TENSILE, FLEXURAL AND IMPACT ANALYSIS OF CARBON-KEVLAR HYBRID COMPOSITE LAMINATES

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Abstract – *A hybrid composite consisting of carbon and Kevlar is tested for its tensile stress, flexural deformation and impact resistance through computer simulation. Likewise, for the simulation, five plates are chosen with different stacking sequences of carbon and Kevlar to identify which combination has better properties. Carbon is chosen due to its strength and Kevlar for its impact resistance and load bearing capabilities. The application of the composite can be found in aerospace industries regarding structural stability and providing strength towards the objects. The observations after simulation says that the combination of the plate with alternating layers of two carbon and two Kevlar layers seems to be exceling at properties mentioned above. Also, the study on stacking sequences on the properties of the composite is done.*

***Key Words*: Tensile stress, Flexural deformation, Impact resistance, Simulation etc.**

1.INTRODUCTION

Composite materials are a form of material systems which consists of two or more macro constituents differing in various material composition and that are insoluble with each other.

In the current advancements in technology and the need of reduction in cost of the material as well as very strong and durable materials. Previously metals and their alloys were used widely for the production of various products which includes buildings and the manufacture of automobiles, electrical appliances etc. These all changed with the advent of plastic,

They were initially expensive at the time of its production but as plastics found its way around in the manufacture of containers and buckets and hence its manufacturing costs came down as a result and due to their comparatively low strength, they cannot be used for the manufacture of automobile components and aerospace parts. Hence, composite materials have attracted engineers and manufacturers for their desirable properties and is also attracting a large number of research regarding the properties of the composite materials.

1.1 Hybrid composites

Hybrid composites are those composites in which there can be an arrangement of two or more layers of matrix or one or more layers of reinforced fibres or it can be a combination of both matrix and reinforced fibres oriented in different ways can be attributed to hybrid composites.

The properties of these composite materials generate far more range as compared to composites having the layers of the same material. In this case the properties of two of those materials are combined

The given panels are arranged in sequences mentioned below:

PANEL 1: Full carbon fibre laminates

PANEL2: Full Kevlar fibre laminates

PANEL 3: C/K/C/K....

PANEL 4: C/C/K/K....

PANEL 5: C/C/C/C/C/C/K/K/K/K/K/K

Each panel has twelve layer each equating the thickness about 3mm.

1.2 Properties of hybrid composite

- Tensile stress properties of composites are calculated by the strength and volume content of the fibre reinforcement.

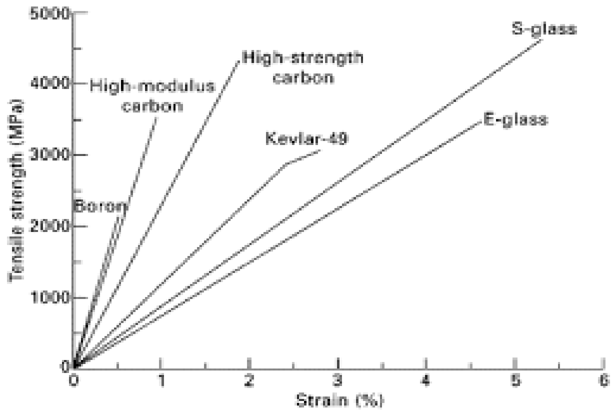

Fig 1.1 Tensile strengths of various materials

- Flexural deformation of material is defined as the ability to resist deformation at under load. It is also known as the maximum bending stress that can be applied before it yields.

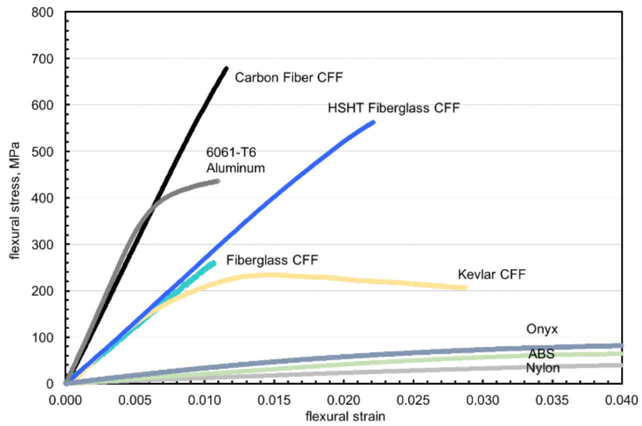

Fig 1.2 Flexural stresses of various materials

- Impact resistance is a situation where the impact applied to a material will result in how much joules of energy has the material taken, this type of energy is coined as the strain energy. Such emery can travel through the body of the composite in a lateral manner in a short amount of time and can cause shear and normal stresses as captioned by the plate theory.

