EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF UNTREATED AND CRYO-TREATED HEMP FIBER REINFORCED POLYMER COMPOSITES

A PROJECT REPORT

submitted by

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TKM20MECI12

to

the APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

Master of Technology

In

Computer Integrated Manufacturing.

Department of Mechanical Engineering

TKM College of Engineering

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DECLARATION

I, Renju C Daniel, hereby declare that the project report “EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF UNTREATED AND CRYO-TREATED HEMP FIBER REINFORCED POLYMER COMPOSITES” submitted for partial fulfillment of the requirements for the award of degree of Master of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by me under supervision of Dr. Mubarak Ali. M, Assistant Professor, Department of Mechanical Engineering, TKM College of Engineering, Kollam. This submission represents my ideas in my own words and where ideas or words of others have been included, I have adequately and accurately cited and referenced the original sources. I also declare that I have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Place: Kollam

Date: 12/09/22

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CERTIFICATE

This is to certify that the report entitled '**EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF UNTREATED AND CRYO-TREATED HEMP FIBER REINFORCED POLYMER COMPOSITES**' submitted by '**RENJU C DANIEL (TKM20MECI12)'** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Computer Integrated Manufacturing, Mechanical Engineering is a bonafide record of the project work carried out by him under my guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

Emerging research is primarily concerned with environmental and economic challenges associated with the development of new materials for future industries. Various industry sectors have been attempting to replace synthetic fibers used as reinforcement in polymer composites with natural fibers over the past few decades. Because of their favourable and remarkable properties, composite materials have long provided a significant quantity of research and industrial effort. Composite materials are made up of two materials that have diverse physical and chemical characteristics. When they are joined, they generate a substance that is specialized to fulfil a certain purpose. It consists of reinforcement phase and matrix phase. Fiber reinforced polymers employ fiber as a reinforcement phase to offer strength to the composite. Natural fibers are more environmentally friendly, renewable, inexpensive, non-hazardous, nonabrasive, and widely available than synthetic fibers. In this project, Hemp fiber is employed as the reinforcing phase while DGEBA epoxy is used as the matrix phase. The Hemp Fiber Reinforced Polymer (HFRP) composites were fabricated using Vacuum Assisted Resin Transfer Moulding (VARTM) method. The mechanical properties of HFRP composites were tested by selecting two samples untreated HFRP and Cryo-treated HFRP. Tensile test, Flexural test, Hardness test, water absorption study along with analysis study also done. Ansys ACP prepost software used for the validation. The study shows that the cryo-treated samples shows a better flexural strength, hardness and less water absorption rate compared to untreated sample. But it shows less tensile strength compared to untreated sample.

Keywords: Hemp, HFRP, DGEBA, Cryo-treated, Ansys ACP prepost

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ABBREVIATIONS

PMC	–	Polymer Matrix Composites
CMC	–	Ceramic Matrix Composites
MMC	–	Metal Matrix Composites
THC	–	Tetra Hydro Cannabinol
HFRP	–	Hemp Fiber Reinforced Polymer
DGEBA	–	Diglycidyl Ether Bisphenol A Epoxy
BADGE	–	Bisphenol A Diglycidyl Ether
DETA	–	Diethylene Triamine
TH 7301	–	Cycloaliphatic amine Hardener
RHN	–	Rockwell Hardness Number
ASTM	–	American Society for Testing and Materials
VARTM	–	Vacuum Assisted Resin Transfer Moulding

NOTATIONS

L	–	Millimetre, mm
M	–	Mass, gm
W	–	Water Absorption rate, %
V	–	Volume, mm^3

Greek Symbols

ρ	–	Density, g/cm^3
σ	–	Tensile strength, MPa

CHAPTER 1

INTRODUCTION

Rapid development in the industrial sector has created a demand for materials that are stronger, stiffer, denser, cheaper, and more sustainable. Composite materials have become one of the materials with such improved qualities that they may be used in a wide range of applications. Composite materials are made up of two or more elements, one of which is in the matrix phase and the other of which may be in the reinforcement phase. Construction, mechanical, automotive, aerospace, biomedical, and marine industries have all found important uses for the use of natural or synthetic fibers in the creation of composite materials. The structural, mechanical, and tribological characteristics of fiber-reinforced composite (FRC) material have significantly improved over many traditional materials, according to research findings over the last two decades. Although composite materials were successful in making products more durable, there is today a serious worry about the buildup of plastic waste in the environment. Researchers from all around the globe have been driven by this concern to create ecologically friendly materials linked to cleaner manufacturing methods. The development of novel composite materials based on biodegradable resources, such as natural fibers as an affordable and environmentally benign alternative to synthetic fibers, has received a lot of attention as a consequence of these environmental concerns. Natural fibers that are employed in composite materials include flax, sisal, and hemp. The stiffness and strength of the composite material are typically governed by the fibers. A polymer with directional fibers added to it is significantly stronger in the direction of the fibers than a polymer without them. The increase in stiffness is less noticeable when seen perpendicular to the fiber path. Due to the fibers' function as stress concentrators, the strength in that direction is reduced. In reality, fibers are frequently integrated into a variety of orientations.

Hemp is an environmentally friendly fibers, and fiber-reinforced composites employ it as reinforcement. The stalks of the Cannabis sativa plant are used to make the fibers used to create hemp cloth. For millennia, this plant has been known as a source of incredibly strong and long-lasting textile fibers, but more recently, the psychoactive properties of Cannabis sativa have made it more challenging for farmers to grow this hugely advantageous crop. Cannabis sativa has been developed over thousands of years for two different uses. On the one hand, this plant has been selectively developed over many generations of growers to be high in Tetra Hydro Cannabinol (THC) and other intoxicating chemical components are known as cannabinoids. However, some growers have repeatedly bred Cannabis sativa to create fibers that are stronger and better while purposely lowering the number of psychotropic cannabinoids that are generated. The hemp plant's stalks are composed of two layers: The inner layer is made up of woody pith, while the outer layer is made up of strands that resemble rope. After the hemp plant's outer covering of bast fibers has been removed, it can be processed and turned into rope or yarn. Hemp rope is recognized for being an outstanding fabric for clothing that outperforms cotton and synthetic fabrics by most criteria. Because it is so robust, hemp rope was originally the top option for rigging and sails on nautical boats.

The plants used to make hemp fabric are cut using a specific machine, and after that, they are left to rett in the field for 4-6 weeks, which naturally aids in pectin elimination through exposure to the weather. These hemp stalks are then formed into hay-like bales, and the fibrous outside of the plant is separated from its woody core using breakers or a hammer mill. Following separation, the bast fibers are carded into strands and treated to eliminate contaminants. After this stage, producers can either utilize steam explosion to turn raw hemp into a weaveable fiber, matting to create mats and fleeces, or pulping to create paper goods. Hemp is prepared for spinning into yarn and weaving once the steam explosion process is finished. The Hemp fabric is available according to the direction in which the fibers are arranged in the cotton fabrics, for example unidirectional, bidirectional, and multidirectional.

The amount of crimp in a woven fabric determines how well it conforms to the resin's volume reduction during curing. The ease with which a cloth adopts an imposed form is linked to drapeability. The more the potential variations in direction a textile may have in the mould, the less prone it is to creasing, and the more drapeable it is. However, this reduces the amount of control you have while managing the draped material over the direction of the fibers. The characteristics of a ply are significantly influenced by the weave. Although the usage of thermoplastics in NFRP composites is rising, natural fiber-reinforced thermosets continue to account for the bulk of natural fiber composites. Polyester, epoxy, and vinyl ester are the most popular thermosets. Natural fiber thermoset composites are extremely solvent resistant, strong, and creep resistant. The fibers in these composites may bear up to 80% of the load.

The mechanical properties of the fiber and matrix as well as their interfacial bonding determine the mechanical properties of thermoset biocomposites. The natural fiber's surface has numerous hydroxyl groups in its chemical composition. The structure that forms hydrogen bonds with the main matrix hydroxyl groups backbone network. A promising candidate for the development of innovative composites is hemp fiber. Due to the material's high strength and modulus, as well as the additional benefit of having a high lignin content concentration. Because of the high lignin content, the composites created with these fillers are more weather resistant and hence more suited for use as construction materials. Hemp fiber is also widely utilized in the manufacture of things such as furniture, rope, and so on. Because of its low cellulose content, the fiber absorbs less moisture.

Epoxy resins are a class of cross-linkable materials that all include the same sort of reactive functional group, either epoxy or oxirane. The most common thermosetting polymers utilized in aeroplane construction are epoxy resins. Epoxy resins are utilized as the matrix phase in FRP composite aircraft constructions, and also as adhesive in aircraft structural joints and repairs. An epoxy resin is a chemical compound that comprises two or more epoxide groups per monomer and a tight C—O—C ring structure. The hardener opens the C—O—C rings during polymerization, and the bonds are rearranged to unite the monomers into a three-dimensional network of cross-linked chain-like molecules. Certain types of epoxy resins cure quickly at ambient temperature, however many high strength epoxides used in aeroplanes must be cured at elevated temperatures (120-180 °C). Because of their low volatile reduction and release during curing, strong strength, and exceptional endurance in hot and damp settings, epoxy resins are the polymer of choice in many aviation applications.

Advantages of composite design

Stiffness and strength qualities that are oriented.

- Engineer-customizable material qualities.
- Modify the fiber and matrix type, fiber volume percentage, fiber orientation, stacking order, layer thickness, and manufacturing process parameters.
- Significantly lighter than metal. Elevated stiffness and strength-to-weight characteristics. High fatigue resistance (e.g. carbon fiber)., Specific material qualities that could exist (e.g. thermal stability due to the negative coefficient of thermal expansion of carbon fibers).

CHAPTER 2

LITERATURE REVIEW

Hand-lay-up procedure is a manufacturing technique used to create hemp fiber reinforced epoxy composites. The raw material goes through many stages to produce the composite block in accordance with ASTM requirements, including dissolving, solution preparation, and production of reinforcement. Different machines are used for the experiment, and a particular specimen is prepared for each machine. Based on the results of those experiments, it has been shown that density decreases with increased hemp fiber percentage since the fiber is thinner and there are fewer voids [1].

The findings of this study show that adding hemp fibers to epoxy resin, whether modified or unmodified, may cause increase in the stiffness of material. The tensile characteristics of hemp fibers are compromised when they are altered with alkali, enzymes, or steam. However, all of the alterations significantly reduce the fibers' hygroscopicity, which results in less water absorption [2]. The interaction of hemp fiber molecules with epoxy may be seen in the Fourier transform infrared (FTIR) data, which may help with mechanical reinforcing. Flexural and tensile experiments comparing mechanical properties revealed that epoxy composites with 30 vol% continuous and aligned hemp fibres tended to have higher strength and modulus [3].

The integrated impact of a composite is determined by its reinforcing and load transformation properties. This research investigates the direction of reinforcement on composite structures made with various materials. It is suggested to categorise multi-layer composite test specimens structurally and geometrically, where the matrix connects several layers of various textiles including hemp, carbon, and kevlar. The study's finalised layers are superior to existing vests in that they are stronger, lighter, and more flexible. Finite element models of the tensile test against multi-layer composite structures were made using the Ansys ACP software [4]. Kenaf and cotton are agricultural commodities that are utilized in a variety of applications all over the world. Polymer composite laminates with natural reinforcing fibers are widely used due to their high strength-to-weight ratio and robust tensile characteristics. Because of their ease of moulding, chemical stability, mechanical and physical properties superior substrate-to-fiber bonding, and ability to be used in a wide range of applications. In this work, the mechanical properties of hybrid green kenaf cotton composite laminates made using a dissolved mixture of chloroform and Polylactic Acid as matrix material were examined experimentally. Furthermore, FEM analysis was used to determine the characteristics of this structure [5].

The paper compares the experimental and analytical results of FRP-reinforced beams for flexural loading. Two beams were modeled using the ANSYS, one without FRP and the other with Hemp Fiber Reinforced Polymer (HFRP) strengthened beams. The derived findings demonstrate good agreement with the experimental data in terms of load-deflection relationships, fracture pattern, and ultimate load [6]. Hemp fibers offer qualities that make them a good replacement for Hemp fibers as reinforcing in composite materials. Their biggest problem is that their characteristics vary. Various fiber surface modifications have been found to improve interfacial adhesion between hemp fiber and matrix, resulting in improved mechanical properties. Another disadvantage of hemp fiber composites is moisture absorption, which may be reduced by using proper fiber surface treatment [7].

Damage processes and failure behavior were also influenced by the fiber properties such as chemically treatment, the hybrid configuration, fiber orientation and fiber design. Fiber pullout, fiber fracture, and matrix cracking are major failure mechanisms for FRP composites, while delamination is the major failure factor for hybrid composites. Only fiber pull-out and fiber breakage were seen in the composite containing alkali-treated fibers/additives [8]. Hemp fiber composites using graphene and epoxy resin showed excellent mechanical characteristics. Graphene is the lightest substance and yet the strongest - nearly 200 times stronger than steel. There are several uses for graphene composites, and extensive research is being carried out to develop unique and creative materials. Graphene composites' prospective applications include medical implants, aeronautical engineering materials, renewable energy resources, and much more [9].

Laminated composite material is made up of several layers of a composite mixture made up of fibers and a matrix. Under various stacking sequences, each layer may have variable fiber orientations and comparable or dissimilar material characteristics. The design of these laminated composites is fraught with unresolved problems. The design engineer must take into account a number of options, including the optimal stacking order, the ideal fiber angles in each layer, as well as a number of layers depending on parameters like reaching the maximum natural frequency. The analysis's findings, which are directly related to the stress-strain properties of each material, must be carefully taken into account in light of the differences in the stress-strain properties of various steel grades and multiple Aluminium alloys [10].

Composites used for the automobile sectors are reinforced with fibers like Hemp will witness a rise in demand. A similar trend in the usage of hemp fiber may be found in construction materials, hemp shingles, and lime uses. The fiber-matrix interaction must be improved, and more effort is necessary in this area. The development of composite materials based on the reinforcement of two or more fibers in a single matrix, resulting in hybrid composites with a wide range of material properties, can be one method of increasing the mechanical properties and decreasing the water absorption behaviour of hemp-reinforced composites [11]. An experimental examination was carried out in this work to explore the effect of hybridization of Hemp fiber with untreated hemp fiber and treated hemp fiber on mechanical characteristics. The Hemp fiber was alkaline treated, and its physical characteristics were investigated. According to the experimental results, HFRP composite has high tensile strength with poor impact strength and hardness values compared to hybrid composite [12].

Researchers are working hard to produce effective and new materials, particularly in the development and use of NFRP in the automotive sector due to elevated demand and environmental consciousness. The paper focus on the usage of NFRP and plastic recycling in the automotive industry, as well as considerations for replacing natural fibers in the reinforcement phase of FRP composites [13]. When exposed to the external environment, NFRP materials confront the critical obstacle of deterioration. Chemical, mechanical, climatic, and fire degradation are all recognized types of degradation. This causes a weak fiber/matrix interaction and decreases the material's strength. Oxidation and enzyme reactions drive biodegradation. Because natural fibers are hydrophilic, they absorb moisture from their surroundings. The major component of fiber is hemicellulose. To solve some of the problems highlighted, fibers require numerous treatments, including improved interfacial fiber/matrix adhesion that absorbs moisture [14]. The primary goal of this research is to look into the ILSS of laminated hybrid and non-hybrid composites consisting of Hemp fiber reinforced polymer and carbon fiber reinforced polymer. Delamination is the most prevalent failure mode observed in FRP beams owing to poor ILSS. When carbon fiber reinforced polymer is combined with Hemp fiber reinforced polymer, interfacial bonding improves. Strengthening is also important in the current investigation. Interlaminar shear failure most commonly happens at beam joints, particularly in I-section, T-section, and box section beams comprised of fiber-reinforced polymer laminates [15].

The paper concludes that these NFRPCs outperform synthetic FRP composites. These Natural fibers are abundant in nature, making them inexpensive and sustainable resources. Chemical treatments, coating of various materials on NFs, and hybridization procedures are all used to improve the mechanical and physical qualities of NFRPCs. NFRPCs have little environmental impact, making them appropriate for a wide range of sustainable engineering applications. For the mechanical characterization of composite materials, numerical techniques might be beneficial. The use of numerical tools to predict mechanical behaviour of materials for the development of new and unique materials [16-18].

Tensile strength is reduced when hemp fibers are reinforced in an HDPE matrix. When compared to specimens constructed of 50% fresh and 50% recycled HDPE, the tensile strength of the composite reduces from 0.53 MPa to 2.20 MPa as the hemp percentage increases from 10% to 30%. However, the composite comprising 20% hemp fibers has a 0.28 MPa greater tensile strength than the HDPE sample using 50-50 blends of fresh and recycled HDPE [19, 20].

By properly bonding with epoxy resin, the Luffa Cylindricafiber may be successfully employed as a reinforcing agent in the fabrication of composites. The strength, modulus, and work of fracture rise as the fiber content increases, and the optimal combination is obtained with Double Layered composite. Chemical treatment of the fiber surface promotes fiber matrix adherence, which in turn improves the mechanical characteristics of the composite. Moisture absorption and thickness swelling values rise as fiber loading increases. Both values are greater in a saline environment than in a distilled water environment. These values, however, are significantly lowered when the fiber is chemically treated [21].

Deep cryo-treatment improves the toughness of composites, which reduces the tensile strength of composites without sacrificing their hardness attribute. Deep cryo treatment improves both hardness and tensile characteristics of composites. Cryogenic treatment and interfacial alteration in Basalt fiber hybridization were explored for their influence on the mechanical characteristics of Hemp Fiber/PLA composites. The study found that combining Basalt Fibers with hemp fibers raised the mechanical characteristics of composites substantially, and that cryogenic treatment and interface modification of BFs greatly improved the performance of hybrid composites [22-25].

The design and analysis of a composite drive shaft are examined in this paper. The composite material offers several benefits, including great strength and stiffness. The author is working on replacing steel drive shafts with a composite material in this article. Where design parameters are minimized in order to achieve the goal of minimizing shaft weight. FEM techniques were utilized to analyze composite materials. The FEM analysis is analyze used to study the composite drive shaft ANSYS 16 [26]. To improve the strength and adhesiveness of the fiber, it is treated with an alkali (NaOH) solution. A parametric investigation of flexure strength is conducted by altering alkali concentration, alkali treatment period, and fiber volume. For simplicity, the Taguchi L9 Orthogonal array is used in the design of the experiment's approach. The ANOVA approach is used to generate regression equations that show the amount of effect of each parameter on the flexure strength of the composite [27].

The mechanical behaviour of the composites was examined to determine how fiber alignment and alkalization affected them. When compared to composites manufactured from as-received fibers, alkalized and long fiber composites had greater flexural modulus and flexural strength. Alkalized long kenaf-polyester composites outperformed alkalized long hemp-polyester composites in terms of mechanical characteristics. A high flexural modulus and a high flexural strength are coupled with a low work of fracture in hemp-polyester composites. SEM micrographs of the treated hemp and kenaf fibers revealed the lack of surface imperfections that were evident on the untreated fibers [28].

The tensile strengths of NFRP composites grow with fiber content until they reach a maximum or optimal value, at which point they decrease. The Youngs modulus of NFRP composites, on the other hand, increases with fiber loading. The tensile strength and Young's modulus of composites reinforced with bleached hemp fibers rose dramatically as fiber loading increased. There was also talk of mathematical modeling. The anticipated and observed tensile strength of several natural fibers reinforced HDPE composites were found to be extremely near to each other. The Halpin-Tsai equation was discovered to be the most successful in estimating Young's modulus of composites comprising various types of natural fibers [29, 30].

