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HEMP FIBRE REINFORCED –GRAPHENE COMPOSITE MATERIAL

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Abstract: The present study aims at the model development and critical analysis of a composite material based on hemp fibre, graphene and epoxy resin. The performance of the natural fibre composites depends directly on the fibres counting, length, shape, arrangement and also the interfacial adhesion with the epoxy resin. Hemp fibres have been found to possess excellent mechanical strength and young's modulus, and good insulation properties. Hemp fibers have properties that make them a suitable material to replace glass fibers as reinforcements in composites. The composites made of hemp fibre with graphene and epoxy resin have exhibited good mechanical properties. Graphene is the thinnest material and also amazingly strong - about two hundred times stronger than steel. Graphene composites have lots of possible applications, with much research going on to create unique and innovative materials. The future of graphene composites includes medical implants, engineering materials for aerospace and renewable energy resources and much more. The under study, Hemp fibre-reinforced graphene composite material (HFRGCM) is modeled by using ANSYS Workbench (ACP). ANSYS Mechanical solves linear or non-linear static or dynamic issues for structural analysis of composite.

Keywords: Composite materials, Epoxy resin, Fibre-reinforced composites, Graphene, Hemp.

1. INTRODUCTION

According to Beghezan, "the composites are compound materials which vary from alloys by the fact that the individual components maintain their characteristics but are so integrated into the composite as to take benefit only of their attributes and not of their short comings, in order to achieve enhanced materials". Van Suchetclan has explained, "the composite materials as assorted materials consisting of more than one variety of solid phases, that unite in appreciated contact with one another on a microscopic scale; and these materials will be next to consideration about as homogeneous materials on an infinitesimal scale among the sense that any part of it is reaching to have the same property". As per Jartiz, "the composites are the multifunctional material systems that provide characteristics not available from any discrete material, as they are cohesive structures made by physically combining two or more companionable materials, dissimilar in composition and characteristics, and sometimes in form". Kelly ha explained that, "the composites should not be regarded just as a simple mixture of two materials, because this new combination has its own distinct properties". According to modern concept composites are statically homogeneous structures created by physically combining a variety of compatible materials that are completely different in composition and characteristics.

A composite has two main constituents; one is reinforcement and the other being a matrix. A good reinforcement should be discontinuous, hard and strong material; and these characteristic are also well satisfied by fibres from the vegetable sources. The use of these natural fibres as reinforcement material has lead to the development of natural fibres reinforced composites. To tailor these natural fibre-reinforced composites with the desired properties, various matrix materials have been developed and characterised.

The present study discusses the process of modelling, developing and analysis of the various parameters of Hemp fibre -reinforced graphene composite material (HFRGCM) using ACP module included in ANSYS Workbench. The ACP module of ANSYS has presented itself as a strong tool for designing and also providing an option to define the structure, individual phase properties and authentication of final properties of the composite materials. The materials used for developing the model of HFRGCM are hemp fibres, epoxy resin and graphene. A detailed analysis has been done on various physical parameter using ANSYS software.

1.1 Natural Fibre Reinforced Composite

Fibres are among the main ingredients of the fibre-reinforced composite materials. These fibres can even be tangled into sheets to form merchandise like paper or felt. Fibres are of two types: natural fibres and manmade or artificial fibres.

The natural fiber element is wood, sisal, hemp, coconut, cotton, kenaf, flax, jute, abaca, banana leaf fibres, bamboo, and wheat straw or similar fibrous material. In various earlier works, these fibres have been extracted and analyzed for their use in developing the fibre-reinforced composite materials.

1.2 Hemp Fibre

After sisal, hemp fibres stand as the second natural fibres, the researchers are more interested in to use in natural fibre-reinforced composites due to its cost effectiveness.

Hemp is an annual plant inhabitant to central Asia and acknowledged to have been full-fledged for more than 12,000 years. It probably reached Central Europe in the Iron Age and there is substantiation of its growth in the UK by the Anglo Saxons (800-1000 AD). At the present it is grown-up frequently in the EU, Central Asia, Philippines, and China. As said by Food and Agriculture Organisation (FAO), approximately half of the world's industrial hemp supply is grown in China, with the majority of the remainder being cultivated in Chile and France. In hemp plant, fibres are restricted within the tissues of the stems which help to hold the plant vertical. In doing so, these fibres impart strength and stiffness to the plant. This high strength and stiffness of hemp fibres makes them a useful material to be used as reinforcement in composite materials. There has been an exponential raise in the use of hemp for various applications in recent years. According to FAO, World production of hemp fiber grew from 50,000 tons in 2000 to almost 90,000 tons in 2005. Hemp at present, accounts for less than 0.5% of the total world production of natural fibres.