2) MATERIALS

2.1) Carbon fiber

Carbon fibres are also known as graphite fibres. They have high tensile strength and are extremely strong for their size. Carbon fibre is made from organic polymer which consists of molecules held together by carbon atoms. They are mostly made from polyacrylonitrile (PAN) and a small percentage are made from rayon or petroleum pitch process.

Thickness	**0.3 mm**
Area Weight	**200 g/m²**
Tensile Strength	**353 MPa**
Modulus in tension	**230 GPa**
Elongation	**1.5%**

Table 2.1 properties of Carbon fibre

2.2) Kevlar fibre

The chemical composition of Kevlar is poly para-phenyleneterephthalamide (PPD-T) and is properly as para-amid.

It is made from a condensation reaction of para-phenylene diamine and terephtaloyl (PPD-T) chloride. The product is aromatic and amide groups to give them rigidity like the polymers.

The Kevlar fibre is an array of molecules arranged in parallel to each other. This orderly arrangement of molecules is a crystalline structure. This is formed by the method of spinning, which describes the method of extruding molten polymer through holes.

Table 2.2 properties of Kevlar fibre

Width	**1000 mm**
Thickness	**0.28 mm**
Density	**1.44 g/cm³**
Tensile Strength	**276 MPa**
Weight (± 10%)	**220 g**

3) DESIGNING

Characteristics of the material is given as input for the ANSYS workbench

1) Carbon fibre

Density(ρ): 1600 kg/m³
Young's modulus(ε): 135 GPa
Poisson's ratio(η): 0.3

2) Kevlar fibre

ρ = 1400 kg/m³
ε = 30 GPa
η = 0.2

Resin hardener
ρ = 1205 kg/m³
ε = 4.1 GPa
η = 0.35

The dimension of the plate is given as 200 mm length and 20 mm for width with the fibre thickness is given as 0.2 mm and 0.1 mm for resin volume thickness. For impact resistance however the dimensions are 65mm for length, 10mm for width. The overall thickness of the material to 3mm, this is accordance with ASTM standards ASTM D68 for tensile stress, ASTM D790 for flexural deformation and ASTM A370 for impact test.

- In ansys design modular software, open the sketch option and choose the XY plane and sketch the rectangular fiber phase with the aforementioned dimensions given for input.
- Extrude the fiber phase up to 0.2 mm for giving the fiber the right amount of volume for deformation and applied stresses.

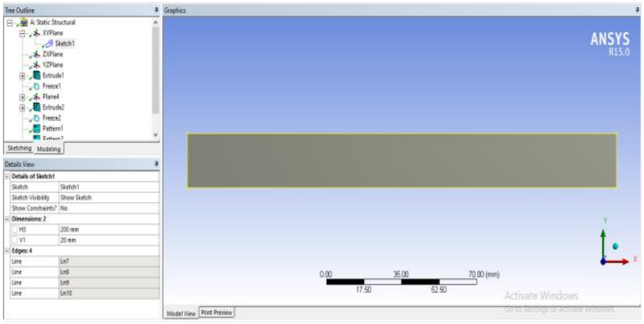

Fig 3.1: Sketching and extrusion of one layer

- Freeze the process completed and select the fiber phase and using the same dimensions used for the fiber phase create another rectangle for the resin phase and extrude it for 0.1 mm to get the volume.

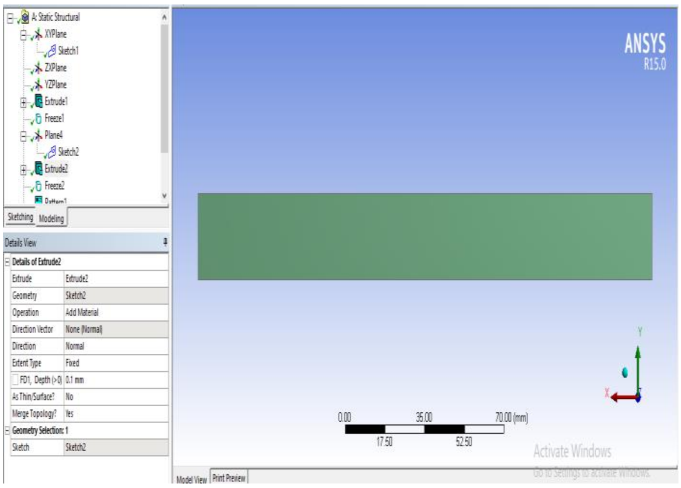

Fig 3.2 Freezing one layer of the composite

- Repeat the process for creating 11 layers of fabric and 10 layers of resin volume which gives the total thickness of the composite 3 mm.