2.1 PROBLEM STATEMENT

Composites have gained widespread application attention in a variety of industries ranging from consumer goods to aircraft. Various industries are attempting to replace synthetic fibers in polymer composites with natural fibers. Natural fibers are more ecologically friendly, renewable, inexpensive, nonhazardous, nonabrasive, and widely available than synthetic fibers. Hemp has been discovered to be more durable than any other natural fiber in FRP composites. There is no relevant research on hemp fiber-reinforced polymer composites. Mechanical characteristics of both neat and cryo-treated HFRP samples were examined in this project. The Ansys ACP pre-post simulation work aids in identifying the layer-wise stress distribution and deformation of composite. As a result, the composites may be tailored by adjusting the fiber angle and stack up.

2.2 SCOPE OF PROJECT

Fiber-reinforced polymers are non-corrosive and have good strength and modulus values in comparison to their density. FRPs are lightweight, have acceptable deformability, can be tailored, and have great formability, enabling the production of new elements as well as structural rehabilitation of existing sections made of traditional materials. Natural fibers are gaining popularity due to their numerous benefits such as lightweight, biodegradability, high specific strength, low cost, recyclability, and, most importantly, eco-friendliness, and these natural fibers are abundant and easily affordable so the automobile industry desperately needs eco-friendly products for production. As a result, the automobile industry finds it not only easier and more feasible to utilize it as a reinforcing material, but also as a replacement for synthetic fibers.

2.3 OBJECTIVES

The following are the objectives of this investigative experimental study:

- To fabricate the Hemp fiber-reinforced polymer composite.
- To carry out suitable testing of fabricated mould to find out the tensile strength, hardness, flexural strength and moisture absorption rate.
- To validate the testing in analysis and find out the layer-wise stress distribution.
- To compare the neat HFRP and Cryo-treated HFRP samples with numerical validation.

CHAPTER 3

METHODOLOGY

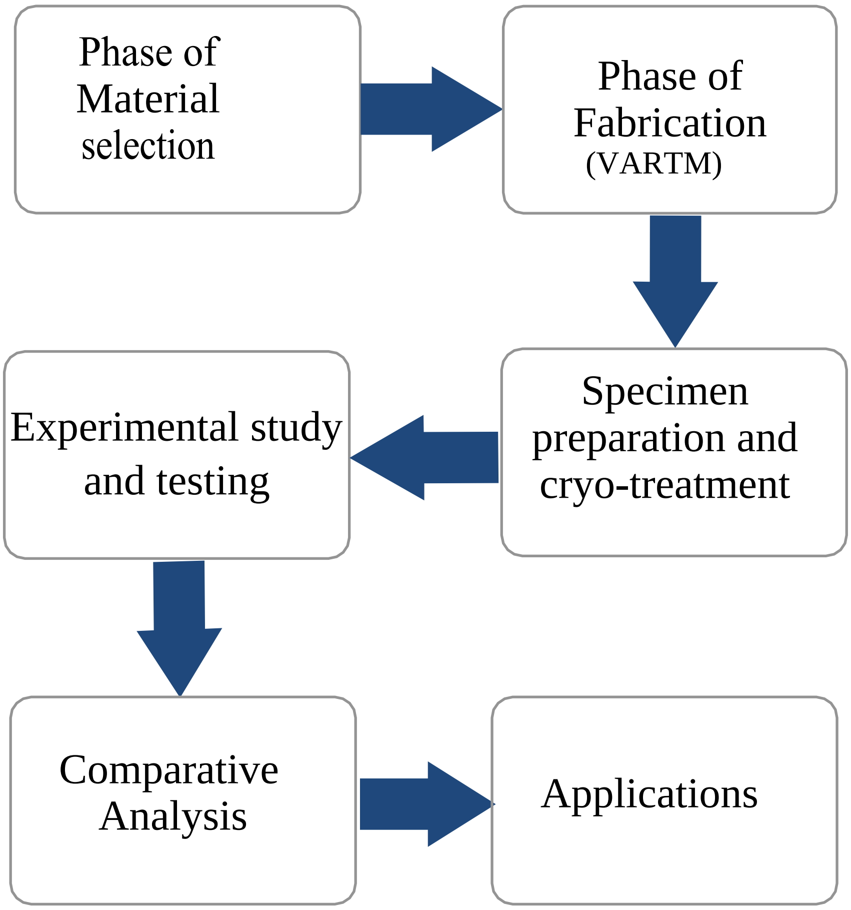


Fig.3.1 Flowchart of methodology.

The exertion starts with the phase of material selection. Proper materials are identified from a library of materials and journal references. The purchase of material takes place in this phase. Phase of fabrication will be initiated just after the first phase. In this phase the HFRP composites is fabricated by Vacuum Assisted Resin Transfer Moulding (VARTM) method. The samples were made in two phases, one without any fiber treatment and the other with cryo-treated hemp fiber. The samples were then collected after curing and tested in accordance with ASTM standards. Tensile strength, flexural strength, water absorption test, hardness test, and other tests were performed on both materials, and a comparison analysis was conducted. The layer wise stress distributions and deformations in each ply are determined using the Ansys ACP prepost software.

3.1 PHASE OF MATERIAL SELECTION

The phase of material selection consists of identifying the proper reinforcement and matrix material. Hemp fiber woven cloths with unidirectional fiber arrangement were found to be easily available. So, the Hemp fiber mat twill type 100% purity were purchased from Vruksha composites, Andhra Pradesh. Then the matrix phase is selected as Epoxy Material. Thermoset matrix material provides adequate strength even at extreme temperature variations. So Diglycidyl Ether Bisphenol A (DGEBA) epoxy resin and Cycloaliphatic grade TH7301 Hardener were purchased from Innovation Coatings PVT LTD, Chandigarh.

3.1.1 Hemp Fiber

Hemp is naturally one of the most environmentally friendly fibers, and fiber reinforced composites employ it as reinforcement. The stalks of the Cannabis sativa plant are used to make the fibers used to create hemp cloth. For millennia, this plant has been known as a source of incredibly strong and long-lasting textile fibers, but more recently, the psychoactive properties of Cannabis sativa have made it more challenging for farmers to grow this hugely advantageous crop. Cannabis sativa has been developed over thousands of years for two different uses. On the one hand, this plant has been selectively developed over many generations of growers to be high in Tetra Hydro Cannabinol (THC) and other intoxicating chemical components known as cannabinoids. However, some growers have repeatedly bred Cannabis sativa to create fibers that are stronger and better while purposely lowering the number of psychotropic cannabinoids that are generated. The hemp plant's stalks are composed of two layers: The inner layer is made up of woody pith, while the outer layer is made up of strands that resemble rope. After the hemp plant's outer covering of bast fibers has been removed, it can be processed and turned into rope or yarn.

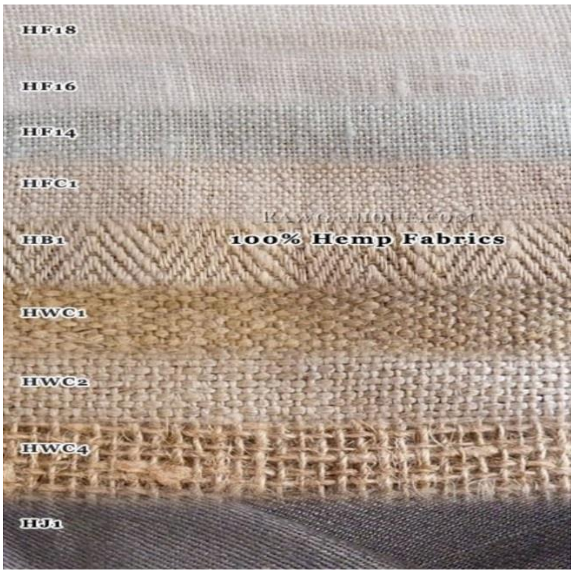


Fig.3.2. Different grades Hemp Fabric

Fig.3.3 Unidirectional Hemp Fiber mat Twill type used as reinforcement.

Different grades of Hemp Fabrics are available according to the fiber orientation and fiber diameter in the woven mat. On the basis of fiber angle, it is classified as unidirectional, bidirectional and multidirectional hemp fabrics.

3.1.2 Epoxy Resin

Epoxy resins and polyester are two popular polymer matrices that are employed with continuous fibers. A polymer known as epoxy has an epoxide group in its chemical structure. DGEBA is an organic liquid having two epoxide groups, as indicated in figure 3.1, and low molecular weight. Several additives are routinely employed to change the characteristics of epoxies. For instance, diluents are used to reduce viscosity. Flexible chemicals are used to make epoxy more flexible. By introducing substances that interact with the epoxy and hydroxy groups between adjacent chains and serve as a curing agent, cross-linking is accomplished. Curing agents typically consist of organic amino or acid molecules. The common curing agent for DGEBA epoxy is diethylene triamine (DETA).

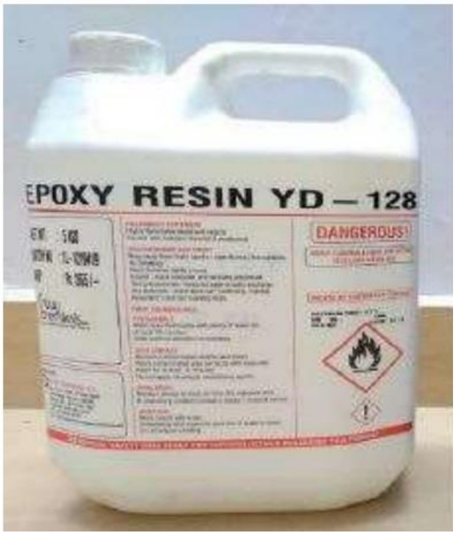


Fig.3.4 DGEBA Epoxy Resin YD-128

Fig.3.5 TH7301 Hardener

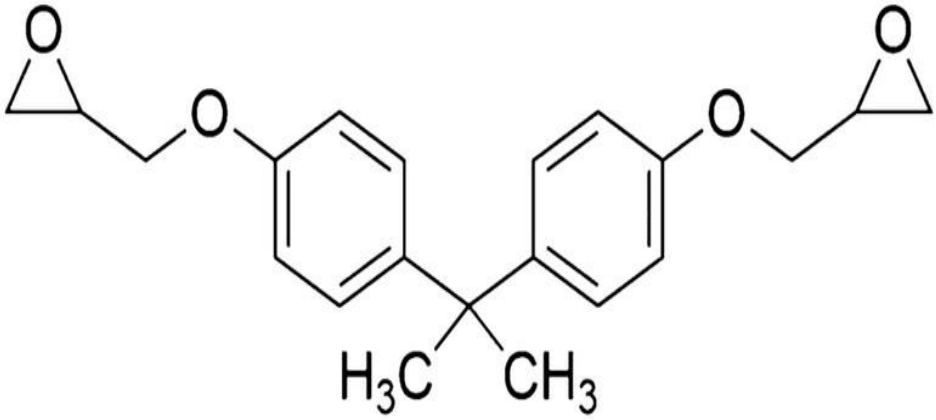


Fig.3.6 Chemical structure of DGEBA epoxy resin

Bisphenol A Diglycidyl ether, also known as BADGE or DGEBA, is an organic compound found in epoxy resins. The material is a colourless solid that melts very slightly above room temperature. Epichlorohydrin is O-alkylated with bisphenol A to produce it. Bisphenol A diglycidyl ether and various oligomers are the main products of this method. The degree of polymerization might be as low as 0.1. Because of high epoxide content, such epoxy resins are intriguing. The equivalent weight (Eq./mol) or the epoxide number (Eq./kg), which is the number of epoxide equivalents per kilogram of resin (Eq./kg), are both commonly used terms for this measure. Because unsymmetrical epoxides are chiral, the bis epoxide possesses three stereoisomers that cannot be separated.

Table 3.1 Details of the Epoxy resin

Sl. No.	**Property**	**Standard**	**Typical value**
1	Appearance	Visual	Clear, colorless to light yellow liquid
2	Epoxy equivalent weight	ASTM D 1652-04	185-194 g/eq
3	Epoxide value	ASTM D 1652-04	5.15 – 5.40
4	Viscosity @ 25℃	ASTM D 2196-05	11,000-14,000 cPs
5	Flash point	ASTM D 93	252 ºC
6	Density @25ºC	ASTM D 1475-98	1.16 g/ml

Materials Required in Fabrication.

- Hemp fabric
- DGEBA Epoxy resin
- TH7301 Hardener
- Cleaning agents such as Acetone
- Peel ply
- Vacuum pump
- Rubber mesh
- Cryo treatment setup
- Liquid Nitrogen
- Scissors
- Cello tape.
- Roller brush.
- Wiping tool.

3.2 PHASE OF FABRICATION

During the fabrication phase, a suitable technique is chosen from a list of composite manufacturing technologies based on compatibility with the selected type of advanced resin and reinforcement. Vacuum Assisted Resin Transfer Moulding (VARTM) is used to produce sample for test the tensile and flexural study with ASTM standards. The hand layup method is used to evaluate materials for water absorption and Rockwell hardness. Because the VARTM process makes it difficult to produce samples with thicknesses more than 10 mm.

3.2.1 Vacuum Assisted Resin Transfer Moulding (VARTM)

The Vacuum Assisted resin transfer moulding (VARTM) technology has been designed to generate homogeneous outcomes. This closed-mold technique is capable of producing high-performance and diverse composites, particularly fiber-reinforced polymer structures, at a low cost. The procedure entails basically performing the fibers or textile fabrics in the required configuration. These textiles are frequently kept together by a binder and pre-pressed to the mould form. A matching mould tool is clamped over the first, vacuum-sealed, and employed as a deformable vacuum bag. The pressured resin and hardener mixture is then pumped into the cavity using a vacuum pump. Following that, the laminate is formed, and both injection and curing can take place at either ambient or heated temperatures. Any fiber can be used in this procedure, although stitched fabrics perform well since the gaps allow for quick resin movement. When compared to the traditional composite manufacturing technique utilized in the aviation area, this is a faultless procedure employing low-cost composite materials without prepregs and autoclaves. The resin cup is normally exposed to the environment, resulting in a pressure difference between the intake and exit that draws the resin into the layup.

Advantages of VARTM method are**:** It is adaptable in terms of tooling design and material choices. Process large and complicated composite pieces with greater precision. Mold may be easily adjusted to process various shapes. A detachable vacuum needle is used to take air out of an apparent dry area that appears during the resin infusion process. The resin and catalyst can be kept separate and combined immediately before infusion. Only in resin mixing can a low level of volatile organic compound (VOC) emission occur. The sample produced by this method possesses good bearing and structural strength.

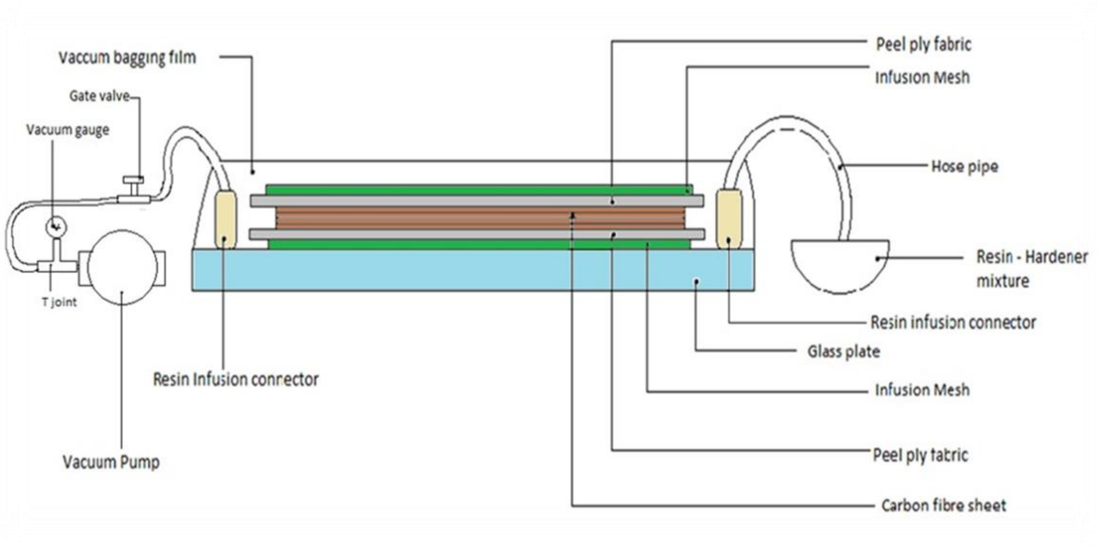


Fig.3.7 VARTM fabrication technique

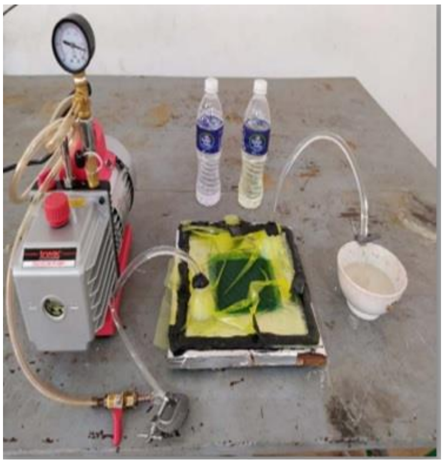


Fig.3.8 VARTM setup

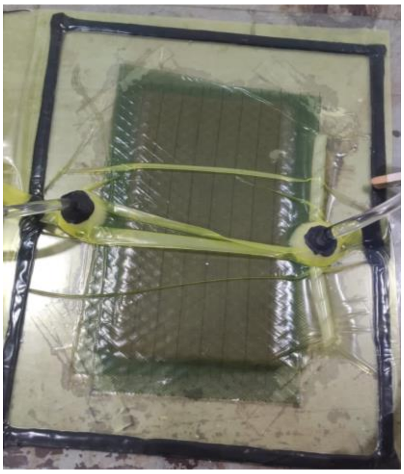


Fig.3.9 Infusion region for resin under vacuum

Fig.3.10 Fabricated composite

To regulate the resin flow rate and guarantee that the Hemp fiber sheets are completely wet, gate valves on the outflow line are controlled. The resin begins to flow to the outflow pipes after thoroughly moistening the Hemp sheets, and the gate valve is then shut fully. To prevent gas from leaking into the sealed bag, clamps are put on the inlet and outlet ports, and the vacuum pump is turned off. The created composite after it is demoulded after one overnight of curing. After sufficient curing, these laminates are cut into the required dimensions. The Hemp fiber is taken in order to obtain 30% volume fraction, so 90gm of Hemp with 240gm of Epoxy resin and 120gm Hardener in the ratio of 2:1 is used for fabrication.

Steps carried out in VARTM technique follows:

- A proper Hemp fiber mat is taken (6 layers of 2mm overall thickness).
- A glass base is taken for fabrication and it is wiped with Acetone to remove impurities.
- Wax is spreaded on it in order to avoid stickiness after curing.
- Peel ply of accurate size is fixed on it.
- Required amount of Resin epoxy and Hardener is taken.

- VARTM Setup were done with one end connected to vacuum pump and other end dipped in the Epoxy-Hardener mix.
- Adequate pressure is applied with the help of vacuum.
- The epoxy mix were infused through the layers and after wetting the both ends were closed and leave for curing.
- After 72 hours the cured mould was taken for further testing.

