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RESEARCH ARTICLE

EVALUATION OF MECHANICAL PROPERTIES OF CNT REINFORCED FRP HONEYCOMB CORE SANDWICH COMPOSITES

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ABSTRACT

Honeycomb panels are widely used in various engineering fields to increase structural stiffness under light weight, or to control vibration & noise. It is also common practice to attach honeycomb bands to original structures, such as aircraft skins, train and car bodies to increase the structural stiffness or to improve the structural dynamics with light addition of weight. This research is concerned with studying the characteristics of Carbon Nanotubes (CNT) reinforced with Fiber-reinforced plastic/carbon fiber. The study contains experimental studies of Nano-composites. The tensile and compressive strength of the CNT Reinforced Honey comb sandwich core is determined by conducting a series of tensile and compression tests in accordance with the ASTM D3039 and ASTM D695 standard on the FRP honeycomb sandwich panels with different percentage of CNT. Increasing the percentage of CNT in FRP honeycomb sandwich composites increases the strength of the structure to certain extant. However addition of CNT behind 2% decreases the strength.

INTRODUCTION

Engineers are constantly endeavoring to create, combine or redesign, to produce materials that are as suitable as possible for a particular application. In many fields, the desired material needs to be both light weight and strong for functionality, while economic considerations require the characteristics of low cost and ease of manufacture. Ideal materials have a combination of properties that allow multi-functionality, where a single component can perform a number of roles. Composite materials should have been developed as part of this pursuit, with the capacity to have enhanced properties when compared to the constituent materials. Composites are normally made by incorporating some reinforcement such as fibers in a bulk material known as the matrix. The properties of composites can also be tailored according to specific design requirements, directional and spatial properties. At present composite materials have found wide spread applications in aeronautics and space sector due to their lightweight and high strength. Almost all modes of transportation and the sports equipment also use a considerable amount of composites, due to their capacity to withstand harsh loading conditions. The standard hexagonal honeycomb is the basic and most common cellular honeycomb configuration, and is currently available in many metallic and non-metallic materials. Nowadays, sandwich structures with different percentage of CNT and core thickness are increasingly used in various applications. Sandwich structures have many advantages, including high stiffness-to-weight and strength-to weight ratios, high damping capacities, good thermal insulation properties, excellent water and vapour barrier performance, good corrosion resistance, and low cost.

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MATERIALS AND METHODS

Hand Lay-up method: This is a manual approach, in which layers of fabric and resin are successively applied onto a mould. This method is perhaps the simplest, oldest and least complicated. The mould is first designed to the shape of the final composite structure. The fiber layers are oriented in such a way, as to develop the desired strength and stiffness. After each layer of fabric is placed, a roller is used on the composite, so that a strong bond results, and excess resin is squeezed out. The stacking of the fabric materials and resin is done until the required thickness is achieved. This method is labour-intensive and only suitable for production in low volume. In recent years, the advances in manufacturing technology have resulted in some improvement in this manual process. Today, the hand lay-up has become automated in several applications.

Resin Transfer Moulding method: In Resin Transfer Moulding (RTM), resin is injected into a mould in which the fibers and the core material are placed in the desired position. The resin is fed under gravity or external pressure Curing occurs within the mould, often assisted by heating. The mould is usually made of metal, which gives good heat transfer and lasts for many moulding operations. Relatively large parts can be manufactured in this way.

Manufacture of face sheet: Bi-woven glass 'E' cloth, which is commercially available is used for making the face sheet and is shown in Figure 1. The cloth ply was trimmed to the correct size and impregnated in an adhesive made from a mixture of LY556 epoxy resin and HY 951 hardener, mixed in the ratio of 100:10. The ply was stacked in 0º/90º orientation and was built to a thickness of around 2.0 mm. The Vacuum hand lay-up technique was used to make the facings and is shown in Figure 2. A Vacuum level of 500Hg/mm^2 is maintained for 1 hour to avoid surface undulations and also to avoid air pockets at the interface. The coupons were allowed to cure for about 24 hours at room temperature.