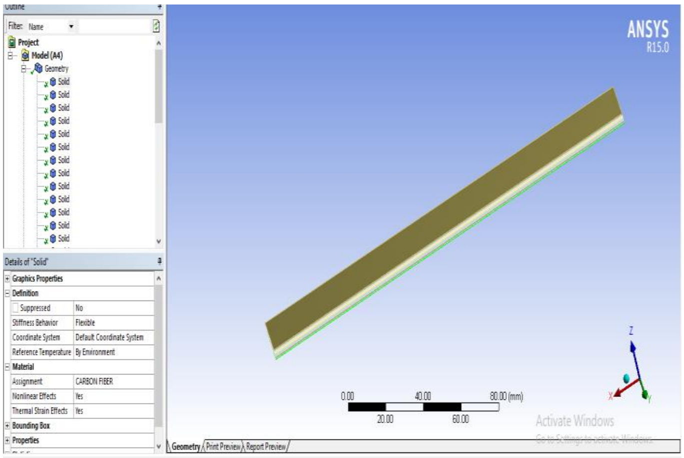

Fig 3.3 The completed design

- Go to the engineering data on the top left corner and a tab opens showing all the data of the materials and choose the material of preference.
- Here select carbon fiber and enter all the details of it characteristics and as well as for Kevlar and the resin hardener by selecting add new.
- Now click on model and then geometry and select solid parts to change the material property.
- On the right hand side, the tab for meshing is available, right click and go to insert and select the body and choose meshing as tetrahedron elements to calculate efficiently

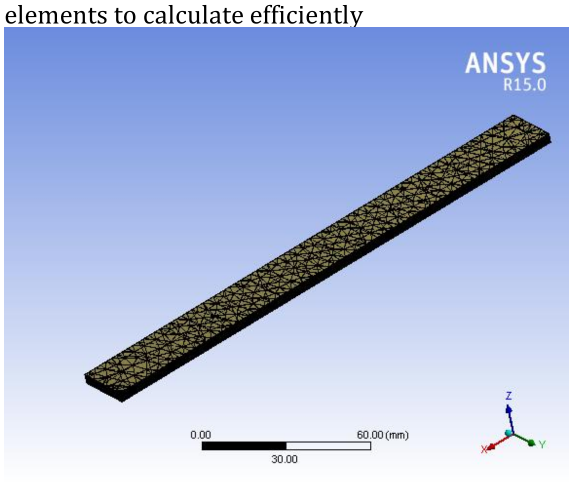

Fig 3.4 meshing of the composite

- Afterwards apply the border conditions, for this select a side and face, finally go to static structure and right click on to insert and onto fixed support, follow the same on the other side for flexural deformation and for impact testing.
- To apply pressure or load go to static structure and there will appear a column for entering the required amount of load or pressure.
- Click on solutions and right click on deformations and select total, go to insert and select stress and strain, for flexural simulation the deformation, and impact testing the strain energy.

4) RESULTS AND DISCUSSION

The plate dimensions for the simulation process is given as 200mm * 20mm * 3mm and flexural simulation also the same dimensions and for impact testing the dimensions are 65mm*10mm*3mm, this is accordance with ASTM standards ASTM D68 for tensile stress, ASTM D790 for flexural deformation and ASTM A370 for impact test.

According to these dimensions the profile of the plates and the boundary conditions are given where to ends are fixed and the load is applied for both the analysis of tensile, flexural and impact values. Start with applying 1MPa pressure one face of the composite for tensile stress simulation, for flexural deformation a load of 1 KN is applied with both ends fixed, for impact simulation a load of 10 KN is taken with both ends fixed.