1.3 Evolution of Hemp fibre composites

In 1941 hemp fibres were used in resin matrix composites for the structure of a Henry Ford car which was capable to defy ten-times the impact on an equivalent metal panel. Regrettably the car did not make into general production due to profitable limitations at the time. The commercial success of glass fiber, having better properties over natural fibres, and simultaneous development of synthetic resins such as unsaturated polyester resins and epoxies during and just after the Second World War led to the mass production of synthetic composites and the equivalent beg off in use of natural fibres in these composites. Ecological concerns of society in issues such as sustainability, recyclability, and environmental safety in 1990s resulted in renewed interest in natural fiber composites. Germany has been at the vanguard of using natural fibres in composite materials for automobile applications. A recent survey found that the use of natural fibres (excluding wood and cotton) in automotive composites almost doubled from 9,600 tons in 1999 to 19,000 tons in 2005. In a study it was marked that the market share of hemp fibres can be enlarged by establishing further processing capacities or by reduction in hemp insulation material market. Likewise the use of natural fiber reinforced composites doubled from 15,000 tons in 1999 to 30,000 tons in 2005. Another study revealed that an average of the 5.4 million customer cars produced in 2005 used 3.6 kg of natural fibres per car.
In 2008, the British company Lotus unveiled its environment responsive car Elise Eco. The car uses hemp and wool fibres in the fabrication of interior trim, roof, seat covers and hard top. Sustainable Composites Ltd. is a British company that was well-known in 2003 to build up a range of ecological manufacturing materials made from sustainable crops such as hemp and castor oil. The company has effectively made surfboard and a dinghy from these materials. A Dutch company NPSP Composite BV is manufacturing diverse products using hemp and flax fibres. It was also sharp out that because of increasing wood prices; the worldwide manufacturers have started to use hemp as an alternate material in lightweight chip boards. The discussion concluded that the demand of hemp fiber was bound to increase in coming years.

1.4 Graphene

Graphene is a one-atom-thick layer of carbon atoms in order in a hexagonal lattice. It is the element of Graphite (which is used, along with others things, in pencil tips), but graphene is an extraordinary substance on its own - with a multitude of surprising properties which repeatedly earn it the title "wonder material". Graphene is the thinnest material known to man at one atom thick, and also as the extremely strong material - about 200 times stronger than steel. Due to availability of one unpaired electron in the unhybridized p_z orbital of sp^2 hybridized C-atom of graphene, it is an excellent conductor of heat and electricity and has attractive light incorporation abilities. This wonder-material could change the world, with unlimited possible incorporation in almost any industry. It is an extremely miscellaneous material, and can be combined with other elements (including gases and metals) to produce different materials with better properties. Researchers all over the world continue to constantly explore and patent graphene to learn its wide range of properties and likely applications.

1.5 Graphene and Composite materials

Composite materials (also referred as composition materials or simply composites) are formed by combining two or more materials with different properties to produce an end material with sole characteristics. These materials do not blend or liquefy together but remain distinct within the final composite structure. Composites can be made to be stronger, lighter or more hard-wearing than conventional materials due to properties they gain from combination of their different components.

Various studies have revealed that graphene has a myriad of unparalleled attributes, any number of which could potentially be used to make astonishing composites. The presence of graphene can boost the conductivity and strength of bulk materials and help produce composites with better qualities. Graphene composites have many potential applications, with much research going on to create sole and ingenious materials. The applications seem never-ending as one graphene-polymer proves to be light, flexible and an admirable electrical conductor; while another dioxide-graphene composite was found to possess eye-catching photocatalytic efficiencies, with many other possible pairing of materials to someday make all kinds of composites. The future of graphene composites includes medical implants, engineering materials for aerospace and renewable energy resources and much more.

1.6 Mechanical Strength of Graphene

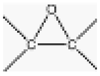
Graphene's stand-out properties lie in its intrinsic strength. Due to the potency of its 0.142 nm-long carbon bonds, graphene is the strongest material ever discovered, with an ultimate tensile strength of 130,000,000,000 Pascals (or 130 gigapascals), compared to 375,700,000 Pascals for aramid fibres. Not only is graphene astonishingly strong, it is also very light at 0.77 milligrams per square meter (for comparison purposes, 1 square metre of paper is roughly 1000 times heavier).

1.7 Applications of Graphene

Dynamic graphene research towards industrial applications requires synchronized efforts, **such as the billion-euro EU project Graphene Flagship.** After the first phase that lasted numerous years, Flagship researchers produced a refined graphene applications roadmap that pinpoints the most capable application areas such as composites, energy, telecommunications, electronics, sensors and imaging, and biomedical technologies.

1.7 Epoxy Resins

Epoxy resins (also known as polyepoxides) comprise a group of cross-linkable materials, which hold the same type of reactive functional group, the epoxy or oxirane group.


(An epoxide group)

Epoxy resins are the most universal thermosetting polymers used in aircraft structures. Epoxy resins are used as the matrix phase in carbon-fibre composites for aircraft structures and as an adhesive in aircraft structural joints and repairs.
An epoxy resin is a chemical compound containing two or more epoxide groups per monomer, and this molecule contains a tight C—O—C ring structure. During polymerization, the hardener opens the C—O—C rings, and the bonds are rearranged to join the monomers into a three-dimensional network of cross-linked chain-like molecules. The heal reaction for certain types of epoxy resins occurs rapidly at room temperature, although many of the high-strength epoxides used in aircraft need to be cured at an eminent temperature (120–180 °C). Epoxy resins are the polymer of choice in many aircraft applications because of their low reduction and low release of volatiles during curing, high strength, and good durability in hot and moist environments.

