Thermal Degradation Study On Hybrid Fibers Binded With Thermoset Plastic Used In Aerospace Application

[1]Akash S J, [2]Deekshith T S, [3]Vishnu Vijay, [4]Antony Wilfred
[1]Student, [2]Student, [3]Student, [4]Student
[1]Department of Aeronautical Engineering,
[1]Srinivas Institute of Technology, Mangaluru, India

Abstract:

Composites are extensively used in aircrafts for their best strength to weight ratio. They are anisotropic, can be designed for best strength in a particular direction. Adding filler material to the composites enhances its properties. Carbon NANO Tubes is one such filler material that has low moisture and oil absorption, low volatile content and high impact resistance which could be a potential combination of composite material, for use in interiors of the aircraft. In this work, Carbon NANO Tubes in different composition (0%, 1%, 2% and 3%) was added to the E-glass/Epoxy composite and the resulting composite was tested to evaluate the mechanical properties and thermal ageing. Thermal ageing was done for each specimen before the tests for 72 hours at 40 degree Celsius. Fibre reinforced composites offer many advantages over conventional structural materials. They have high strength and modulus-to-weight ratios, are fatigue and corrosion resistant and require low maintenance. The effect of exposure to heat, moisture, hydrocarbons, fatigue and static loads and more importantly a combination of these parameters may degrade the material's stiffness and strength. The lack of long term data for fibre reinforced composites has led for an accelerated ageing methodology that will predict the effect of such a degradation that might have on the residual properties. Hence thermal ageing is performed before testing. Thermal ageing is performed at various temperatures and room temperature.

I. INTRODUCTION

A composite material can be defined as amalgamation of two or more materials that results in better properties than those of the individual components used alone. In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties. Composites are kind of materials which are created by integrating dissimilar materials of having different characteristics which are united macroscopically to get desired characteristics of new materials. The main objective of combining alternative features of different materials is to get high strength, stiffness, toughness and also to improve good wear resistance properties (tailoring the properties).In this work, choice of e-glass fibre/epoxy composite with carbon nano tube as an additive is obvious for the following reasons. For best strength to -weight ratio and impact resistance, hybrid composites made of Epoxy, E-glass fibres and carbon nano tubes can be used. Also, the addition of carbon nano tube to the E-Glass fibre/Epoxy composites increases the bending properties of the E-Glass fibre composite. Carbon nano tubes can also be used for high strength, stiffness and can be used in aerospace, automobile, marine and lightweight article applications. E-Glass fibres, especially produced in a bi-directional form, offer sufficient resistance to an object during impact with low material cost as compared with carbon fibres, which make them more attractive for many structural applications. Among all different kinds of thermosets, epoxies are well-known for their outstanding mechanical properties such as resistance to micro-cracking, chemical inertness, good thermal and dimension stabilities. In current aircraft and automotive composite components, epoxies are mostly used.

II. METHODOLOGY

Methodology deals with the systematic representation of the methods used in the research or an analysis. With reference to our project it encompasses the theoretical analysis of the methods, principles used, quantitative or qualitative techniques to fabricate and test the polymer matrix composite. It also includes a consideration of concepts and theories which underlie these methods.
The whole methodology may be divided as fabrication of composite material followed by testing. While fabrication of composite material is done for various percentages of CNT (Carbon Nano Tubes) material via 0%, 1%, 2% and 3%, testing is done to evaluate mechanical properties of composite. Hand Lay-Up method was used for the fabrication of the composite. Tensile test, bending test and impact test were conducted to evaluate the mechanical properties. Thermal ageing was also performed at 40 degree Celsius temperature for 72 hours. The thermally aged specimens were used for impact test, tensile test and bending test. Hot ovens were used for thermal ageing. For the micro-structural analysis of the tested composite, digital UTM was used.

2.1 Fabrication

It is a manufacturing process in which an item is fabricated from raw material to finished material. Fabrication of composite materials is totally different from the methods used to fabricate metal components. As it's a mixture of matrix and reinforcement, proper adhesion of these two is requires. Various fabrication methods used for composites are; Hand-lay-up.