3.2.2 Hand Layup Method

Hand layup is performed with aspects like as controllability, compatibility, and production efficiency in mind. Curing procedures for advanced composites production are of great academic and industry interest. During the "hand layup" production process, prepreg, a form of reinforcement, is physically placed down in individual layers or "plies." This is made up of several fibers that have been pre-impregnated with resin, bundled into tows, then either bidirectionally or unidirectionally weaved together.

Multiple materials are combined to create composite materials, which have extraordinarily high specific weight and stiffness properties while maintaining a light weight for the item. A discontinuous strong reinforcement and a continuous matrix make up a composite. Epoxies and polyesters are two of the most widely used matrices. Composite components are distinctive in that they can be made to withstand loads coming from a particular direction.

The Hand lay-up technique is one of the foremost methods of composite material processing technique. The infrastructural requirement for this method is also very minimal. The processing steps are quite easy. First of all, a release gel or wax is sprayed on the mould surface to remove the sticking of Epoxy resin to the surface. Hemp fiber reinforcement, in the shape of woven mats, is cut into fit the mould size. The liquid mixture of epoxy and hardener is then poured onto the surface of the mat that has previously been put in the mould. With the help of a brush, the polymer is uniformly spread. The polymer surface is then covered with successive layers of mats, and a roller is gently moved across the mat-polymer layer to remove any trapped air as well as any excess polymer. The method is continued for each polymer and mat layer until the desired number of layers are stacked.

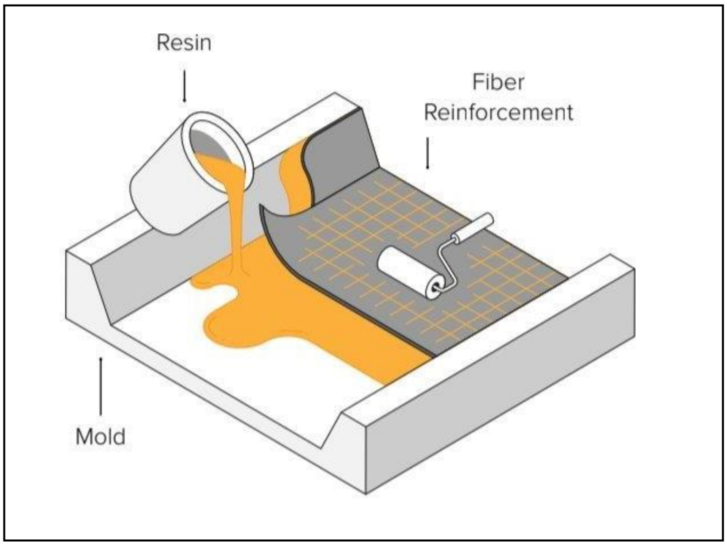


Fig.3.11 Hand layup technique.

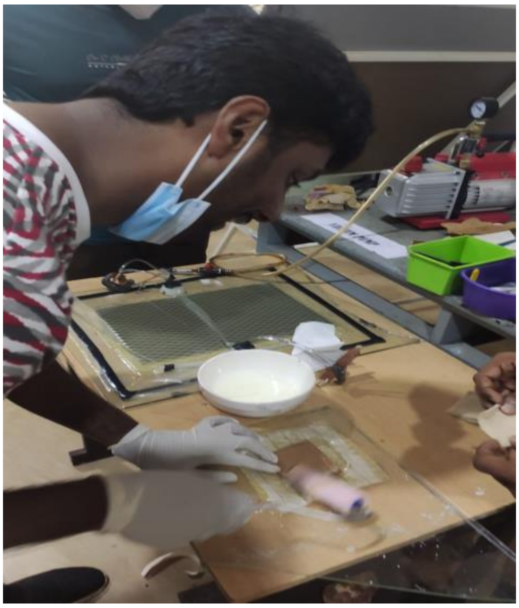


Fig.3.12 Hand layup Procedure (Space lab, TKMCE).

Fig.3.13 HFRP fabricated by Hand layup method

Steps carried out in hand layup technique follows:

- A proper Hemp fiber mat is taken (6 layers of 2mm overall thickness).
- A glass base is taken for fabrication and it is wiped with Acetone to remove impurities.
- Wax is spreaded on it in order to avoid stickiness after curing.
- Peel ply of accurate size is fixed on it.
- Required amount of Resin epoxy and hardener is taken.
- 6 layers of Hemp woven mat were taken and adequate amount of the resin epoxy mix is applied consecutively and covered with peel ply.
- Adequate pressure is applied with the help of roller brush.
- Taken for curing.

Fig.3.14 Acetone used for cleaning.

Acetone (CH3COCH3), known colloquially as 2-propanone or dimethyl ketone, is an organic solvent with enormous chemical and industrial significance. It is the most basic and prominent of the aliphatic (oil-derived) ketones. Pure acetone boils at 56.2 °C (133°F), is transparent, moderately fragrant, combustible, and mobile. Acetone is a liquid solvent that can disintegrate and break down other materials.

Acetone is widely used in the following fields:

- Industrial
- Solvent
- Acetylene carrier
- Chemical intermediate
- Laboratory Chromatography
- Cleaning
- Low-temperature bath
- Histology
- Lewis base properties
- Medical

- Drug solvent and excipient
- Skin defatting
- Anticonvulsant
- Domestic and other niche uses

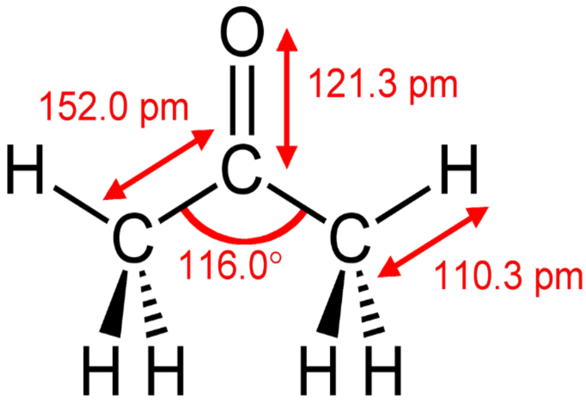


Fig.3.15 Full chemical formula of Acetone

Fig.3.16 Peel ply

3.2.3 Cryo-treatment setup

The Cryo-Processor is a liquid nitrogen media used in the cryo-treatment procedure. The deep cryo-treatment involves treating material at -196°C temperatures. The material is reduced to 2°C per minute at room temperature and held at that temperature for 24 hours before being heated to 2°C per minute until it reaches room temperature. Quenching and heating aid in achieving the necessary structural strength. Cryogenic treatment is used to eliminate residual stresses and restore the wear resistance of composites by treating workpiece material at cryogenic temperatures, i.e., below -190°C (310°F). Furthermore, cryogenic treatment seeks to improve stress relief and stability, as well as wear resistance.

Fig.3.17 Cryo-treatment setup

Fig.3.18 Hemp woven cloth in cryo-bath

CHAPTER 4

MATERIAL TESTING

For many different reasons, materials testing can provide a lot of information about the tested samples, prototypes, or product samples. The information acquired during testing and the test results themselves are very useful in the engineering sector. After curing, hemp fiber reinforced polymer composite material is taken for testing. Various mechanical tests are conducted on the material to demonstrate its applicability. Five samples from each of the two instances are collected for analysis. Both untreated and cryo-treated HFRP samples are included.

Fig.4.1 Fabricated composite by VARTM

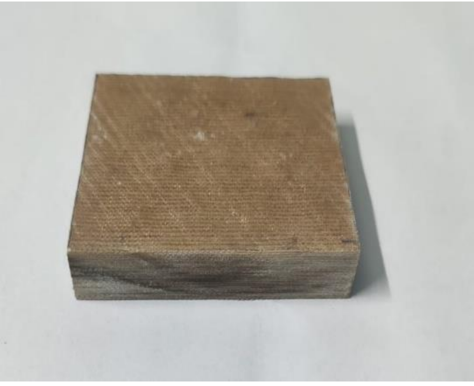


Fig.4.2 Fabricated composite by Hand layup method.

4.1 TENSILE STRENGTH TEST

The utmost load that HFRP material can bear without being fracture when it is stretched is experimentally identified by tensile strength (σ) test. Five specimens from samples of untreated HFRP and cryo-treated HFRP respectively were taken for testing. These specimens tested for tensile strength values by UTM machine at SOM Lab, TKMCE. Tensile testing for neat and cryo-treated HFRP were performed at room temperature (RT). Dimensions of the test specimen: 250 x 25 x 3.5mm (ASTM 3039). Compared to samples that have been cryo-treated, the breaking load for clean HFRP is greater. The cryo treatment method increased the brittleness of the fibers, lowering their tensile strength.

Fig.4.3 Tensile testing in UTM

The ASTM D3039 tensile testing procedure is used to determine the amount of force required to break a polymer composite specimen as well as how far the specimen stretches or elongates before it breaks. The tensile modulus is determined using a stress-strain diagram produced by tensile experiments. To design parts that can withstand application stress, specify materials, and perform material quality control checks, information is frequently employed. At a predetermined grip separation, specimens are loaded into the grips of a universal test machine and pulled till failure. The time to failure or the material specification can be used to establish the test speed for ASTM D3039 (1 to 10 minutes). Standard test specimens are typically run at a pace of 2 mm/min (0.05 in/min). The measurement of elongation and tensile modulus is done with an extensometer or strain gauge. Testing in multiple orientations may be required, depending on the reinforcement and kind.

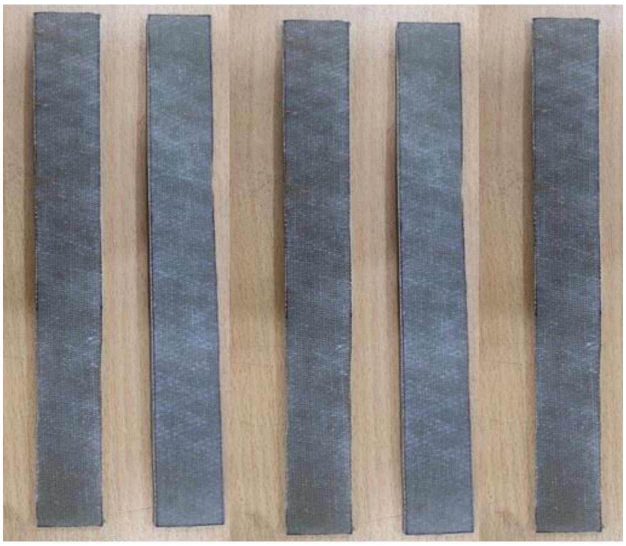


Fig 4.4 Tensile test specimen (ASTM D3039)

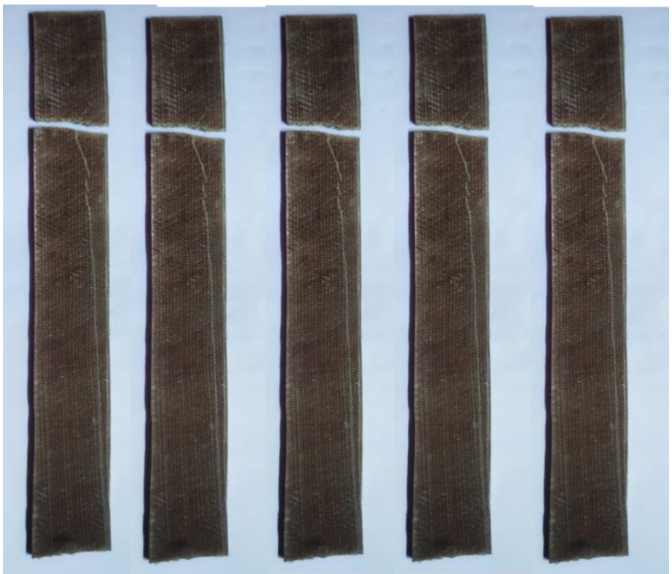


Fig 4.5 Specimen after Tensile test (ASTM D3039)

The most typical ASTM D3039 specimen is a continuous rectangular cross-section that is 250 mm long and 25 mm broad. To avoid gripping damage, optional tabs can be attached to the specimen's ends.

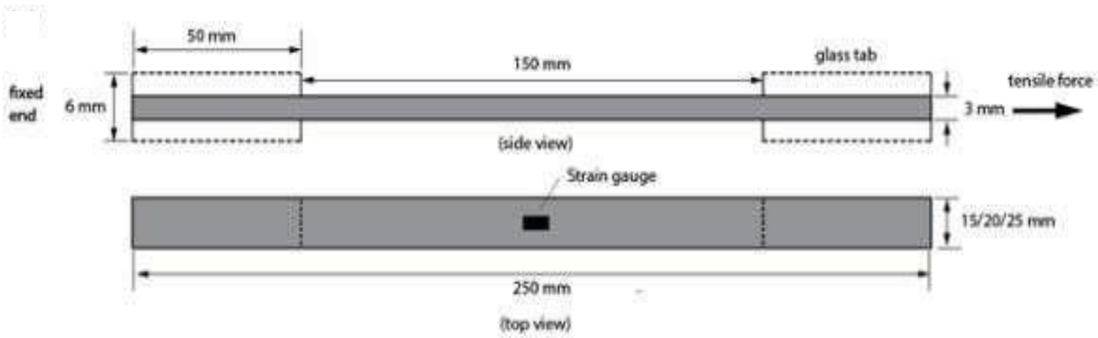


Fig.4.6. Tensile test specimen ASTM standard D-3039 dimension

4.2 THREE-POINT BENDING TEST

The flexural test is done to determine the flexural characteristics of polymer matrix composite materials under the specified conditions, such as flexural strength, stiffness, and load/deflection behaviour. According to ASTM D-7264 standards, three- point bending test is one type of flexural tests which includes central loading on a simply supported beam. This test procedure was created for continuous-fiber reinforced polymer matrix composites to use to their full potential. The schematic diagram of 3-point bending test is as shown in the figure.

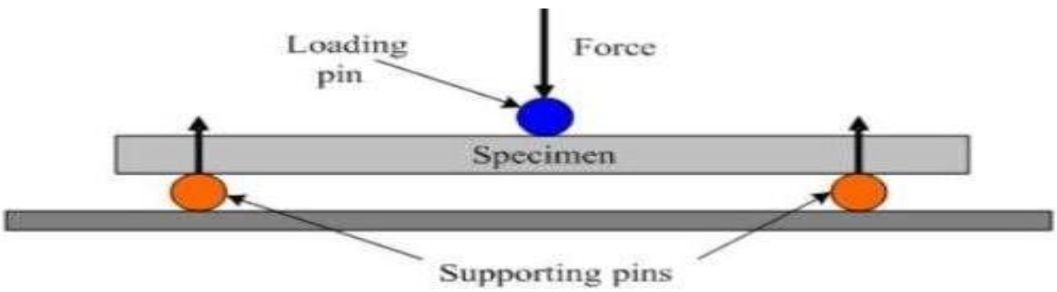


Fig. 4.7. Schematic diagram of 3-point bending test

Even when perfect symmetry is intended, no laminate is totally symmetric, therefore flexural properties may change depending on which surface of the specimen is compressed. These differences may cause the neutral axis to move, and even little asymmetry in the laminate will have an influence. To assess composites, static or rotating loading noses are frequently utilized. The kind of loading nose can affect the findings because non-rolling twin supports on either the compression or tension side of the specimen produce minor longitudinal forces and resistive moments on the beam that superimpose with the desired loading. The loading noses must also touch the specimen uniformly over its breadth. Flexural properties may be impacted by an absence of consistent contact by causing crushing damage and unevenly loading the beam. The supporting rollers are likewise cylindrical with a 3.0 mm radius to guarantee uniform loading. Standard support span-to-thickness ratios for flexural strength are created so that failure only results from the bending force at the outside surface of the specimens. The standard specimen thickness is 4 mm and the standard specimen width is 13 mm, with the standard specimen length being around 20% longer than the support span. The span-to-thickness ratio is typically 32:1.

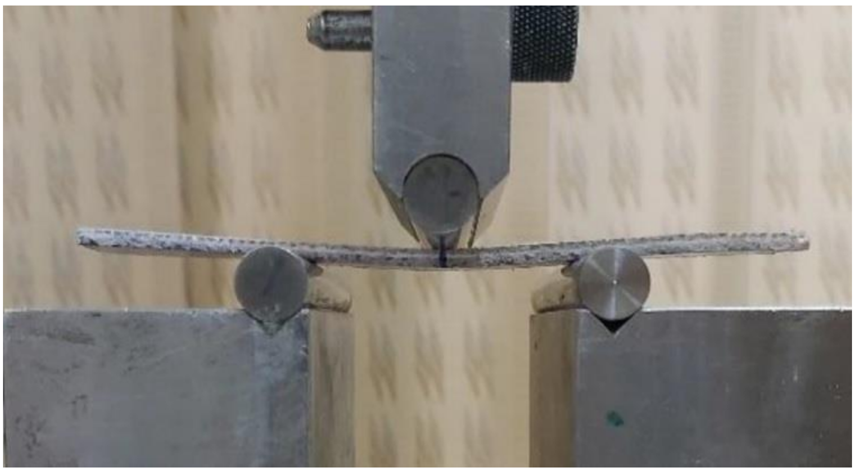


Fig.4.8. 3-point bending test (Dept. of Polymer Science and Rubber technology CUSAT)

4.3 ROCKWELL HARDNESS TEST

The Rockwell test is often simpler and more accurate than other hardness testing procedures. The Rockwell test technique is employed on all metals except when the test metal surface conditions cause too many changes. The permanent depth of indentation generated by a load on an indenter is measured using the Rockwell technique. To begin, a preliminary test force is applied to a sample with a diamond or ball indenter. This preload penetrates the surface, reducing the impact of surface finish. The baseline depth of indentation is measured after holding the preliminary test force for a predetermined dwell period. Following the preload, an additional load known as the main load is added to achieve the entire needed test load. This force is maintained for a set period of time (dwell time) to allow for elastic recovery. This primary load is then relieved, allowing the preparatory load to resume. The ultimate depth of indentation is measured after retaining the preliminary test force for a defined dwell period. The Rockwell hardness value is calculated by subtracting the baseline and final depth values. This measurement is turned into a hardness number. The preliminary test force is withdrawn, as well as the indenter from the test specimen.

Fig. 4.9 Rockwell Hardness Tester

Fig.4.10 Neat HFRP sample

Fig.4.11 Cryo-treated HFRP sample

4.4 WATER ABSORPTION TEST

Hemp fibers are more naturally water-absorbent. The hydrophilic properties of fibers will affect the strengths of composite materials. Cellulose is bonded in a matrix of hemicelluloses and lignin and found in the microfibrils of the stem's cell wall. It has been discovered that water sorption in fibers and biocomposites has a considerable impact on their dimensional and structural characteristics. The tensile and flexural characteristics of hemp fiber reinforced unsaturated polyester composites decreased as the percentage moisture absorption rate. The composite samples' water absorption was evaluated in accordance with ASTM D 2842-01. The specimen was 40 x 40 x 20 mm. The composite specimens were tested for water absorption by immersing them in distilled water in a beaker at room temperature for 7 days (168 h).

The weight difference was used to determine moisture absorption. The % weight increase of the samples was calculated using the following equation at various time intervals:

$$\text{W (\%)} = \frac{(m2-m1)}{m1} \times 100 \tag{1}$$

where m1 and m2 are the dry and wet sample weights. Various models have been devised to characterize the composite's water absorption phenomena.

