective reinforcement requires good bonding between the fiber sand the matrix. For a unidirectional composite, the longitudinal tensile strength is quite independent of the fiber-matrix bonding, but the transverse tensile strength and the flexural strength (for bending in longitudinal or transverse directions) increases with increasing fiber-matrix bonding. On the other hand, excessive fiber-matrix bonding can cause a composite with a brittle matrix (e.g., carbon) to become more brittle, as the strong fiber-matrix bonding causes cracks to propagate straight, in the direction perpendicular to the fiber-matrix interface without being deflected to propagate along this interface In conclusion, it is utmost important that in a given composite fiber and matrix shows a good compatibility. The mechanisms of fiber-matrix interaction include chemical bonding, vender Waals bonding, and mechanical interlocking. Chemical bonding gives the largest bonding force, provided that the density of chemical bonds across the fiber-matrix interface is sufficiently high. This density can be increased by chemical treatments of the fibers or by sizing on the fibers. Mechanical interlocking between the fiber sand the matrix is an important contribution to the bonding if the fibers form a three-dimensional network. Otherwise, the fibers should have a rough surface in order to form a small degree of mechanical interlocking. Both chemical bonding and vender Waals bonding requires the fibers to be in intimate contact with the matrix. For intimate contact to take place the matrix or matrix precursor must be able to wet the surfaces of the carbon fibers during infiltration of the matrix or matrix precursor into the carbon fiber performs. Chemical treatments and coatings can be applied to the fibers to enhance wetting. The choice of treatment or coating depends on the matrix. Another way to enhance wetting is the use of a high pressure during infiltration.

Another method is to add a wetting agent to the matrix or matrix precursor before infiltration. As the wet ability may vary with temperature, the infiltration temperature can be chosen to enhance wetting. The occurrence of a reaction between the fiber sand the matrix helps the wetting and bonding between the fiber sand the matrix. However, an excessive reaction degrades the fibers, and the reaction products may be undesirable for the mechanical, thermal, or moisture resistance properties of the composite. Therefore, an optimum amount of reaction is preferred. Carbon fibers are electrically and thermally conductive, in contrast to the non-conducting nature of polymer matrices. Therefore, carbon fiber scan serve not only as reinforcement, but also as an additive for enhancing the electrical or thermal conductivity. Furthermore carbon fibers have nearly zero coefficient of thermal expansion, so they can also serve as an additive for lowering the thermal expansion. The combination of high thermal conductivity and low thermal expansion makes carbon fiber composites useful for heat sinks in electronics and for space structures that require dimensional stability. As the thermal conductivity of carbon fibers increases with the degree of graphitization, applications requiring a high thermal conductivity should use the graphitic fibers, such as the high-modulus pitch-based fiber sand the vapor grown carbon fibers.

Fabrication of Honey comb Sandwich Panels

The Methodology involves in the preparation of facings, honey comb, and sandwich specimens according to ASTM standards using 'vacuum bagging technique'. In all, five specimens were prepared with different core thicknesses, different core densities, and with or without an insert face sheet. Appropriate test methods as per standards and guidelines are used to evaluate the flexural properties and maximum load carrying capacity for clear understanding of static behavior of sandwich beams.

Preparation of Honeycomb core material

Each honeycomb material provides certain properties and has specific benefits. The most common core material used for aircraft honeycomb structures is Aramid paper (NOMEX). The properties of aramid papers are flame resistance, fire retardant, good insulating properties, low dielectric properties and good formability.

Nomex honeycomb

Nomex honeycomb is made from nomex paper .It is widely used for light weight interior panels for aircraft in conjunction with phenolic resins in the skins. Special grades for use in fire retardant applications can also be made which have the honeycomb cells filled with phenolic foam for added bond area and insulation.

The cells of the honeycomb structure can also be filled with rigid foam. This provides a greater bond area for the skins, increases the mechanical properties of the core by stabilizing the cell walls and increases thermal and acoustic insulation properties. Honeycomb cores can give stiff and very light laminates. Properties of honeycomb materials depend on the size of the cells and the thickness and strength of the web material

Preparation of face sheets

The 1mm and 2 mm face sheets are manufactured by stacking layer by layer of Carbon fiber sheets and are allowed to dry for 90 minutes as shown in fig 1. The vacuum system facilitates good resin distribution and consolidation of the laminates.