Table 1Materials used for fabrication

Fiber	E glass(bi directional fiber)
Resin	Epoxy (LY 556)
Hardener	TETA(Triethylenetetramine)
Filler	Carbon Nano Tubes(multi walled)

(a) (b) (c)

Figure 1: (a) Epoxy resin, (b) Carbon Nano Tube, (c) E glass fiber

2.2 Cutting and Sizing according to ASTM standards

Table 2 ASTM standards for testing

Mechanical Test	ASTM Standards	Dimensions
TENSILE TEST	ASTM D 3039	168*20, thickness- 4mm
BENDING TEST	ASTM D 790	127*13, thickness- 4mm
IMPACT TEST	ASTM D 3763	75*10, thickness- 4mm

Two samples for each filler composition and for each testing are cut using electric cutter and is then filed for smooth edges. The samples marked and cut according to the ASTM standards are shown in Figure below.

(a) (b) (c)

Figure 2: (a) Sample market according to ASTM standards, (b) and (c) Samples cut using electric cutter

2.3 THERMAL AGEING

Fibre reinforced composites offer many advantages over conventional structural materials. They have high strength and modulus-to-weight ratios, are fatigue and corrosion resistant and require low maintenance. However, because of their unknown long term properties when exposed to a combination of in-service loads and environments, they are not used in primary load bearing structures. The effect of exposure to heat, moisture, hydrocarbons, fatigue and static loads and more importantly a combination of these parameters may degrade the material’s stiffness and strength. The lack of long term data for fibre reinforced composites has led for an accelerated ageing methodology that will predict the effect of such a degradation that might have on the residual properties. Hence thermal ageing is performed before testing. Thermal ageing is performed at temperature of 40 degree celsius. The specimens are kept in the freezer for cooling cycles at the desired temperature for 72hrs and in hot air oven for heating cycles for 72 hrs. This results in change in micro-structure, the structural degradation depending on the temperature and the ageing time.

2.2 Universal Testing Machine

There are many types of testing machines. The most common are universal testing machines, which test materials in tension, compression or bending.

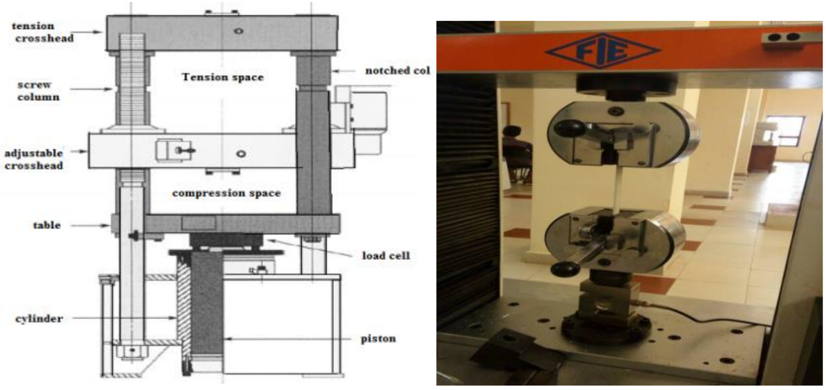

Figure 3:Universal Testing Machine used for tensile and bending tests

2.3 Tensile test

The primary use of the testing machine is to create the stress-strain diagram. Tensile test determines the strength of the material subjected to a simple stretching operation. Typically, standard dimension test samples are pulled slowly and at uniform rate in a testing machine while the strain and stress is defined as:

Engineering Strain = (change in length)/ (original length)

Engineering Stress = (applied force)/ (original area)

The aim of the test is to assess some mechanical characteristics of testing material: its elasticity, ductility, resilience and toughness.

2.4 Bending/flexural test

Flexural tests of composite materials are useful as an alternative or supplementary method to determine tensile and compressive properties. Visual examination of failure behavior and simple bending stress analysis allow the use of flexural strengths to mathematically determine other composite material strength values.

2.5 Impact test

Notched-bar impact test of metals provides information on failure mode under high velocity loading conditions leading sudden fracture where a sharp stress raiser (notch) is present. The energy absorbed at fracture is generally related to the area under the stress-strain curve which is termed as toughness in some references.

Figure 4: Impact Testing Machine

III. RESULTS AND DISCUSSION

A series of tests were conducted to evaluate the mechanical properties and the thermal ageing response of the composite material with four different compositions and at different temperatures respectively. After conducting the tests of the specimens according to the methodology specified in the previous chapter, the following results were obtained, which are presented here under.