1.8 Applications of Epoxy resins

Epoxy resins have initiated a wide range of applications, mainly because the appropriate selection of resin, modifiers, and cross-linking agent allow the properties of the cured epoxy resin to be customized to attain definite performance characteristics. This adaptability has been a major factor in the sturdy growth rate of epoxy resins over the years.
Besides this versatility feature, properly cured epoxy resins have other attributes:

- Outstanding chemical resistance, particularly to alkaline environments.
- Outstanding adhesion to a selection of substrates.
- Awfully high tensile, compressive, and flexural strengths.
- Low shrinkage on cure.
- Admirable electrical insulation properties and retention thereof on aging or exposure to difficult environments.
- Amazing resistance to corrosion.
- An elevated degree of resistance to physical abuse.
- Ability to cure over a broad range of temperatures.
- Better fatigue strength.

2. Literature Review

N. Decordea, R.C.T. Howea, F. Tomarchioa, C. Pauknerb, J. Joaugb, K. Koziolb, T. Hasana, A.C[1]demonstrated 3d printing of a graphene-polymer filament by FMD. Graphene powder formed from methane plasma cracking is blended with PLA using two different routes: wet mixing in chloroform and dry mixing at 250°C. The composite is then extruded at 160°C into a solid filament and 3d printed by FMD. Figs.1d,e show pure polymer and graphene composite 3d-printed objects. The electrical and mechanical properties of the 3d printed structures are investigated by conductivity and tensile strength measurements.
Michael Satches[2]in his research required to create a graphene reinforced, polymer matrix nano-composite that is feasible in commercial 3D printer technology, study the effects of ultra-high loading percentages of graphene in polymer matrices, and determine the efficient upper limit for loading. Loadings varied from 5 wt. % to 50 wt. % graphene nanopowder loaded in Acrylonitrile Butadiene Styrene (ABS) matrices. Loaded sample were characterized for their mechanical properties using three point bending, tensile tests, as well as dynamic mechanical analysis.

V. K. Srivastava, et al. [3] study of particles loaded fibre composites for the assessment of effective material properties with the difference of shape and size.

Noorunnisa Khanam, et al. [4] studied the tensile, flexural and compressive strength of hybrid composites with different fibre lengths of coir/silk in unsaturated polyester matrix.Coir/silk fibres taken ratio of 1:1 and integrated with unsaturated polyester resin with dissimilar lengths such as 1, 2 and 3 cm. Mylsamy and Rajendran, et al. [5] reinforced raw and alkali treated chopped agave fibres in epoxy matrix. Its maked 3 mm, 5 mm and 7 mm length raw and alkali treated fibres. It found alkali treated fibre withstood additional fracture strain than the other one. Out of the three unlike fibre length reinforcements, alkali treated 3 mm agave fibre reinforcement superior better mechanical properties. Frederico, et al. [6] investigated the dynamic-mechanical behavior of epoxy matrix composites reinforced with ramie fibres. The temperature variation of the dynamic mechanical parameters of epoxy matrix composites integrated with up to 30% in volume of ramie fibre was investigated by DMA tests. factors storage modulus, loss modulus and tangent delta are examine temperature from 20 to 200°C in apparatus in use in its flexural mode at 1 Hz under nitrogen. Abdullah, et al. [7] analysis unlike materials for pallet design using Ansys. [8] The outcome of fibre properties was studied by comparing experimental information obtained from the S-glass/8552 epoxy laminates with the results reported for IM7-carbon/8552 epoxy laminates for the same scaled quasi-static indentation tests.

A pallet designed and analyzed by compare an assortment of materials on Pro-E and ANSYS respectively, analysis considering homogeneously distributed static force on pallet. ANSYS show result, PVC made pallets exceptional compares other pallets because less deformation in shape as compared to other material.

A large number of research has been done on natural fibre reinforced fibre composites but research on Hemp, Sisal, Banana and Roselle are not so well-known. Polymer composites are very rare. Against this background, the present research work has been undertaken, with an objective to discover the latent of the above said fibre composites and to study the mechanical and material characterization of different composites. After the deep analysis of the various works done in the field of graphene composite material, which has been listed below:

- The strength of graphene composite material increases by adding hemp fibre and epoxy resin.
- The strength of composite material increase by adjusting orientation of hemp.
- The strength conjointly will increase by creating variety of ply at specific angle.

The present project aims at the preparation of a composite material based on hemp fibre, graphene and epoxy resin which is strongest, lightest and cost effective and which replaces the use of carbon fibre and glass fibre.

3. Research Methodology

The light, strong and all-round properties of composite materials make them eye-catching for many types of manufacturing. Composite materials like carbon fibre (CFRP), typically used in the aerospace and automotive sectors, are being used ever more in energy, sports, construction and marine applications. Their composite nature, makes accurate simulation a challenge.

Geometry modeling in the ansys workbench environment is highly programmed and also provides users the elasticity to customize according to the type of analysis or application. The feature-based, parametric ansys design modeler software can be used to create parametric geometry from scratch or to prepare an existing CAD geometry for analysis.