4.1) Tensile stress analysis

PLATE 1: Fully carbon fiber laminated panel

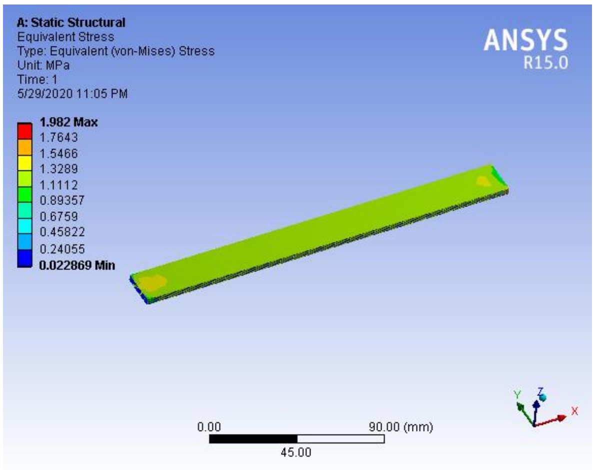

Fig 4.1: Tensile Stress simulation for panel 1

PLATE 2: Fully Kevlar fiber Laminated plate

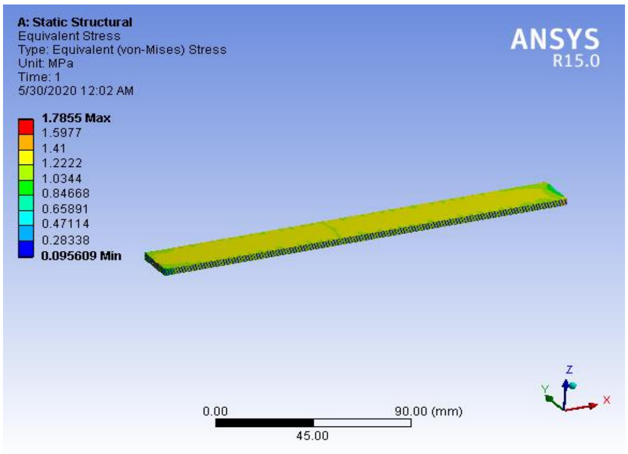

Fig 4.2: Tensile stress simulation on panel 2

PLATE 3: C/K/C/K/C/K....

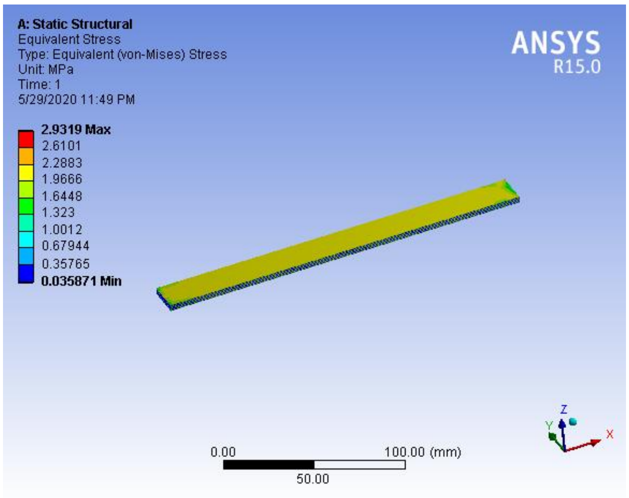

Fig 4.3: Tensile stress simulation of panel 3

PLATE 4: C/C/K/K.........

