# Experimental Evaluation of Carbon Fibre Epoxy Laminate and Analysis Using ANSYS 17

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***Abstract***- *Our project represents the experimental evaluation of the carbon fibre reinforced epoxy laminate. Recent researches are processing on the manufacturing of the aircraft using carbon fibre composite to reduce the weight and increase its strength .The carbon fibre's tensile strength, compressive strength and flexural strength have been estimated and computational analysis for different loads at zero orientation. The carbon fibre reinforced epoxy composite laminate have been fabricated and tested. The various strength have been tested in the computerized universal testing machine with different loading conditions to calculate the strengths. Also they have been analysed using Ansys 17. The two values of the strength i.e., experimental and computational analysis values of different strength of the bidirectional carbon fibre and they are compared also the percentage of the error is found for the strength. And the application of the laminate for the suitable aircraft component is found comparing the results of the strength using experimental and the computational analysis.*

## I. INTRODUCTION

### 1. COMPOSITES

Composite is a combination of two or more chemically distinct and insoluble phases. Constituent materials or phases must have significantly different properties for it to combine them: thus the metal and plastics are not considered as composite although they have a lot of fillers and impurities. The properties and performance of composites are far superior to those of the constituents. Composites consist of one or more discontinuous phases (reinforcement) embedded in a continuous phase (matrix).

### 1.1 CARBON FIBRE COMPOSITES

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Carbon fabric reinforced polymeric composites are very used for manufacturing components as flaps, aileron, landing-gear doors, and other artifacts used in aeronautical industry. Additionally, the composites can be used in other areas like home construction, navy, automotive and sport industries.

In general, aeronautical polymeric composites are classified as advanced and present continuous fiber reinforcement (for example, carbon, glass or aramid) of high-modulus or high-strength embedded in a thermoset or thermoplastic polymeric matrix. The appropriate performance of these composites during use is mainly related to their mechanical properties and thermal resistance as a result of the adequate combination of reinforcement (tapes or fabrics), polymeric matrix and processing technique. Polymeric composites reinforced with carbon reinforcements show mechanical properties similar or higher than the conventional metallic materials. The mechanical properties of carbon fiber are

- High Strength to weight ratio
- Good Rigidity
- Carbon fiber do not absorb water
- Corrosion resistant
- Electrically Conductive
- Fatigue Resistant and do not show any creep or relaxation
- Good tensile strength (2500-6000Mpa)
- Fire Resistance/Not flammable
- High Thermal Conductivity in some forms
- Low coefficient of thermal expansion
- Non poisonous
- Biologically inert
- X-Ray Permeable

Among the polymeric matrices, the polyester resins (thermoset polymer type) are very used in aeronautical area, because they generally attend the mechanical strength, chemical resistance and service temperature requirements. The polyester resin also allows modifications in its chemical structure depending on the required application. Despite the several advantages of the polymeric composites over the metallic materials, the former is more susceptible to mechanical damages when they are subjected to great efforts of tension, compression and impact, which can lead to interlayer delamination. The modification of polyester matrix with thermoplastic polymers and/or elastomers is a tendency of the aeronautical industry, aiming to reduce the mechanical damage of polymeric composites by impact loads12, 18. So, the use of modified polymeric matrix in the composite manufacture requires a systematic evaluation of the mechanical properties. In this work, laminate composites with modified matrices were evaluated by tensile tests according to the aeronautical industry requirements.

The tensile tests are used to determine both strength and modulus values to be used in component projects and also to verify technical specifications and quality assurance of projects. The fracture surfaces, resultant of the tests, are used to support the failure mode analysis. The literature shows that these parameters have been evaluated involving the polymer composites characterization. Carbon-fiber-reinforced polymers are composite materials. In this case the composite consists of two parts: a matrix and reinforcement. In CFRP the reinforcement is carbon fiber, which provides the strength. The matrix is usually a polymer resin, such as epoxy, to bind the reinforcements together. Because CFRP consists of two distinct elements, the material properties depend on these two elements.