3.1 Material Data

3.1.1 Graphene

graphene > Constants

Density	2267 kg m^-3

TABLE 341
graphene > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.0342e+012	0	3.4474e+011	5.1711e+011

TABLE 342
graphene > Tensile Yield Strength

Tensile Yield Strength Pa
1.3e+011

3.1.2 Hemp Fibre

hemp fibre > Constants

Density	1.47e+012 kg m^-3

TABLE 344
hemp fibre > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	1.7e+010	9.e-002	6.9106e+009	7.7982e+009

3.1.3 Epoxy Resin

Resin_Epoxy > Isotropic Elasticity

Temperature C	Young's Modulus Pa	Poisson's Ratio	Bulk Modulus Pa	Shear Modulus Pa
	3.78e+009	0.35	4.2e+009	1.4e+009

TABLE 347

Resin_Epoxy > Tensile Yield Strength

Tensile Yield Strength Pa
54.6

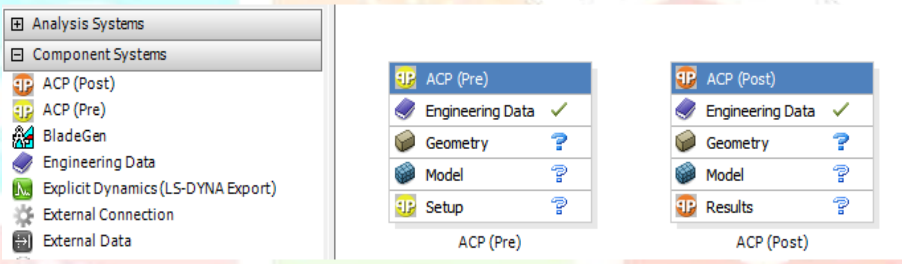
4. Simulation and Designing Procedure

4.1 Analyzing Composites in 16.0

ANSYS workbench provides superior CAD connectivity, meshing and easy structure to execute design optimization. ANSYS Composite PrepPost is used and layer definitions are imported in the assembly model in ANSYS Mechanical.

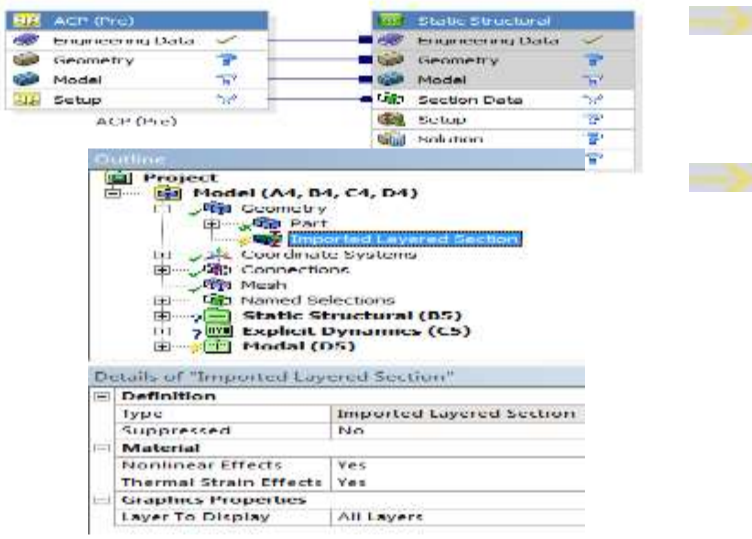
4.2 Data Integrated ACP with Workbench

- ACP introduced as a component system inside workbench.
- Like a typical workbench system, file management and standard actions like update, duplicate.
- Consume materials from Engineering Data.