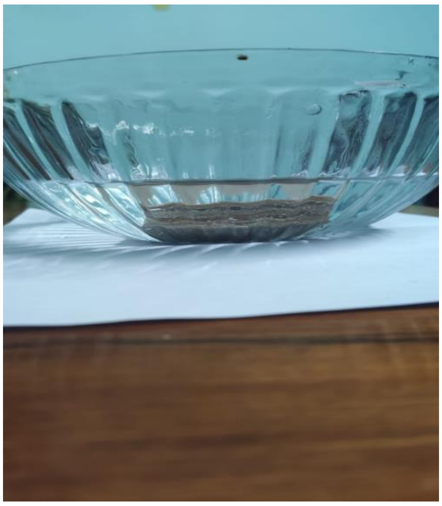


Fig.4.12 HFRP sample kept in distilled water

Fig.4.13 Cryo-treated HFRP before and after study

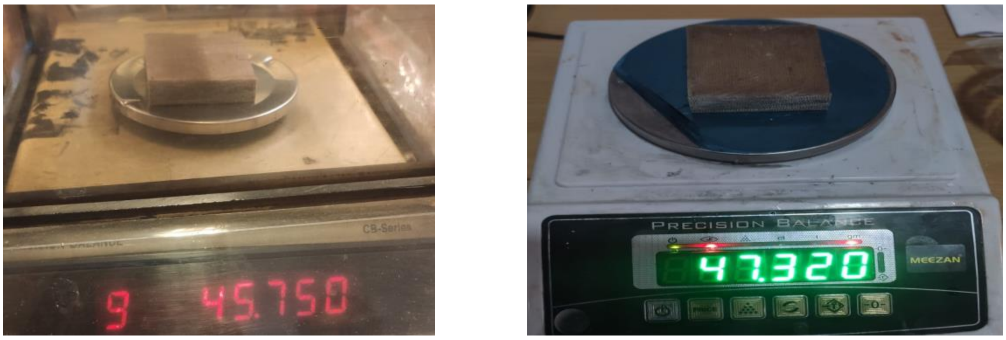


Fig.4.14 Untreated HFRP before and after study

CHAPTER 5

STRUCTURAL ANALYSIS

Ansys Composite PrepPost (ACP) is a built-in tool in the Workbench platform for modeling composite laminates (pre) and displaying the results of advanced analyses (post) utilizing specific tools for failure. ACP employs the Ansys Mechanical solvers to conduct implicit/explicit structural and thermal simulations, as well as fluid-structure interactions. It enables the construction of FEM models with various lamination zones defined layer-by-layer. ACP enables for appropriately specifying stacking sequences to cover the complete structure in the Pre-processing phase, starting with the description of the material data (UD, Fabric, Stack-up). For sub-modeling investigations or to look into the consequences of delamination and bonding, it is feasible to convert from shell modelling to solid modelling. On double curvature surfaces, drapery simulation and "flat wrap" outcomes are offered. The Ansys Composite PrepPost software is intended for engineers who develop and analyze multilayer composites. It will address how to apply this technology correctly and efficiently to overcome some of the fundamental issues in composite modelling, such as collecting fiber orientation, model inspection, failure analysis, and parameterization.

5.1 ANSYS PROCESS CHART

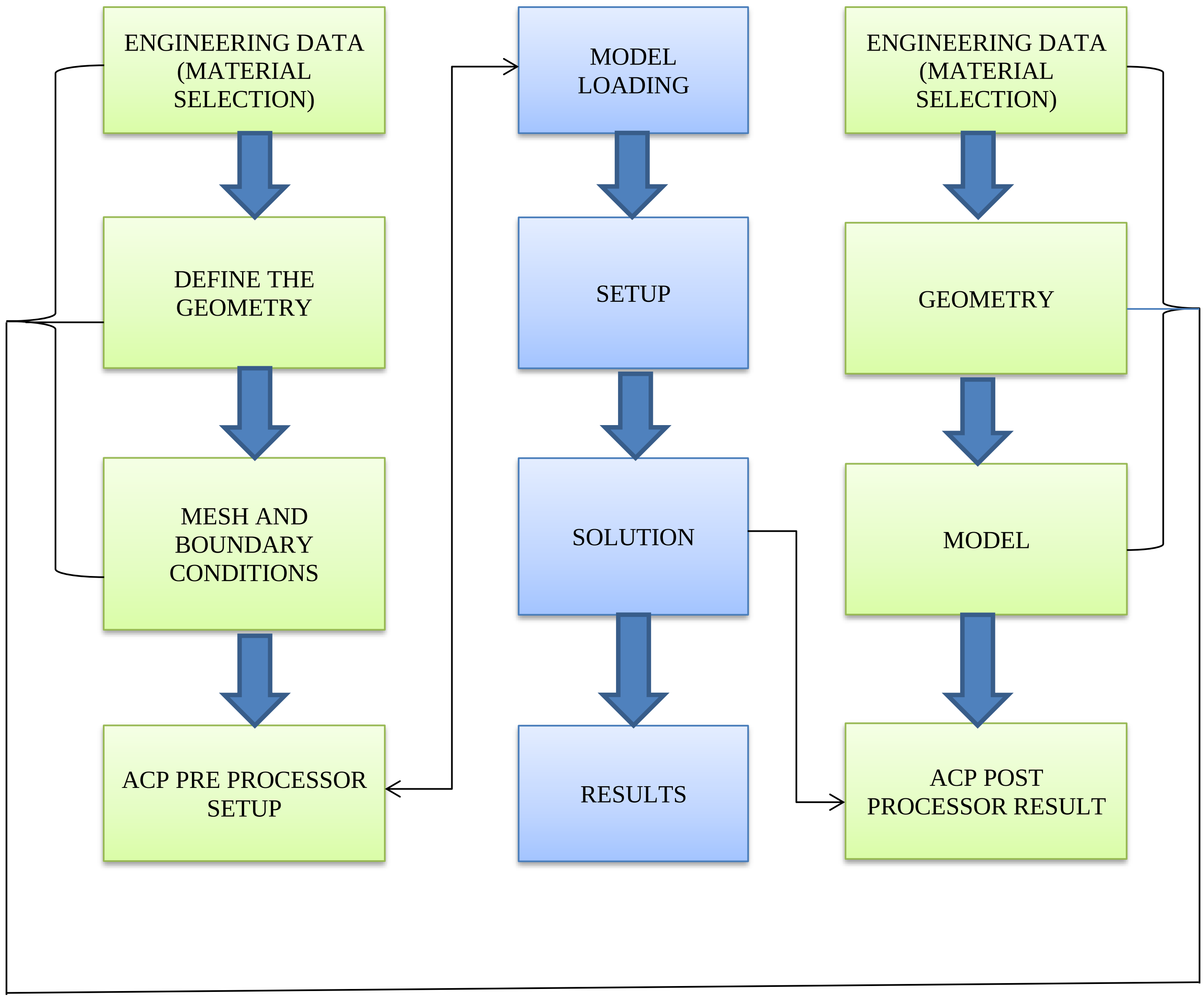


Fig.5.1 ANSYS flow Chart

Ansys ACP pre-post used to analyze strains, stresses and failure criteria of composite laminate requires to model the single layers a composite design is built up by. There are three types of approaches are used to evaluate the composite structure

- Micro-scale approach (fiber level)
- Meso-scale approach (Ply level)
- Macro-scale Approach (Laminate level)

Among these approaches ANSYS composite pre post is mainly used to prepare and evaluate composite specific results of a design using the Meso-scale Approach. It requires the material properties and thicknesses for each layer of the design.

Single plies coordinate system consist of following directions.

- 1 direction: parallel to the fiber direction (II direction, L direction, or also x direction)
- 2-direction: perpendicular to the fiber direction (I-direction, T-direction, or also Y-direction)
- 3-direction: normal to position ("out-of-plane" or z-direction)

Functionalities that can be applied in ANSYS ACP software:

1. **Build Composite Designs as Shells or Solids**
    - Evaluate the assembled design
    - Define complex composite layers layer by layer high
    - Define fiber direction and direction
    - Composite design modification and optimization
    - Analyze design properties of composites

- Generate manufacturing information

2. Evaluate the assembled design

- Evaluate designs against combined failure criteria
- Assess matrix, fiber and sandwich reserves   Failure
- Evaluate ply strain and stress
- Quick access to important layer information
- Detailed analysis of regions by sub-modeling
- Low hygroscopicity.
- Vibration damping.

5.2 TENSILE TEST OF HFRP COMPOSITE IN ANSYS ACP PREPOST

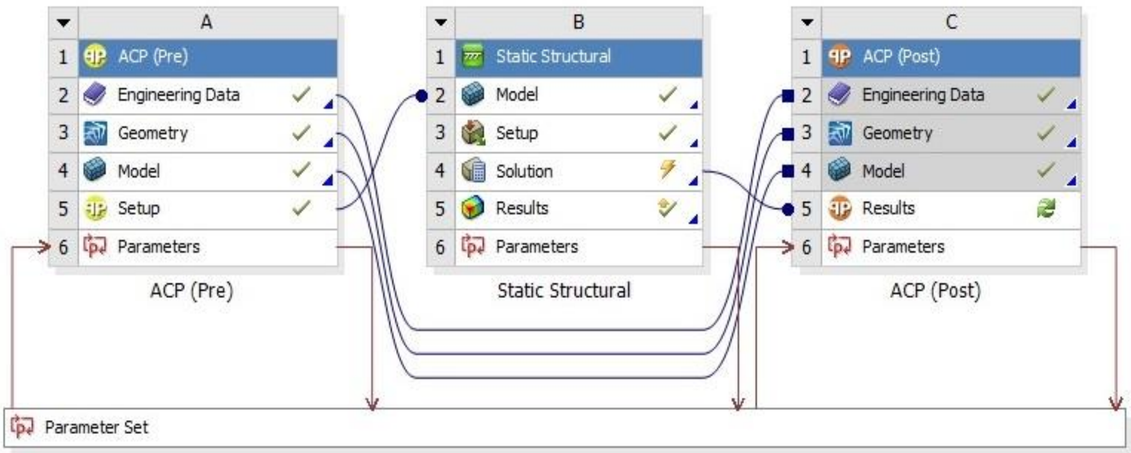


Fig.5.2 Ansys ACP pre-post Tensile strength analysis

Composite layup steps consist of:

1. Defining Material Data: Material Data are defined in the ANSYS Workbench Engineering Data. Material Data includes the fabrics defining and allocation of

mechanical properties such as Young's modulus, Shear Modulus, Density, and Poisson's ratio.

2. Oriented Selection Sets: Oriented selection sets define the basis for the layup definition. It contains the following important details for a composite layup; (a) The area which is later used to apply layers on (b) The direction defining the fiber direction (c) The direction in which layers are applied.
3. Composite characteristics are defined on the simulation model as on the real parts. Ply's locations are defined on the geometry using fabrics or stack up.

5.2.1 Engineering Material Data considered before analysis:

Table 5.1 Engineering Data for ANSYS

ENGINEERING DATA	HEMP FIBER	EPOXY RESIN
DENSITY (g/cm^3)	1.249	2.160
YOUNGS MODULUS (N/mm^2)	1.7×10^4	8.5×10^7
POISSONS RATIO	0.09	0.23
BULK MODULUS (N/m^2)	6.9106×10^9	4.2×10^9
SHEAR MODULUS (N/m^2)	7.7982×10^9	1.4×10^9

5.2.2 Layer-wiser Thickness Calculations for Ansys Input Data

Number of sheets of Hemp fiber used = 6 numbers

Thickness of 6 layers of Hemp fiber sheets = 6×0.25 = 1.5 mm

Approximate/total thickness of the composite casted using VARTM = 3.5 mm

Number of epoxy layers = 7 layers

The thickness of 7 layers of epoxy layers

= Approximate/total thickness of the composite - Thickness of 6 layers of Hemp fiber sheets

= 3.5- 1.5 = 2 mm

$$\text{Thickness of one layer of epoxy} = \frac{\text{Thickness of 7 layers of epoxy layers}}{\text{Number of epoxy layers}} = \frac{\mathbf{2}}{\mathbf{7}}$$

