DESIGN AND ANALYSIS OF INNOVATIVE HYBRID FIBRE COMPOSITE - IMPLEMENTING CORRECTIVE MEASURES FOR AIRCRAFT ISSUES

A DESIGN PROJECT REPORT

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BONAFIDE CERTIFICATE

Certified that this project report titled "**DESIGN AND ANALYSIS OF INNOVATIVE HYBRID FIBRE COMPOSITE - IMPLEMENTING CORRECTIVE MEASURES FOR AIRCRAFT ISSUES** " is the bonafied work of **"J.ALWIN (730921101004) , M.GOKUL (730921101014) , J.JAYASEELAN (730921101019) , KUMBARA RANGANATHA (730921101024)** who carried out the project under my supervision. Certified further, that to the best of my knowledge the work reported here in does not form part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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DECLARATION

We jointly declare that the project report on **"DESIGN AND ANALYSIS OF INNOVATIVE HYBRID FIBRE COMPOSITE - IMPLEMENTING CORRECTIVE MEASURES FOR AIRCRAFT ISSUES"** is the result of original work done by us and best of our knowledge, similar work has not been submitted to **"ANNA UNIVERSITY CHENNAI"** for the requirement of Degree of B.E Aeronautical Engineering.

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ABSTRACT

To give solutions for the material problems in roof panel and overhead bins of an aircraft by using composite. This research presents the design and analysis of a novel hybrid fiber composite solution addressing critical challenges in aircraft roof panel structural integrity, weight reduction, and sustainability. The proposed composite integrates carbon, glass, and aramid fibers with advanced polymers to create a lightweight, high-strength, and durable material. Finite Element Analysis (FEA) and simulation testing were employed to evaluate the mechanical properties, damage tolerance, and stability of the composite.The increasing demand for lightweight, high-strength materials in the aerospace industry has driven the development of innovative composite materials. This research presents the design and analysis of a hybrid fiber composite solution aimed at addressing structural challenges in aircraft. Hybrid composites, combining different types of fibers such as carbon, glass, and aramid, are explored to achieve a balance of stiffness, strength, and impact resistance while maintaining low weight. The study employs finite element analysis (FEA) to evaluate the mechanical properties and performance of these composites under various loading conditions encountered in aircraft roof panels. The design focuses on optimizing the fiber orientation and matrix selection to enhance durability, fatigue resistance, and damage tolerance. Simulation validation through mechanical testing, such as tensile, compression, and impact tests, is conducted to verify in both simulation results.

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LIST OF SYMBOLS AND ABBREVIATIONS

PMC	-	Polymer matrix composite
CMC	-	Ceramic matrix composite
MMC	-	Metal matrix composite
CFRC	-	Carbon fibre reinforced composite
SGF	-	Structural glass fibre
CFRP	-	Carbon fibre reinforced polymer
ECH	-	Epichlorohydrin
FA	-	Flyash
FBC	-	Fluidized bed combustion
Mpa	-	Megapascal
Gpa	-	Gigapascal
g/cm3	-	gram per cubic centimetre
N	-	Newton
mm	-	millimetre

1. INTRODUCTION

1.1 COMPOSITE MATERIALS

Composite materials are the combination of two or more materials that have their unique properties. Different types of composite materials are in use today, meeting the challenges and requirements of a technologically advanced world. For example applications of composite materials can be found ranging from space shuttles to huge construction sites. Another reason for the increase in the uses of composite materials, apart from the combined characteristics of materials are properties, such as being less expensive, light in weight, and stronger when compared to common materials. Therefore, the applications of composite materials are found in diverse fields falling under the material application definition i.e. requiring materials to achieve the making of an object with specified properties.

The composite material definition can be simply made from the introduction of composite materials. Thus, composite materials are the materials that are produced from the combination of two or more constituent materials. Although the constituent materials might have different and unique properties, they are merged together to form material unlike the individual materials and having the beneficial properties of all the constituents. The difference between composite materials and mixtures and solid solutions is that within the end product the individual components remain separate and distinct. Thus, composite materials meaning includes in the characteristics of composite materials, the unique properties of a material without actually fusing them into one another.

Some of the typical examples of composite materials include:

- Reinforced concrete,
- Wooden composite materials
- Ceramic material composites

As understood from the composite material definition, a composite material is made up of two or more constituent materials. The classification of composite materials depends upon the two types of categories of constituent materials, which are the matrix and the reinforcement. An optimal combination of a variety of matrix and reinforcement materials is used to make composite materials that impart the required characteristics of composite materials. The matrix provides support to the reinforcement and the reinforcement, in turn, imparts its own physical and mechanical properties to the matrix. Thus, both the matrix and the reinforcement provide durability, sustainability, and utility to the composite material meaning. For making the composite material, the reinforcement is placed on a mould surface or cavity. Depending on the matrix material, it is introduced to the reinforcement after or before being placed in the mould. Following this, the matrix undergoes a melding event setting up the required shape of the composite material. This melding can happen in several ways, such as solidification in the case of melting thermoplastic polymer matrix and chemical polymerization in the case of the thermoset polymer matrix. This process is the formation step of engineered composite materials. The moulding methods used depend on the requirements of the end-product. The nature of matrix and reinforcement materials influence this step which later defines the characteristics of composite materials.

Figure 1.1 Fabrication of composite material

PROPERTIES OF COMPOSITE MATERIAL

High Strength to Weight Ratio

Fiber composites are extremely strong for their weight. By refining the laminate many characteristics can be enhanced. A common laminate of say 3mm Chopped strand mat, is quite flexible compared to say a 3 mm ply. However it will bend a long way more than the ply before yielding. Stiffness should not be confused with Strength. A carbon fiber laminate on the other hand, will have a stiffness of many times that of mild steel of the same thickness, increased ultimate strength, yet only be less than 1/4 of its weight.

Light Weight

A standard Fiberglass laminate has a specific gravity in the region of 1.5, compared to Alloy of 2.7 or steel of 7.8. When you then start looking at Carbon laminates, strengths can be many times that of steel, but only a fraction of the weight.

Fire Resistance

Fire Retardant - Are self-extinguishing laminates, usually made with chlorinated resins and additives such as Antimony trioxide. These release CO_2 when burning so when the flame source is removed, the self-extinguish.

Fire Resistant - More difficult and made with the likes of Phenolic Resins. These are difficult to use, are

cured with formaldehyde, and require a degree of post curing to achieve true fire resistance.

Electrical Properties

Fiberglass Developments Ltd produced the Insulator Support straps for the Tranz Rail main trunk electrification. The straps, although only 4mm thick, meet the required loads of 22kN, as well as easily meeting insulation requirements.

Low Thermal Conductivity

Fiberglass Developments has been involved in the development and production of specialized meat containers which maintain prime cuts of chilled meat at the correct temperature for Export markets. They are manufactured using the RTM process, with special reinforcing and foam inserts.

Design Flexibility

Because of the versatility of composites, product design is only limited by your imagination.

ADVANTAGES OF COMPOSITE MATERIAL

- A higher performance for a given weight leads to fuel savings. Excellent strength-to weight and stiffness-to-weight ratios can be achieved by composite materials. This is usually expressed as strength divided by density and stiffness (modulus) divided by density. These are so-called "specific" strength and "specific" modulus characteristics.

- Laminate patterns and ply buildup in a part can be tailored to give the required mechanical properties in various directions.

- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.
- Part count is reduced.
- Production cost is reduced. Composites may be made by a wide range of processes.

DISADVANTAGES OF COMPOSITE MATERIAL

- Composites are more brittle than wrought metals and thus are more easily damaged. Cast metals also tend to be brittle.
- If rivets have been used and must be removed, this presents Problems of removal without causing further damage.
- Repair at the original cure temperature requires tooling and pressure.
- Composites must be thoroughly cleaned of all contamination before repair.
- Composites must be dried before repair because all resin matrices and some fibers absorbmoisture.

APPLICATION S OF COMPOSITE MATERIALS

- **Aerospace**

Thermoset composites are being specified for wings, fuselages, bulkheads, and other applications in commercial, civilian and military aerospace applications.

- **Automotive**

  Composites are now being used in vehicle and equipment applications, including, panels, frames, interior components and other parts.

- **Civil Infrastructure**

  Some composite infrastructure applications include buildings, roads, bridges and pilings.

- **Corrosive Environments**

  Composites are ideal for applications in corrosive environments, such as chemical processing plants, pulp and paper converting, oil and gas refineries and water treatment facilities. Common applications include fans, grating, tanks, ducts, hoods, pumps and cabinets.

- **Electrical**

  With strong dielectric properties including arc and track resistance, Thermoset components include substation equipment, microwave antennas, standoffs and pole line hardware and printed wiring boards. Applications and components include switchgear, motor controls, standoff insulators, control system components, circuit breakers, arc chutes, arc shields, terminal blocks, terminal boards, metering devices, bus supports and lighting components.

- **Marine**

  With their corrosion resistance and light-weighting attributes, Marine composite applications include boat hulls, bulkheads and other components for military, commercial and recreational boats and ships.

1.2 REINFORCEMENT

Crack propagation is prevented considerably, while rigidity is added normally by the reinforcement. Thin fibers can have very high strength, and they can increase substantially the overall properties of the composite provided they are linked mechanically to the matrix. Fiber-reinforced composites have two types, and they are short fiber-reinforced and continuous fiber-reinforced. Sheet moulding and compression moulding operations usually use the long and short fibers. These are available in the form of chips, flakes and random mate (which also can be produced from a continuous fiber laid randomly till the desired thickness of the laminate/ply is attained). A laminated or layered structure is usually constituted in continuous reinforced materials. The continuous and woven fiber styles are usually available in various forms, being pre-impregnated with the given matrix (resin), dry, uni-directional tapes of different widths, plain weave and harness satins, braided, and stitched.

Reinforcement uses some of the common fibers such as carbon fibers, cellulose (wood/paper fiber and straw), glass fibers and high strength polymers, for example, aramid. For high- temperature applications, Silicon carbide fibers are used.

FIBRES AND ITS TYPES

Fiber reinforced composites have emerged as viable structural materials due to their advantageous stiffness, thermal expansion, strength and density properties. These properties are derived in a composite through the dominance of high stiffness/ high strength fibers over relatively soft, low strength matrix. Good fibrous reinforcements are generally brittle in character; they deform.

1. **Natural Fibers**

Natural fibers can be classified according to their origin. The vegetable, or cellulose-base, class includes such important fibers as cotton, flax, and jute. The animal, or protein-base, fibers include wool, mohair, and silk. An important fiber in the mineral class is asbestos.

- Cashmere
- Cotton
- Hemp
- Linen
- Silk
- Wool

2. **Man-Made fibers**

The synthetic man-made fibers include the polyamides (nylon), polyesters, acrylics, polyolefin, vinyl, and elastomeric fibers, while the regenerated fibers include rayon, the cellulose acetates, the regenerated proteins, glass, and rubber fibers. The term synthetic describes any manufactured fiber made from chemical synthesis. Synthetic materials vary in their properties. Many are engineered to imitate and replace natural materials. The benefit of engineered fibers is that special qualities can be added and undesirable traits eliminated. Synthetic fibers can provide specific characteristics such as high absorbency or the ability to hold pleats. The most common synthetic fibers in 20th- century collections are nylon, polyester, acrylic.

- Carbon fibers
- Kevlar
- Spandex
- Polyester
- Nylon
- Acrylics
- Rayon

1.3 MATRIX

The matrix is basically a homogeneous and monolithic material in which a fiber system of a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, serves to transfer load, and provides finish, texture, color, durability and functionality.

TYPES OF MATRIX COMPOSITES

There are three main types of composites based on the type of matrix they employ – polymer matrix composites (PMC), ceramic matrix composites (CMC), and metal matrix composites (MMC).

CERAMIC MATRIX COMPOSITES

Ceramic matrix composites (CMCs) are a subgroup of composite materials. They consist of ceramic fibers embedded in a ceramic matrix, thus forming a ceramic fiber reinforced ceramic (CFRC) material. The matrix and fibers can consist of any ceramic material. CMC materials were designed to overcome the major disadvantages such as low fracture toughness, brittleness, and limited thermal shock resistance, faced by the traditional technical ceramics.

METAL MATRIX COMPOSITES

Metal matrix composites (MMCs) are composite materials that contain at least two constituent parts – a metal and another material or a different metal. The metal matrix is reinforced with the other material to improve strength and wear. Where three or more constituent parts are present, it is called a hybrid composite. In structural applications, the matrix is usually composed of a lighter metal such as magnesium, titanium, or aluminum. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common. Typical MMC's manufacturing is basically divided into three types: solid, liquid, and vapor. Continuous carbon, silicon carbide, or ceramic fibers are some of the materials that can be embedded in a metallic matrix material. MMCs are fire resistant, operate in a wide range of temperatures, do not absorb moisture, and possess better electrical and thermal conductivity. They have also found applications to be resistant to radiation damage, and to not suffer from outgassing. Most metals and alloys make good matrices for composite applications.

POLYMER MATRIX COMPOSITES

Polymer matrix composites (PMCs) can be divided into three sub-types, namely, thermoset, thermoplastic, and rubber. Polymer is a large molecule composed of repeating structural units connected by covalent chemical bonds. PMC's consist of a polymer matrix combined with a fibrous reinforcing dispersed phase. They are cheaper with easier fabrication methods. PMC's are less dense than metals or ceramics, can resist atmospheric and other forms of corrosion, and exhibit superior resistance to the conduction of electrical current.