Preparation of facings using Wet Lay-up Technique:

- Commercially available carbon cloth laminates are used for making the facings. The cloth ply was trimmed to the correct size and stacked orientation and was built to a thickness of around 0.20 mm. The surfaces were thoroughly cleaned in order to ensure that they are free from oil, dirt, etc. before bonding at room temperature.
- An adhesive made from a mixture of **LY5052** resin and **HY 5052** hardener mixed in the ratio of 10:1 by weight was then applied.
- Wet lay-up technique with vacuum level of 1 bar for 4 hour was made used to avoid surface undulations of air pockets at the interface. These are cured for about 4 hours at room temperature. Wet lay-up process is a closed molding process; it virtually eliminates potentially harmful Volatile Organic Compound (VOC) emissions.

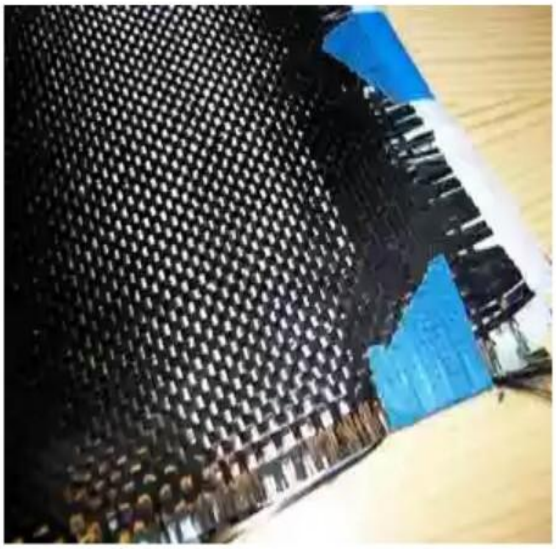

Fig 1. Bi directional Carbon Sheet

Fabrication of Composite Sandwich Structures

The sandwich structures were impregnated and laminated by hand lay-up technique. Three layers of fabric were wetted by epoxy resin in order to form lower face sheet and then core material was placed on the lower face sheet, the upper face sheet was laminated with three layers of fabric on the core. Manufacturing process was made in a mould, coated with a mould release agent

Vacuum Bagging

In this technique, fabrics are wetted by the resin in a mould; the core material is put between the fabrics after the lamination a vacuum bag is sealed on the laminate. By adding pressure to the laminate, excess resin can be eliminated which will reduce overall weight and optimize strength. Vacuum bagging is used in order to add pressure without crushing the part and vacuum is run into the sealed area as shown in fig 2.

Fig 2. Vacuum Bagging Process

The resulting vacuum pressure squeezes out excess resin. A vacuum pump is required and the process is usually conducted while the part is in a mould.