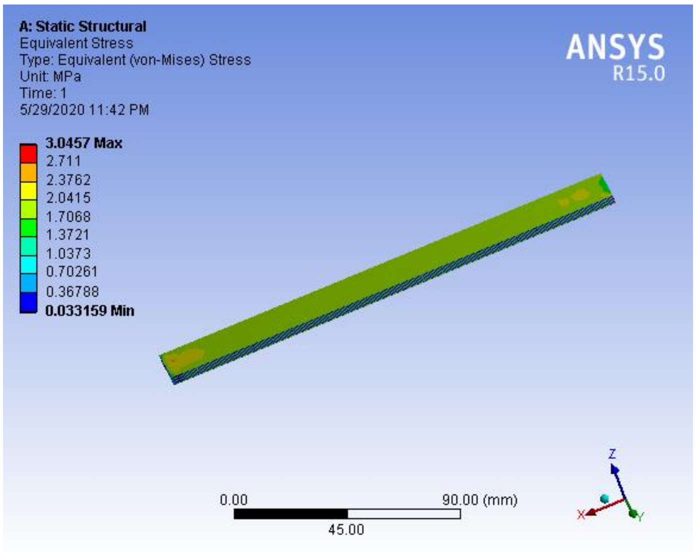

Fig 4.4: Tensile stress simulation for panel 4

PLATE 5: 6 layers of carbon fiber and next 6 layers of Kevlar fiber

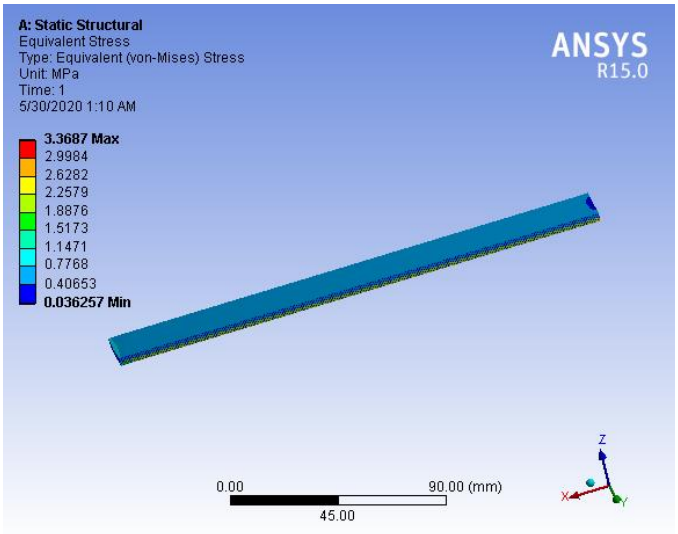

Fig 4.5 Tensile stress simulation for panel 5

Table 4.1 Tensile stresses for various panels:

	STRESS (MPa)
PLATE1	1.982
PLATE 2	1.7855
PLATE 3	2.9319
PLATE 4	3.0457
PLATE 5	3.3687

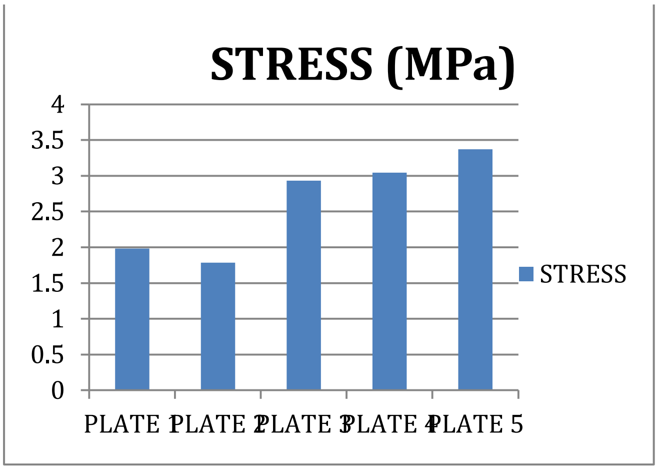

Fig 4.6 Graph showing the various stresses of panels

After finding the simulated results for tensile stresses for the various plates by applying a load of 1 Mpa at its end and the other fixed, plate 5 which consists of first 6 carbon layers and then 6 Kevlar layers is found to be having the greater tensile stress at 3.3687 Mpa which is a 70% increase in strength compared to carbon laminated plate.

4.2) Flexural deformation analysis

For the purpose of simulation of specimen to get flexural strength assume a force of 1KN face side and while the both the ends are fixed.