Carbon-fiber-reinforced polymer is used extensively in high-end automobile racing. The high cost of carbon fiber is mitigated by the material's unsurpassed strength-to-weight ratio, and low weight is essential for high-performance automobile racing. Race-car manufacturers have also developed methods to give carbon fiber pieces strength in a certain direction, making it strong in a load-bearing direction, but weak in directions where little or no load would be placed on the member. Conversely, manufacturers developed omnidirectional carbon fiber weaves that apply strength in all directions. This type of carbon fiber assembly is most widely used in the "safety cell" monocoque chassis assembly of high-performance race-cars.

## II. LITERATURE SURVEY

**K.Marcus (2004), University of Cape Town(UCT)** illustrates that recycling carbon fibers from waste composite materials would only be efficient if it were possible to separate the fibers and the matrix and to re-use the recycled fibers as new reinforcements. The challenge is to use non-continuous fibers to produce high-strength materials. The formation of defects in ‘‘semi-long’’ fiber composites has not yet been taken into account. In this paper the influence of fiber length and fiber alignment on the strength and the modulus of composite material generation composite material would be. The tensile properties of natural fibre reinforced polymer composites and identified a major drawback of using natural fibers as reinforcement in plastics is the incompatibility, resulting in poor adhesion between natural fibers and matrix resins, subsequently lead to low tensile properties. In order to improve fibre–matrix interfacial bonding and enhance tensile properties of the composites, novel processing techniques, chemical and physical modification methods are developed.

**Bilek Ali (2007), MouloudMammeri University of Tizi-Ouzou** states that the production and characterization of low modulus carbon fibers is reported from a commercially available regenerated cellulose fiber. The fibers were heat treated before graphitization at a temperature of 200$^{o}$C .Fibres was then further heat treated and graphitized at a temperature of 2000$^{o}$C. Polarized Raman spectra of carbonized/graphitized fibers were recorded. The ratio of two Raman peaks located at 1350 cm (D-band) and at 1600 cm (2D band) – the ID/IG ratio was used to follow the onset and development of the carbon/graphitic structure. It is shown, using tensile testing, that single carbon fibers processed at 2000 $^{0}$C have a modulus of 70 GPa and strain at break >2%.Tensile and flexural properties of single carbon fibers identified the tensile and flexural tests of single filaments for commercially available ultrahigh strength PAN-based, ultrahigh modulus pitch-based and high ductility pitch-based carbon fibers were performed to evaluate the potential of them. The tensile and flexural test of high strength and high modulus PAN-based carbon fibers were also performed for comparison. The Weibull distributions of the tensile and flexural strength were evaluated.

**Miroslav Trajanvoic (1999),** University of Nis, Serbiainvestigated the fracture mechanisms of different types of carbon fibers, in terms of skin-core differences in single fibers, flaw size and fracture toughness. The fibre strength distribution was measured precisely using the fragmentation test for single-fibre composites. The failure probability for intermediate/ high modulus types fibers was found to be constant with fibre strength in the range 2–4 GPA, but in contrast the strength scatter for high modulus type fibers was reduced. The fracture toughness of the carbon fibers, determined by introducing notches with lengths in range 60–200 nm, was found to be about 1.1 MPa m1/2. The average flaw size of the carbon fibers increased with increasing fibre modulus, suggesting that the crack growth of surface flaws on the tens-of-nm scale occurred. This appears to be the main reason for the reduction in tensile strength during the carbonization treatment.

## III. SELECTION OF MATERIAL

Selection of a method for a particular part will depend on the materials, the part design and end-use or application. Composite fabrication processes involve some form of moulding, to shape the resin and reinforcement. A mould tool is required to give the unformed resin / fibre combination its shape prior to and during cure .The composite specimens are manufactured by the hand layup method. The various volume fraction of the filler and fibre are to be mixed with resin to prepare the composite by using compression moulding process. The layering pattern are used to prepare the composites with suitable volume fraction of fillers.