Heat treated flexural test

Pre-treatment: 72hours at 40°C in Hot Air Oven
Test date: 13-04-2019
Machine data: ZWICK-ROELL Z020, LOADCELL 20 KN
Pre-load: 0.1 MPa
Test speed: 2 mm/min

Table 3 Tabulation of bending test for heat treated specimen

Legends	Specimen	FMax N	FLEX MODULUS MPa	FLEX THICKNESS MPa	THICKNESS Mm	WIDTH Mm	L mm
🟥	1	1120.8	12900	416	4.02	16	64
🟩	2	902.77	12300	399	4	13.58	64
🟦	3	702.97	12600	308	3.85	14.76	64
🟧	4	952.07	9690	259	4.52	17.25	64

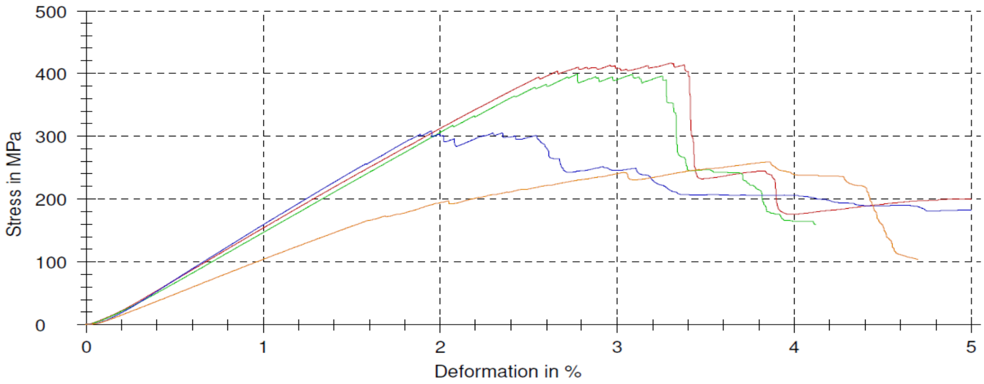

Figure5: Stress VS Deformation for heat treated specimen

From above graph we can observe that the heat treated sample with zero percent carbon deforms even at lower loads, but as the carbon content increases the deformation of the material is delayed when they are exposed to bending loads.

Table 4 Tabulation of bending test for heat treated specimen

Exposed n=4	F Max N	Flex Modulus MPa	Flex strength MPa	Thickness Mm	Width Mm	Length Mm
X	919.67	11900	346	4.098	15.4	64
S	172.02	1480	74.5	0.2917	1.583	0
V	18.70	12.43	21.54	7.12	10.87	0

Non-heat treated flexural test

Test date: 13-04-2019
Pre-load: 0.1 MPa
Test speed: 2 mm/min
Machine data: ZWICK-ROELL Z020, LOAD CELL 20kN

Table 5 Tabulation of bending test for non-heat treated specimen

Legends	Specimen	FMax N	Flex modulus MPa	Flex thickness MPa	Thickness Mm	Width Mm	Length Mm
🟪	1	1155.7	13400	442	4.07	15.14	64
🟦	2	822.53	12000	321	3.75	17.51	64
🟨	3	771.15	13100	277	3.98	16.85	64
🟥	4	633.23	6580	191	4.87	13.4	64

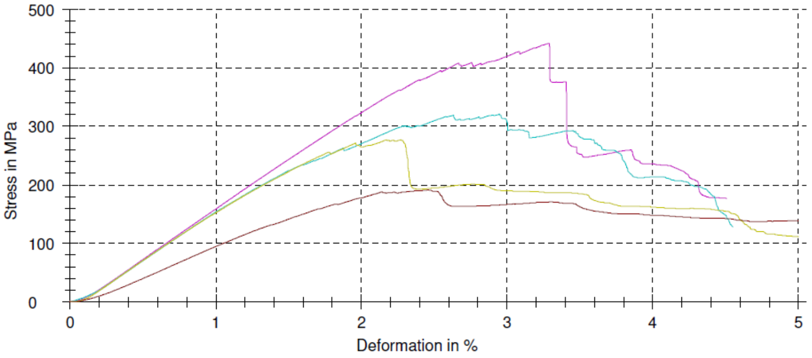

Figure 6: Stress VS Deformation for non-heat treated specimen

From above graph we can observe that the non-heat treated sample with zero percent carbon deforms even at lower loads, but as the carbon content increases the deformation of the material is delayed when they are exposed to bending loads.