PLATE 1

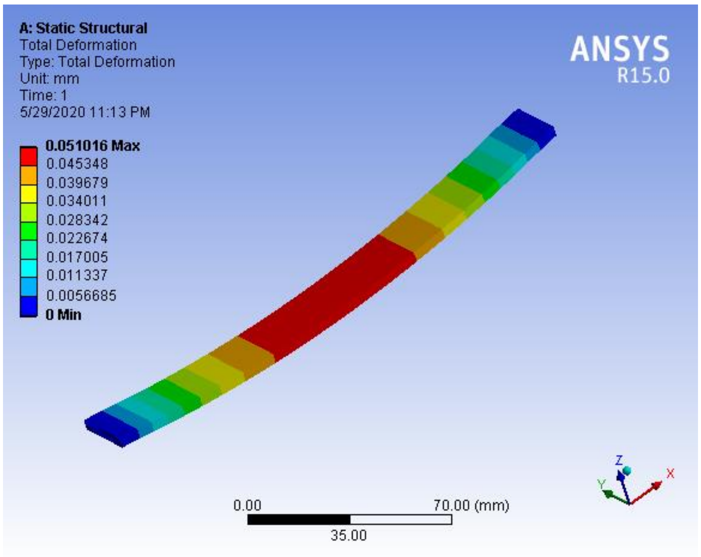

Fig 4.7: Deformation in plate 1

PLATE 2

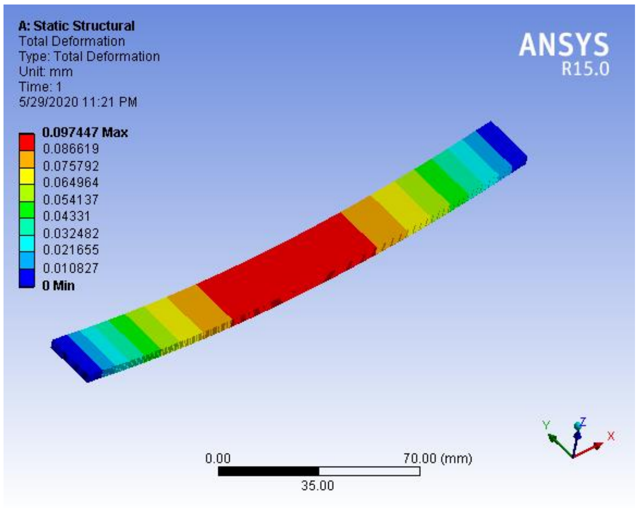

Fig 4.8: Deformation in plate 2

PLATE 3

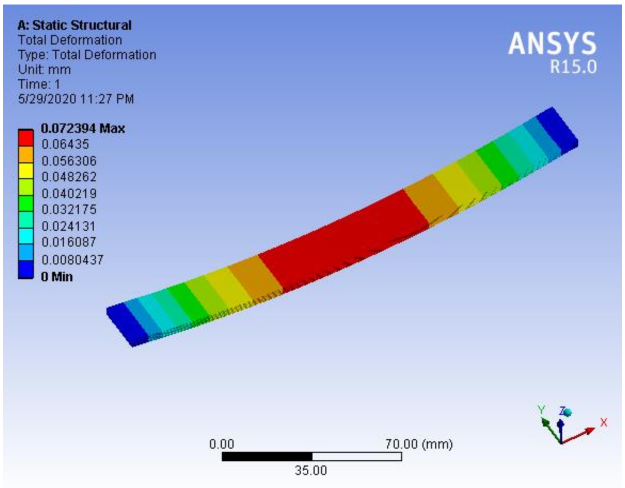

Fig 4.9: Deformation in plate 3

PLATE 4

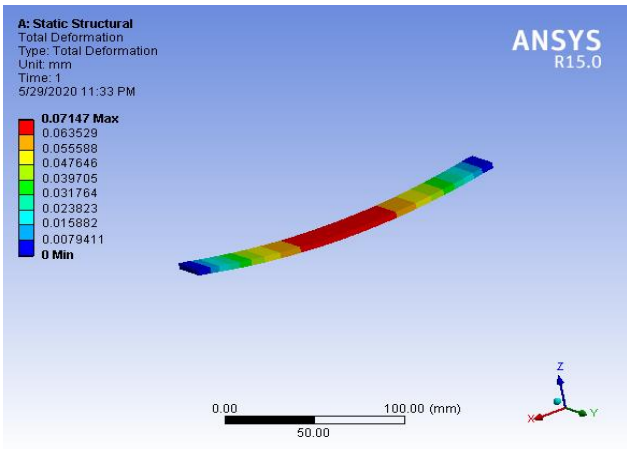

Fig 4.10: Deformation in plate 4

PLATE 5

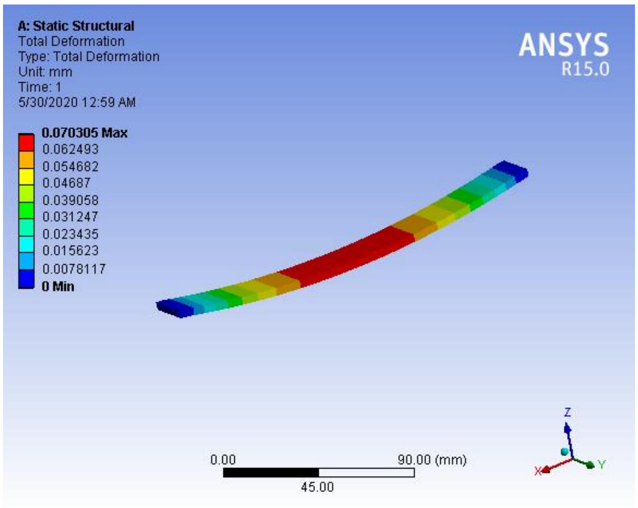

Fig 4.11: Deformation in plate 5

Table 4.2 Simulated flexural deformation values

	TOTAL DEFORMATION (mm)
PLATE 1	**0.051016**
PLATE 2	**0.097447**
PLATE 3	**0.072394**
PLATE 4	**0.07147**
PLATE 5	**0.070305**