1.4 RESIN AND TYPES

Secondary metabolites are organic compounds that are produced by bacteria, fungi, and plants. These molecules do not control growth, development, and reproduction directly. They are generally called specialized molecules. These molecules mainly exist as toxins, secondary products or natural products. Resin is a type of secondary metabolite. In this article, we have covered all the important points like Resin definition, the structure of Resin, and its composition.

Types of Resin:

Resin can be divided into two types, depending on the nature of synthesis. Resin is of two types:

- Natural Resin
- Synthetic Resin

Natural Resin

These types of Resin have a natural source. They are obtained from nature. Mostly they originate from the plants. Therefore, it is known as plant Resin. It can be isolated by the whole plant, specific part, or exuded by plants because of injury/incision. Rarely, some natural Resin is obtained from the animal.

Examples of plants from which Resin can be obtained-: Benzoin, ginger, podophyllum, asafoetida, and capsicum.

Examples of the animal from which Resin can be obtained:- Shellac or lac, and fossils.

Synthetic Resin

These types of Resin are produced in the industry. Synthetic Resins are produced by the curing of the rigid polymer. When they undergo a curing process, they contain reactive end groups like epoxides or acrylates. It can be of various types:

1. Thermoplastic Resins
2. Epoxy Resins
3. Casting Resins
4. Epoxy Resins
5. Ion exchange Resins
6. Acetal Resins
7. Acrylic glass

1.5 FILLERS

Composite fillers and reinforcements are used to change and improve the physical and mechanical properties of plastics. Fillers and reinforcements may also be used to lower material costs by reducing the volume of matrix resin required. Fillers are used to modify or enhance properties such as thermal conductivity, electrical resistivity, friction, wear resistance, and flame resistance.

2. LITERATURE SURVEY

Overview of Composites in Aviation: Brief introduction to composite materials and their advantages in aircraft applications, focusing on lightweight, high strength, corrosion resistance, and fatigue performance. Evolution of Composite Roof Panels: The shift from traditional metal alloys to fiber-reinforced composites in roof panels to achieve weight savings and improve durability. Purpose of Using Multi-Material Layers: Explanation of why multiple layers with different materials are used in a single panel for optimized structural performance.

S-Glass Fiber: Properties: Discuss its tensile strength, stiffness, thermal stability, and impact resistance. Compare S-glass with E-glass in terms of durability and weight considerations. Applications in Aerospace: [1] Overview of S-glass applications in aircraft components where high impact resistance and moderate weight savings are needed.Performance in Structural Layers: Evaluation of S-glass as a reinforcing layer to provide impact strength in multilayer composite designs.

Aramid Fiber: Properties: Discuss aramid fibers for their high tensile strength-to-weight ratio, exceptional resistance to wear, low flammability, and energy absorption characteristics. [17] Benefits in Aircraft Applications: [3]Widely used in protective layers, ballistic applications, and honeycomb cores in aerospace structures due to its resilience under stress. Role in New Roof Panel Design: [15]Evaluation of how aramid fiber in the skin layer contributes to weight reduction, damage tolerance, and reduced impact on thermal expansion coefficients.

Carbon Fiber: Properties: Discuss carbon fiber’s high strength-to-weight ratio, exceptional stiffness, and good fatigue resistance, alongside limitations such as cost and brittleness[2]. Applications in Aerospace: Essential in high-performance structures where maximum strength and rigidity are required, including fuselage sections, wings, and tail structures. [13]Integration into Roof Panels: Discussion on the role of carbon fiber in the middle layer of the new design to enhance stiffness and overall panel rigidity.

Design and Simulation Techniques

Multi-Material Layering: Explanation of the multi-material layer approach in composite panels to enhance structural performance. [5] Emphasize how the layering arrangement,S-glass and carbon fiber layers achieves an optimal balance of strength, stiffness, and weight.

Honeycomb and Core Materials: Overview of honeycomb aramid cores versus solid carbon cores. Comparison of how each core material impacts weight, compressive strength, and impact absorption.

Performance and Simulation of Composite Panels [10]

Simulation Testing: Studies on tensile, compressive, and impact tests for panels with mixed layers of aramid, S-glass, and carbon fiber to evaluate durability, stiffness, and failure mechanisms [9].

Similar Applications in Aircraft Design: Case studies where similar composite layering techniques are used in other structural parts, such as control surfaces, fuselage panels, and doors.

Comparative Analysis: [8] Evaluation of weight reduction, fuel efficiency, and performance gains from using layered composites with a mix of aramid, S-glass, and carbon fibers compared to traditional materials.

Limitations and Challenges: Discussion on the trade-offs in using multi-material layers, including increased manufacturing complexity, cost factors, and maintenance challenges.[16]

Summary of benefits derived from the innovative roof panel design with layered aramid, S-glass, and carbon fibers. Potential for further research on optimizing layer sequences and exploring alternative core materials. [18] Future outlook for the integration of mixed-fiber composites in broader aerospace applications as lightweight, high-strength materials evolve.

3. MATERIAL SELECTION

Material used in composite

The composite material consists of the composites in different ratios. In which the reinforced fibre phase was the S-glass fibre, carbon fibre and aramid fibre, the matrix phase was one of the resin called standard epoxy resin and hardener, industrial waste phase was flyash for enhancement.

3.1 S-GLASS FIBRE

A fiberglass is a form of fiber-reinforced plastic where glass fiber is the reinforced plastic. This is the reason perhaps why fiberglass is also known as glass reinforced plastic or glass fiber reinforced plastic. [1] The glass fiber is usually flattened into a sheet, randomly arranged or woven into a fabric. According to the use of the fiberglass, the glass fibers can be made of different types of glass. [16] Fiberglass is lightweight, strong and less brittle. The best part of fiberglass is its ability to get molded into various complex shapes. This pretty much explains why fiberglass is widely used in bathtubs, boats, aircraft, roofing, and other applications. The glass fiber used for the fabrication is show in figure 3.1.

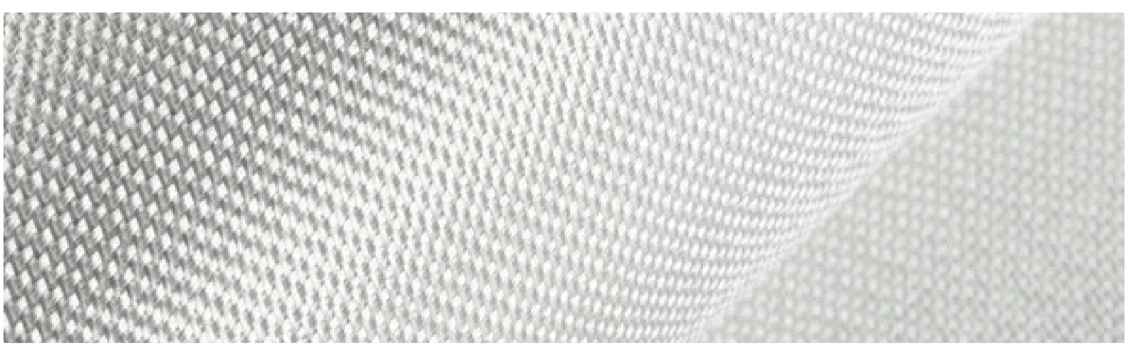


Figure 3.1 S-Glass fibre

3.2 CARBON FIBRE

Carbon fibers are usually combined with other materials to form a composite. For example, when permeated with a plastic resin and baked, it forms carbon-fiber-reinforced polymer (often referred to as carbon fiber), which has a very high strength-to-weight ratio and is extremely rigid although somewhat brittle. [2] Carbon fibers are also composited with other materials, such as graphite, to form reinforced carbon-carbon composites, which have a very high heat tolerance.

Carbon fibers or carbon fibres (alternatively CF, graphite fiber or graphite fibre) are fibers about 5 to 10 micrometers (0.00020–0.00039 in) in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages: high stiffness, high tensile strength, high strength to weight ratio, high chemical resistance, high-temperature tolerance, and low thermal expansion. [13] These properties have made carbon fiber very popular in aerospace, civil engineering, military, motorsports, and other competition sports. However, they are relatively expensive compared to similar fibers, such as glass fiber, basalt fibers, or plastic fibers.

To produce a carbon fiber, the carbon atoms are bonded together in crystals that are more or less aligned parallel to the fiber's long axis as the crystal alignment gives the fiber a high strength-to-volume ratio (in other words, it is strong for its size). [18] Several thousand carbon fibers are bundled together to form a tow, which may be used by itself or woven into a fabric.

Figure 3.2 Carbon fibre

3.3 ARAMID FIBRE

Aramid fibers, short for aromatic polyamide, are a class of heat-resistant and strong synthetic fibers. They are used in aerospace and military applications, for ballistic-rated body armor fabric and ballistic composites, in marine cordage, marine hull reinforcement, as an asbestos substitute,[3] and in various lightweight consumer items ranging from phone cases to tennis rackets. [15]

The chain molecules in the fibers are highly oriented along the fiber axis. As a result, a higher proportion of the chemical bond contributes more to fiber strength than in many other synthetic fibers. Aramids have a very high melting point (>500 °C (932 °F)).

Aramid fiber is an organic fiber of the aromatic polyamide family. It has good mechanical properties in terms of low density, high tenacity, and high impact resistance. [17] Aramid fiber is a good insulator of electricity and heat and is resistant to organic solvents, fuels, and lubricants.

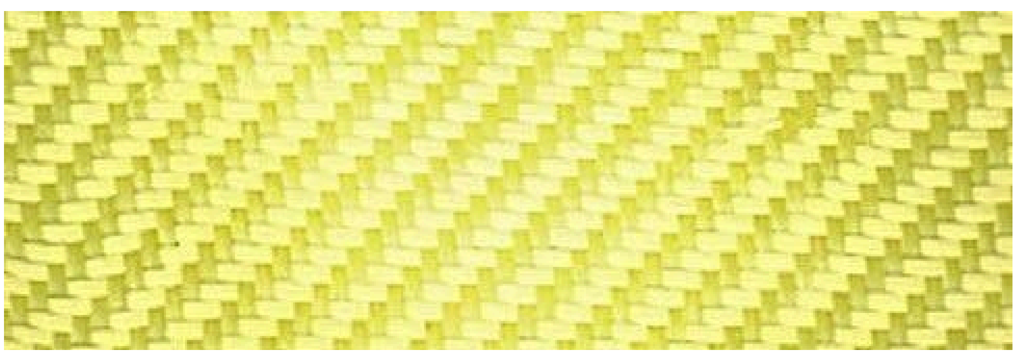


Figure 3.3 Aramid fibre

3.4 EPOXY RESIN

Epoxy resin are categorised as compounds with one or more epoxide (or oxirane) groups. Most epoxies can be categorised as glycidated, epoxied oils or cycloaliphatic resins. The most popular epoxy resins are either diglycidyl ethers of bisphenol A, which is created by reacting bisphenol A (BPA) with epichlorohydrin (ECH). The molecular weight is controlled by adjusting the ratio of ECH to BPA; high ratios generate lower molecular weights. Within this, an increase of BPA adds strength in the form of rigidity and high-temperature characteristics. Conversely, the ECH adds chemical resistance; hydroxyl and epoxy groups add adhesive properties. Curing, also known as hardening, is a vital part of realising the physical and chemical attributes of epoxy. Epoxy resins are no different and curing is often triggered by adding a gardener. Amine- based hardeners are particularly popular. Versus polyester resin curing, where the resin is catalysed by adding a small amount of catalyst (e.g., 1 – 4 % MEKP), epoxies require a curing agent to be added in a significantly higher amount. Typically, this ranges from 1:1 to 2:1 resin to hardener. Further strengthening of the epoxy can be achieved by adding a thermoplastic polymer. The epoxy resin filled with plastic bottle which is used for the fabrication process is show in Figure 3.4.

Figure 3.4 Epoxy resin

3.5 HARDENER

A hardener is a component of certain types of mixtures. In some mixtures a hardener is used simply to increase the resilience of the mixture once it sets. In other mixtures a hardener is used as a curing component. A hardener can be either a reactant or a catalyst in the chemical reaction that occurs during the mixing process. Hardeners are almost always necessary to make an epoxy resin useful for its intended purpose. Without a hardener, epoxies do not achieve anywhere near the impressive mechanical and chemical properties that they would with the hardener. The correct type of hardener must be selected to ensure the epoxy mixture will meet the requirements of the application. Research should always be done on both the resin and the hardener to make sure the final epoxy mixture will perform satisfactorily. Common examples of epoxy hardeners are anhydride-based, amine-based, polyamide, aliphatic and cycloaliphatic. Hardeners are used to cure epoxy resins. However, simply adding a hardener to an epoxy resin may not cause the epoxy mixture to cure quickly enough. If this is the case a different hardener may be required. Also, hardeners with certain additives can be used. The Hardener filled with plastic bottle which is used for the fabrication process is show in Figure 3.4.

Figure 3.5 Hardener

3.6 FLYASH

Fly ash is produced from the combustion of coal in electric utility or industrial boilers. There are four basic types of coal-fired boilers: pulverized coal (PC), stoker-fired or traveling grate, cyclone, and fluidized-bed combustion (FBC) boilers. The PC boiler is the most widely used, especially for large electric generating units. The other boilers are more common at industrial or cogeneration facilities. Fly ashes produced by FBC boilers are not considered in this document. Fly ash is captured from the flue gases using electrostatic precipitators (ESP) or in filter fabric collectors, commonly referred to as baghouses. [4] The physical and chemical characteristics of fly ash vary among combustion methods, coal source, and particle shape.