= 0.28 mm

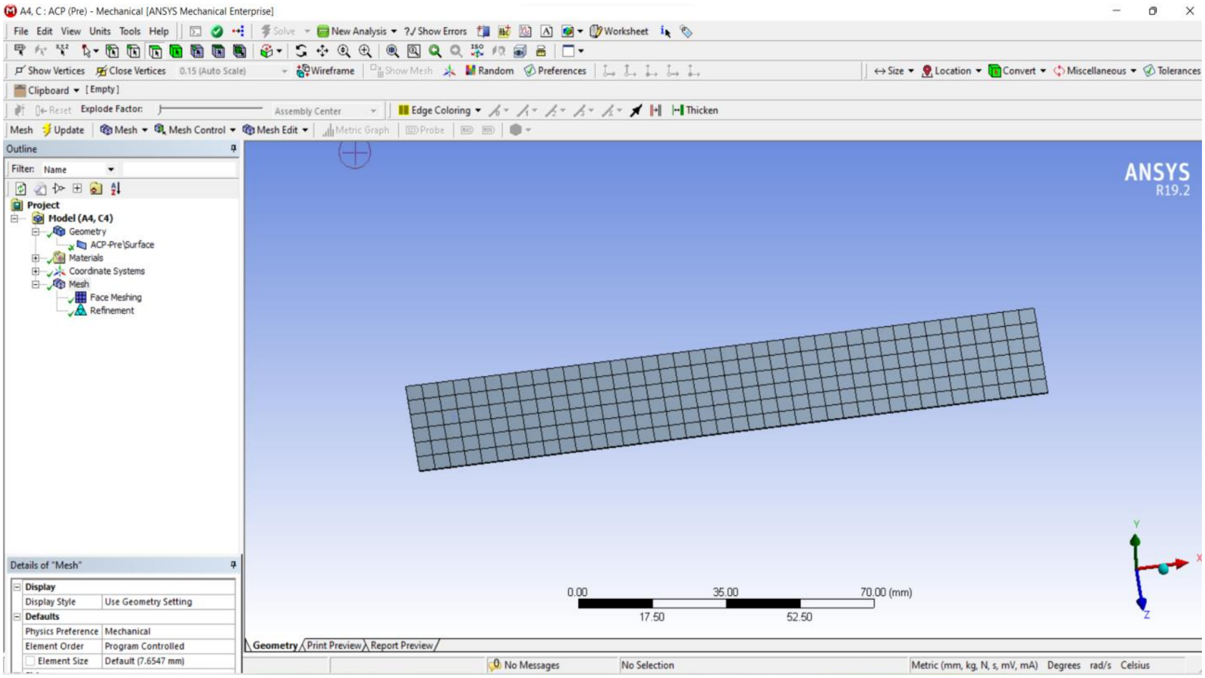


Fig.5.3 Defining the mesh elements

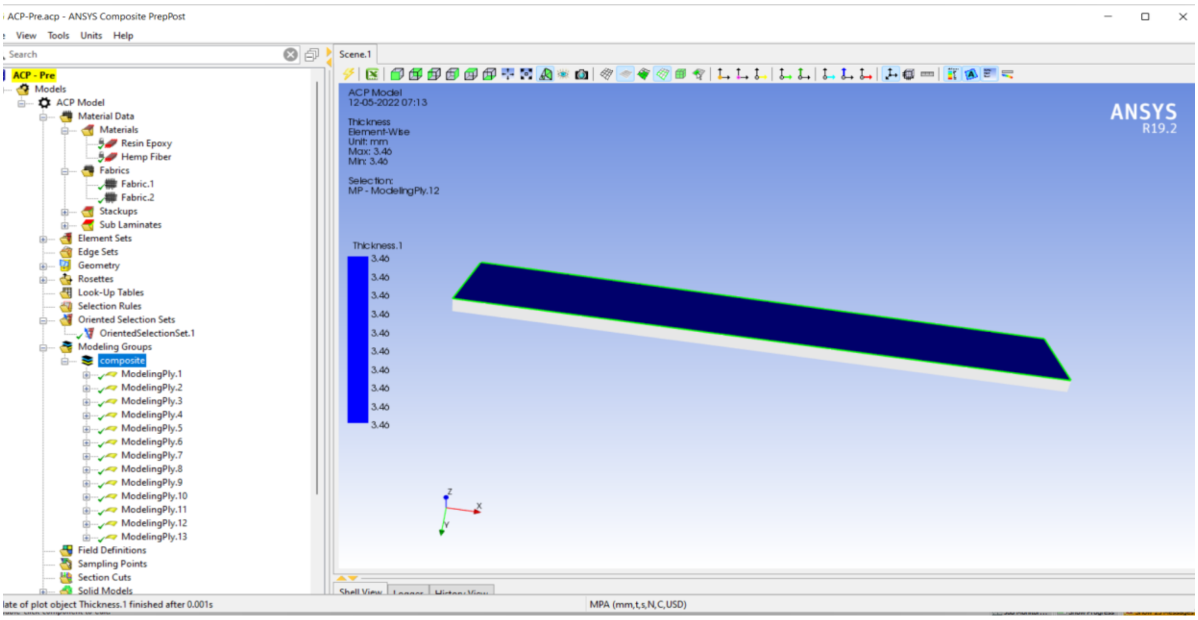


Fig.5.4 Ansys ACP preprocessor setup

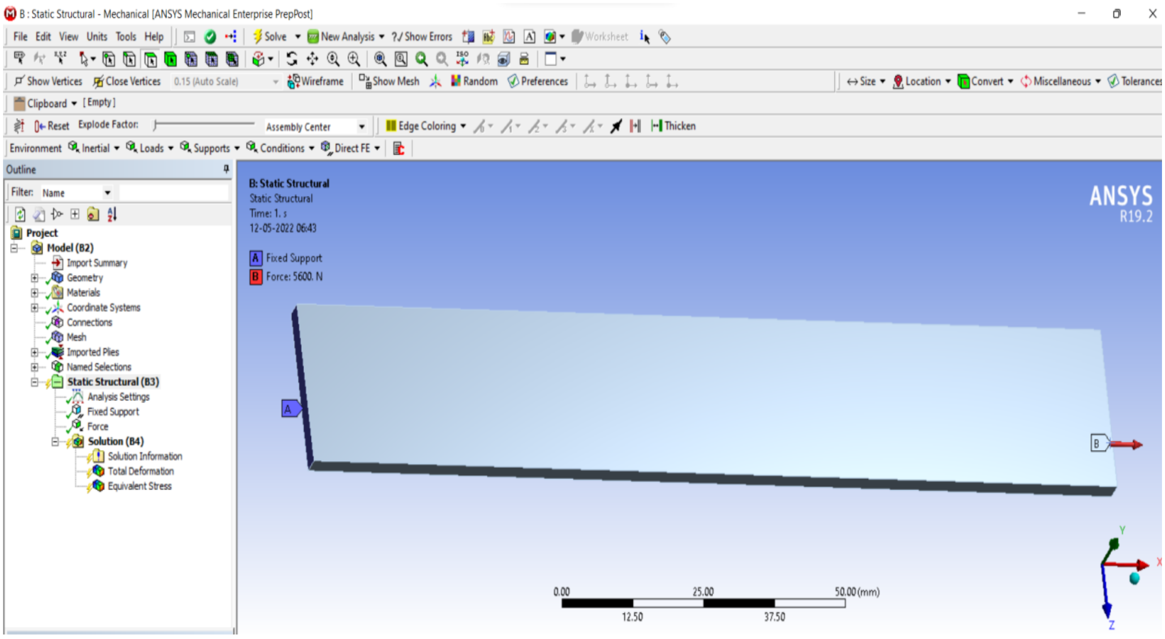


Fig.5.5 Applying the boundary conditions in Static Structural

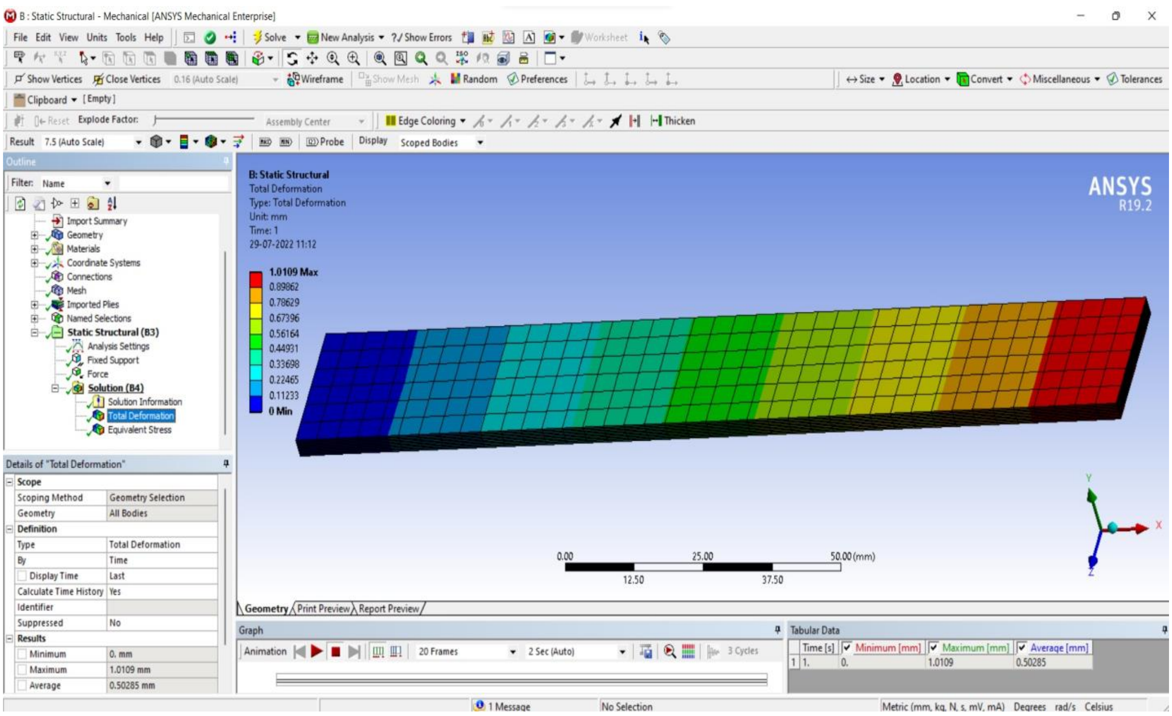


Fig.5.6 Total deformation after load application

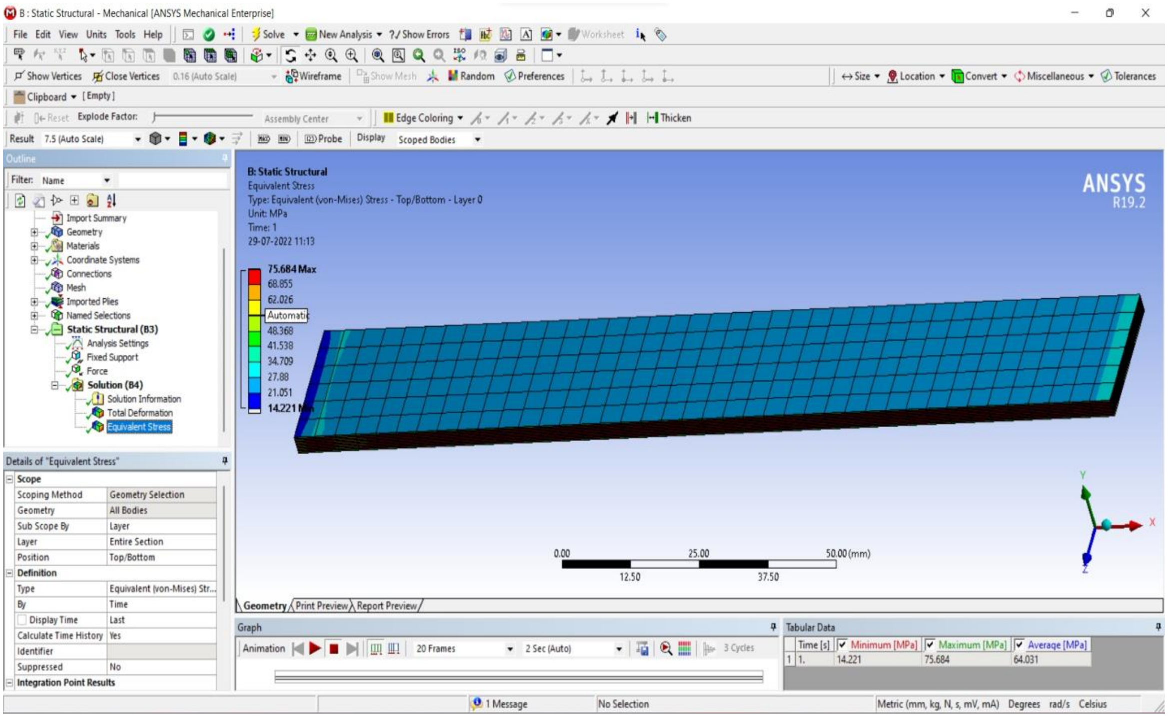


Fig.5.7 Equivalent von mises stress after tensile loading

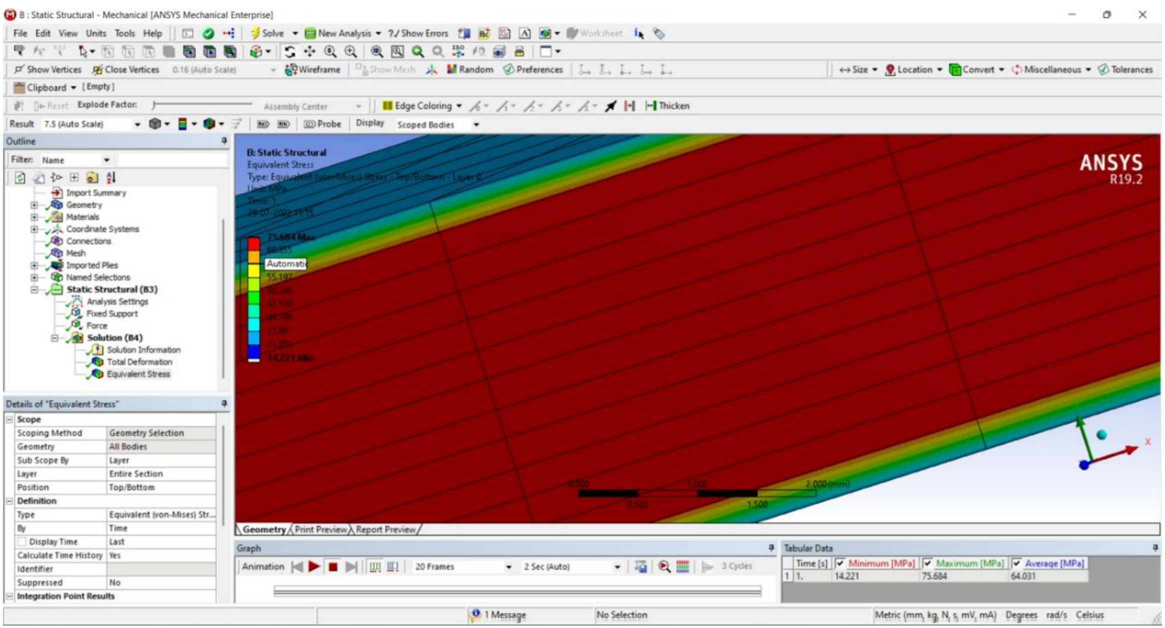
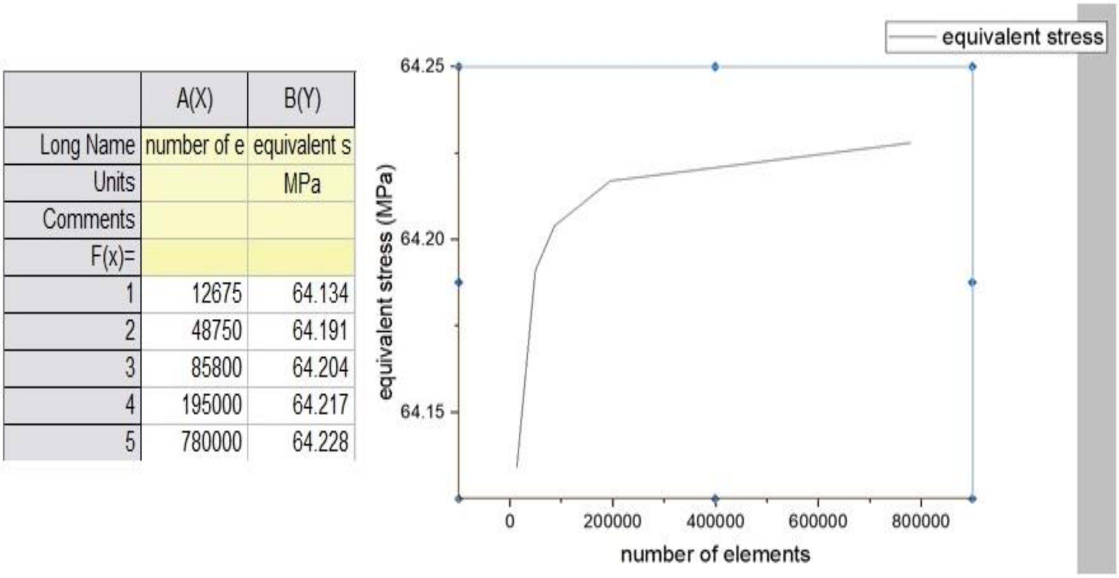


Fig.5.8 Detailed view of Equivalent von mises stress after tensile loading



	A(X)	B(Y)
Long Name	number of e	equivalent s
Units		MPa
Comments		
F(x)=		
1	12675	64.134
2	48750	64.191
3	85800	64.204
4	195000	64.217
5	780000	64.228