Table 5 Tabulation of bending test for non-heat treated specimen

Unexposed n=4	F Max N	Flex Modulus MPa	Flex strength MPa	Thickness Mm	Width Mm	Length Mm
X	845.50	11300	308	4.168	15.73	64
S	221.32	3200	104	0.4873	1.844	0
V	26.18	28.33	33.92	11.69	11.73	0

Heat treated tensile test
Pre-treatment: 72hours at 40°C in Hot Air Oven
Test date: 13-04-2019
Machine data: ZWICK-ROELL Z020, LOADCELL 20 KN
Pre-load: 0.1 MPa
Test speed: 2 mm/min

Table 6 Tabulation of Tensile test for heat treated specimen

Legends	Specimen	FMax N	Tensile modulus MPa	Tensile strength MPa	Strain at break %	Thickness mm	Width Mm
🟥	1	12066	915	307	6.2	3.74	10.50
🟩	2	13711	734	289	6.3	3.87	12.25
🟦	3	19036	1220	373	7.6	3.82	13.36
🟧	4	18186	916	304	9.9	4.50	13.30

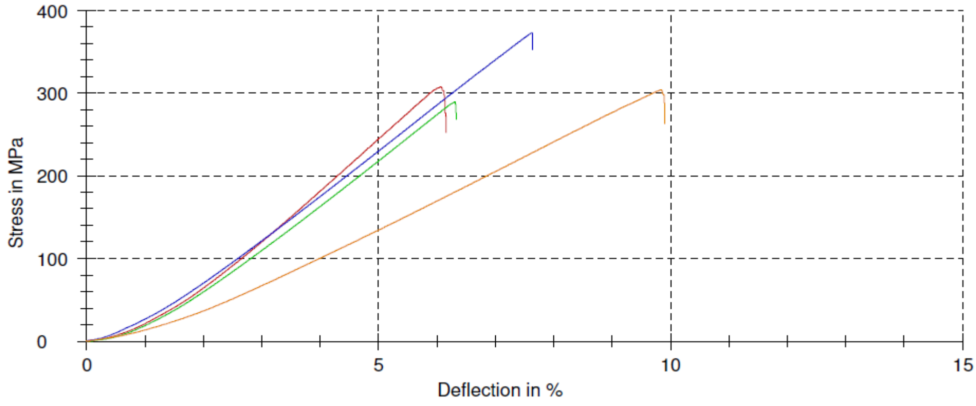

Figure 7: Stress VS Deformation for heat treated specimen

From above graph we can observe that the heat treated sample with zero percent carbon deforms even at lower loads, but as the carbon content increases the deformation of the material is delayed when they are exposed to tensile loads.

Table 7 Tabulation of Tensile test for heat treated specimen

Exposed n=4	F Max N	Flex Modulus MPa	Flex strength MPa	Thickness Mm	Width Mm	Length Mm
X	15750	945	318	7.5	3.96	12.35
S	3389	200	37.3	1.7	0.35	1.34
V	21.52	21.14	11.71	22.96	8.77	10.82

Non-heat treated tensile test
Test date: 13-04-2019
Machine data: ZWICK-ROELL Z020, LOADCELL 20 KN
Pre-load: 0.1 MPa
Test speed: 2 mm/min

Table 8 Tabulation of Tensile test for non-heat treated specimen

Legends	Specimen	FMax N	Tensile modulus MPa	Tensile strength MPa	Strain at break %	Thickness Mm	Width Mm
🟪	1	19420	1230	355	8.3	3.98	13.72
🟦	2	16734	833	326	7.3	4.01	12.80
🟩	3	13845	1290	226	6.4	3.72	16.50
🟥	4	18040	590	281	10.4	4.42	14.50