Carbon sheet is taken and cut for the dimensions of the die to be used and the die is cleaned well and then epoxy resin is taken and of accelerator is added. To the mixture the hardener is added at the final stage of stirring. This mixture is poured into the die and spread well. Above to the mixture a layer of carbon sheet is placed and then rolled well by hand lay out method. The above procedure is repeated for the total number of required layers. After setting up the final layer with resin compression moulding process is employed. Then after curing the specimens are taken for testing.

### 3.1 HARDNER

- It is mainly used for the bond formation between the fibre and the resin.
- A substance or mixture added to a composition to promote or control curing by taking part in it.

## IV. WEIGHT ESTIMATION

### 4.1VOLUME FRACTION:

Consider a composite material that composite of fibre and matrix material. The volume of the composite material is equal to the sum of the volume of the fibre and the volume of the matrix.

$V_c = V_f + V_m$
$V_f = V_f/V_c$
$V_m = V_m/V_c$

Such that the sum of volume fraction is

$V_f + V_m = 1$

### 4.2WEIGHT FRACTIONS:

Assuming that the composite material consist of fibre and matrix material, the weight of the composite material is equal to the sum weight of the fibre and the weight of the matrix.

$W_c = W_f + W_m$, $W_f + W_m = 1$

### 4.3DENSITY FRACTION:

Density of the composite material can be defined as the ratio of weight of composite material to the volume of the composite material and is expressed.

$\rho_c = Wc/Vc$

but, $Vc = Vf + Vm$, and $V = W/\rho$, therefore the above equation can be rewritten as.

$W_c/\rho_c = W_f/\rho_f + W_m/\rho_m$
$1/\rho_c = 1/\rho_f \; W_f/W_c + 1/\rho_m \; W_m/W_c$

By writing in term o weight fraction.

$1/\rho_c = W_f/\rho_f + W_m/\rho_m$
$\rho_c = 1/ W_f/\rho_f + W_m/\rho_m$

The equation $W_c = W_f + W_m$, can be rewritten as.

$\rho_c V_c = \rho_f V_f + \rho_m V_m$
$\rho c = \rho f \; vf/vc + \rho m \; vm/vc$

Writing term of volume fraction, the density of the composite material is written as.

$\rho c = \rho f Vf + \rho m Vm$

### 4.4CALCULATIONS:

We know that the following values,
Density of the carbon fibre = 1.925 Kg/m3
Density of the epoxy resin = 1.5 Kg/m3
Weight of the fibre = 500gms
Weight of the resin= 1000gms
From the composites as shown that in figure.
Length of the fibre (l) =250 mm
Breadth of the fibre (b) = 60 mm
Thickness of the fibre (t) = 4mm
Volume of the composite= l*b*t
= 250*60*4
Volume of the composite=$6*10^{-5}$ $m^3$

**Weight fraction:**

$W_c = W_f + W_m$

$W_c = 300+1000$
$W_c = 1300$ gms
$W_f = W_f/W_c = 300/1000$
$\mathbf{W_f = 0.3}$ **or 30.3%**
$W_m = W_m/W_c$

**Density and volume fraction:**

$1/\rho_c = W_f/\rho_f + W_m/\rho_m$
$\rho_c = 1.525$ Kg/m$_3$
$\rho_c = \rho_f V_f + \rho_m V_m$
$1.525 = \rho_f V_f + \rho_m V_m$
$1.525 = 2.5\ V_f + 1.5\ V_m$

Solving the above two equation we get,

$V_f = 0.392$
$V_m = 0.36$

Volume fraction will be given as,

$V_f = 0.392*9.10^{-5}$
$V_f = 3.528*\ 10^{-5}\ m^3$
$V_m = 0.36*9*10^{-5}$
$V_m = 3.24*10^{-5}\ m^3$

## V. TESTING OF COMPOSITE

### 5.1 COMPONENTS of UTM

**Load frame:** Usually consisting of two strong support for the machine .Some small machines have single support.

**Load cell:** A force transducer or other means of measuring the load is required. Periodic calibration is usually required by governing regulations or quality system.