Fig.5.9 Mesh convergence study

5.3ACP Post processor results

Deformation in ACP

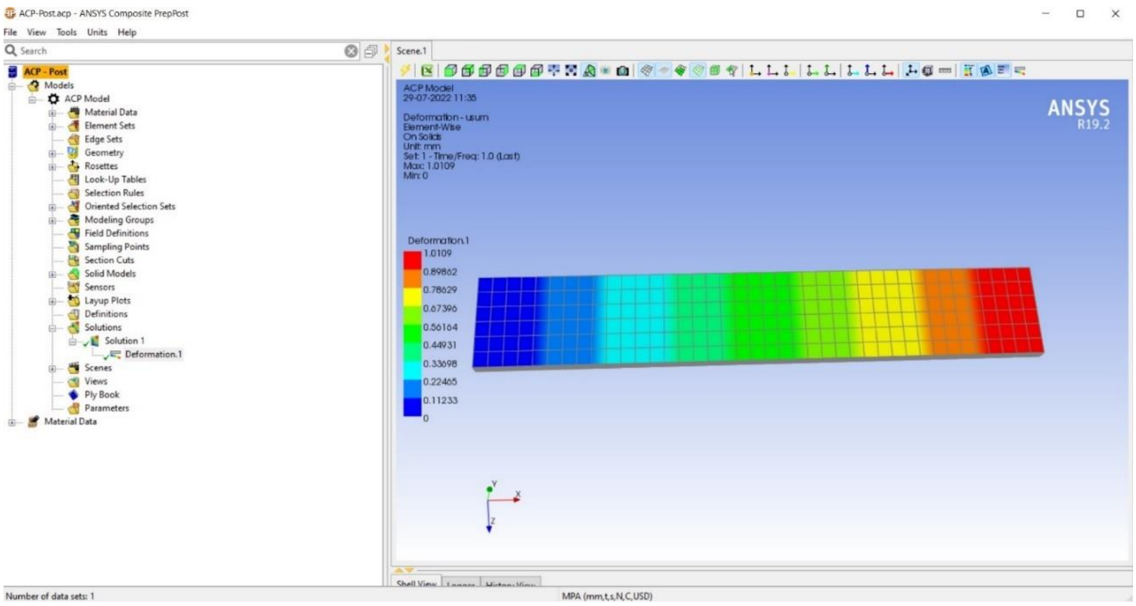


Fig.5.10 Deformation results in ACP

Layer-wise stress Distributions

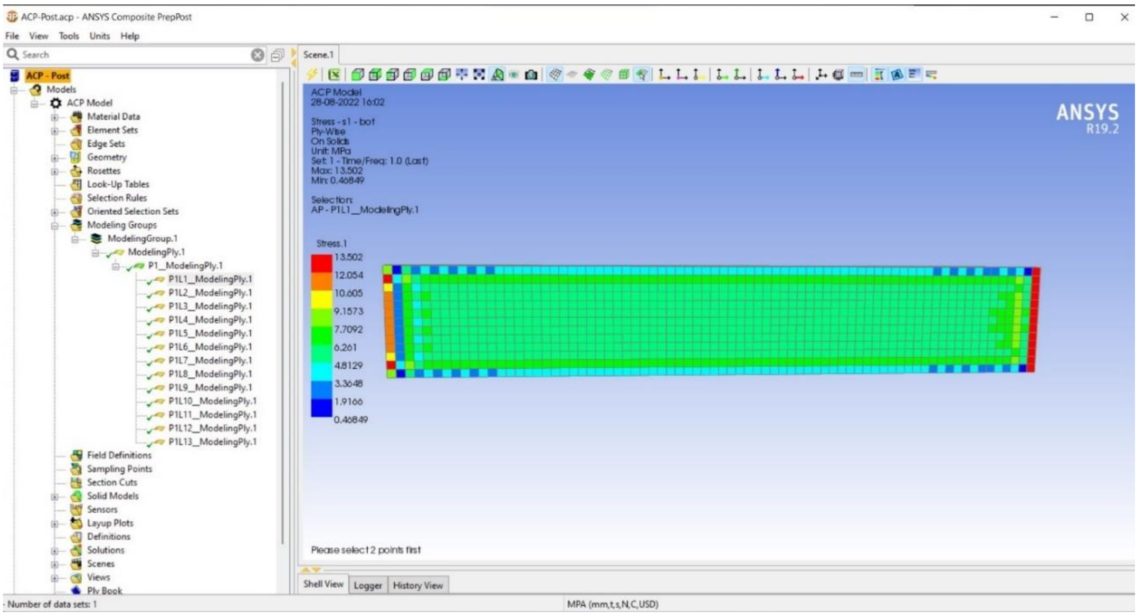


Fig.5.11 Stress distribution in layer 1

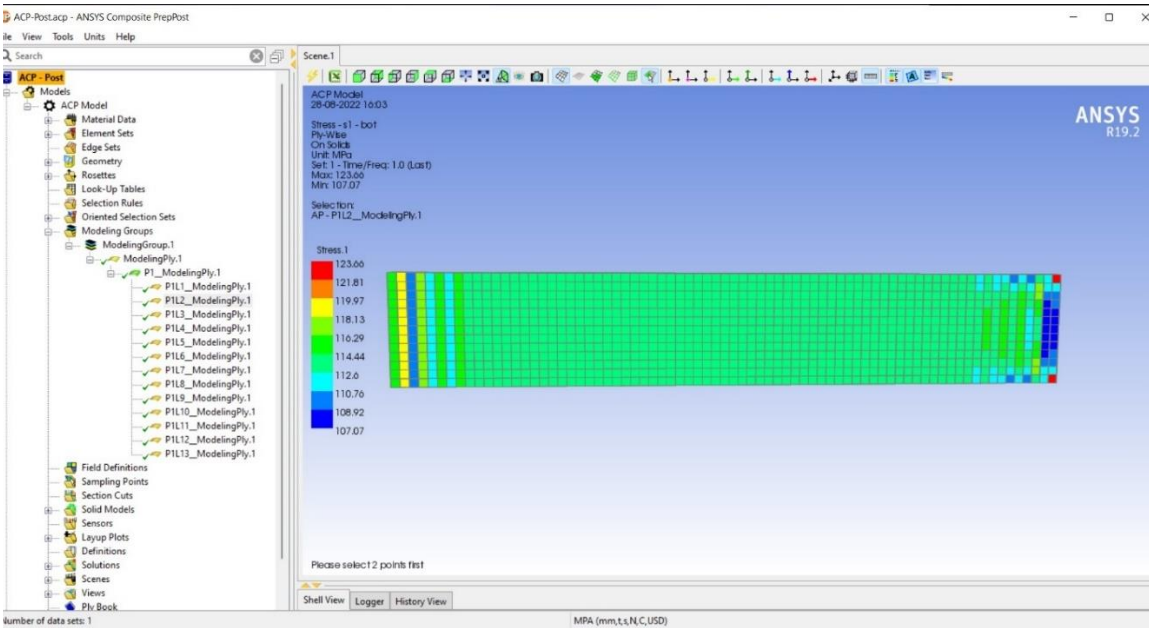


Fig.5.12 Stress distribution in layer 2

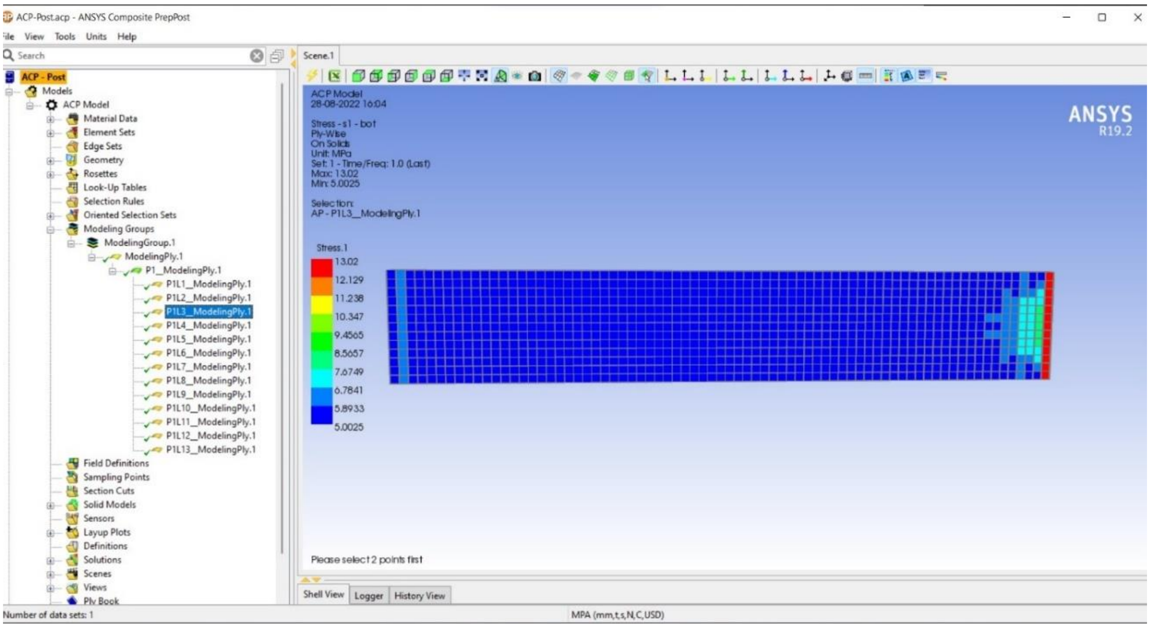


Fig.5.13 Stress distribution in layer 3

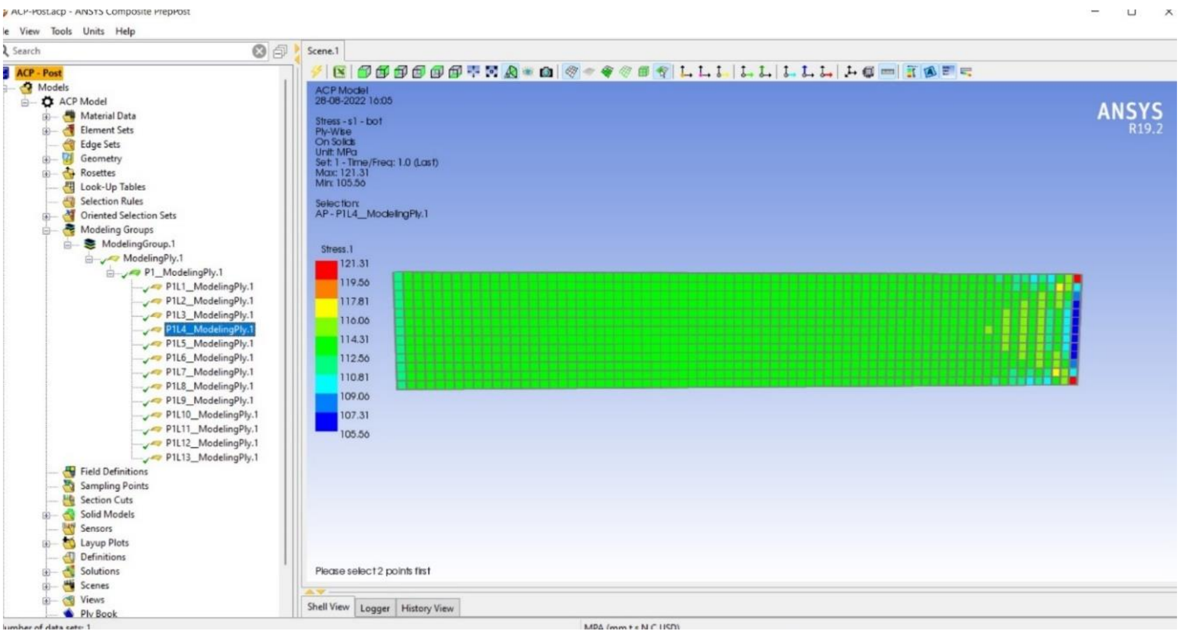


Fig.5.14 Stress distribution in layer 4

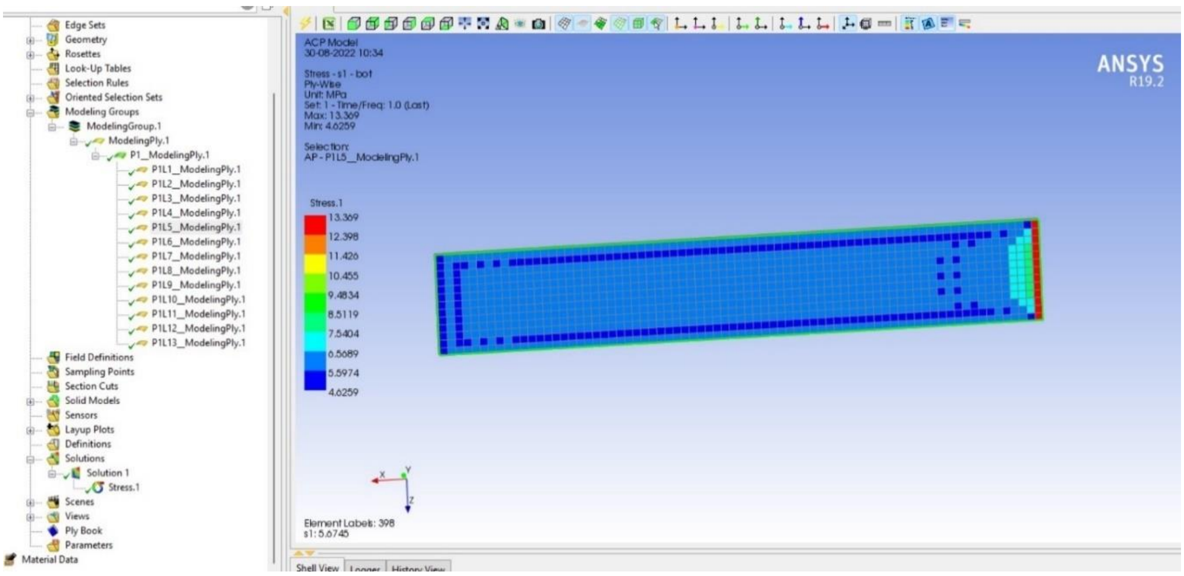


Fig.5.15 Stress distribution in layer 5

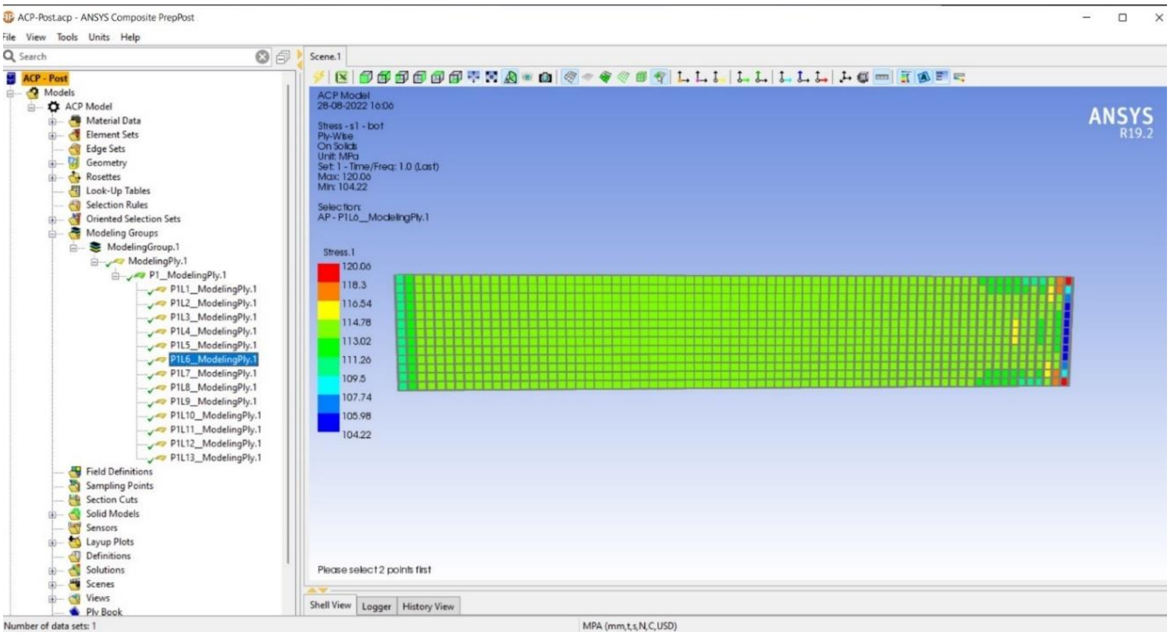


Fig.5.16 Stress distribution in layer 6

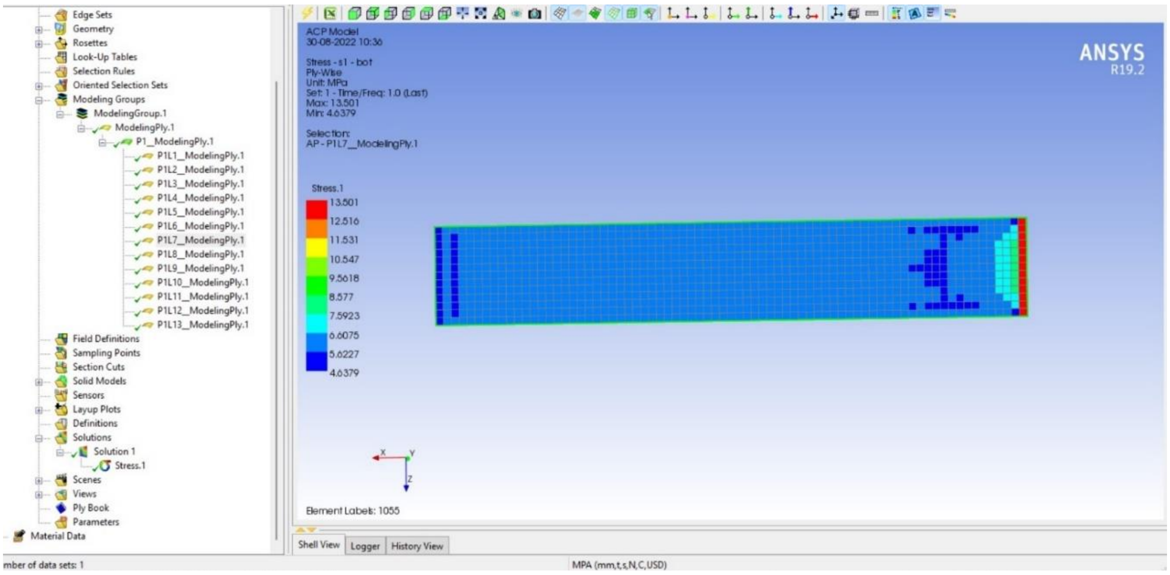


Fig.5.17 Stress distribution in layer 7

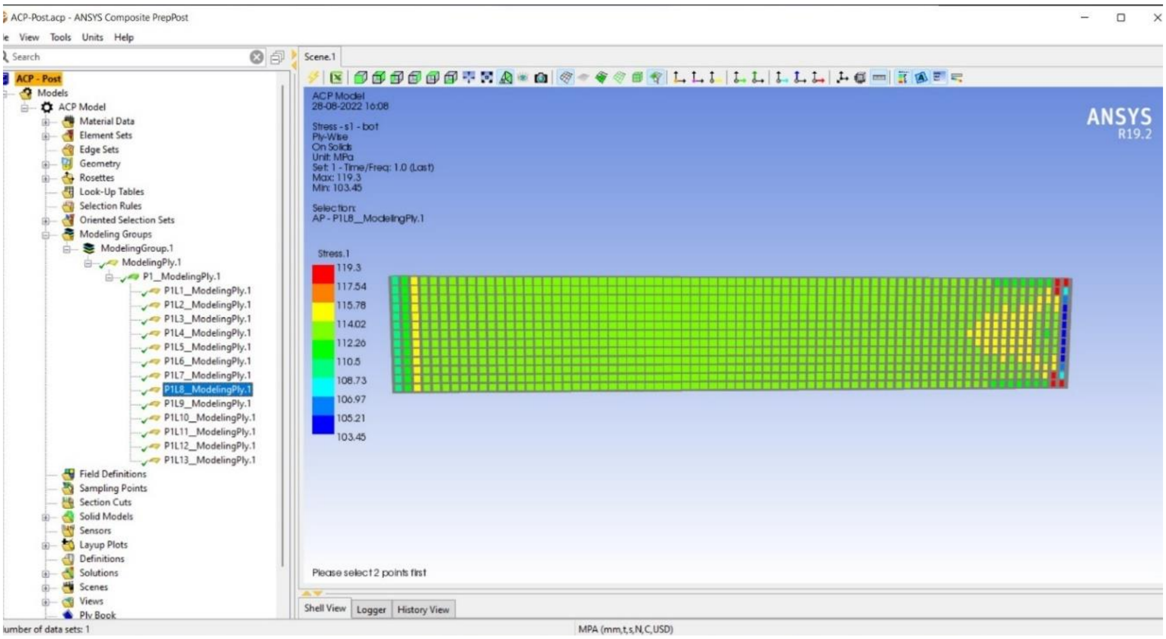


Fig.5.18 Stress distribution in layer 8

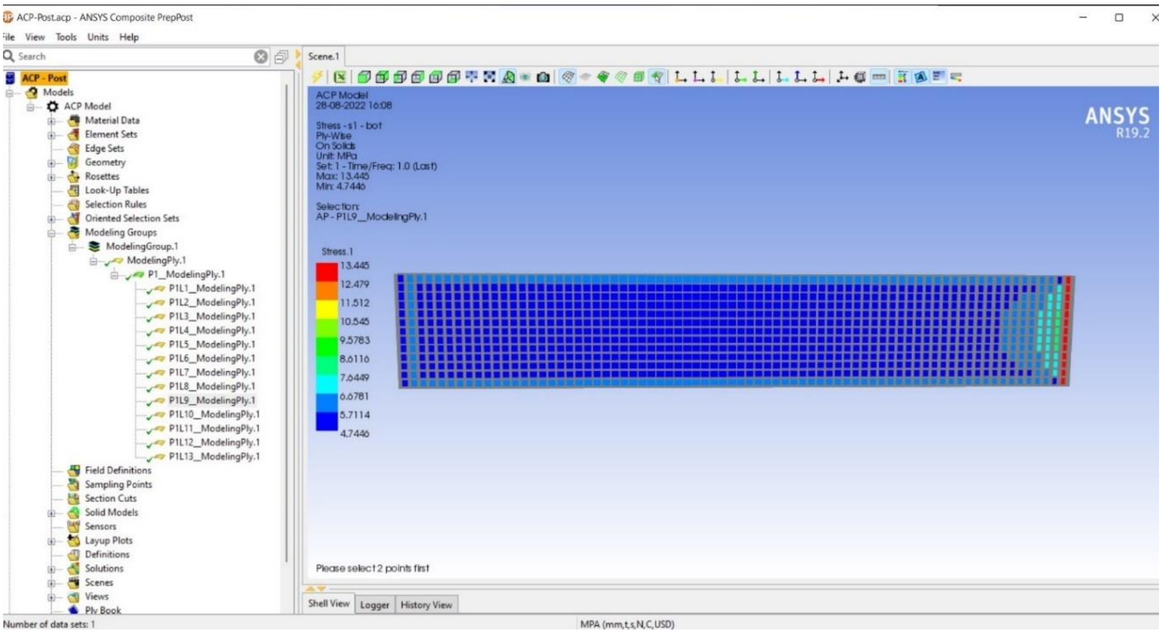


Fig.5.19 Stress distribution in layer 9

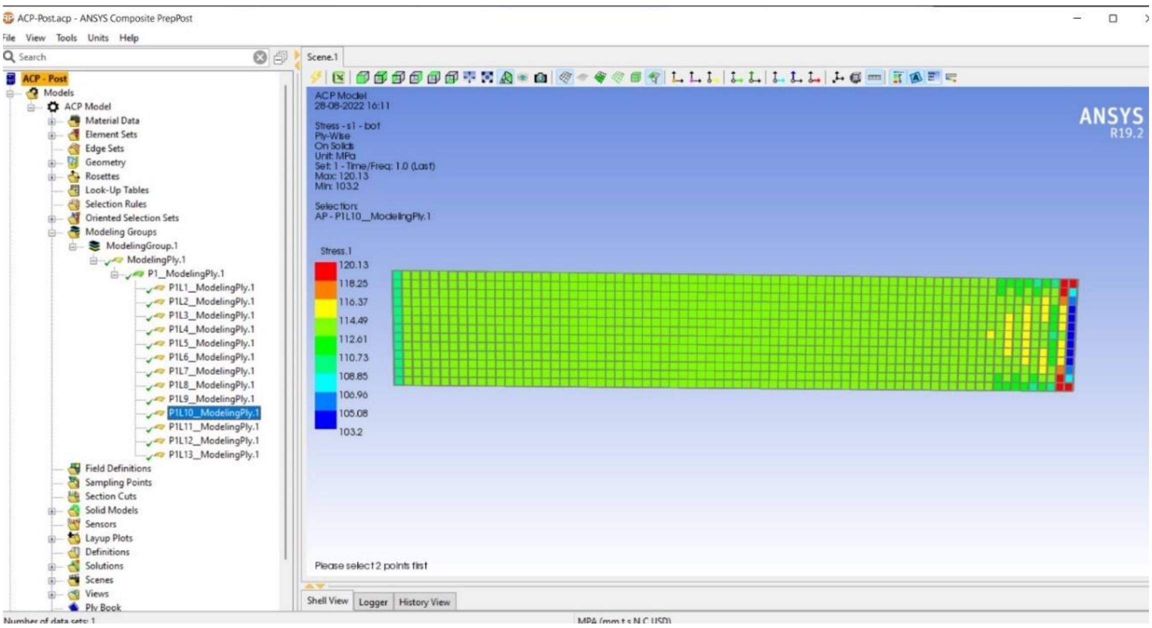


Fig.5.20 Stress distribution in layer 10

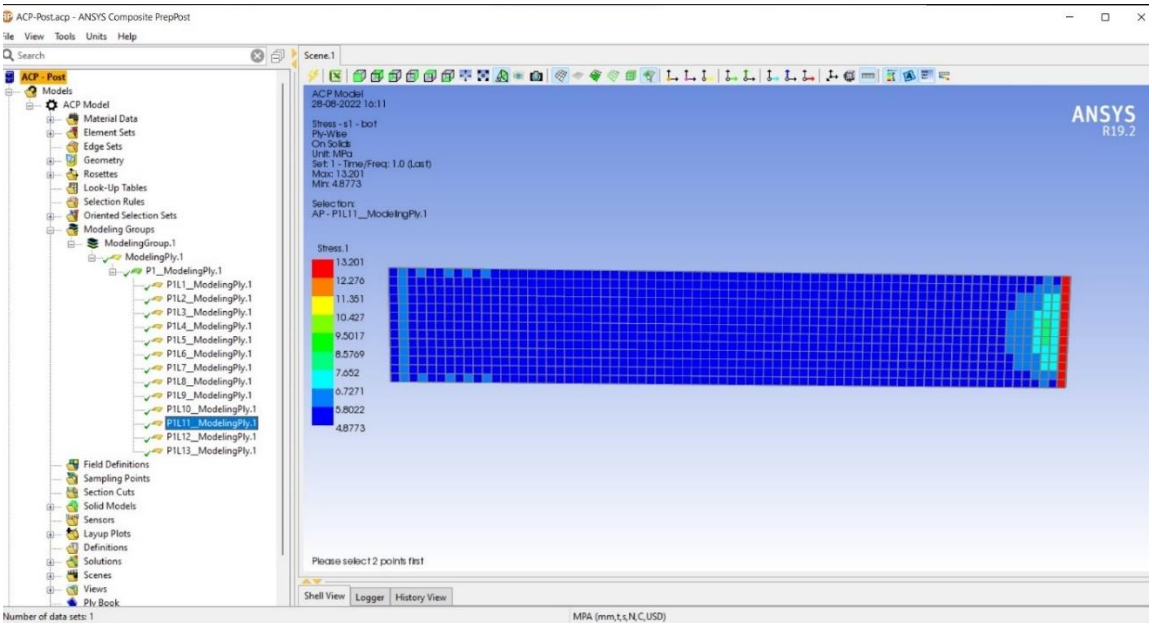


Fig.5.21 Stress distribution in layer 11

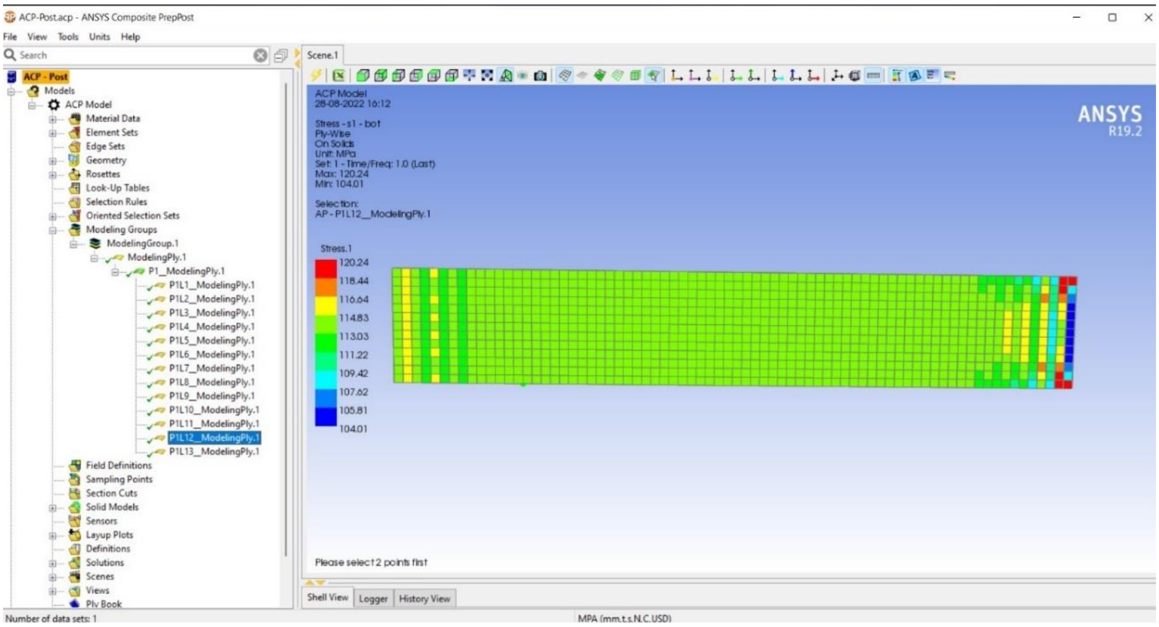


Fig.5.22 Stress distribution in layer 12

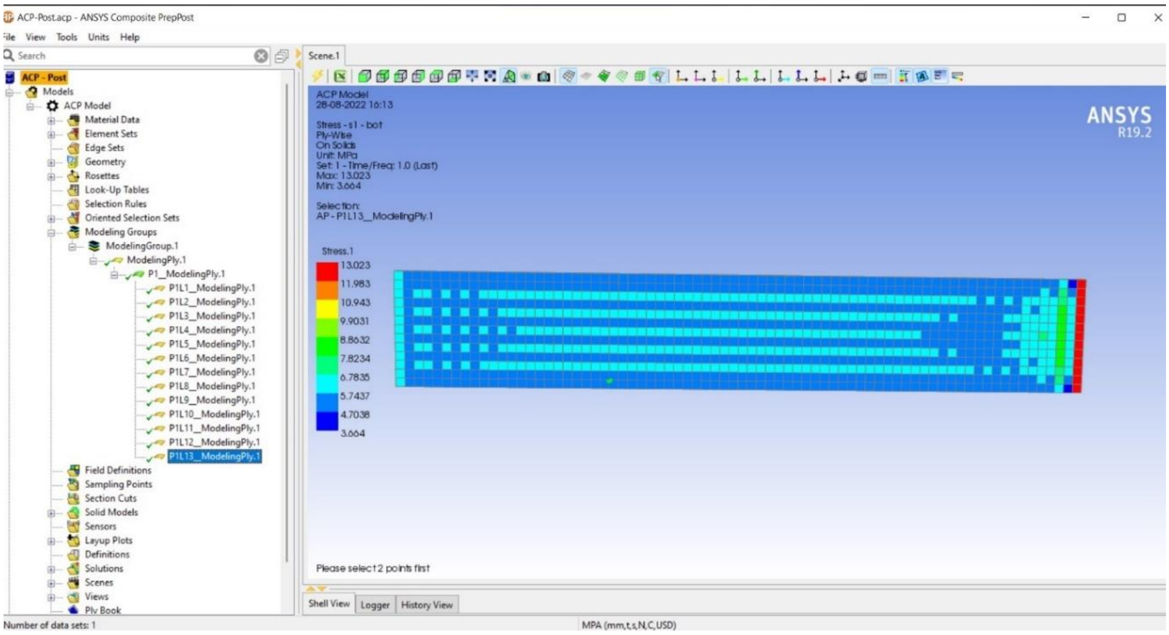