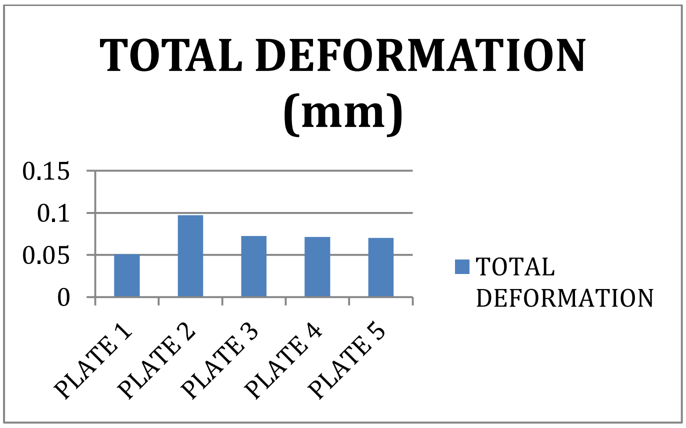

Fig 4.12 Graph showing the various deformations

As the simulations suggest there is a clear indicator that the plate1 which consists of all carbon laminates and due to its homogeneity there is less deformation as Kevlar has the highest amount of deformation while all the hybrid composites have little to non-difference at all as they have the overall flexural properties of both materials.

4.3) Impact resistance analysis

Impact resistant is also simulated in the ansys software, for the results an applied a force of 10 KN on the top faced side and the two sides are fixed so as to get the maximum results.