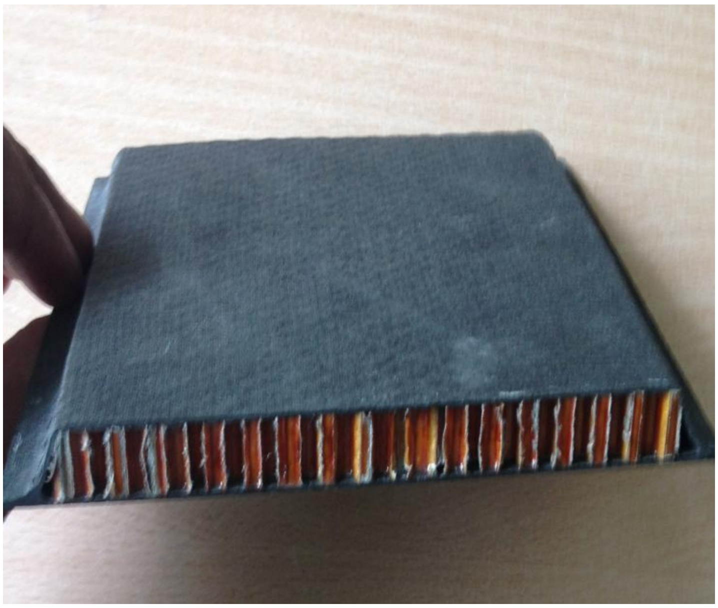

Fig 3. Sample Composite

RESULT AND DISCUSSION

Table I. Flatwise Tensile Test

Material	*Buckling Load KN*	*Maximum Displacement mm*	*TSS KN/m^2*	*Speed mm/min*	*Area mm^2*	*Remarks*
HEX CORE 8 mm	4.5	2.6	11.25	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	5.8	3.4	14.50	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	3.7	3.0	9.25	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	4.8	2.8	12.00	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	5.07	4.0	12.68	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	4.96	4.2	12.40	1	250	CORE FAILURE Acceptable
HEX CORE 8 mm	4.53	3.59	8.98	1	250	CORE FAILURE Acceptable

Table II. Inter Laminar Shear Test

Material	*Buckling Load KN*	*Inter Laminar Shear N/mm^2*	*Speed mm/min*	*TYPE OF FAILURE*	*Remarks*
Carbon G 939	1.69	63.4	1	TENSION	Acceptable
Carbon G 939	1.7	63.8	1	TENSION	Acceptable
Carbon G 939	1.59	59.6	1	INTERLAMINAR	Acceptable
Carbon G 939	1.89	70.9	1	INTERLAMINAR	Acceptable
Carbon G 939	1.74	65.3	1	TENSION	Acceptable
Carbon G 939	1.72	64.5	1	TENSION	Acceptable
Carbon G 939	1.87	70.1	1	TENSION	Acceptable
Carbon G 939	1.93	72.4	1	INTERLAMINAR	Acceptable
Carbon G 939	1.77	66.4	1	TENSION	Acceptable
Carbon G 939	1.79	67.1	1	INTERLAMINAR	Acceptable

Table III. Flatwise Tensile Test

Properties	***Polyethersulfon PES***	***Polyether etherketone PEEK***	***Polyetherimide PEI***	***Poly phenylsulphide PPS***	***Polyimide PI***	***Epoxy***
Glass Transition Temperature (°C)	230	170	225	86	256	-
Decomposition Temperature (°C)	550	590	555	527	550	-
Processing Temperature (°C)	350	380	350	316	304	<200
Tensile Strength (MPa)	84	70	105	66	138	30-100
Modulus of Elasticity (GPa)	2.4	3.8	3	3.3	3.4	2.8-3.4
Ductility (% of elongation)	30-80	50-150	50-65	2	5	0-6
Izod Impact (ft lb/in)	1.6	1.6	1	<0.5	1.5	-
Density gm/cm^3	1.37	1.31	1.21	1.3	1.37	1.25

Conclusions

In this study, Carbon Fiber Reinforced Polymer (CFRP) composites were tested both at coupon and panel level for their mechanical properties (stress, stiffness and modulus) under bending and tension. Properties were discussed in terms of different manufacturing process parameters and constituent material characteristics.

Mechanical Properties of CFRP Composites

Compression Laminates

- Under tension and bending, CFRP composites with VE matrix cured at room temperature (RT) results in better mechanical properties with tensile modulus 25% higher and 27% higher elasticity modulus than that of high temperature (HT) cured composites.
- Addition of CSM layer significantly reduces the tensile modulus by about 10.5%, maximum stress by about 7.8%, flexural modulus by about 29.6 % and 32.4% drop in bending stress.
- The polymer is a thermoset or thermo plastics. Thermosets (especially epoxy) have long been used as polymer matrices for carbon fibre composites. The properties of several thermoplastic resin with carbon fibre are listed in Table 3 in comparison with epoxy. In contrast, epoxies have tensile strengths of 30-100 MPa, modulus of elasticity of 2.8-3.4 GPa, ductility of 0-6% and a density of 1.25g/cm^3**.**
- With epoxy matrix, with an extended curing time was observed to have slightly poorer properties. e.g., reduction in average maximum stress by 2.5% and tensile stress by 3.8%.
- Maximum stress for epoxy composites was 24% higher than those VE composites and tensile modulus for epoxy specimens was about 20% higher than those VE specimens.
- 3D Orthotropic solid model is concluded to accurately represent sandwich panel response under static loads including deflection, bending stress and shear stress.
- 3D orthotropic solid model closely predict response of small scale CFRP panels with about 5% deviation. In particular, it very well predicts bending stress and shear stress in accordance with experimental results. The below fig 3 is representing the resin tensile strength and modulus.