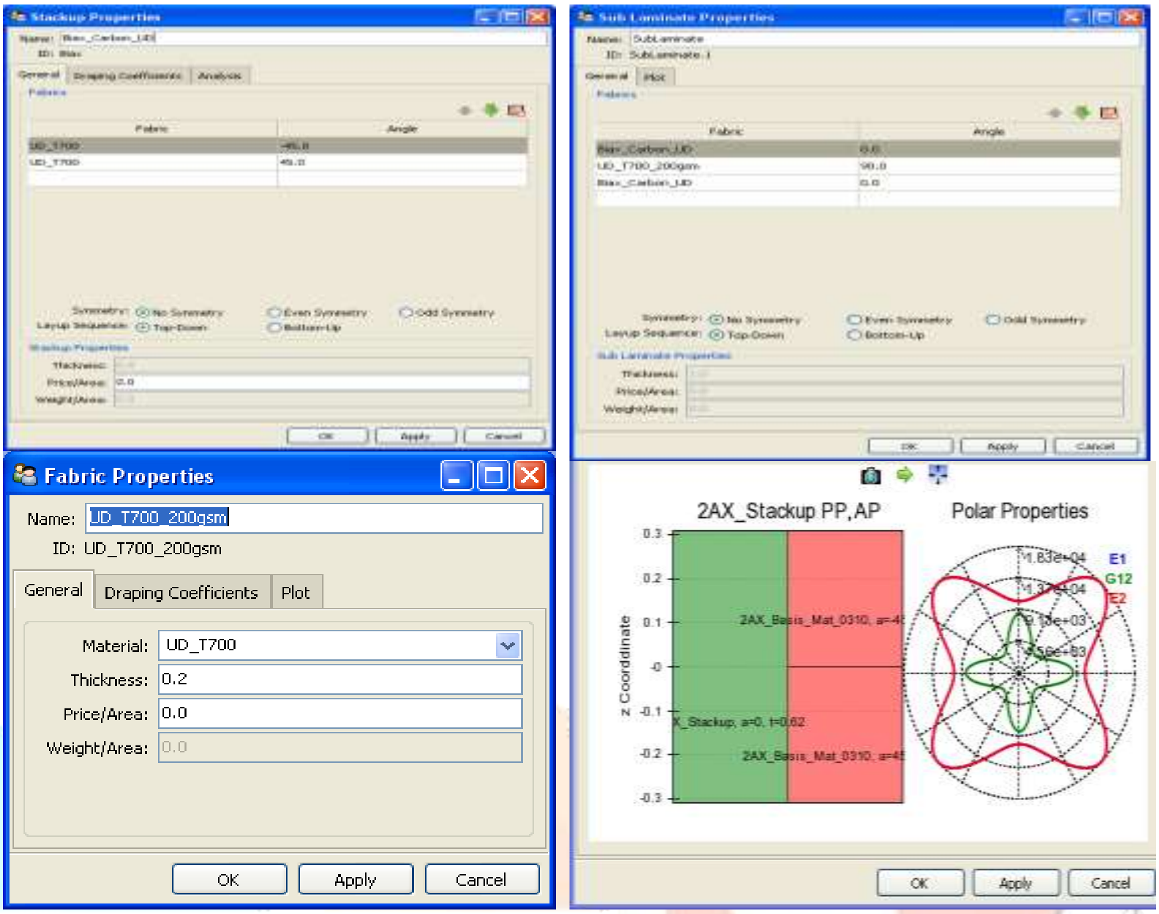
4.3 ACP-Mechanical Linkage

- ACP Pre contains EDA, Geometry, Model and Setup (same as 'Mechanical' system).
- Group cell launches ACP Editor.
- Mesh (shell) is transfer from Mechanical into ACP.
- ACP then pass, discrete section data to Mechanical as 'Imported Layered Section' object.



4.4 Material Definition

You can describe added composite layers using the **co**ncept of fabricsand stackups.

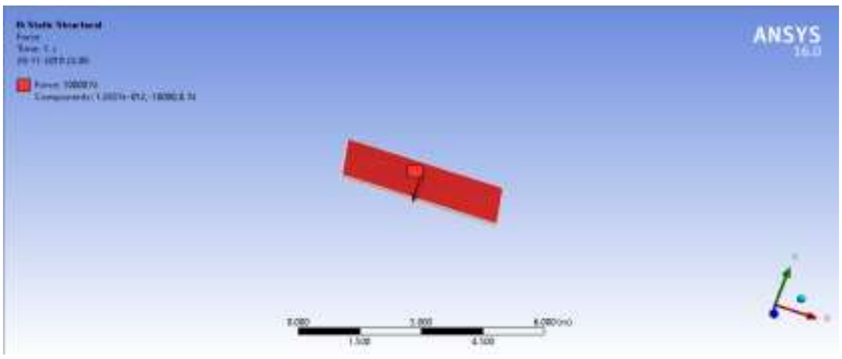


5. Result And Discussion

This chapter deals with the the finite element model is generated in the ANSYS 16 software and the stresses, deflections, strain, thermal strain and the strain energy are obtained. The results are taken for composite material (Graphene, hemp fibre, Epoxy).

5.1 Structural Analysis in ANSYS

- Open model cell in static structural and pick static structural from model tree.
- Apply force of 1000N on surface body.



- Select Total deformation, Von misses, shear strain, shear stress and strain energy from Solution option and perform the solution.
- At assignment representation right click on solution cell from static structural and select "Transfer data" to model.
- unlock model workbench and opt for total deformation option from solution part.

- Perform the solution and evaluate the results.