Fly ash (FA)—a coal combustion residue of thermal power stations—has been recognized as a soil ameliorator throughout the world. Usually, FA contains essential plant micro- and macronutrients and unique physicochemical properties. Besides, several hazardous substances, such as metal(loid)s, organic pollutants, and radioactive elements, are present in FA. FA disposal on land leads to unwanted changes in soil systems, including contamination with hazardous pollutants. Practical value of FA application in land offers extensive chances in soil systems, mainly for nutrient supplementation, pH correction, and ameliorating the soil physical conditions. In general, nitrogen and organic carbon are absent in FA. Moreover, phosphorus is also present in unavailable form.

Figure 3.6 Flyash

3.7 PROPERTY TABULATION

In the table , the properties such as tensile strength, elastic modulus, poisson's ratio and density of the s-glass fiber, carbon fiber, aramid fiber, Epoxy resin , hardener were shown. In this, the tensile strength wear in the unit of Mpa and elastic modulus were in the unit of Gpa, density in terms of g/cm³ whereas the there was no unit for poisson's ratio.

PROPERTY	CARBON FIBRE	ARAMID FIBRE	S-GLASS FIBRE	EPOXY RESIN
Tensile strength	5650 Mpa	3000 Mpa	2000 Mpa	0.11
Elastic modulus	228Gpa	140Gpa	73 Gpa	4.1
Poisson's ratio	0.28	0.62	0.33	0.33
Density	2(g/cm³)	1.44(g/cm³)	2.58(g/cm³)	1.22(g/cm³)

3.7 Properties of material

4. EXPERIMENTAL SETUP AND PROCEDURE

This project main role is to give solutions for the problems occured in roof panel and overhead bins of an aircraft. So, the materials used in the existing panel are altered by giving new materials based upon their properties to solve the problems.

Problems occured in existing panel are:

- cracking and fatigue - roof panel skin
- corrosion - around fasteners, rivets
- delamination - composite skins
- lightining strike damage - causes roof panel damage
- hail damage the roof panel
- water leakage - causes corrosion
- paint & coating degradation - requires repainting
- age related wear

There are three layers in the existing panel as the both skin layers are consists of S-Glass fibre and the middle layer is of honey comb the honey comb structure is made up of aramid fibre. These layers are fabricated by the matrix called phenolic prepreg.

While, considering the problems occured in the existing panel a new type of innovative panel has been made by based upon the properties of the materials.

Innovative panel has five layers in the panel as both skin layers are madeup of aramid fibre , 2nd and 4th layers are madeup of S-Glass fibre and the 3rd middle layer is madeup of carbon fibre.

Aramid fibres are given to skin for attaining better corrosion resistance and to prevent the water leakage. S-Glass fibre are given to prevent the cracks and fatique occured in roof of the aircrafts.

Carbon fibre plays the most vital role in the innovative panel to give more strength to withstand the compression and impacts loads such as lightining strike and hail damage.

These both panels are designed in CATIA V5 and analysed through two simulation softwares.

4.1 Design of the Existing panel

To draw a panel with specific dimensions and honeycomb structure :

1. Start a New Part

1. Open CATIA V5.
2. Go to File > New and select Part to create a new part.

2. Create the Panel

1. Go to the Sketcher workbench, and select the XY Plane to start sketching.
2. Draw a rectangle with the length of 1.5 ft and width of 0.75 ft. Convert these to inches (1 ft = 12 inches):

Length: 1.5 x 12 = 18 inches
Width: 0.75 x 12 = 9inches

3. Exit the sketch.
4. Go to the Pad feature and specify the panel's height as 0.175 ft (convert to inches: 0.175 x 12 = 2.1 inches.)
5. Click OK to create the solid panel.

3. Add the Honeycomb Structure

To create a honeycomb with a wall thickness of 0.125 inches and a cell size of 0.03 inches:

1. In the Sketcher workbench, select the top face of the panel.
2. Draw a hexagon with a cell size of 0.03 inches (this is the distance across the hexagon).
3. Use the Rectangular Pattern or Circular Pattern tool to replicate the hexagon pattern across the surface of the panel.
4. Exit the sketch.
5. Use the Pocket feature to extrude the honeycomb cut through the thickness of the panel (0.125 inches).
6. Ensure Pattern is set to cover the entire panel surface and adjust the spacing as necessary.
7. Use Save As to store the completed design.

4.2 Measurements of the existing panel

Given dimensions :	Our Convenient dimensions :
Dimensions - 72 x 36 x 8 inches 5 lbs - 2.268 kg Era - 2000s	Dimensions - 18 x 9 x 2.1 inches 5 lbs - 0.567 kg Era - 500s
Glass fiber :	**Glass fiber :**
6 ft = 1828.8 mm (length) 3 ft = 914.4 mm (width) 0.7ft = 213.36 mm (height)	1.5 ft = 457.2 mm (length) 0.75 ft = 228.6 mm (width) 0.175 ft = 53.34 mm (height)
Honey comb :	**Honey comb :**
0.5 - inch/13mm thick with a 0.12 - inch/ 3mm cell size	0.125 - inch/3.25mm thick with a 0.03 - inch/ 0.75mm cell size

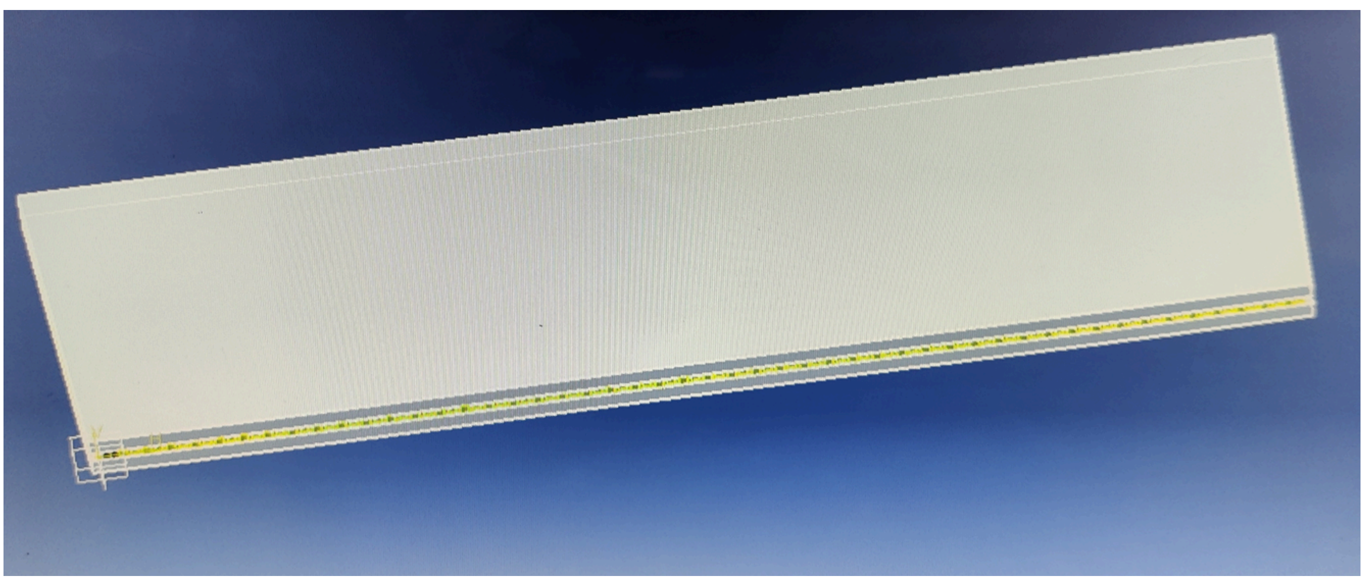
Represents :

→ Glass fiber

→ Aramid fiber

Matrix used :

phenolic prepreg



4.2 Design of the Existing panel (G/A-honeycomb/G)

4.3 Design of the Innovative panel

1. Start a New Part

1. Open CATIA V5.
2. Go to File > New and select Part to create a new part file.

2. Create the Base Panel Layer

1. Go to the Sketcher workbench and select the XY Plane.
2. Draw a rectangle for the base layer with the required length and width:

Length: 1.5 ft (convert to inches: 1.5 x 12=18 inches)
Width: 0.75 ft (convert to inches: 0.75 x 12= 9 inches)

3. Exit the sketch
4. In the Part Design workbench, use the Pad feature to extrude the rectangle to the specified height:

Height: 0.175 ft (convert to inches: 0.175 x 12=2.1 inches).

3. Duplicate the Layer for a 5-Layer Panel

1. Select the base panel layer created in the previous step.
2. Go to Insert > Transformations > Translation to create a copy of the layer.
3. In the Translation options:

Select Upward (along the Z-axis).
Set the distance to 2.1 inches (the height of each layer).
Set the Instances to 5 (to create five layers in total).

4. Click OK to apply the transformation.

4. Final Adjustments and Assembly

1. You should now have five identical layers stacked vertically with the specified dimensions.
2. Use Assembly constraints if required to adjust the alignment of the layers precisely.
3. Save the completed design by going to File > Save As.

4.4 Measurements of the innovative panel

Dimensions :

Dimensions - 18 x 9 x 2.1 inches
5 lbs - 0.567 kg
Era - 2000s

S - Glass fiber :

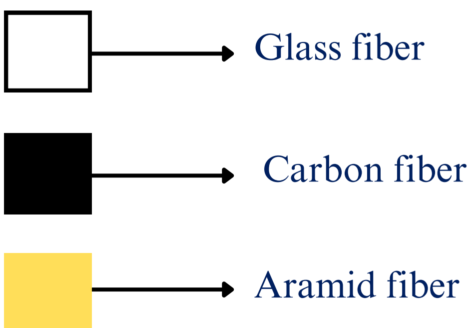
1.5 ft = 457.2 mm (length)
0.75 ft = 228.6 mm (width)
0.175 ft = 2x 10.668 mm (height)

Carbon fiber :

1.5 ft = 457.2 mm (length)
0.75 ft = 228.6 mm (width)
0.175 ft = 10.668 mm (height)

Aramid fiber :

1.5 ft = 457.2 mm (length)
0.75 ft = 228.6 mm (width)
0.175 ft = 2x 10.668 mm (height)

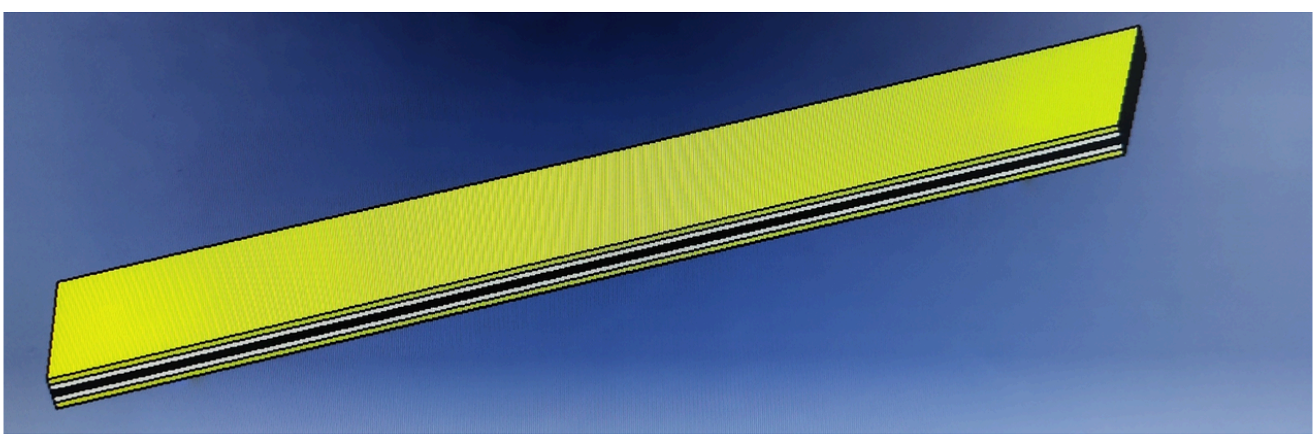


Matrix used :

Epoxy resin & hardener

Industrial waste :

Fly Ash



4.4 Design of the Innovative panel (A/G/C/G/A)

5. SIMULATION USING ANSYS

5.1 Analysing the Existing panel

Step 1: Pre-Processing in ANSYS

1. Import Geometry: Make sure the geometry is correctly imported from CATIA into ANSYS, and verify the dimensions.

2. Define Materials:

S-Glass Fiber:

- Define properties like Young's modulus, Poisson's ratio, density, and strength.
- S-glass fiber is anisotropic, so you may need to define its orthotropic or anisotropic properties.

Aramid Honeycomb:

- Define properties like Young's modulus, shear modulus, density, and failure criteria specific to aramid.
- Aramid honeycomb structures often have orthotropic properties due to their fiber orientation and cellular structure.

3. Set Up Composite Layers:

In the Composite Pre-Processor in ANSYS, define a 3-layer setup:

Layer 1 (Top): S-glass fiber.
Layer 2 (Middle): Aramid honeycomb core.
Layer 3 (Bottom): S-glass fiber.

Specify the thickness of each layer is 0.175 ft, assign thickness values accordingly, ensuring the honeycomb layer occupies the middle position.
For the honeycomb layer, you may need to use shell or beam elements to capture the cellular structure accurately.