Fig.5.23 Stress distribution in layer 13

5.4 FLEXURAL TEST OF HFRP COMPOSITE IN ANSYS ACP PREPOST

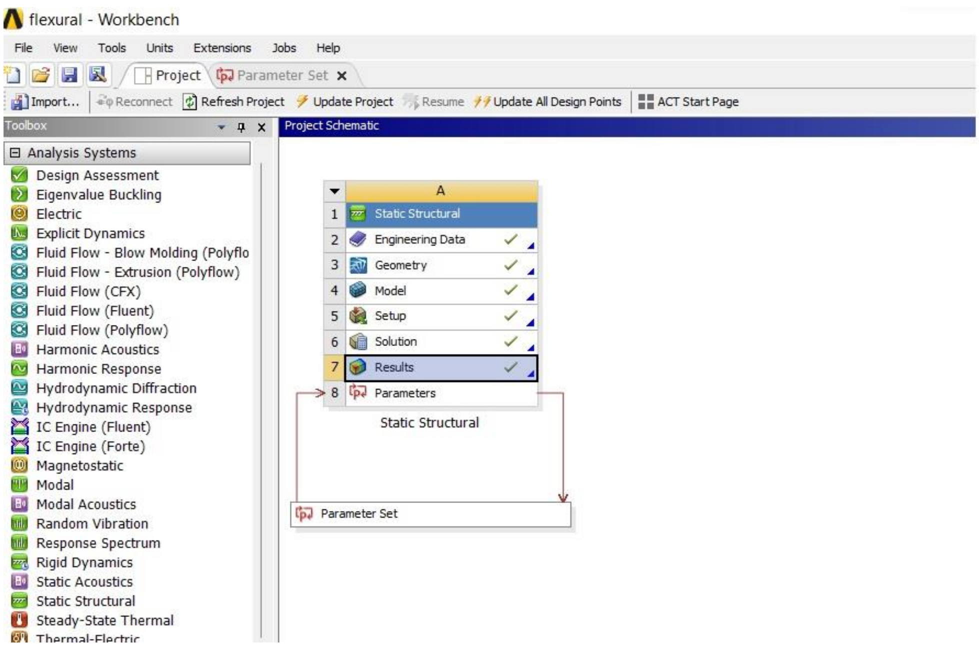


Fig.5.24 Flexural strength analysis in Ansys Static structural

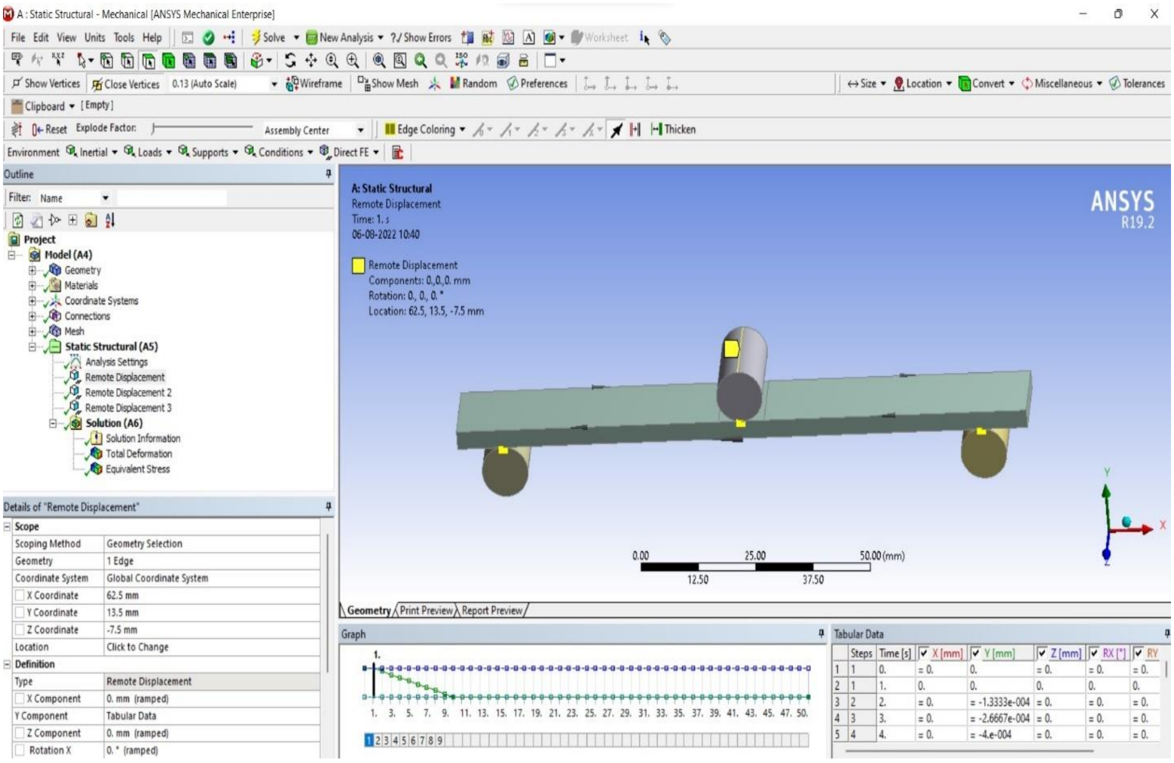


Fig.5.25 Applying Boundary conditions in Ansys Static structural

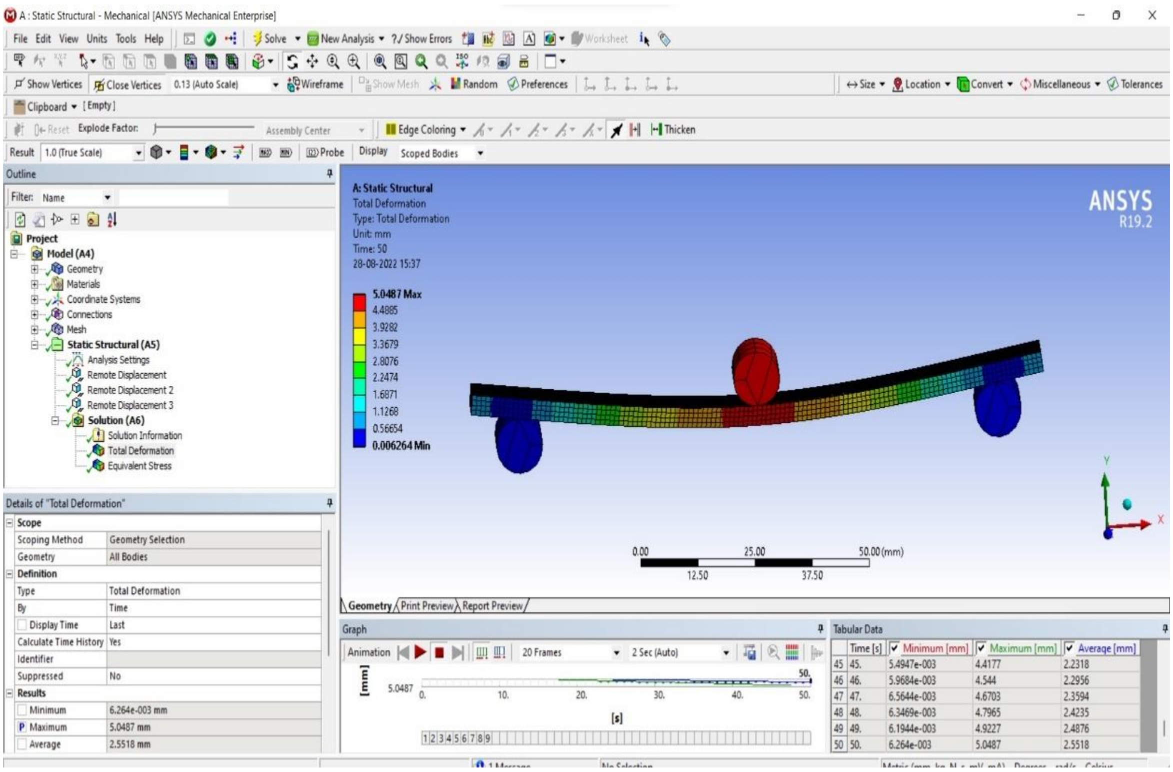


Fig.5.26 Total flexural deformation

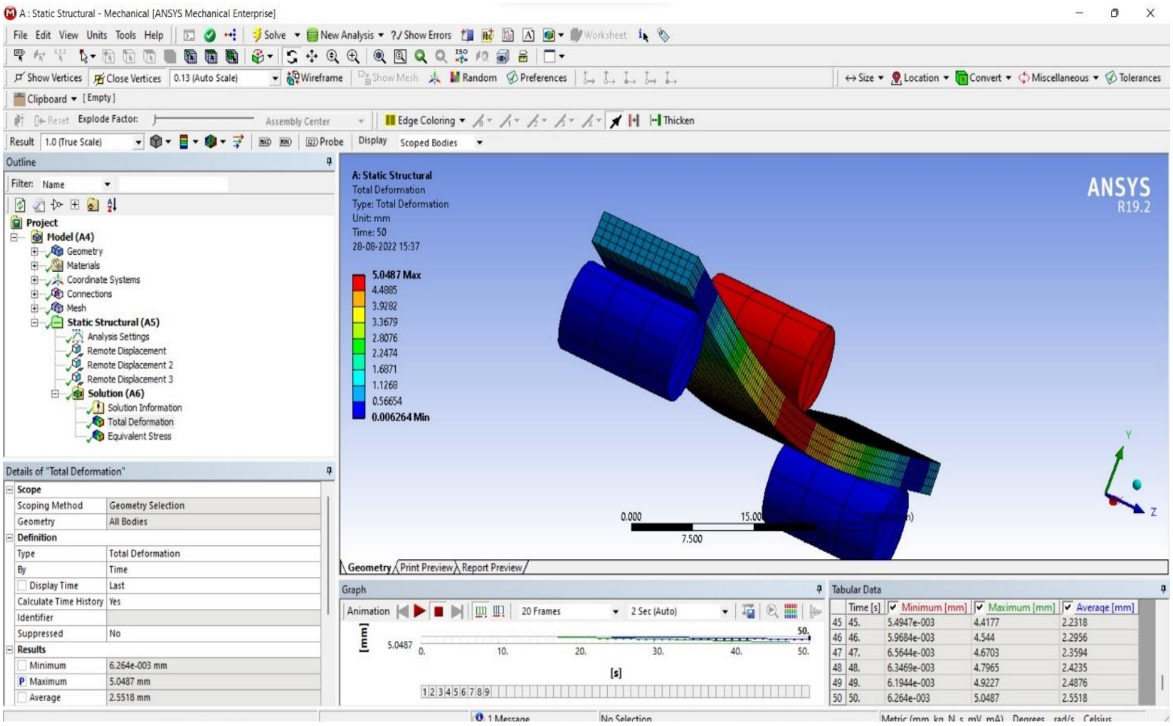


Fig.5.27 Flexural deformation in another view

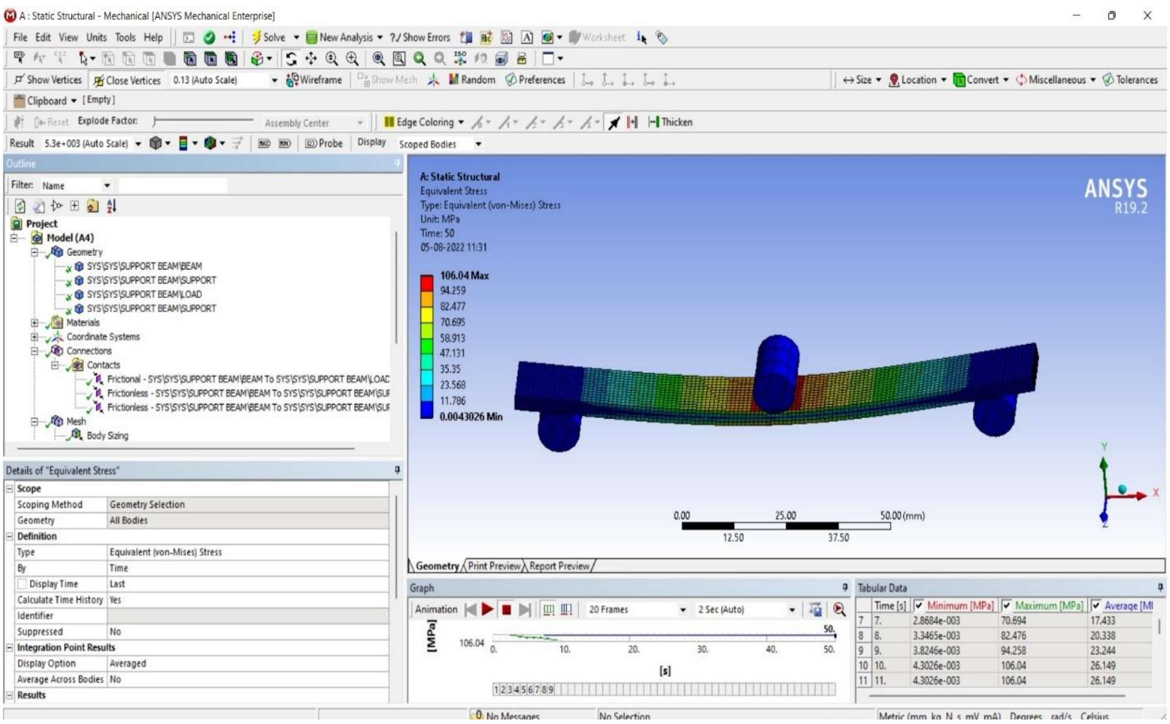


Fig.5.28 Bending stress obtained in ANSYS

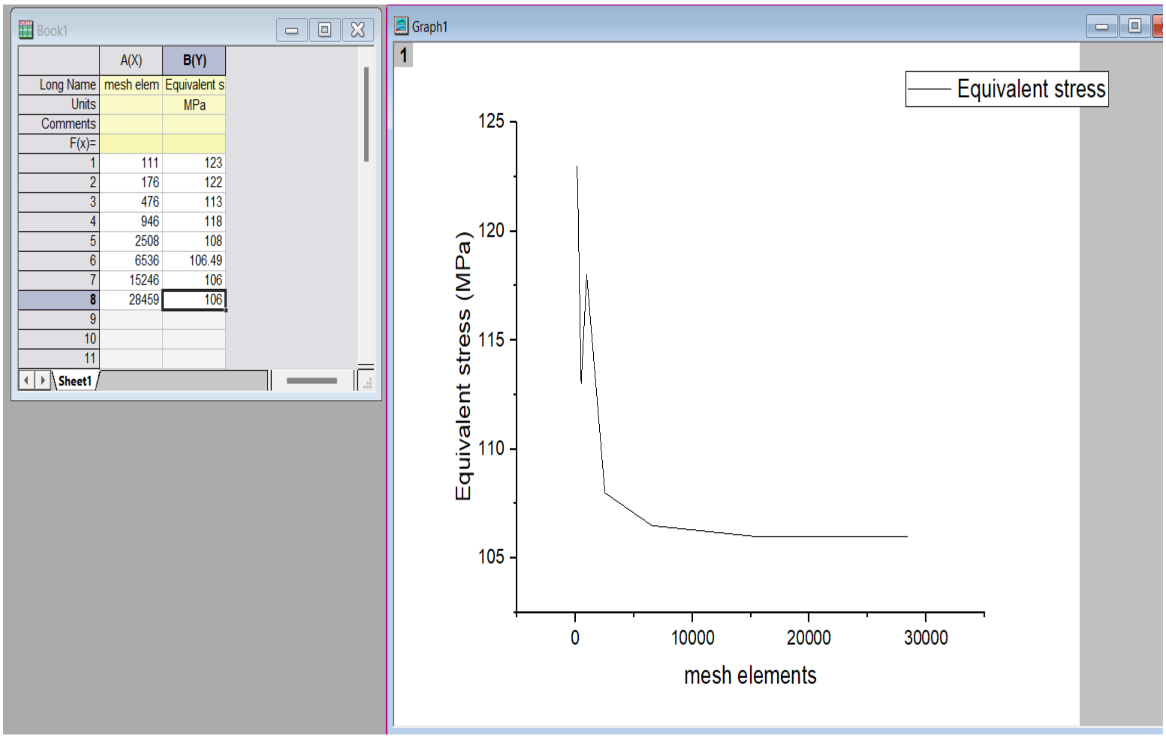


Fig.5.29 Mesh Convergence study

CHAPTER 6

RESULTS AND DISCUSSION

Tests to determine mechanical properties such as tensile strength, flexural strength, Hardness test, Water absorption test were performed on two sets of specimens. One of them is a sample at room conditions. Although shown as 'untreated' (UT) samples, cryo-soaked samples are referred to as 'cryo-treated' (CT). Cryo-treated samples were obtained by submerging or immersing the samples in a freezing bath containing a sufficient amount of Liquid Nitrogen. The test was run Immediately after removing the sample from the cryo-bath.