PLATE 1

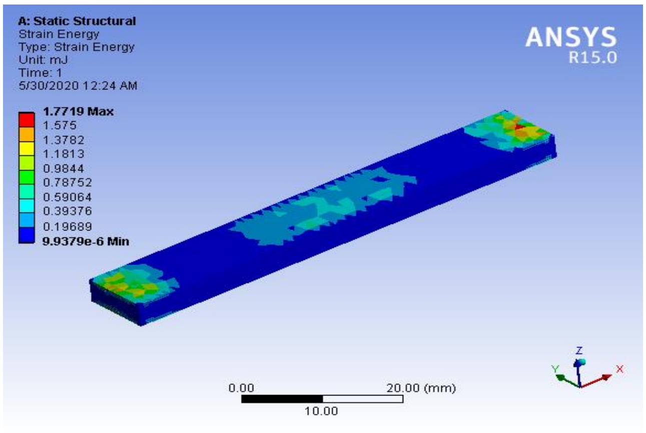

Fig 4.13: Strain energy of plate 1

PLATE 2

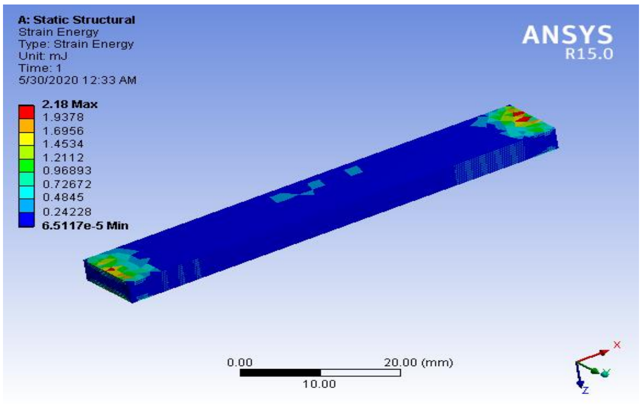

Fig 4.14: Strain energy of plate 2

PLATE 3

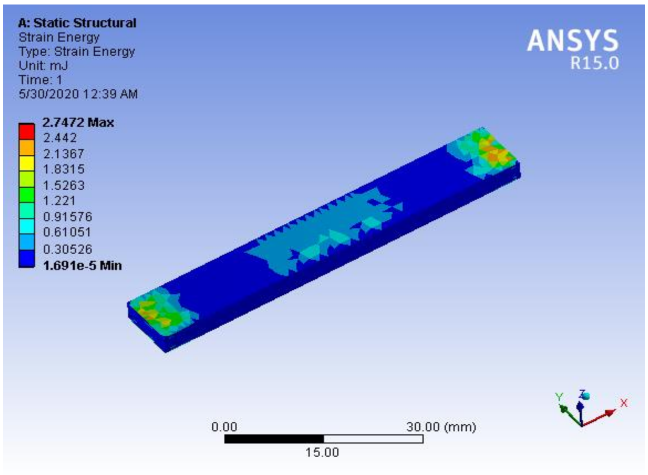

Fig 4.15: Strain energy of plate 3

PLATE 4

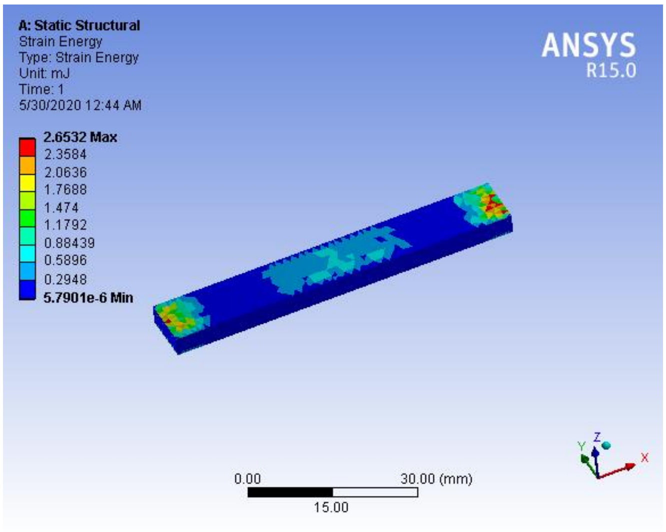

Fig 4.16: Strain energy of plate 4

PLATE 5

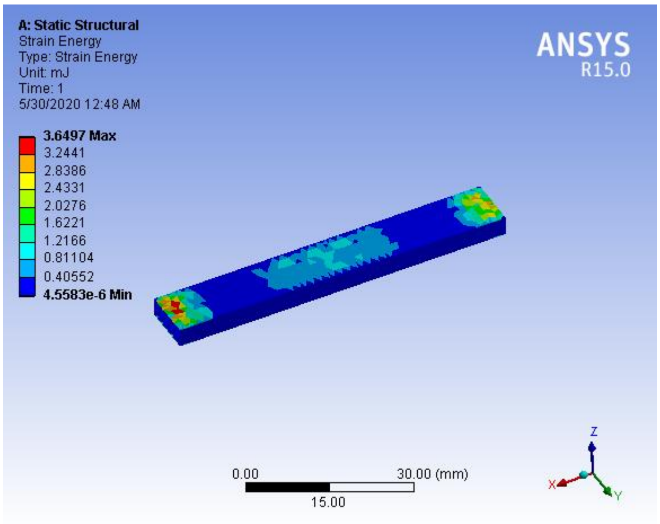

Fig 4.17 Strain energy of plate 5

Table 4.3 Simulated values for strain energy absorption due to impact

	STRAIN ENERGY (MJ)
PLATE 1	1.7719
PLATE 2	2.18
PLATE 3	2.7472
PLATE 4	2.6532
PLATE 5	3.6497

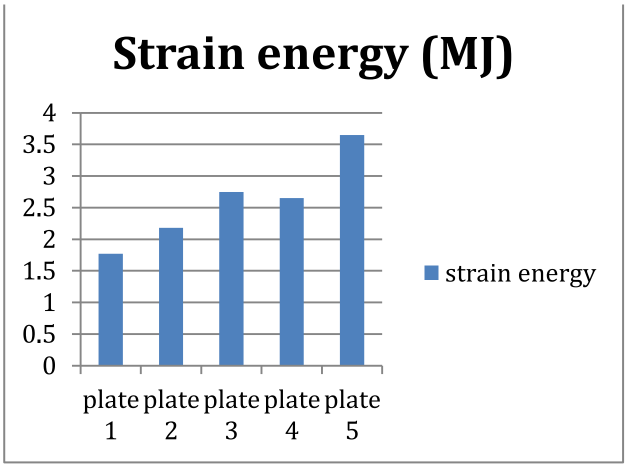

Fig 4.18 Graph showing the strain energy of different plates

The simulated results show that plate 5 which consists of 6 layers of carbon fibre first and then the bottom with second half with Kevlar fibre showed a high amount of energy absorption due to the way how its stacked giving an edge over others and because of this stacking sequence that there is an increase in the impact resistance which causes more absorption of energy. In saying that there is an increase of 59% in strain energy comparing with carbon fibre.

5) CONCLUSION

Panel 5 which consists of first 6 layers of Carbon fibre and bottom 6 layers of Kevlar fibre is shown to have very high tensile stress as well as high impact strength but an average flexural deformation which is lower than carbon laminated plate due to the reasons mentioned above, taking this into consideration plate 5 has a potential for being used in places of high structural strength with an exception of a lower flexural value.

To give a few examples Carbon-Kevlar composites can be used to line the fuel tank in the wings of the aircraft as it is significantly lighter than aluminum which can provide much better efficiency and won't wither easily which makes it a great replacement and can be implemented anywhere.

Therefore, the combination of Carbon and Kevlar have drastic advantages over other forms of hybrid composites by providing an overall improvement in mechanical properties and wide range of applications from industries and personal use.

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