4. Mesh Generation:

Generate a mesh with a finer resolution at the honeycomb core for accurate stress distribution analysis. Shell elements work well for the honeycomb core and laminated surfaces.

Step 2: Setting Up the Analysis

1. Compression Test

Boundary Conditions: Fix one end of the panel and constrain the opposite end where the compressive load of 10,000 N will be applied.

Loading: Apply the compressive load of 10,000 N on the opposite end.

Analysis Settings: Choose Static Structural Analysis and enable large deformation settings if the honeycomb core has significant deformation.

Solution Outputs: Request outputs for total deformation , equivalent stress and equivalent strain.

2. Impact Test

Boundary Conditions: Fix the panel's edges or support the panel based on the test setup.

Loading: Use an impulse force to simulate the impact. If the impact speed is known, specify it as an initial velocity; otherwise, apply an impulse equivalent to the expected impact load.

Analysis Type: Use Explicit Dynamics for the impact. Explicit dynamics is usually preferable for handling complex impact events.

Solution Outputs: Total deformation , equivalent stress and equivalent strain.

3. Tensile Test (100 mm Displacement)

Boundary Conditions: Fix one end of the panel and apply a displacement boundary condition of 100 mm to the opposite end.

Loading: Instead of applying a force, apply a displacement of 100 mm in the tensile direction.

Analysis Type: Use Static Structural Analysis to account for the material and geometric nonlinearity.

Solution Outputs: Total deformation , equivalent stress and equivalent strain.

Step 3: Solving the Analysis

- Solve each test separately. For impact and tensile tests, you may need to enable large deformations and contact nonlinearity (especially for bonded layers).
- Monitor the solution for any convergence issues, particularly in transient dynamics or explicit simulations for the impact test.

Step 4: Post-Processing Results

1. Compression Test:

- Analyze the stress distribution across the S-glass layers and the honeycomb core.
- Check for buckling or delamination, especially around the interfaces between the S-glass and honeycomb layers.

2. Impact Test:

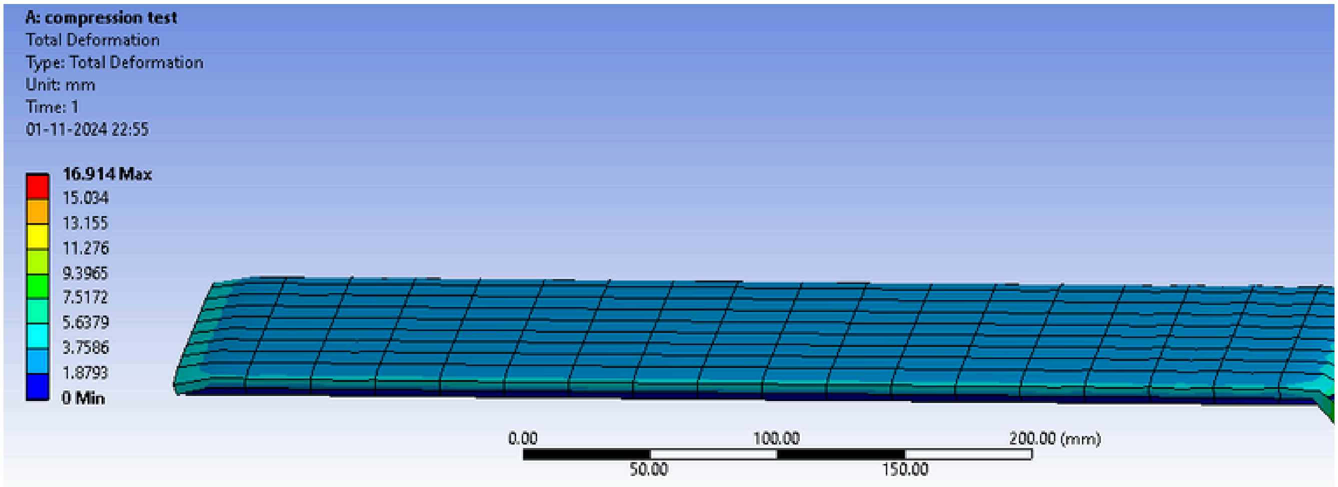
- Observe the stress and strain distributions, focusing on the regions where impact occurs.
- Evaluate energy absorption to understand how the honeycomb structure dissipates energy.

3. Tensile Test:

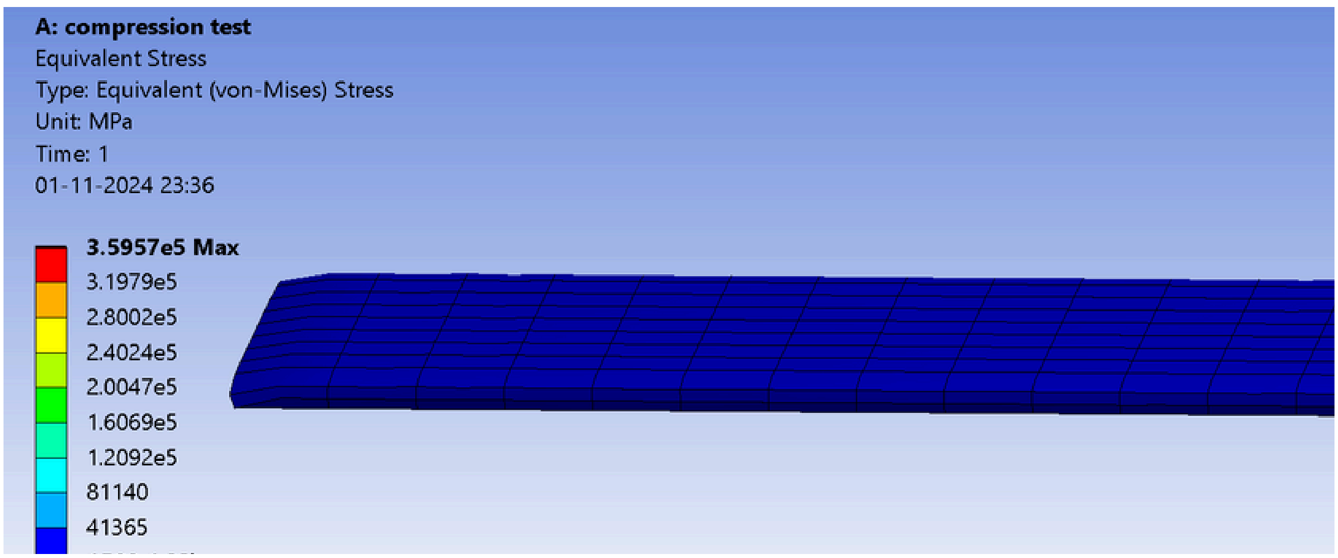
- Check for stress concentration at the interfaces between the S-glass and aramid core.
- Verify if the 100 mm displacement results in failure or delamination within the layered structure.

5.2 Result of Existing panel

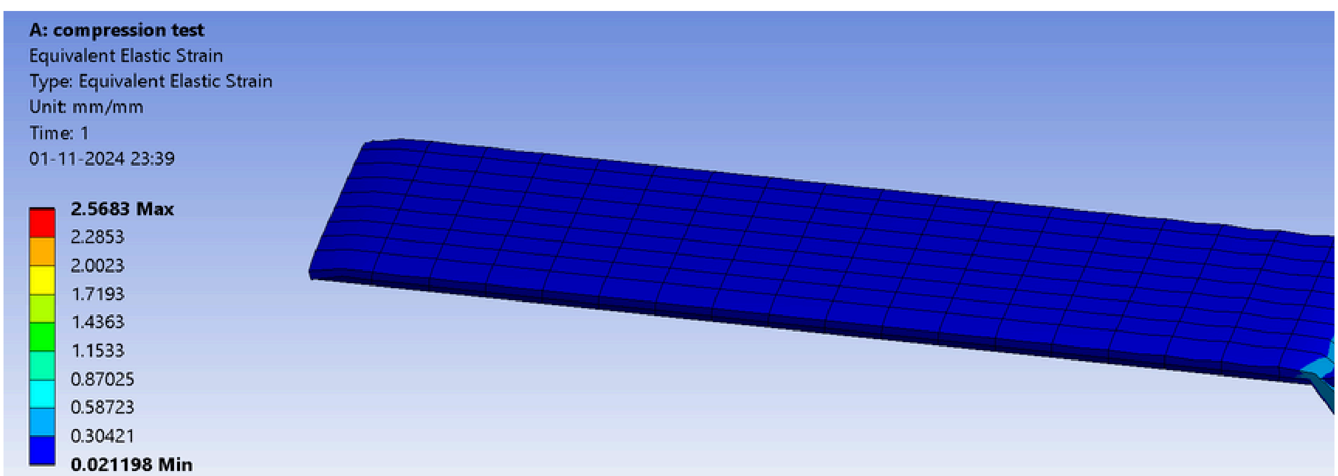
5.2.1 Static structural (Compression) :



A) Total deformation



B) Equivalent stress

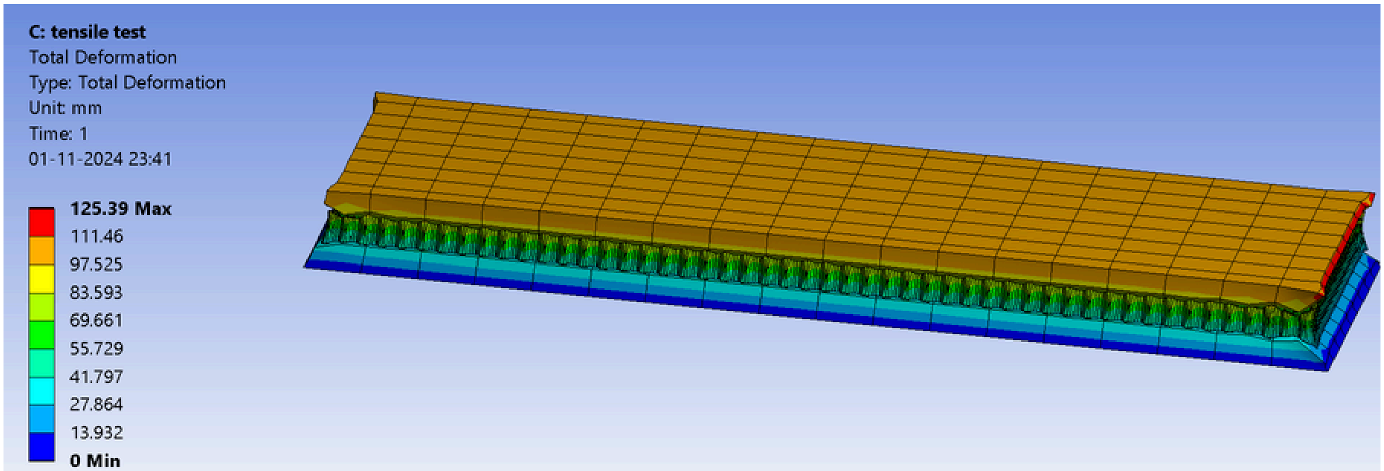


C) Equivalent strain

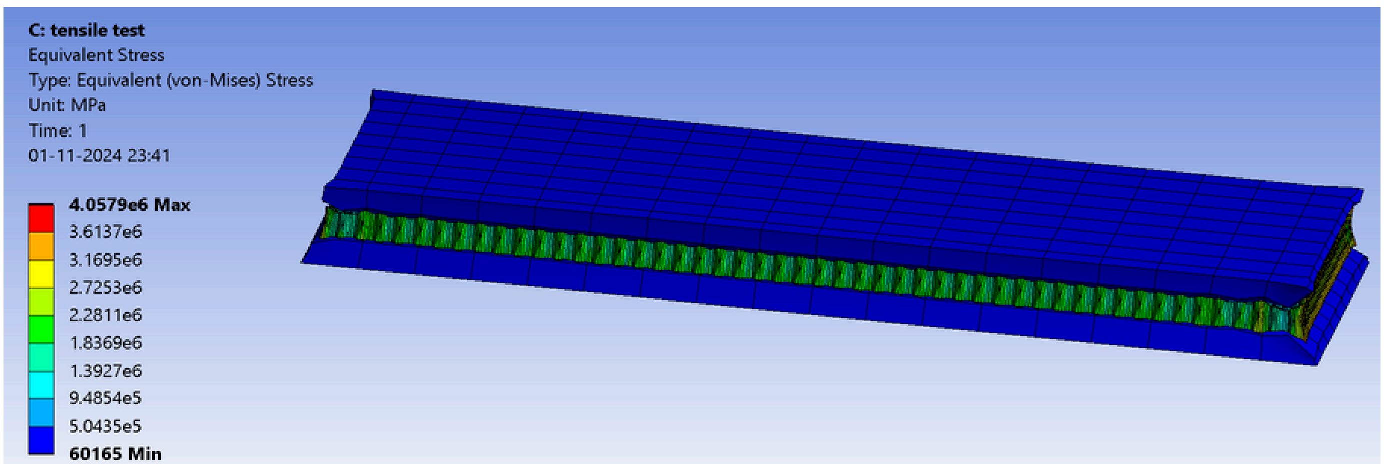
Total deformation : **Max** 16.914 mm	**Min** 0	**Avg** 1.5205 mm
Equivalent stress : **Max** 3.5957e5 Mpa	**Min** 1589.1 Mpa	**Avg** 45025 Mpa
Equivalent strain : **Max** 2.5683 mm	**Min** 2.1198e-2 mm	**Avg** 0.32794 mm