5.2 Specimen Dimension

Length =15cm

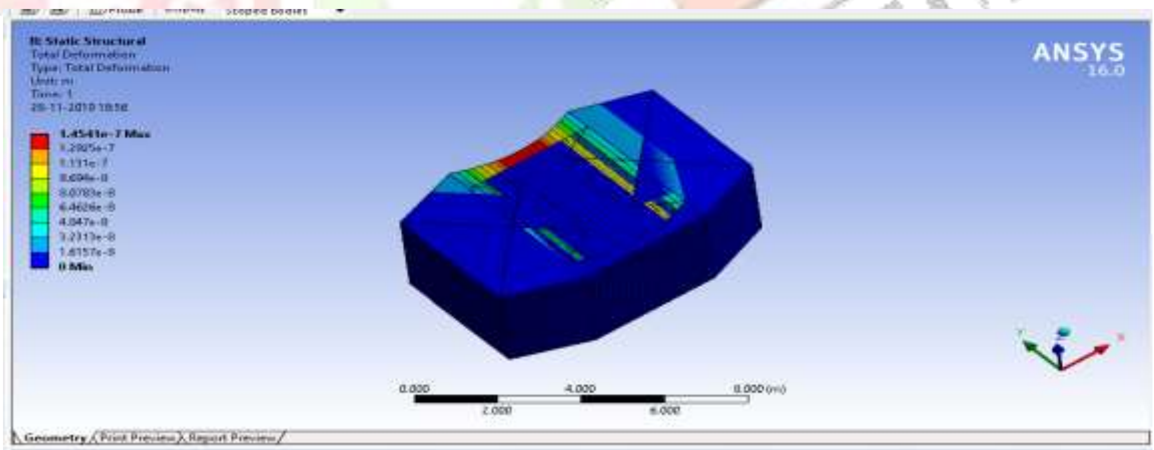
Width = 10cm

Thickness = 2.5cm

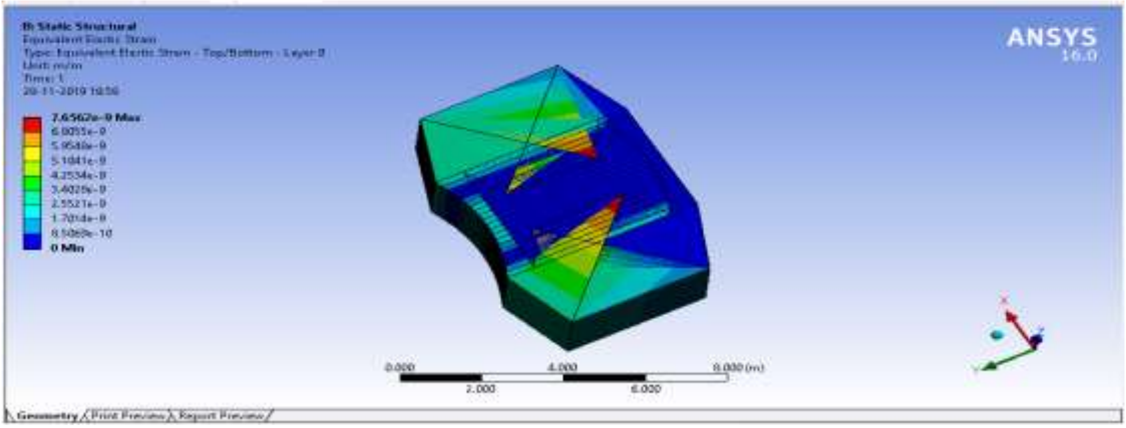
5.3 Results

Object Name	Total Deformation	Equivalent Elastic Strain	Equivalent Stress	Strain Energy	Thermal Strain
State	Solved				
Scope					
Scoping Method	Geometry Selection				
Geometry	All Bodies				
Sub Scope By		Layer			Layer
Layer		Entire Section			Entire Section
Position		Top/Bottom			Top/Bottom
Definition					
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Strain Energy	Thermal Strain
By	Time				
Display Time	Last				
Calculate Time History	Yes				
Identifier					
Suppressed	No				
Orientation					X Axis
Coordinate System					Global Coordinate System
Results					
Minimum	0. m	0. m/m	0. Pa	0. J	0. m/m
Maximum	1.4541e-007 m	7.6562e-009 m/m	99.96 Pa	3.0217e-006 J	0. m/m
Information					
Time	1. s				
Load Step	1				
Substep	1				
Iteration Number	1				
Integration Point Results					
Display Option		Averaged			Averaged
Average Across Bodies		No			No