Recommendations

1. Mechanical properties of CFRP composites greatly depend on fiber-matrix adhesion and fiber content. An attempt should always be made to manufacture composites with high fiber content, minimal void content and good fiber-matrix interaction

2. Specimens for mechanical testing should be representative, uniform and reproducible.

3. 3D stitching effect needs to be quantified by analysis of large number of specimens.

ADVANTAGES OF CARBON FIBRES

Carbon fibers are most widely used for fiber reinforced composites. For this study carbon fibers in form of stitched fabric are used for fabrication purpose. The properties of carbon fibers vary widely depending on the structure of the fibers. In general, attractive properties of carbon fibers include the following:

- Low density, high tensile modulus and strength
- Low thermal expansion coefficient
- Excellent creep resistance
- Chemical stability, particularly in strong acids
- Biocompatibility
- High thermal conductivity, low electrical resistivity
- Availability in a continuous form
- Decreasing cost with advanced production technology

APPLICATIONS

- Weight saving provided by composites vary considerably with the type of aircraft and component. These tend decrease as the overall composite weight fraction increase.
- In the present day scenario, use of advanced composite material has been extending to a large number of aircraft components both structural and non-structural. Carbon fibre polymer matrix composites are predominantly used for the aerospace industry due to the low cost of carbon fibre.
- One area of aerospace applications is space vehicles.
- Another major area uses composite structure is military aircraft.
- Outer and front section of the engine utilizes and epoxy matrix.

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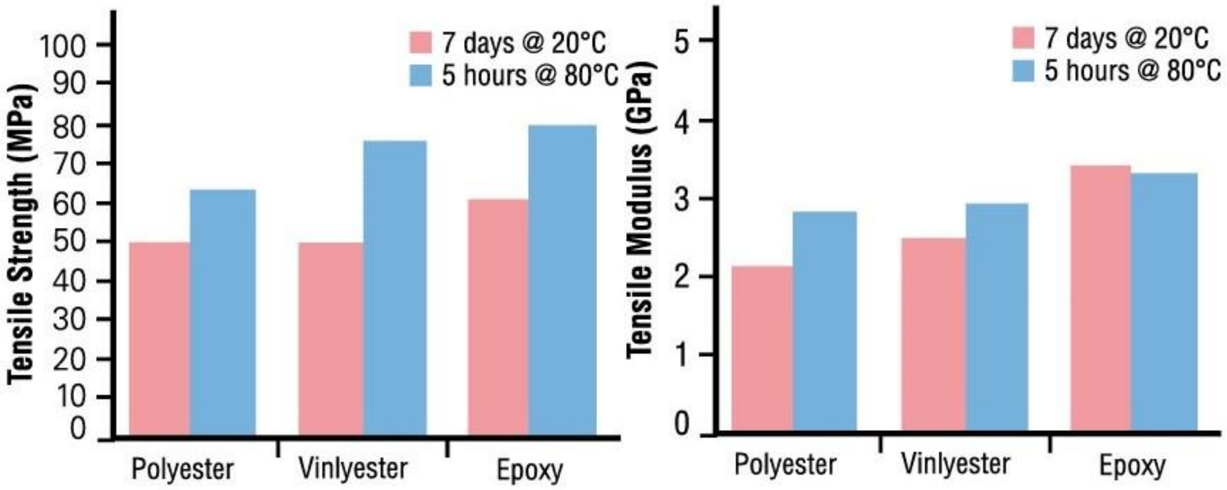

Fig 3. Comparison of resin Tensile Strength and Modulus

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