Table 5.2.1 Simulated compression values

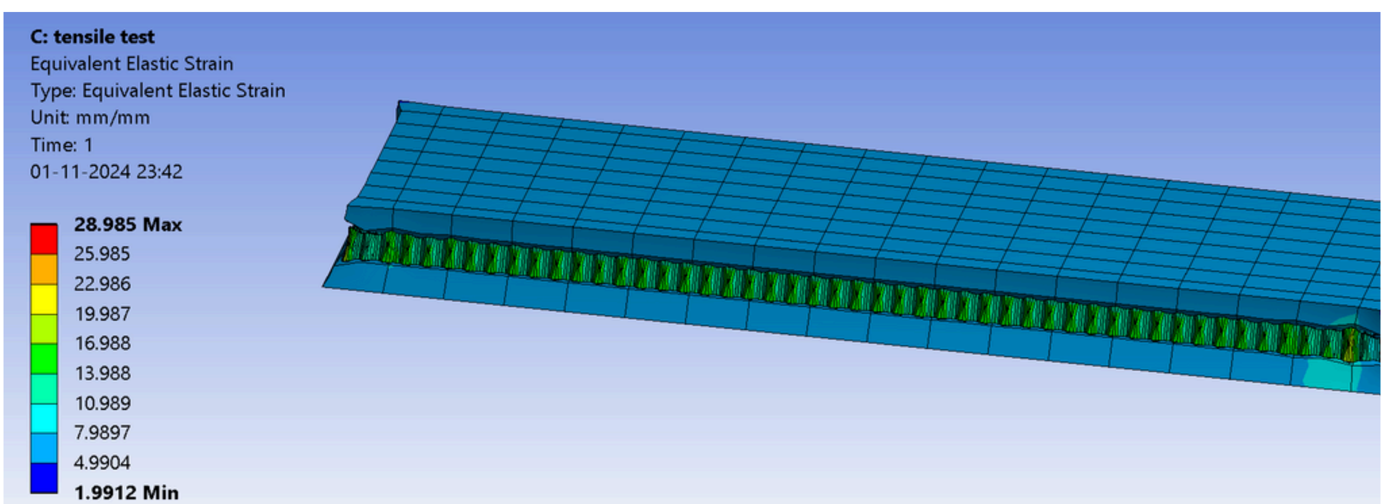
5.2.2 Static structural (Tensile) :



A) Total deformation



B) Equivalent stress

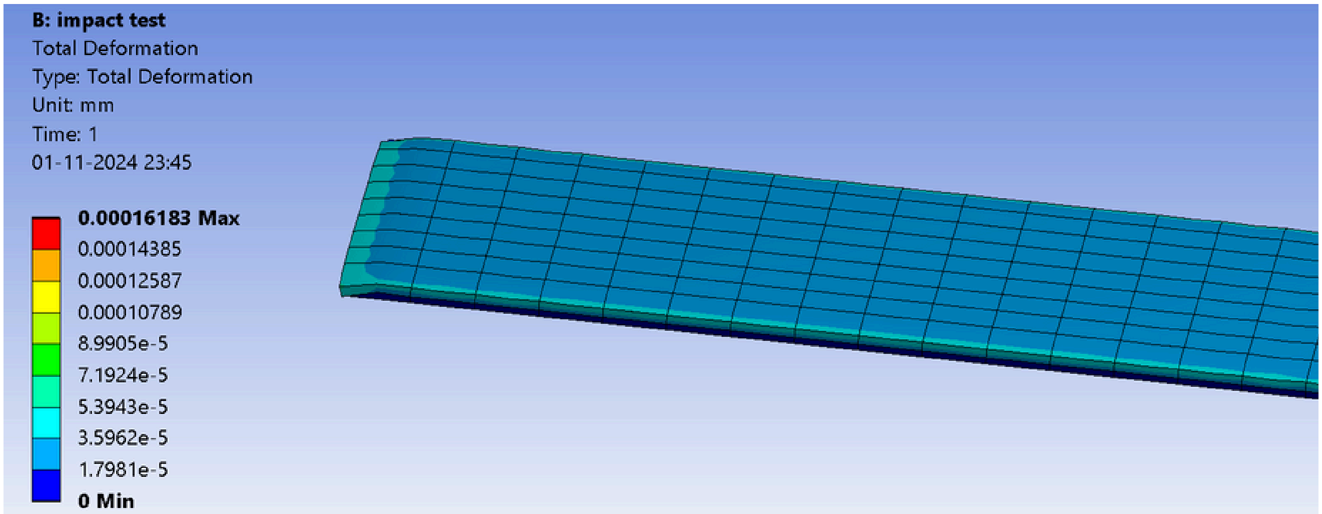


C) Equivalent strain

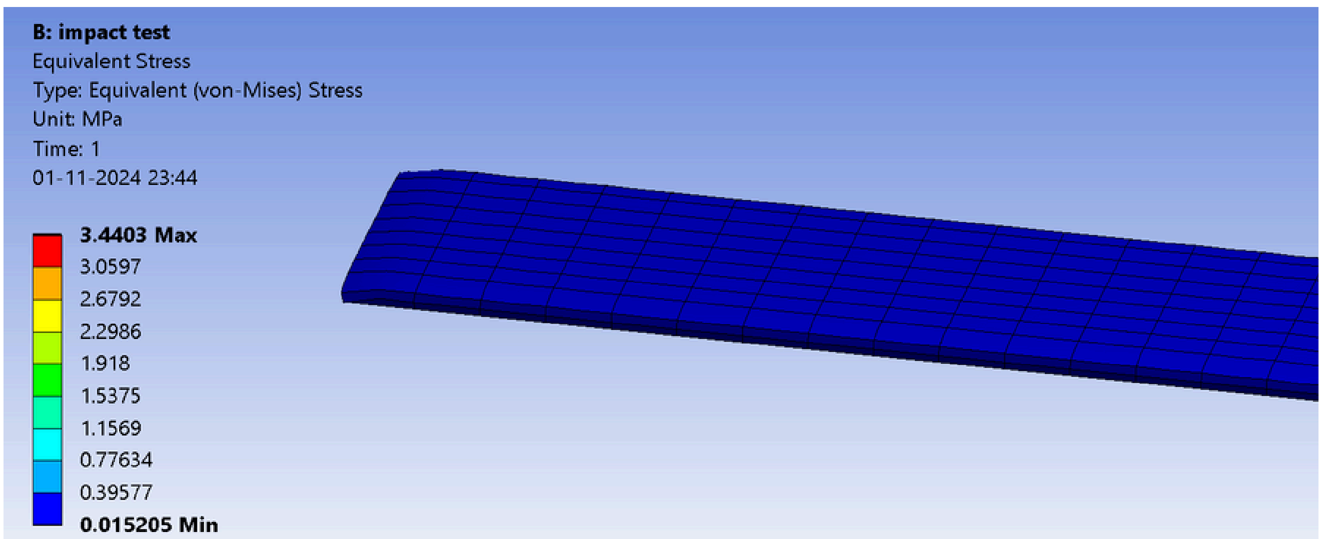
Total deformation : **Max** 125.39 mm	 **Min** 0	 **Avg** 50.533 mm
Equivalent stress : **Max** 4.0579e6 Mpa	 **Min** 60165 Mpa	 **Avg** 1.483e6 Mpa
Equivalent strain : **Max** 28.985 mm	 **Min** 1.9912 mm	 **Avg** 10.798 mm

Table 5.2.2 Simulated tensile values

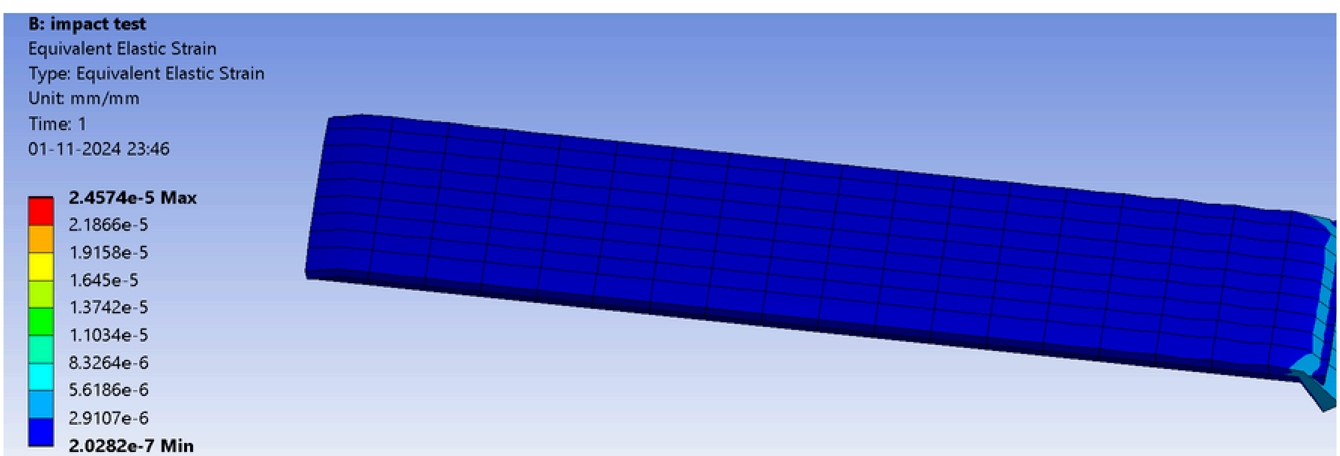
5.2.3 Static structural (Impact) :



A) Total deformation



B) Equivalent stress



C) Equivalent strain

Total deformation : **Max** 0.00016183 mm	**Min** 0	**Avg** 1.4548e-5 mm
Equivalent stress : **Max** 3.4403 Mpa	**Min** 0.015205 Mpa	**Avg** 0.4308 Mpa
Equivalent strain : **Max** 2.4574e-5 mm	**Min** 2.0282e-7 mm	**Avg** 3.1377e-6 mm

Table 5.2.3 Simulated impact values

5.3 Analysing the Innovative panel

Step 1: Pre-Processing in ANSYS

1. Import Geometry: Verify that the geometry imported from CATIA has the correct dimensions and structure.

2. Define Material Properties:

Aramid Fiber (1st and 5th layers):
Define material properties for aramid fiber, including Young's modulus, Poisson's ratio, density, and strength parameters.

S-Glass Fiber (2nd and 4th layers):
Define orthotropic or anisotropic properties as required for S-glass fiber.

Carbon Fiber (3rd layer):
Define properties for carbon fiber, considering its high stiffness and strength. Carbon fiber is also anisotropic, so define its directional properties based on the orientation.

3. Mesh Generation:

- Use a fine mesh to accurately capture stress and strain distributions, especially around interfaces between different layers.
- For complex composite structures, use shell or layered solid elements to accurately model each layer.

Step 2: Setting Up the Analysis

1. Compression Test

Boundary Conditions:
Fix one end of the panel.Apply a compressive load of 10,000 N uniformly on the opposite end.

Analysis Settings: Use Static Structural Analysis. Enable large deformation settings if significant deformation is expected.

Outputs: Specify total deformation, equivalent stress, and equivalent strain as solution outputs.

2. Impact Test

Boundary Conditions:
Fix the panel's edges or apply supports based on the experimental setup.

Loading:
Define an impact load as an initial velocity if you know the impact speed or as an equivalent impulse force over a short duration.

Analysis Type: Use Explicit Dynamics to handle the high-rate loading conditions of impact.

Outputs: Specify total deformation, equivalent stress, and equivalent strain at key time steps to observe stress waves and peak responses.

3. Tensile Test (100 mm Displacement)

Boundary Conditions:
Fix one end of the panel.Apply a 100 mm displacement boundary condition on the opposite end.

Loading: Instead of applying a force, apply the prescribed displacement to achieve tensile loading.

Analysis Type: Use Static Structural Analysis to account for large deformations if necessary.

Outputs: Request total deformation, equivalent stress, and equivalent strain for analysis.

Step 3: Solving the Analysis

- Run each simulation separately to ensure the solver handles each load case effectively.

- For the impact analysis, choose a small time step to capture the transient effects accurately.

Step 4: Post-Processing Results

For each loading scenario, examine the following results:

1. Total Deformation:

Assess the deformation across the panel, particularly at the interfaces between layers, as different materials may respond uniquely to loading.

2. Equivalent Stress:

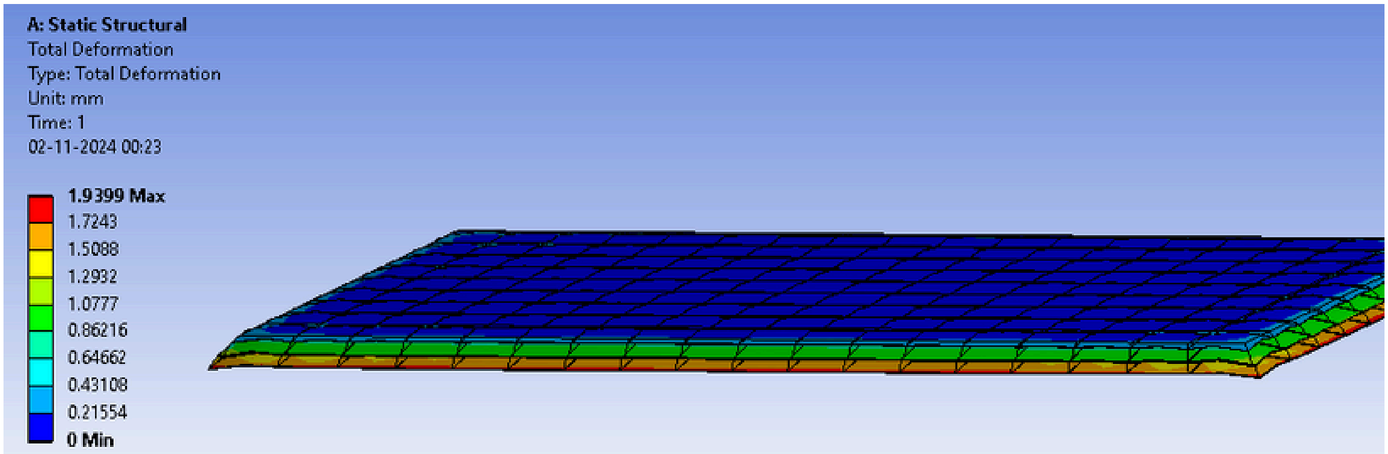
Evaluate stress distribution within each layer. High stresses at interfaces may indicate potential failure or delamination areas.