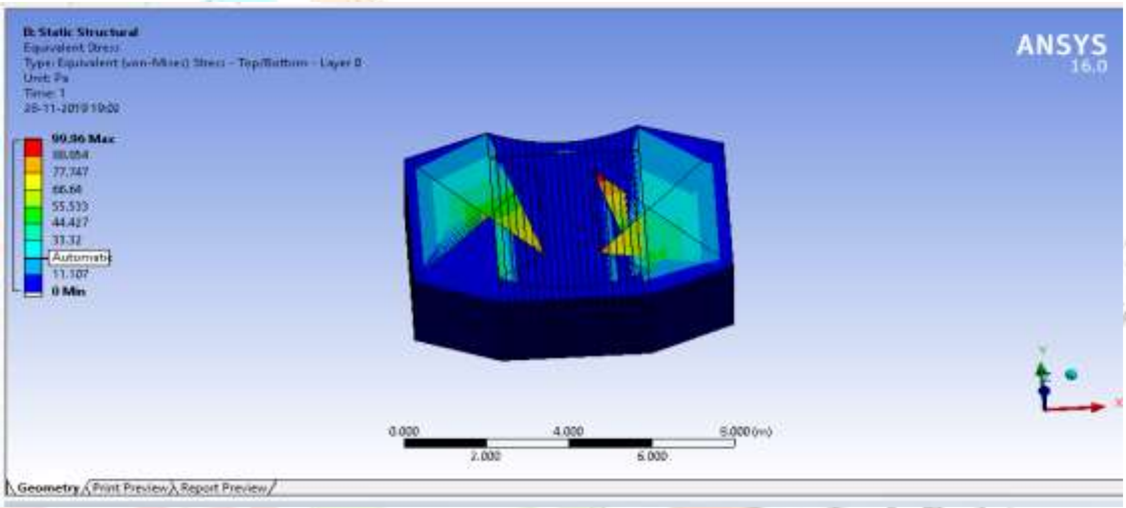
5.4 Total Deformation



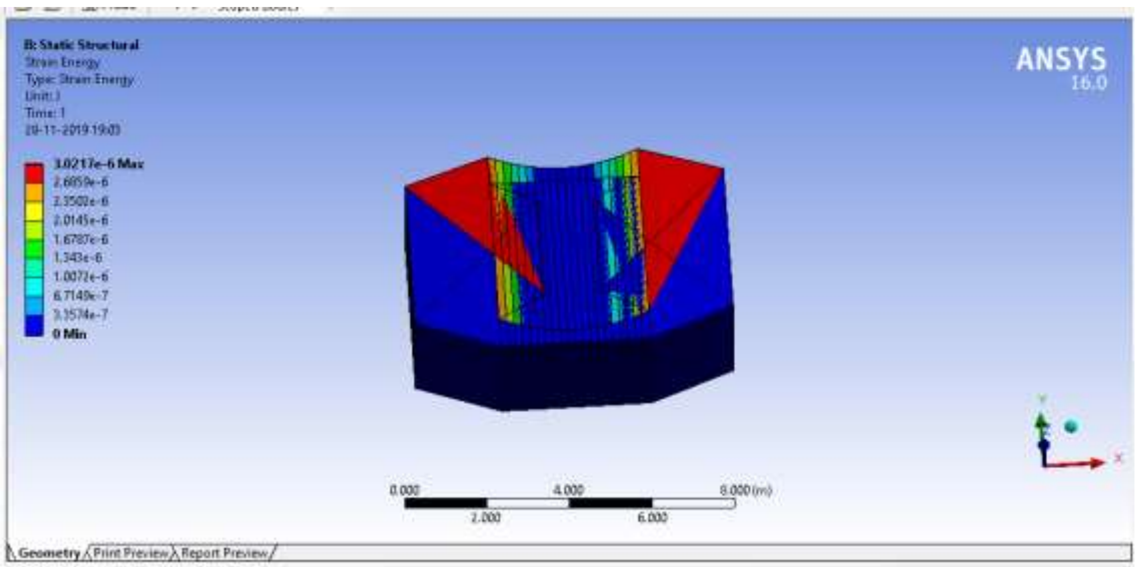
5.5 Elastic Strain



5.6 Von Mises Stress



5..7 Strain Energy



5.8 Analysis Of Step Load

Graph of Step Load at Interval Of 1 Second under different loading Condition.

The following graph are as follows:

- Total deformation
- Elastic Strain
- Elastic Stress
- Strain energy

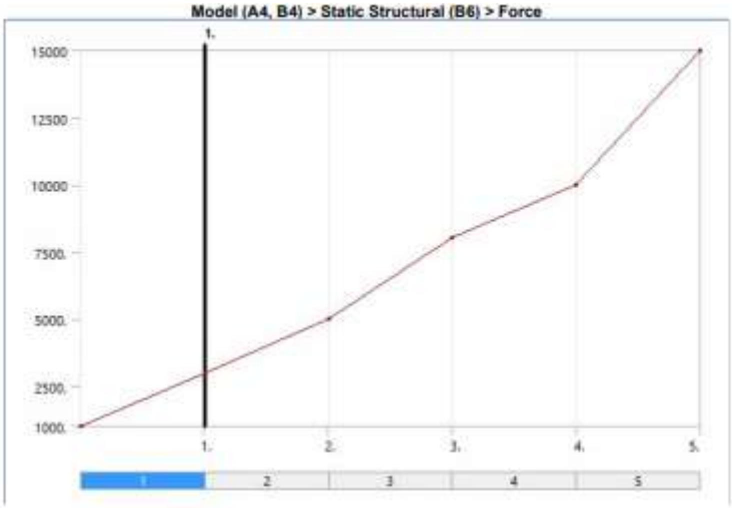


TABLE 43
Model (A4, B4) > Static Structural (B6) > Force

Steps	Time [s]	Force [N]
1	0.	1000.
	1.	3000.
2	2.	5000.
3	3.	8000.
4	4.	10000
5	5.	15000

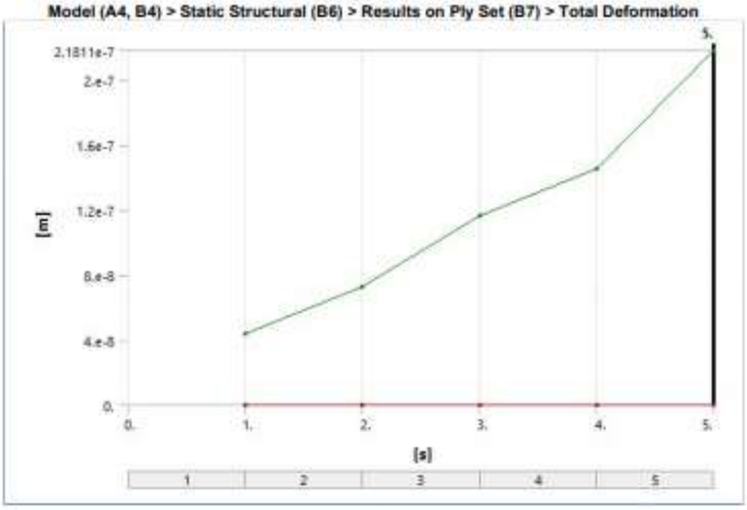


TABLE 47
Model (A4, B4) > Static Structural (B6) > Results on Ply Set (B7) > Total Deformation