Figure 1. Bi-woven glass 'E' fabric

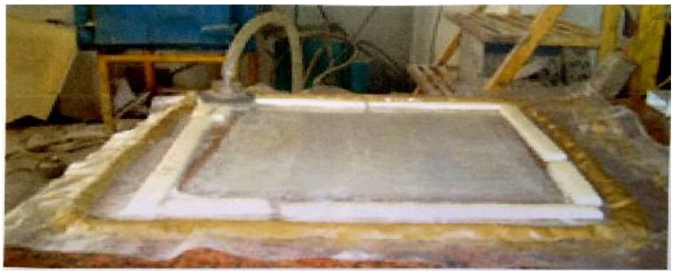


Figure 2. Hand lay-up technique

Manufacture of Honeycomb core: For the manufacturing of the honeycomb core the matrix used is epoxy resin LY 556 mixed with a hardener HY 951 and the reinforcement is glass 'E' fabric. The resin and hardener are mixed in the weight ratio of 10:1. To maintain the optimum strength, the resin glass ratio is found to be 35:65. The molding tool used is hexagonally machined split molding tool made of chromium plated mild steel.

Manufacture of Sandwich panels: For the fabrication of the sandwich panel, the facings comprising of the glass 'E' fabric impregnated with the above said resin mixture, are coupled with the open honeycomb structure using epoxy resin, and compacted by means of the vacuum bagging technique. After curing, the sandwich panel is subjected to post curing in a hot-air oven at 100ºc up to 2 hours. The vacuum method provides higher reinforcement concentrations, 'better adhesion between layers', and more control over the resin/glass ratio compared to the hand lay-up process. Figure 4 shows the honeycomb sandwich panel under vacuum. Four types of sandwich panels of size 300 x 300mm are fabricated with different cell sizes, i.e., 7mm. The cell shape of the honeycomb core is a regular hexagon. The membrane wall thickness of the core is 0.5 mm and the height of the core is fixed at 6 mm. The thickness of the top and bottom face sheets has been kept constant at 1 mm.

Figure 3. Fabrication of the honeycomb core

Figure 4. Fabrication of honeycomb sandwich panel

Testing of Composites

Tension Test

A Tensile test was conducted on the sandwich panel to determine the tensile strength of the composite sandwich panel, as per the ASTM D 3039. The test specimens were sectioned from the composite panels with the width of 25 mm, thickness of 7 mm and gauge length of 50 mm. The Test specimens were bonded with composite tabs of 4" in length at both the ends. The tabs distribute the gripping stresses and prevent specimen failure caused by grip jaws. As the face sheet exhibits a similar behaviour for 0^0 and 90^0 directions, only one direction is tested. The specimens were tested using the universal test machine.

Compression Test

Flat wise compression tests of sandwich panels are conducted in accordance with the ASTM D695 standard to determine the flat wise compressive strength and modulus. The test specimens were sectioned from the composite panels with the width of 12.25 mm, thickness of 7 mm and length of 140 mm. In order to prevent local crushing at the edges of the honeycomb cores, the edges were stabilized with thin facings, so that the load which causes failure in the core does not cause any damage to the facings.

RESULTS AND DISCUSSIONS

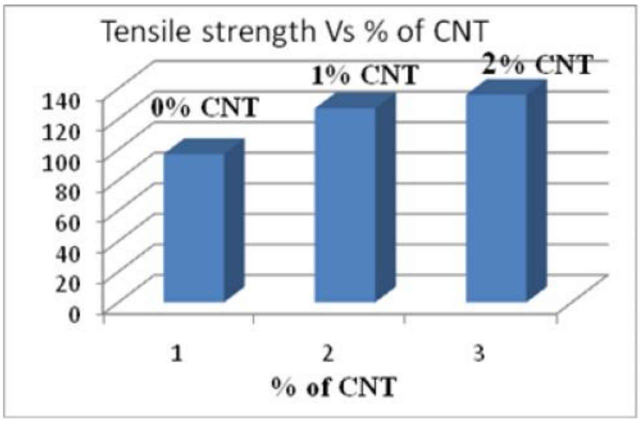
Tensile strength

It is clear that tensile strength increases with increase in percentage of CNT. Tensile tests of the CNT reinforced FRP honeycomb core sandwich composites specimens are carried out as per the ASTM D3039.