3. Equivalent Strain:

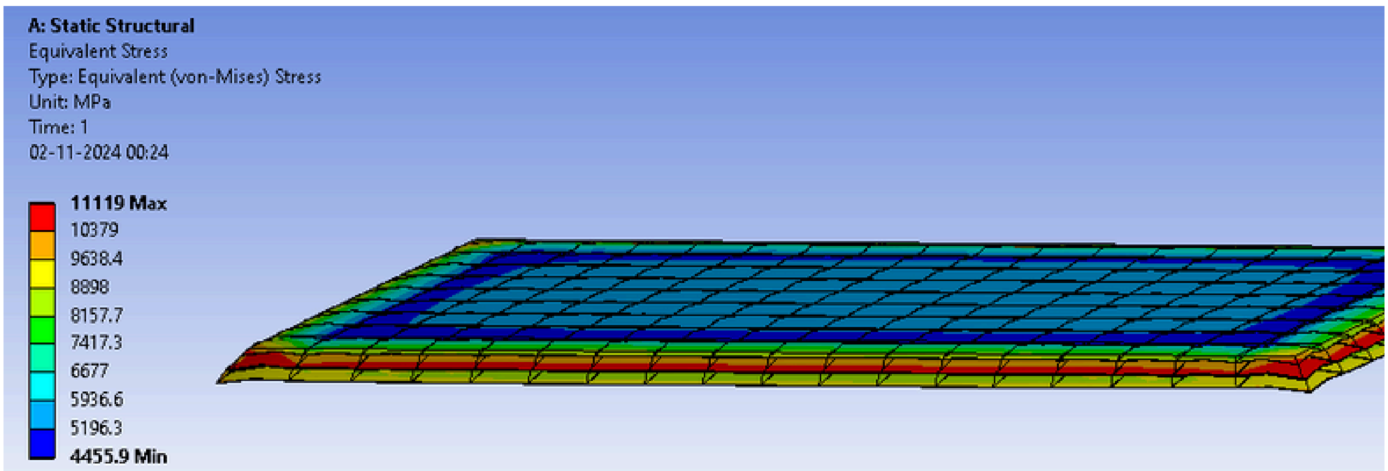
Check strain concentrations, especially in the carbon fiber layer (3rd layer), since it is stiffer and may experience different strain levels compared to the aramid and S-glass layers.

5.4 Result of Innovative panel

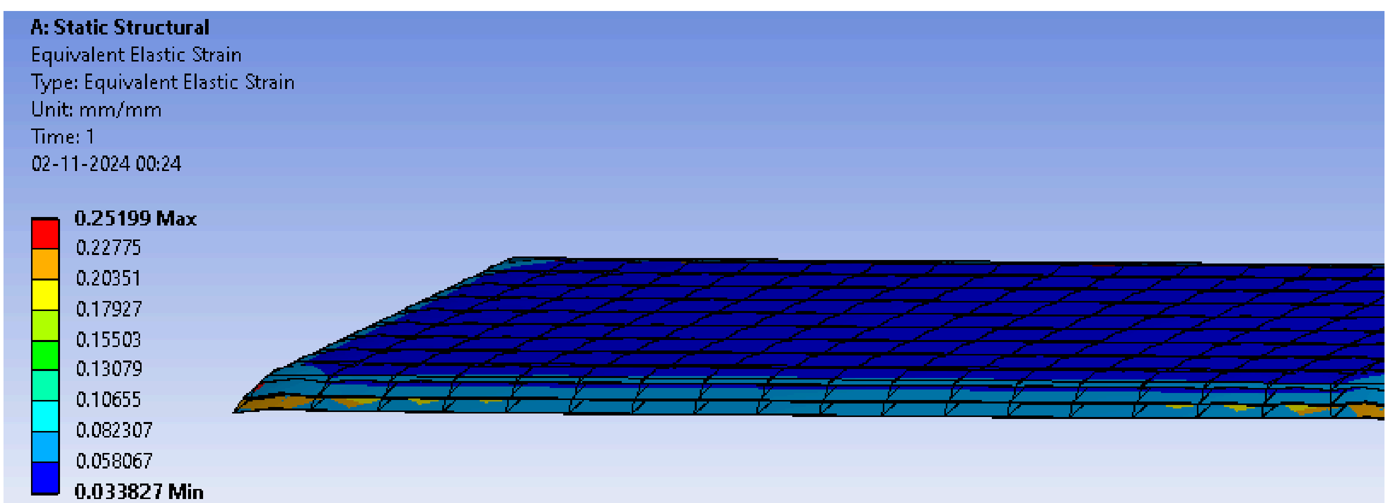
5.4.1 Static structural (Compression) :



A) Total deformation



B) Equivalent stress

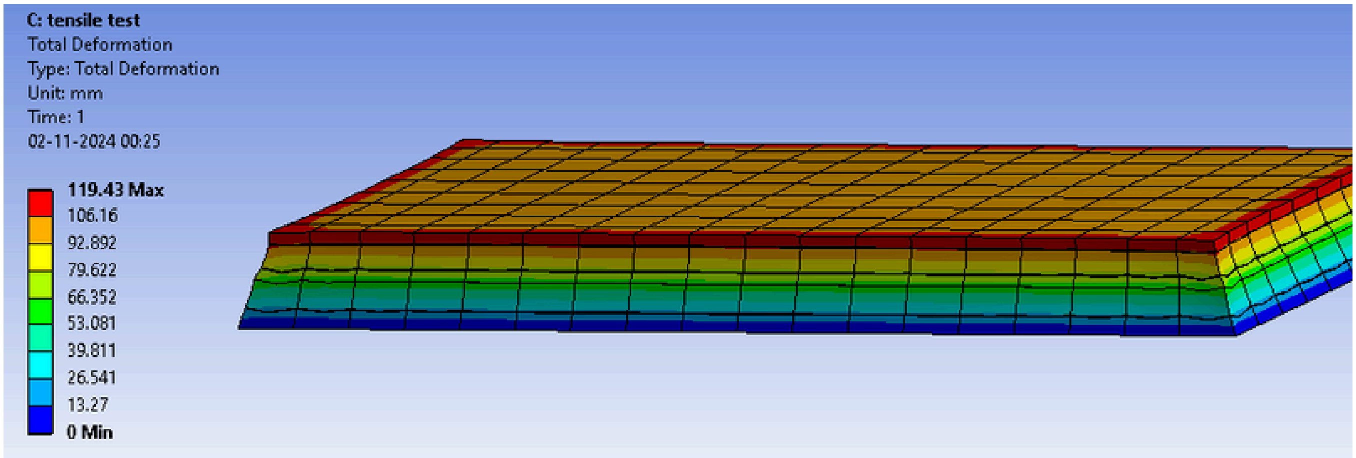


C) Equivalent strain

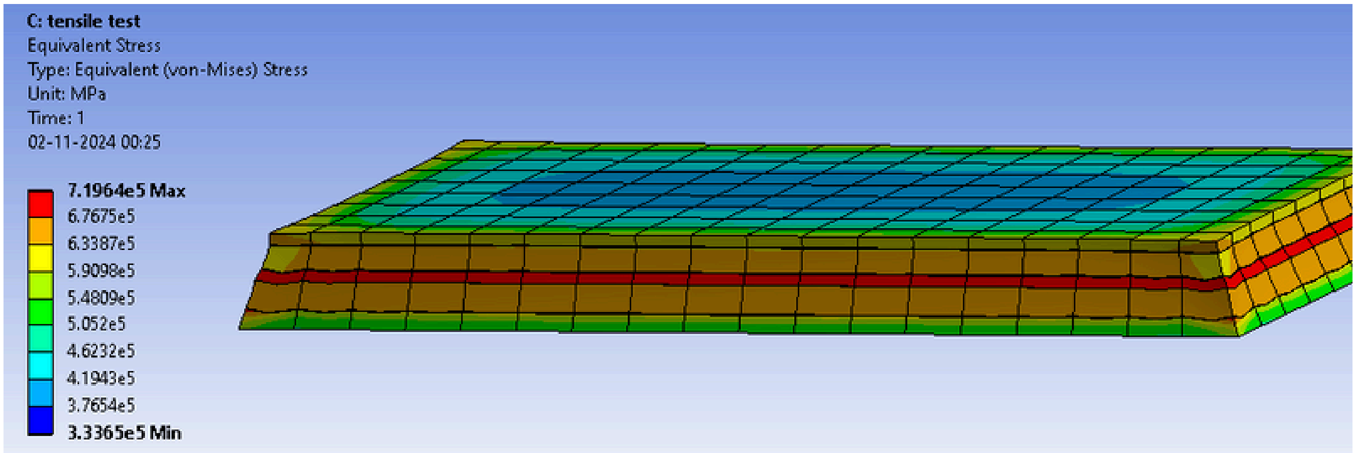
Total deformation : **Max** 1.9399 mm	**Min** 0	**Avg** 0.76906 mm
Equivalent stress : **Max** 11119 Mpa	**Min** 4455.9 Mpa	**Avg** 8310.2 Mpa
Equivalent strain : **Max** 0.25199 mm	**Min** 3.3827e-2 mm	**Avg** 0.10431 mm

Table 5.4.1 Simulated compression values

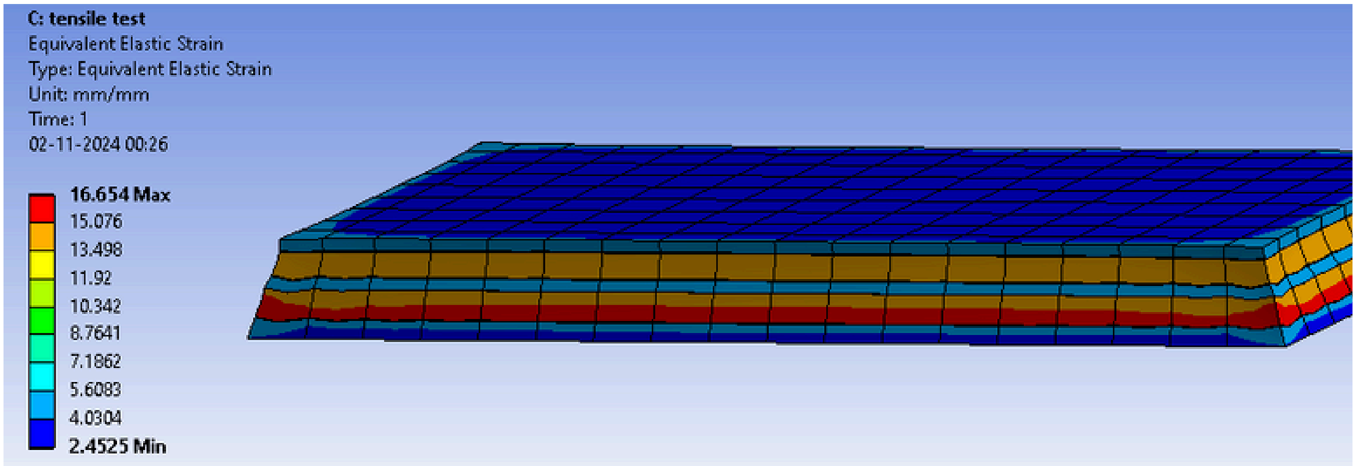
5.4.2 Static structural (Tensile) :