**Uses**

- Elastic limit
- Proportionality limit
- Elastic limit

The following test are conducting for laminates.

1. Tensile Test
2. Flexural Test
3. Impact Test

The laminate will be tested should have the ASTM standards as per the test specimen dimensions

**Figure 5.1 Universal Testing Machine**

### 5.2 TENSILE TEST

Tensile test is a measurement of the ability of material that reacts to force that are applied in the form of tension on different material such as plastic, textile, rubber etc

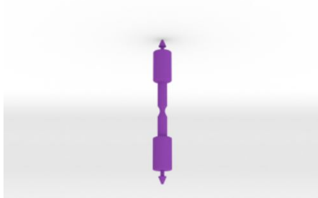

**Figure 5.1Tensile test of the specimen.**

Thus the American Standard for Testing Material (ASTM)

Length will be 165 mm
Breadth will be 20 mm.

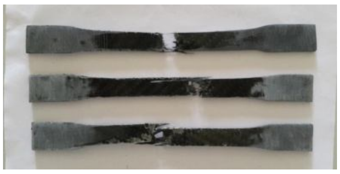

**Figure 5.2 Test specimen after tensile test**

### 5.3 COMPRESSION TEST

A compression test can be performed on (UTM) by keeping the test piece on base block and moving down the central grip to apply load. It can also be performed on a compressive testing machine. A compressivetesting machine. Thus the ASTM Standard for the compressive test (ASTM D3410) will be given below.

Length will be 155 mm.
Breadth will be 30mm.

### 5.4 FLEXURAL TEST:

The three point bending flexural test provides value for the modulus of elasticity in bending. Flexural stress, flexural strain and the flexural stress strain response of the material. The main advantage of the three point flexural test is the ease of the specimen preparation testingThus the ASTM

Standard for compression test (ASTM D790) will be given below.

Length will be 64 mm.
Breadth will be 13mm.

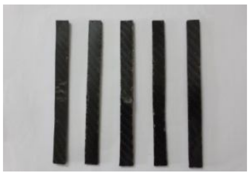

**Figure 5.3 Test specimen for flexural test**

## VI. EXPERIMENATAL RESULT

Tensile load is the load as the material is being pulled, we will find its strength. Tensile load is shown in figure.

### 6.1 Tensile test

Tensile load is the capacity of the material withstand loads tending to increase size. Tensile load on the laminate will be given.
Thus the all specimens of each laminate are used to have the test over the universal testing machine and strength values are determined. Thus the laminates to be analyzed of each loading will be mention below.

**Table 6.1 Testing values for tensile test**

| S No | LOAD(N) | EXTENSION(mm) |
|---|---|---|
| 1 | 2250 | 5.0849 |
| 2 | 2500 | 5.4584 |
| 3 | 2750 | 5.8319 |
| 4 | 3000 | 6.1715 |
| 5 | 3250 | 6.5111 |
| 6 | 3500 | 6.8421 |
| 7 | 3750 | 7.1392 |
| 8 | 4000 | 7.4279 |
| 9 | 4100 | 7.5637 |
| 10 | 4842 | 7.5892 |

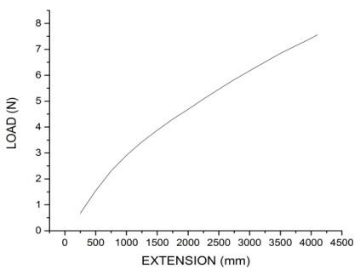


**Fig 6.1 Tensile test graph**

### 6.2 FLEXURAL TEST

Compositions of the specimens are same as that of the specimens made for the tensile test. The flexural test results are tabulated in table 6.2.