Time [s]	Minimum [m]	Maximum [m]
1.	0.	4.3623e-008
2.		7.2705e-008
3.		1.1633e-007
4.		1.4541e-007
5.		2.1811e-007

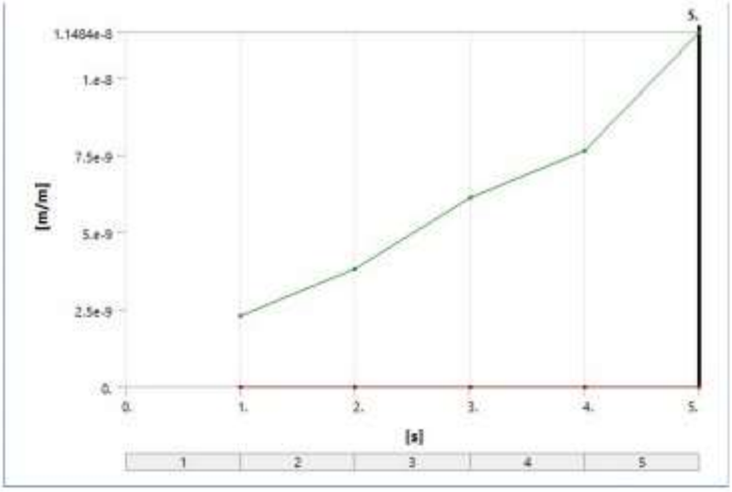


TABLE 48
Model (A4, B4) > Static Structural (B6) > Results on Ply Set (B7) > Equivalent Elastic Strain

Time [s]	Minimum [m/m]	Maximum [m/m]
1.	0.	2.2969e-009
2.		3.8281e-009
3.		6.125e-009
4.		7.6562e-009
5.		1.1484e-008

Model (A4, B4) > Static Structural (B6) > Results on Ply Set (B7) > Equivalent Stress

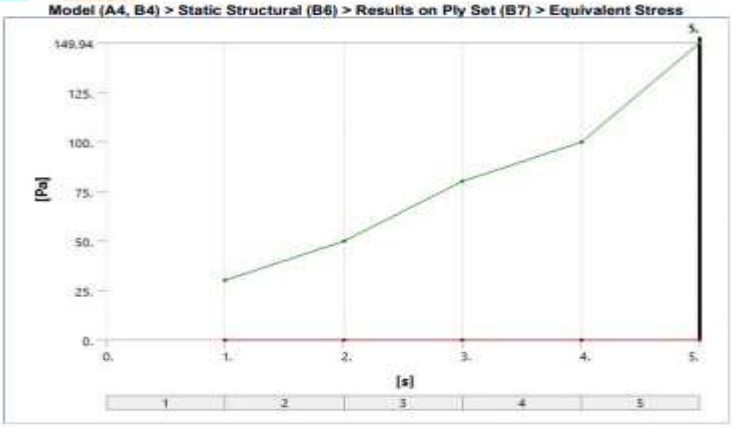
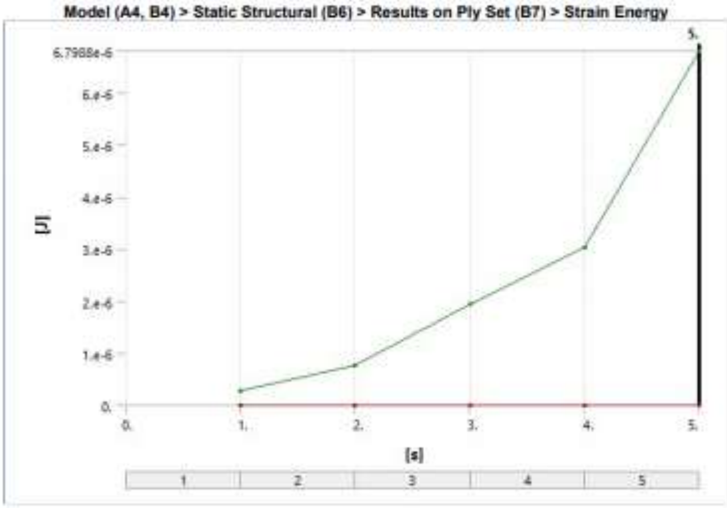


TABLE 49
Model (A4, B4) > Static Structural (B6) > Results on Ply Set (B7) > Equivalent Stress

Time [s]	Minimum [Pa]	Maximum [Pa]
1.	0.	29.988
2.		49.98
3.		79.968

Model (A4, B4) > Static Structural (B6) > Results on Ply Set (B7) > Strain Energy



6. Conclusions

The aim of this study was to illustrate the process of modelling, developing and analysis of the various parameters of Hemp fibre reinforced –graphene composite material (HFRGCM) using ACP module included in ANSYS Workbench. The ACP module of ANSYS has presented itself as a strong tool for designing and also providing an option to define the structure, individual phase properties and authentication of final properties of composite material. It also provides a possibility to recognize the weakest layer of complex composite material.

From the ANSYS analysis, the composite, HFRGCM, under study has been found to possess excellent mechanical properties and heat dissipation rate. This theoretical analysis may prove its worth as a guide to prepare HFRGCM, a novel composite material to be used in racing vehicle manufacturing and similar industries.

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