6.1 TENSILE TEST

Tensile strength of the neat HFRP samples and cryo-treated HFRP samples were obtained by conducting tensile test in an UTM, according to the ASTM D3039 standards. The tests were done for samples at room temperature as well as for the cryo-treated samples. The tensile strength values of untreated (UT) and cryo- treated (CT) samples are shown in the Table 6.1

Table 6.1 Tensile strength values

Sample type	Test Method	Tensile stress (MPa)	Average tensile strength (MPa)
Untreated HFRP	ASTM 3039	70, 72, 68, 71, 69	70
Cryo-treated HFRP	ASTM 3039	66, 67, 68, 69, 70	68

The breaking load for neat HFRP is higher than that of cryo-treated samples. The brittle property of fibers was enhanced by the cryo-treatment process which leads to the reduction in tensile strength. Due to this brittleness of HFRP cured after cryo-treatment which causes reduction in tensile properties. So, the average tensile strength obtained from the neat sample exhibit larger value compare to the cryo-treated HFRP sample.

6.2 THREE-POINT BENDING TEST

The ultimate load required for the fracture of Cryo-treated sample is high compared to neat sample. Cryo-treatment causes micro cracking on the surface of the Hemp fiber which enhance the bonding between with the matrix phase. Due to this increase in frictional bonding interfacial strength of fiber matrix interface increases which causes the increase of flexural strength in cryo- treated sample.

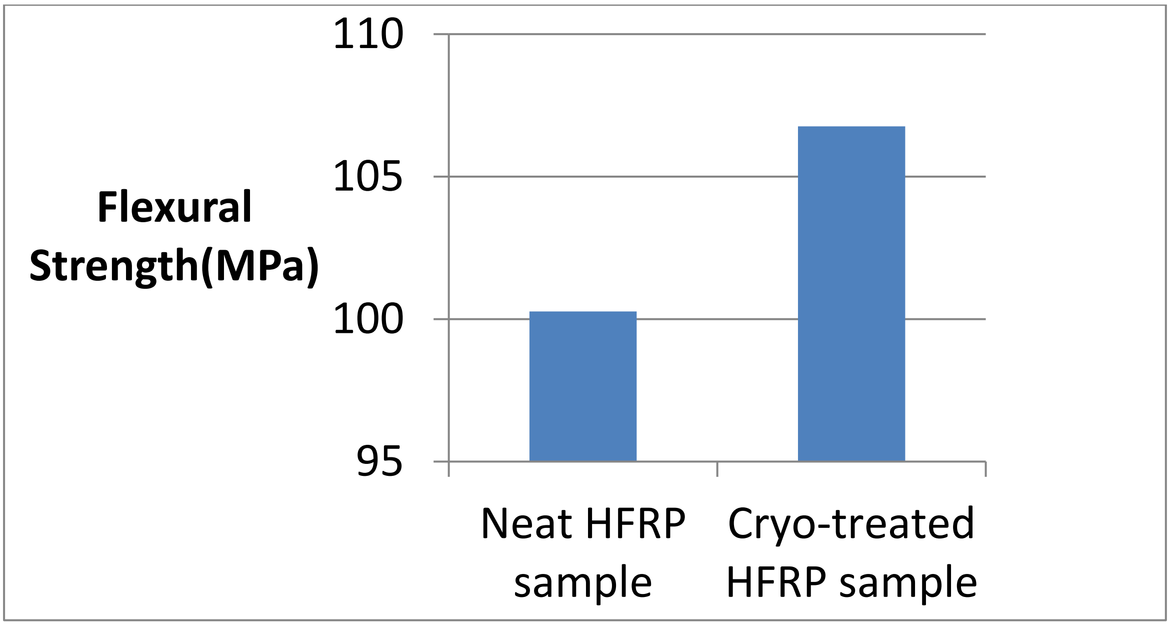


Fig.6.1 Bar graph showing bending stress

6.3 ROCKWELL HARDNESS TEST

Table 6.2 Rockwell hardness values

SAMPLE	LOAD (Kg)	HARDNESS VALUE (RHN)	MEAN VALUE
NEAT HFRP	100	27, 33, 22, 28, 27, 28, 27, 28	27.5
CRYO-TREATED HFRP	100	33, 35, 38, 33, 38, 36, 35, 36	35.5

The Hardness value for cryo-treated HFRP sample is higher than that of neat sample. Cryo-treatment on composites has helped in increasing the hardness on composites due to Improvement in wear resistance.

6.4 WATER ABSORPTION TEST

Cryo-treated HFRP sample shows better water-resistant behaviour than neat sample. During cryogenic treatment, the hemicellulose and pectin content from Hemp fiber surface removed partially which cause a reduction in the water absorption rate.

Table 6.3 Water absorption percentage values

SAMPLE	m_1 (gm)	m_2 (gm)	Percentage of water absorption (W%)
Neat HFRP	45.75	47.32	3.43
Cryo-Treated HFRP	55.41	57.22	3.285

CHAPTER 7

COST ANALYSIS AND GANTT CHART

7.1 COST ANALYSIS

Table 7.1 Cost analysis.

Type of expenditure	Specification/Items	Estimate amount (Rs)	Actual amount (Rs)
DGEBA Epoxy Resin	2 litres	1600	1534
Hemp fiber mat twill type 100% purity	5 meters	6800	6751
Raw Materials	Scissors, brush, Rubber mesh	1000	650
Acetone	1 litre	1000	791
Peel ply	1 meter	300	300
Wax	200 grams	100	100
Testing	Hardness, Tensile, Flexural	2000	1500
Miscellaneous			700
Total		12800	12326

Table 7.1 shows the estimated budget for the experimental investigation and the overall expenses of the study. The overall expense of the work does not exceed the estimated budget even though some miscellaneous expense occurs and was budget friendly.

7.2 GANTT CHART

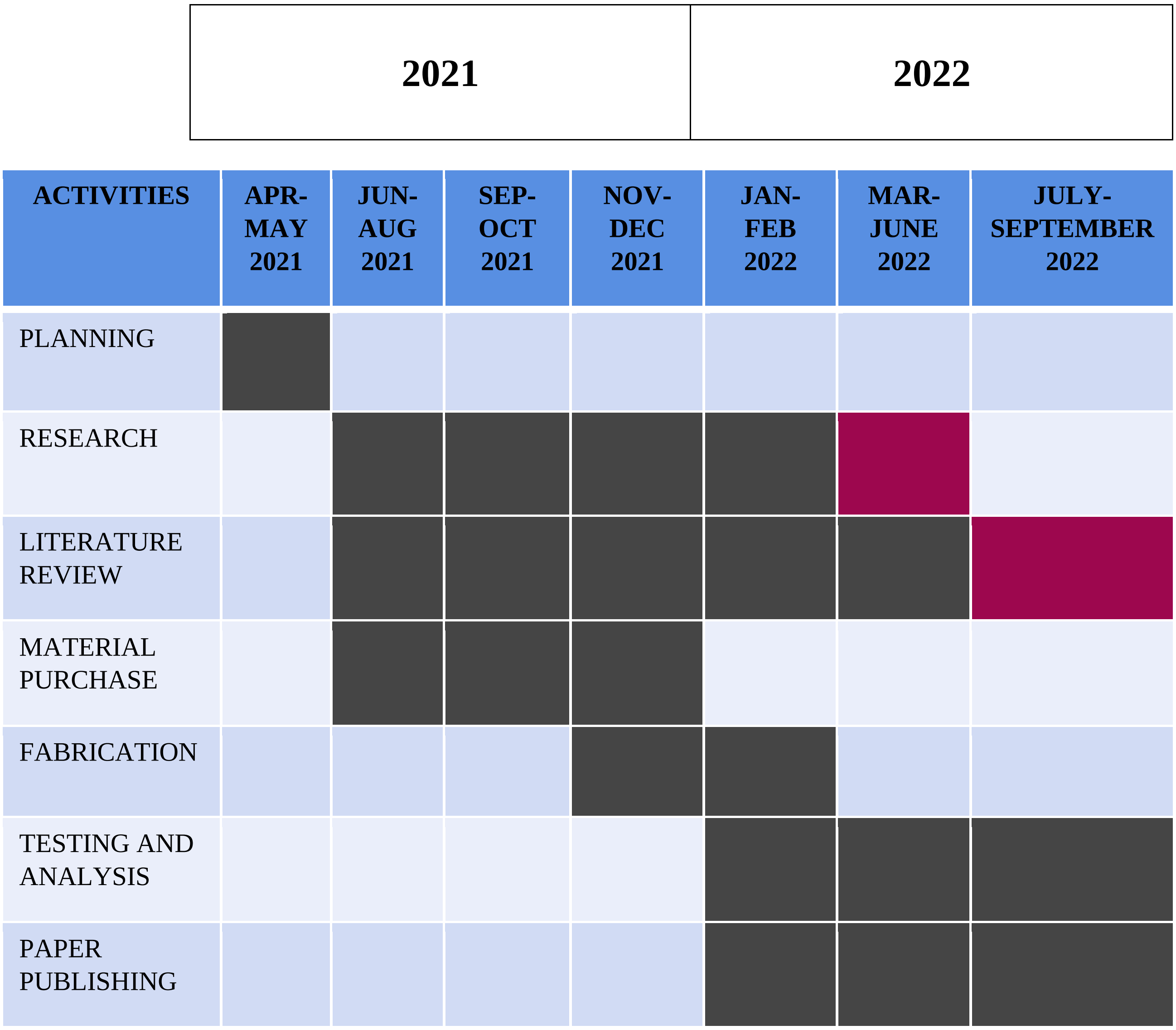


Fig.7.1 Gantt chart

Fig 7.1 shows the Gantt chart form, which represents the total timeline indicating the time of beginning and ending of each stage in the experimental investigation study. It takes around 16 months to complete the entire investigation.

CHAPTER 8

CONCLUSION

The production of high strength-to-weight ratio-based natural FRP composites is of elevated academic and industrial importance when considering low-cost, highly effective curing techniques. Because of their ease of molding, light weight, biodegradability, eco-friendly, chemical resistance, physical and mechanical qualities, excellent bonding of the substrate to the fibers, and capacity to be employed in a wide range of applications. The experimental study and analysis results shows the following conclusions.

- The tensile strength of cryo-treated HFRP is 68 MPa whereas the neat sample shows a value of 70 MPa.
- The brittle property of fibers was enhanced by the cryo-treatment process which leads to the reduction in tensile strength.
- The flexural strength of cryo-treated HFRP is 106 MPa whereas in the neat sample the value is 101 MPa.
- Due to this increase in frictional bonding interfacial strength of the fiber-matrix interface increases which causes the increase of flexural strength in the cryo-treated sample.
- The hardness value of cryo treated sample is 35.5 RHN and for neat HFRP is 27.5 RHN.
- Cryo-treatment on composites has helped in increasing the hardness of composites due to Improvement in wear resistance.
- Cryo-treated HFRP sample shows better water-resistant behaviour than the neat sample.
- During cryogenic treatment, the hemicellulose, lignin, and pectin content from Hemp fiber surface were removed partially which cause a reduction in water absorption rate.
- Analysis on ACP pre-post also shows a similar range of value for tensile and flexural strength.

REFERENCES

1. **Venkatesh.B, Sathyapal Reddy.L, Sathish Kumar.K, Sudheer Gupta.N** (2016), Fabrication and testing of hemp fiber reinforced epoxy composites. Volume: 02 Issue: 02 June 2016 ISSN: 2394 – 4854
2. **Taneli Väisänena, Paolo Batello, Reijo Lappalainen, Laura Tomppo** (2018), Modification of hemp fibers (Cannabis Sativa L.) for composite applications. Industrial Crops & Products 111(2018) 422-429
3. **Anna Carolina C. Neves, Lázaro A. Rohena, Dhyemila P. Mantovani,** (2020), Comparative mechanical properties between biocomposites of Epoxy and polyester matrices reinforced by hemp fiber. J MATER RES TECHNOL. 2020;9(2):1296-1304.
4. **K. Venkatesan, K. Ramanathan, R. Vijayanandh, S. Selvaraj, G. Raj Kumar, M. Senthil Kumar,** (2019), Comparative structural analysis of advanced multi-layer composite materials. Materials today proceedings. https://doi.org/10.1016/j.matpr.2019.11.247
5. **Reza Beigpour, Hassan Shokrollahi, S. Mohammad Reza Khalili,** (2021), Experimental and numerical analysis of a biodegradable hybrid composite under tensile and three-point bending tests. Composite Structures 273(2021) 114255.
6. **Jayalin.D, Prince Arulraj. G, Karthika.V,** (2015), Analysis of composite beam using ansys. eISSN: 2319-1163
7. **Asim Shahzad,** (2011), Hemp fiber and its composites − a review. Journal of Composite Materials DOI: 10.1177/0021998311413623
8. **G. Caprino, L. Carrino, M. Durante, A. Langella, V. Lopresto,** (2015), Low impact behaviour of hemp fiber reinforced epoxy composites, Composite Structures

doi: http://dx.doi.org/10.1016/ j. compstruct.2015.08.029

9. **Alok Kumar Vishwakarma, Dr.Dharamvir Mangal**,(2020) Hemp fiber reinforced –graphene composite material Volume 8, Issue 5 May 2020 ISSN: 2320-2882.
10. **Pankaj Lahariya, Dushyant Dwivedi,** (2018), Comparative Analysis of simulation of composites material with ansys. IJARIIE-ISSN(O)-2395-4396
11. **H. N. Dhakal, Z. Zhang,** (2015). The use of hemp fibers as reinforcements in composites. DOI: 10.1533/9781782421276.1.86.
12. **N. Murugu Nachippan, Mathew Alphonse, V.K Bupesh Raja, Soma Shasidhar.** (2020). Experimental investigation of Hemp fiber hybrid composite material for automotive application. Materials Today: Proceedings
13. **Mohammad Khoirul Huda, Indah Widiastuti** (2020) Natural Fiber Reinforced Polymer in Automotive Application: A Systematic Literature Review, Journal of Physics 1808 (2021) 012015, doi:10.1088/1742-6596/1808/1/012015
14. **Venkatesh Naik, Mohan Kumar, Vijayananda Kaup** (2022) A Review on Natural Fiber Composite Materials in Automotive Applications Eng. Sci., 2022, 18, 1–10, DOI: https://dx.doi.org/10.30919/es8d589
15. **S.B. Singh, Sudhir Vummadisetti, Himanshu Chawla** (2019). Assessment of interlaminar shear in fiber reinforced composite materials, Journal of Structural Engineering Vol. 46
16. **Muhammad Yasir Khalid, Ans Al Rashid, Zia Ullah Arif** (2021) Natural fiber reinforced composites: Sustainable materials for emerging applications. https://doi.org/10.1016/j.rineng.2021.100263
17. **James Holbery, Dan Houston** (2006) Natural-Fiber-Reinforced Polymer Composites in Automotive Applications.
18. **Sanjaykumar M Sajjan, Vittal Kumar A Bongale, Dr. B Yogesha** (2020). Natural Fiber Reinforced Polymer Composites For Automobile Applications: Recent Trends,

International Research Journal of Engineering and Technology e-ISSN: 2395-0056.

19. **Mark C. Symington, W.M. Banks, Opukuro David West, R.A. Pethrick** (2009) Tensile Testing of Cellulose Based Natural Fibers for Structural Composite Applications, Journal of Composite Materials, DOI: 10.1177/0021998308097740.
20. **Sukhdeep Singh, Dharmpal Deepak , Lakshya Aggarwal , V.K. Gupta** (2014) Tensile and flexural behavior of hemp fiber reinforced virgin recycled HDPE matrix composites Procedia Materials Science 6 (2014) 1696 – 1702, doi: 10.1016/j.mspro.2014.07.155.
21. **Sadik Husan, Mohd. Ziaul Haq** (2019) Study of Water Absorption Behaviour of Natural Fiber Reinforced Composites IJSDR Volume 4, Issue 9 ISSN: 2455-2631.
22. **Raghavendra. S., Satish. N. , Ajaykumar B.S. , Dr. Girish T.R.** (2019) Effect of Deep cryotreatment on Hardness and Tensile strength of Aluminium 6061-Sic composites, International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14
23. **Zhirafar S., Rezaeian A., Pugh M.,** (2007) Effect of cryogenic treatment on the mechanical properties of 4340 steel, Journal of Materials Processing Technology,186: (1-3),298-303
24. **Lulay K.E., Khan K., and Chaaya D. (**2002) The Effect of Cryogenic Treatments on 7075 Aluminum Alloy, Journal of Materials Engineering and Performance,11(5) 479-480
25. **Hai Deng, Xinpei Wei, Chao Wang, Jinghao Yang, and Zhigang Li** (2021) Effects of cryogenic treatment and interface modifications of basalt fiber on the mechanical properties of hybrid fiber-reinforced composites e-Polymers 2021; 21: 625–635 https://doi.org/10.1515/epoly-2021-0066
26. **Yogita U. Medhane, Poonam S. Talmale** (2017) Comparative Analysis of Composite Materials by Using Finite Element Method (IJERT) ISSN: 2278-0181,

Vol. 6

27. **G. Venkatachalam, A. Gautham Shankar, Dasarath Raghav** (2015) Flexural analysis of palm fiber reinforced hybrid polymer matrix composite, Materials Science and Engineering 87, doi:10.1088/1757-899X/87/1/012036.
28. **Aziz, S.H., Ansell, M.P**., (2004) The Effect of Alkalization and Fiber Alignment on the Mechanical Thermal Properties of Kenaf and Hemp Bast Fiber Composite. Part 1- Polyester Resin Matrix. Composites Science Technology 64, 1219-1230.
29. **Myisha Ahmed Chowdhury, Shafiul Hossain** (2020) A Review on Tensile and Flexural Properties of Fiber-Reinforced Polymer Composites, IOSR Journal of Polymer and Textile Engineering (IOSR-JPTE) e-ISSN: 2348-019X, Volume 7.
30. **H. Ku, H. Wang, N. Pattarachaiyakoop, M. Trada** (2011) A review on the tensile properties of natural fiber reinforced polymer composites Composites: Part B 42 (2011) 856–873

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