**Table 6.2 Flexural Test Result**

| Sample no. | Flexural Strength (MPA) |
|---|---|
| 1 | 55.179 |
| 2 | 42.628 |
| 3 | 67.746 |
| 4 | 34.792 |
| 5 | 37.756 |

### 6.3 IMPACT TEST

Compositions of the specimens (as shown in figure 6.2) are same as that of the specimens made for the above tests. All the specimens are made using six layers of carbon fibre. The impact test are made by Izod impact testing method and the results are tabulated in table 6.3.

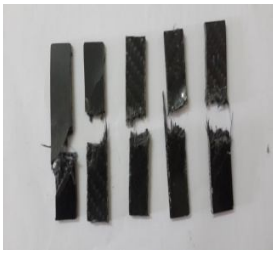

**Fig 6.2 Specimen after Impact test.**

**Table 6.3 Impact Test Result**

| S. No. | IzodImpact(J)((90()Value(J) |
|---|---|
| 1 | 1.35 |
| 2 | 1.40 |
| 3 | 2.10 |
| 4 | 2.40 |
| 5 | 2.10 |

## VII. RESULT ANALYSIS USING ANSYS 17

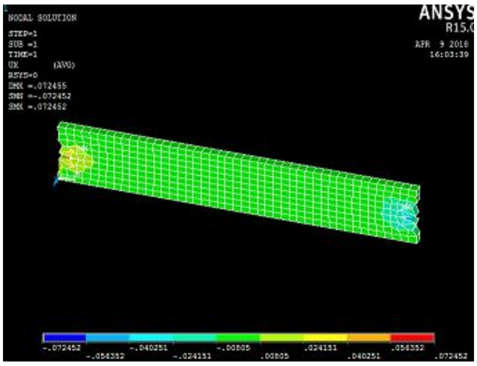


**Fig 7.1 Compressive stess**

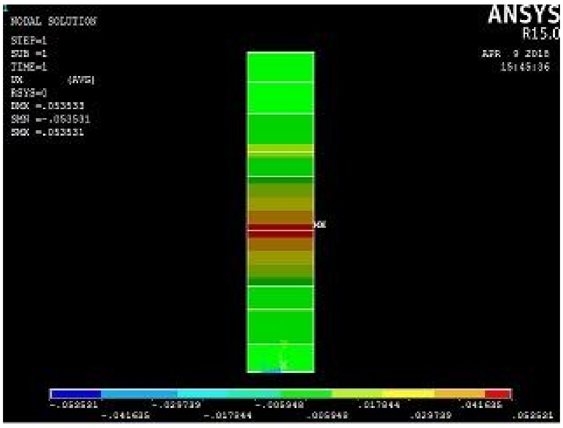


**Fig 7.2 Tensile stress**

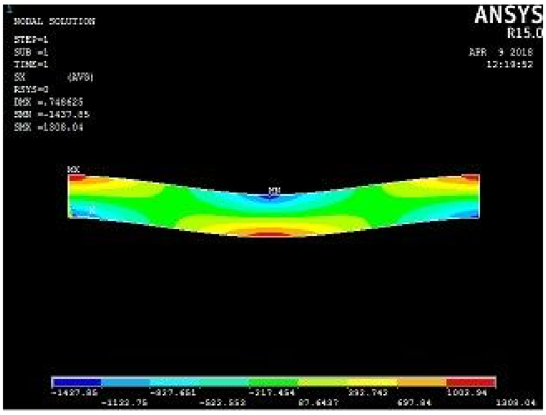


**Fig 7.3 Flexural stress**

## VIII. FUTURE WORK

The carbon composite material is going to be the most important material for the production of the aircraft. Recent researches prove that entire aircraft is to be made on carbon fibre, because of its high strength and very less weight compared to the metals used in the manufacturing. Thus the carbon fiber can be used in the manufacturing of the aircraft components .

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