A) Total deformation



B) Equivalent stress

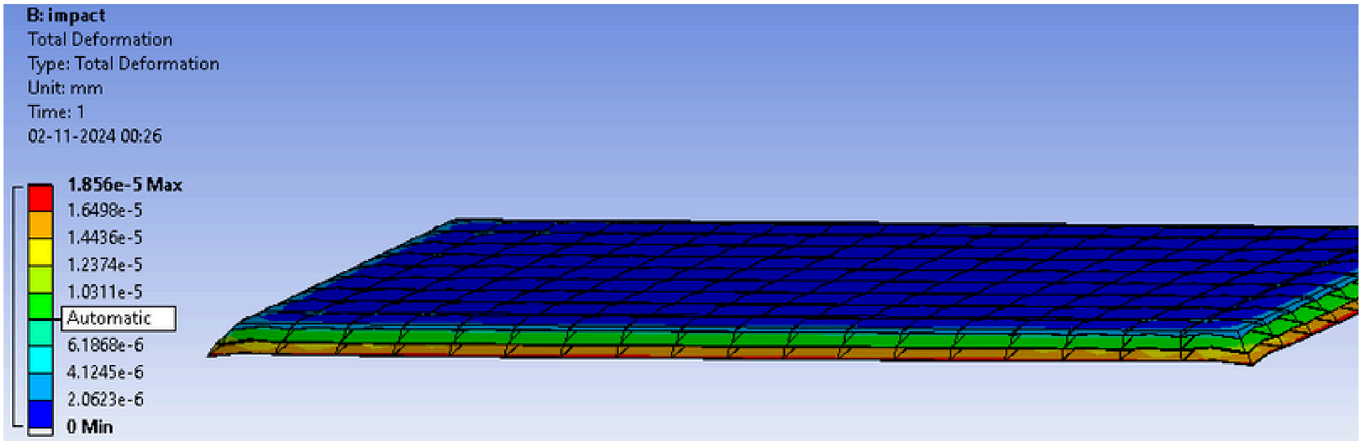


C) Equivalent strain

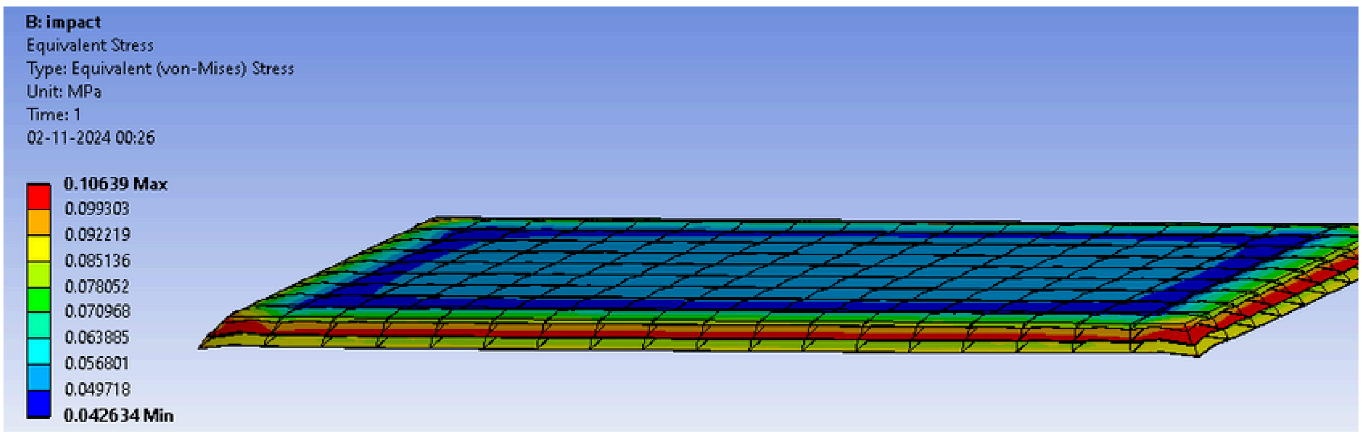
Total deformation : **Max** 119.43 mm	**Min** 0	**Avg** 54.518 mm
Equivalent stress : **Max** 7.1964e11 Mpa	**Min** 3.3365e5 Mpa	**Avg** 5.9082e5 Mpa
Equivalent strain : **Max** 16.654 mm	**Min** 2.4525 mm	**Avg** 7.4361 mm

Table 5.4.2 Simulated tensile values

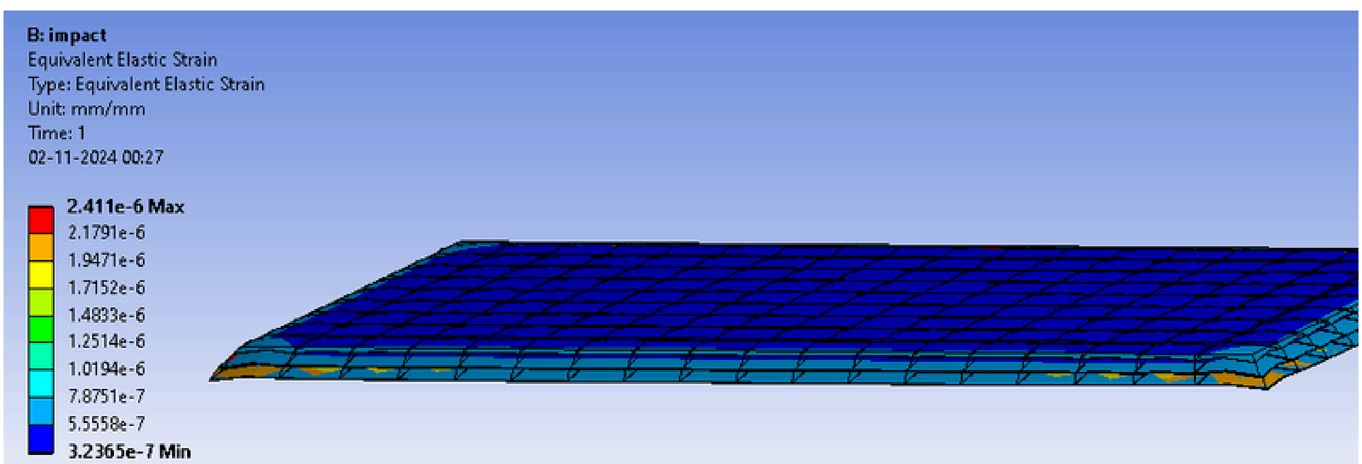
5.4.3 Static structural (Impact) :



A) Total deformation



B) Equivalent stress



C) Equivalent strain

Total deformation : **Max** 1.856e-5 mm	**Min** 0	**Avg** 7.3583e-6 mm
Equivalent stress : Max 0.10639 Mpa	**Min** 4.2634e-2 Mpa	**Avg** 7.9511e-2Mpa
Equivalent strain : **Max** 2.411e-6 mm	**Min** 3.2365e-7 mm	**Avg** 9.9802e-7 mm

Table 5.4.3 Simulated impact values

6. SIMULATION USING MATLAB

6.1 Analysing the Existing panel

To analyze this composite panel structure in MATLAB, we can break down the analysis into several key steps. This will involve defining the geometry, material properties, and loading conditions, and setting up simulations for compression, impact, and tensile testing.

1. Define Material Properties

S-glass fiber layers: Define the elastic and strength properties for S-glass fiber.

Honeycomb Core (Aramid Fiber): Define properties specific to the honeycomb structure, considering the core's effective stiffness and density.

2. Define Geometry and Meshing

Dimensions:

Length = 1.5 ft
Width = 0.75 ft
Height = 0.175 ft

Honeycomb Core:
Thickness = 0.125 ft
Cell size = 0.03 inches

Mesh each layer with appropriate element types, particularly for the composite layers. Use finer meshing for more accurate results, especially near loading and boundary areas.

3. Model Layer-by-Layer Stacking

Set up a composite laminate model in MATLAB using the Composite Laminate Theory if possible, where you can define different properties for each layer.
Layers:
Top layer (S-glass fiber)
Core layer (Honeycomb Aramid Fiber)
Bottom layer (S-glass fiber)

4. Define Boundary Conditions

Compression Load: Apply a 10000 N compressive load over the entire top surface.

Tensile Test: Define boundary conditions to allow a 100 mm displacement.

Impact Load: Use a force function to simulate a transient impact load; typically, this involves a time-dependent force, which can be modeled using MATLAB's ode45 or similar solver for dynamic analysis.

5. Setup for Each Test

Compression Test:
Set boundary conditions to allow only compressive loading on one face while fixing the opposite face.Calculate the stress distribution, particularly at the interface between layers.

Impact Test:
Model the impact as a short-duration, high-magnitude force applied at a particular point on the panel.Use a transient analysis solver to simulate this, accounting for the time variation of the impact load.

Tensile Test:
Fix one end of the panel and apply a displacement of 100 mm at the other end.Measure the stress and strain distributions, especially at the honeycomb core to check for any failure.

6. Execute Analysis in MATLAB

Use MATLAB’s PDE Toolbox or custom FEM code if PDE Toolbox is not suitable for composite materials.

For each test, calculate and visualize:
- Stress distribution across the layers.
- Deformation and strain, especially for tensile and compression tests.
- Check for failure in the S-glass and aramid layers under given loads.

7. Post-Processing

- Visualize results using MATLAB’s plotting functions to show deformation, stress, and strain contours.
- For impact analysis, plot force vs. time or displacement vs. time to observe the panel's response.

6.2 Coding for Existing panel

```matlab
% Given Panel Dimensions (convert to meters)
length = 457.2e-3;  % meters
width = 228.6e-3;   % meters
thickness = 53.34e-3; % meters

% Honeycomb properties (converted to meters)
honeycomb_thickness = 3.25e-3; % meters
honeycomb_cell_size = 0.75e-3; % meters

% Total weight of panel
mass_panel = 0.567;  % kg

% Calculate the cross-sectional area of the panel
area = length * width;  % in square meters

% Material properties (assuming typical values)
E_glass = 89e9;   % Young's modulus for S-glass fiber (Pa)
E_aramid = 70e9;  % Young's modulus for aramid fiber (Pa)
nu_glass = 0.22;  % Poisson's ratio for S-glass
nu_aramid = 0.35; % Poisson's ratio for aramid

% Applied forces and displacement
force_compression = 10000; % N (for compression and impact tests)
displacement_tensile = 100e-3; % 100 mm in meters

%% Compression Test
% Assuming the third layer is fixed (S-glass fiber)
% Stress = Force / Area
stress_compression = force_compression / area; % Pa (N/m^2)
```

```
% Strain in compression test (Hooke's Law: σ = E * ε)
strain_compression = stress_compression / E_glass;
% Total deformation in compression (ΔL = ε * L)
deformation_compression = strain_compression * thickness; % meters
% Equivalent stress and strain for compression (since it's in one material)
sigma_eq_compression = stress_compression; % Pa
elastic_strain_eq_compression = strain_compression;
%% Tensile Test
% Displacement is applied directly, so we calculate the strain
strain_tensile = displacement_tensile / thickness; % (ΔL / L)
% Stress in tensile test (σ = E * ε)
stress_tensile = E_glass * strain_tensile;
% Total deformation in tensile test (same as applied displacement)
deformation_tensile = displacement_tensile; % meters
% Equivalent stress and strain for tensile test
sigma_eq_tensile = stress_tensile;
elastic_strain_eq_tensile = strain_tensile;
%% Impact Test
% Impact force is the same as compression for simplicity (quasi-static)
stress_impact = force_impact / area; % Pa
% Strain in impact test
strain_impact = stress_impact / E_glass;
% Total deformation in impact test
deformation_impact = strain_impact * thickness; % meters
% Equivalent stress and strain for impact test
sigma_eq_impact = stress_impact; % Pa
elastic_strain_eq_impact = strain_impact;
%% Display Results
fprintf('Compression Test Results:\n');
fprintf('Total Deformation: %.6f meters\n', deformation_compression);
fprintf('Equivalent Stress: %.4f Pa\n', sigma_eq_compression);
fprintf('Equivalent Elastic Strain: %.6f\n\n', elastic_strain_eq_compression);
fprintf('Tensile Test Results:\n');
fprintf('Total Deformation: %.6f meters\n', deformation_tensile);
fprintf('Equivalent Stress: %.4f Pa\n', sigma_eq_tensile);
fprintf('Equivalent Elastic Strain: %.6f\n\n', elastic_strain_eq_tensile);
fprintf('Impact Test Results:\n');
```

6.3 Result of Existing panel

Parameters	Compression	Tensile	Impact
Total deformation	5.3565e-06 mm	0.10000 mm	5.3565e-06 mm
Equivalent stress	8.2011e05 Mpa	8.2011e05 Mpa	8.2011e05 Mpa
Equivalent strain	1.1716e-05 mm	0.2187 mm	1.1716e-05 mm

Name	Value	Size	Bytes	Class	Min	Max	Range	Mean	Median	Mode	Var	Std
A	0.0122	1x1	8	double	0.0122	0.0122	0	0.0122	0.0122	0.0122	0	0
d	0.1000	1x1	8	double	0.1000	0.1000	0	0.1000	0.1000	0.1000	0	0
delta_c	5.3565e-06	1x1	8	double	5.3565e-...	5.3565e-...	0	5.3565e-...	5.3565e-...	5.3565e-...	0	0
delta_i	5.3565e-06	1x1	8	double	5.3565e-...	5.3565e-...	0	5.3565e-...	5.3565e-...	5.3565e-...	0	0
delta_t	0.1000	1x1	8	double	0.1000	0.1000	0	0.1000	0.1000	0.1000	0	0
E_g	7.0000e+10	1x1	8	double	7.0000e...	7.0000e...	0	7.0000e...	7.0000e...	7.0000e...	0	0
epsilon_c	1.1716e-05	1x1	8	double	1.1716e-...	1.1716e-...	0	1.1716e-...	1.1716e-...	1.1716e-...	0	0
epsilon_i	1.1716e-05	1x1	8	double	1.1716e-...	1.1716e-...	0	1.1716e-...	1.1716e-...	1.1716e-...	0	0
epsilon_t	0.2187	1x1	8	double	0.2187	0.2187	0	0.2187	0.2187	0.2187	0	0
F	10000	1x1	8	double	10000	10000	0	10000	10000	10000	0	0
L	0.4572	1x1	8	double	0.4572	0.4572	0	0.4572	0.4572	0.4572	0	0
sigma_c	8.2011e+05	1x1	8	double	8.2011e...	8.2011e...	0	8.2011e...	8.2011e...	8.2011e...	0	0
sigma_i	8.2011e+05	1x1	8	double	8.2011e...	8.2011e...	0	8.2011e...	8.2011e...	8.2011e...	0	0
sigma_t	8.2011e+05	1x1	8	double	8.2011e...	8.2011e...	0	8.2011e...	8.2011e...	8.2011e...	0	0
t	0.0533	1x1	8	double	0.0533	0.0533	0	0.0533	0.0533	0.0533	0	0
W	0.2286	1x1	8	double	0.2286	0.2286	0	0.2286	0.2286	0.2286	0	0

6.3 Existing panel result in MATLAB

6.4 Analysing the Innovative panel

To analyze this five-layer composite panel structure in MATLAB, first need to set up each layer's material properties, model the load conditions, and perform simulation steps for compression, impact, and tensile tests.