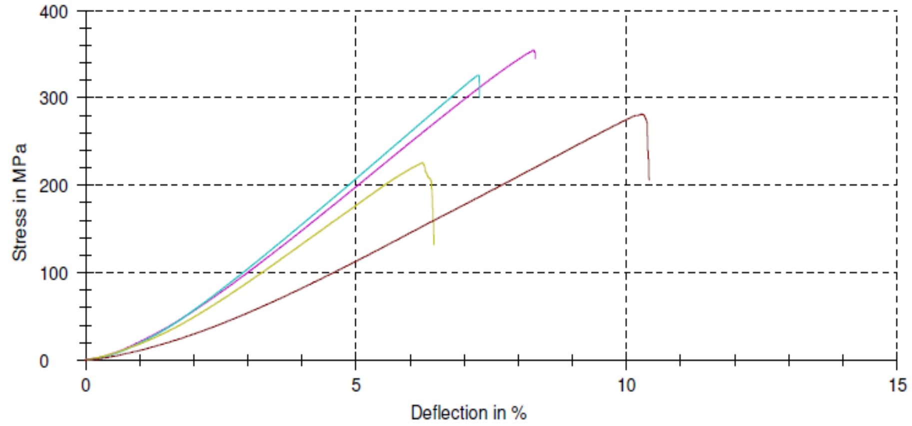

Figure 8: Stress VS Deformation for non-heat treated specimen

From above graph we can observe that the non-heat treated sample with zero percent carbon deforms even at lower loads, but as the carbon content increases the deformation of the material is delayed when they are exposed to tensile loads.

Table 9 Tabulation of Tensile test for non-heat treated specimen

Unexposed n=4	F max N	Tensile modulus MP334a	Tensile strength MPa	Strain at break %	Thickness mm	Width Mm
X	17010	987	297	8.1	4.03	14.39
S	2378	334	56.3	1.7	0.29	1.57
V	13.98	33.82	18.96	21.14	7.17	10.92

Heat treated and non-heat treated impact strength
Pre-treatment 72hours at 40°c in hot air oven
Test date: 15-04-2019

The below bar graph shows the variation of impact strengths of the sample with and without the Carbon content for heat treated and non-heat treated.

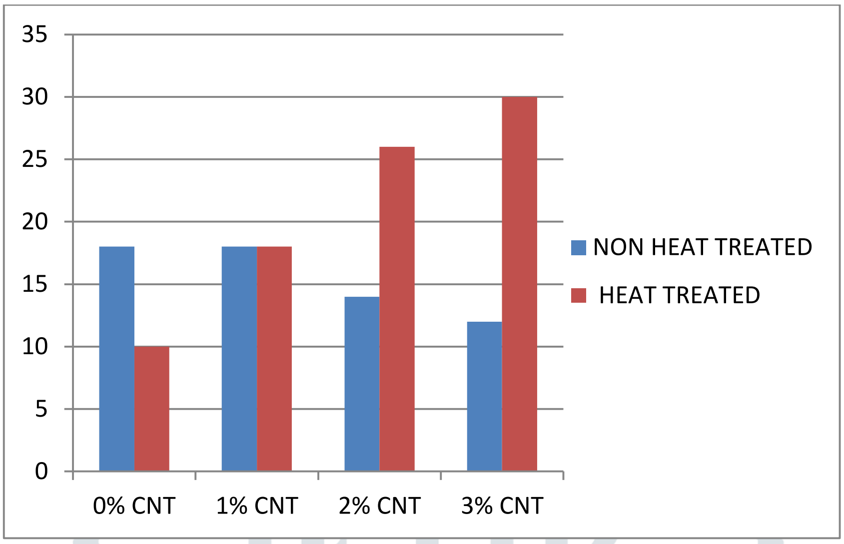

Figure 9: Percentage of CNT VS Impact energy

From above graph we can observe that for non-heat treated samples the impact energy decreases as the carbon content increases. But for heat treated samples the impact energy increases as the carbon content increases.

IV. CONCLUSION

To conclude, the use of carbon nano tube improves the thermal properties of the composite material and also the also the strength to withstand different types of forces acting on the material at different environmental conditions. The strength of the atomic bond in carbon nanotubes allows them to withstand high temperature and its also a very good thermal conductor. Future scope: Extremely small and lightweight making them excellent for replacing heavy weight metalic compounds in aircraft body.

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