Table 1. Tensile Test Results

Specimen designation ASTM D3039	Specimen dimensions (mm)	Gauge Length (mm)	Breaking Load (KN)	Yield stress (N/mm2)	Tensile strength (N/mm2)	Average Tensile strength (N/mm2)
FRP/A (0% CNT)	25.0 x 7.0	50	16.16	70.88	92.34	97.14
FRP/B (0% CNT)	25.0 x 7.0	50	17.84	94.08	101.94	
FRP/A (1% CNT)	25.0 x 7.0	50	22.72	90.83	129.82	126.96
FRP/B (1% CNT)	25.0 x 7.0	50	21.72	97.55	124.11	
FRP/A (2% CNT)	25.0 x 7.0	50	23.08	107.38	131.89	135.92
FRP/B (2% CNT)	25.0 x 7.0	50	24.49	100.56	139.95	

Stress-strain response of the CNT reinforced FRP honeycomb core sandwich composites specimen is non-linear, and there is a sudden drop after the maximum stress at which failure occurs. It is found that the failure is within the gauge length. The carbon fibers have fractured, rather than the de-bonding between the resin and the fiber. The average of maximum tensile strength of the CNT Reinforced FRP Honeycomb core sandwich composites specimen was found to be 135.92 N/mm2 for 2% mixture of CNT.



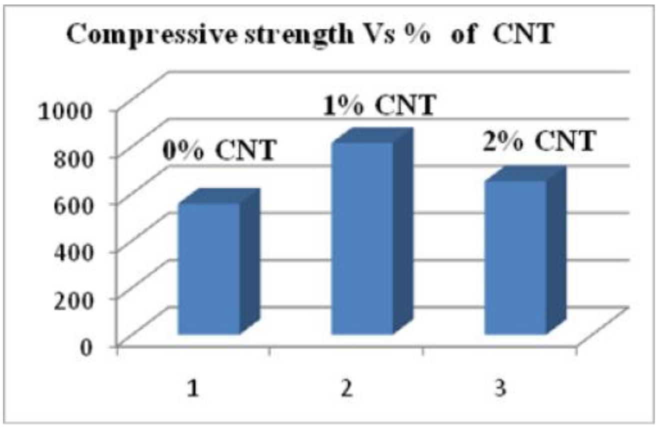
Graph 1. Tensile Strength (N/mm2) Vs % of CNT

Compressive strength

Table 2. Compressive Test Results

Specimen designation ASTM D695	Specimen dimensions (mm)	Length (mm)	Breaking Load/ Peak load (KN)	Compressive strength (N/mm2)	Average Compressive strength (N/mm2)
FRP/A (0% CNT)	12.25x7.0	140	50.51	589.04	557.49
FRP/B (0% CNT)	12.25x7.0	140	45.10	525.95	
FRP/A (1% CNT)	12.25x7.0	140	72.06	840.34	815.56
FRP/B (1% CNT)	12.25x7.0	140	67.81	790.78	
FRP/A (2% CNT)	12.25x7.0	140	52.10	607.69	652.75
FRP/B (2% CNT)	12.25x7.0	140	59.83	697.82	

To determine the compression strength of the honeycomb sandwich core, a series of compression tests are conducted on the sandwich panels with different percentage of CNT. Compressive tests of the CNT reinforced FRP honeycomb core sandwich composites specimens are carried out as per the ASTM D695. In the honeycomb core cell sizes selected as 7mm, the changes in the compressive strength and average compressive strength are given in tables-2 a careful examination of the compressive strength of all specimens is general observation. Increasing percentage of CNT from 0 to 1% in FRP honeycomb core sandwich composites is trend with an increasing the compressive strength and further increasing the percentage of CNT from 1 to 2% is trend with a decreasing compressive strength.



Graph 2. Comp. strength (N/mm2) Vs % of CNT

Conclusions

- Sandwich composite panel with E-glass/Epoxy and different percentage of CNT honeycomb core cell size of 7mm were fabricated. And mechanical tests are carried out by as per ASTM standard.
- The average of maximum tensile strength of the CNT reinforced FRP honeycomb core sandwich composites

specimen was increase from 97.14 to 135.92 N/mm2, with an increasing percentage of CNT from 0 to 2%.

- The compressive strength also shows an increasing trend with an increasing percentage of CNT from 0 to 1% and further increasing the percentage of CNT from 1 to 2% is trend with a decreasing the compressive strength. But in the meantime drop in compressive strength is observed with addition of CNT and the reason may be attributed to agglomeration of the CNT in the FRP. Agglomeration causes poor wet ability in the fiber/matrix interface resulting in weaker adhesion in the interfacial bonding between the CNT enhanced fiber/matrix composite.

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