1. Define Material Properties

Aramid Fiber (1st and 5th layers): Define its elastic modulus, Poisson's ratio, and density.

S-Glass Fiber (2nd and 4th layers): Define elastic modulus, strength, and other mechanical properties.

Carbon Fiber (3rd layer): Define high stiffness and strength properties for carbon fiber.

2. Set Up Geometry and Meshing

Panel Dimensions:

Length = 1.5 ft
Width = 0.75 ft
Height = 0.175 ft

3. Define Composite Layer Stacking

MATLAB supports composite layup modeling through custom functions or the PDE Toolbox. Define each layer’s material properties and stacking sequence:

Layer 1 (Top): Aramid Fiber
Layer 2: S-Glass Fiber
Layer 3: Carbon Fiber
Layer 4: S-Glass Fiber
Layer 5 (Bottom): Aramid Fiber

4. Specify Boundary Conditions and Loads

Compression Load: Apply a 10000 N compressive load over the entire top surface and fix the opposite end.

Impact Load: Simulate a time-dependent load at a specific point on the panel's surface. For an impact test, use a short, high-magnitude force pulse.

Tensile Load: Apply a displacement boundary condition for a 100 mm extension along the length of the panel, with one end fixed.

5. Simulation Setup for Each Test

Compression Test:
Fix one end and apply compressive force at the other end.Analyze the stress and strain distributions through each layer.

Impact Test:
Define a transient load (a time-dependent force) and simulate its effects.Use MATLAB’s time-stepping solvers like ode45 to model the dynamic impact.

Tensile Test:
Apply a fixed displacement boundary condition of 100 mm at one end while fixing the other end. Analyze the resulting stress and deformation across the layers.

6. Set Up the MATLAB Script

Initialize the material properties, geometry, and meshing.

7. Post-Processing

Visualize Results: Use MATLAB’s plotting functions for stress, strain, and displacement results.

Failure Analysis: Check for potential failure in each layer, especially under tensile and compressive loads.

6.5 Coding for Innovative panel

```matlab
% Input dimensions and properties
L = 457.2;   % Length in mm
W = 228.6;   % Width in mm
H = 53.34;   % Thickness in mm
panel_weight = 0.567;  % Weight in kg

% Applied forces
force_compression = 10000; % Force in N for compression
displacement_tensile = 100; % Displacement in mm for tensile
force_impact = 10000; % Force in N for impact

% Pre-allocate arrays for results
deformation_compression = [ ]; % Total deformation during compression test
stress_compression = [ ];      % Equivalent stress during compression test
strain_compression = [ ];      % Equivalent elastic strain during compression test

deformation_tensile = [ ]; % Total deformation during tensile test
stress_tensile = [ ];      % Equivalent stress during tensile test
strain_tensile = [ ];      % Equivalent elastic strain during tensile test

deformation_impact = [ ];  % Total deformation during impact test
stress_impact = [ ];       % Equivalent stress during impact test
strain_impact = [ ];       % Equivalent elastic strain during impact test

% For simplicity, let's assume the arrays above are populated with data from an FEA
simulation

% Perform the calculations for compression test
max_deformation_compression = max(deformation_compression);
min_deformation_compression = min(deformation_compression);
avg_deformation_compression = mean(deformation_compression);

max_stress_compression = max(stress_compression);
min_stress_compression = min(stress_compression);
avg_stress_compression = mean(stress_compression);

max_strain_compression = max(strain_compression);
min_strain_compression = min(strain_compression);
avg_strain_compression = mean(strain_compression);
```

```
% Perform the calculations for tensile test
max_deformation_tensile = max(deformation_tensile);
min_deformation_tensile = min(deformation_tensile);
avg_deformation_tensile = mean(deformation_tensile);
max_stress_tensile = max(stress_tensile);
min_stress_tensile = min(stress_tensile);
avg_stress_tensile = mean(stress_tensile);
max_strain_tensile = max(strain_tensile);
min_strain_tensile = min(strain_tensile);
avg_strain_tensile = mean(strain_tensile);
% Perform the calculations for impact test
max_deformation_impact = max(deformation_impact);
min_deformation_impact = min(deformation_impact);
avg_deformation_impact = mean(deformation_impact);
max_stress_impact = max(stress_impact);
min_stress_impact = min(stress_impact);
avg_stress_impact = mean(stress_impact);
max_strain_impact = max(strain_impact);
min_strain_impact = min(strain_impact);
avg_strain_impact = mean(strain_impact);
% Output results
disp('Compression Test Results:');
fprintf('Max Deformation: %.4f mm\n', max_deformation_compression);
fprintf('Min Deformation: %.4f mm\n', min_deformation_compression);
fprintf('Avg Deformation: %.4f mm\n', avg_deformation_compression);
fprintf('Max Stress: %.4f MPa\n', max_stress_compression);
fprintf('Min Stress: %.4f MPa\n', min_stress_compression);
fprintf('Avg Stress: %.4f MPa\n', avg_stress_compression);
fprintf('Max Strain: %.4f\n', max_strain_compression);
fprintf('Min Strain: %.4f\n', min_strain_compression);
fprintf('Avg Strain: %.4f\n', avg_strain_compression);
disp('Tensile Test Results:');
fprintf('Max Deformation: %.4f mm\n', max_deformation_tensile);
fprintf('Min Deformation: %.4f mm\n', min_deformation_tensile);
fprintf('Avg Deformation: %.4f mm\n', avg_deformation_tensile);
fprintf('Max Stress: %.4f MPa\n', max_stress_tensile);
fprintf('Min Stress: %.4f MPa\n', min_stress_tensile);
fprintf('Avg Stress: %.4f MPa\n', avg_stress_tensile);
fprintf('Max Strain: %.4f\n', max_strain_tensile);
fprintf('Min Strain: %.4f\n', min_strain_tensile);
fprintf('Avg Strain: %.4f\n', avg_strain_tensile);
```

6.6 Result of Innovative panel

Parameters	Compression	Tensile	Impact
Total deformation	0.0333 mm	0.10000 mm	5.0035e-08 mm
Equivalent stress	9.5679e04 Mpa	9.5679e04 Mpa	9.5679e04 Mpa
Equivalent strain	9.3803e-07 mm	1.8748 mm	9.3803e-07 mm

Name	Value	Size	Bytes	Class	Min	Max	Range	Mean	Median	Mode	Var	Std
A	0.1045	1x1	8	double	0.1045	0.1045	0	0.1045	0.1045	0.1045	0	0
avg_deformat...	0.0333	1x1	8	double	0.0333	0.0333	0	0.0333	0.0333	0.0333	0	0
avg_strain	0.6249	1x1	8	double	0.6249	0.6249	0	0.6249	0.6249	0.6249	0	0
avg_stress	9.5679e+04	1x1	8	double	9.5679e...	9.5679e...	0	9.5679e...	9.5679e...	9.5679e...	0	0
compression_...	10000	1x1	8	double	10000	10000	0	10000	10000	10000	0	0
compression_...	9.3803e-07	1x1	8	double	9.3803e-...	9.3803e-...	0	9.3803e-...	9.3803e-...	9.3803e-...	0	0
compression_...	9.5679e+04	1x1	8	double	9.5679e...	9.5679e...	0	9.5679e...	9.5679e...	9.5679e...	0	0
deformation_...	5.0035e-08	1x1	8	double	5.0035e-...	5.0035e-...	0	5.0035e-...	5.0035e-...	5.0035e-...	0	0
deformation_i...	5.0035e-08	1x1	8	double	5.0035e-...	5.0035e-...	0	5.0035e-...	5.0035e-...	5.0035e-...	0	0
deformation_...	0.1000	1x1	8	double	0.1000	0.1000	0	0.1000	0.1000	0.1000	0	0
deformations	[5.0035e-08,0.10...	1x3	24	double	5.0035e-...	0.1000	0.1000	0.0333	5.0035e-...	5.0035e-...	0.0033	0.0577
density_aramid	1440	1x1	8	double	1440	1440	0	1440	1440	1440	0	0
density_carbon	1600	1x1	8	double	1600	1600	0	1600	1600	1600	0	0
density_glass	2500	1x1	8	double	2500	2500	0	2500	2500	2500	0	0
E_aramid	7.0000e+10	1x1	8	double	7.0000e...	7.0000e...	0	7.0000e...	7.0000e...	7.0000e...	0	0
E_carbon	2.3000e+11	1x1	8	double	2.3000e...	2.3000e...	0	2.3000e...	2.3000e...	2.3000e...	0	0
E_eq	1.0200e+11	1x1	8	double	1.0200e...	1.0200e...	0	1.0200e...	1.0200e...	1.0200e...	0	0
E_glass	7.0000e+10	1x1	8	double	7.0000e...	7.0000e...	0	7.0000e...	7.0000e...	7.0000e...	0	0
impact_force	10000	1x1	8	double	10000	10000	0	10000	10000	10000	0	0
impact_strain	9.3803e-07	1x1	8	double	9.3803e-...	9.3803e-...	0	9.3803e-...	9.3803e-...	9.3803e-...	0	0
impact_stress	9.5679e+04	1x1	8	double	9.5679e...	9.5679e...	0	9.5679e...	9.5679e...	9.5679e...	0	0
length	0.4572	1x1	8	double	0.4572	0.4572	0	0.4572	0.4572	0.4572	0	0
max_deforma...	0.1000	1x1	8	double	0.1000	0.1000	0	0.1000	0.1000	0.1000	0	0
max_strain	1.8748	1x1	8	double	1.8748	1.8748	0	1.8748	1.8748	1.8748	0	0
max_stress	9.5679e+04	1x1	8	double	9.5679e...	9.5679e...	0	9.5679e...	9.5679e...	9.5679e...	0	0
min_deformat...	5.0035e-08	1x1	8	double	5.0035e-...	5.0035e-...	0	5.0035e-...	5.0035e-...	5.0035e-...	0	0
min_strain	9.3803e-07	1x1	8	double	9.3803e-...	9.3803e-...	0	9.3803e-...	9.3803e-...	9.3803e-...	0	0
min_stress	9.5679e+04	1x1	8	double	9.5679e...	9.5679e...	0	9.5679e...	9.5679e...	9.5679e...	0	0
strains	[9.3803e-07,1.87...	1x3	24	double	9.3803e-...	1.8748	1.8748	0.6249	9.3803e-...	9.3803e-...	1.1716	1.0824

Fig 6.6 Innovative panel result in MATLAB

7. COMPARISON OF RESULTS

7.1 Total Deformation

Sample	Compression Test	Tensile Test	Impact Test
Existing panel in ANSYS	1.5205mm	13.932mm	0.00016183mm
Existing panel in MATLAB	5.3565e-06 mm	0.10000 mm	5.3565e-06 mm
Innovative panel in ANSYS	0.76906	13.27mm	1.856e-5 mm
Innovative panel in MATLAB	0.0333 mm	0.10000 mm	5.0035e-8 mm

7.2 Equivalent stress

Sample	Compression Test	Tensile Test	Impact Test
Existing panel in ANSYS	3.5957e5 Mpa	4.0579e6 Mpa	0.015205 Mpa
Existing panel in MATLAB	8.2011e05 Mpa	8.2011e05 Mpa	8.2011e05 Mpa
Innovative panel in ANSYS	8310.2 Mpa	5.9082e5 Mpa	0.042634 Mpa
Innovative panel in MATLAB	9.5679e04 Mpa	9.5679e04 Mpa	9.5679e04 Mpa

7.3 Equivalent strain

Sample	Compression Test	Tensile Test	Impact Test
Existing panel in ANSYS	2.1198e-02 mm	1.9912 mm	2.4574e-5 mm
Existing panel in MATLAB	1.1716e-05 mm	0.2187 mm	1.1716e-5 mm
Innovative panel in ANSYS	3.3827e-2 mm	2.4525 mm	9.9802e-7 mm
Innovative panel in MATLAB	9.3803e-7 mm	1.8748 mm	9.3803e-7 mm

8. CONCLUSION

The project titled "Design and Analysis of Hybrid Fiber Composite" successfully investigated the performance of two panels: an existing panel and an innovative panel. Using ANSYS and MATLAB for the analysis, we examined key parameters such as total deformation, equivalent stress, and equivalent strain for both panels under similar conditions.

The results demonstrate that the innovative panel, designed using hybrid fiber composites, outperforms the existing panel in terms of structural capability. It exhibited lower deformation and better stress and strain distribution, indicating a higher capacity to withstand operational loads. This enhanced performance highlights the potential of hybrid fiber composites in improving aircraft structures, leading to better durability, weight optimization, and overall safety.

The study provides a solid foundation for further exploration of composite materials in the aerospace industry, showcasing the efficiency of the innovative panel in addressing the mechanical challenges faced by aircraft structures.

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