INTERNATIONAL JOURNAL OF PROGRESSIVE RESEARCH IN ENGINEERING MANAGEMENT AND SCIENCE (IJPREMS)

www.ijprems.com
editor@ijprems.com

Vol. 04, Issue 03, March 2024, pp: 517-533

e-ISSN : 2583-1062

Impact Factor: 5.725

EXPERIMENTAL AND NUMERICAL ANALYSIS OF IMPACT STRENGTH OF FIBER METAL LAMINATES MADE OF ALUMINIUM WITH GFRP

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ABSTRACT

The fiber metal composite technology combines the advantages of metallic materials and fiber reinforced matrix systems. The increase in demands for lightweight materials leads to the use of fiber metal laminates. In our work fiber metal laminates are made with Aluminium-6061, Glass fiber with single layer, double layer and Triple layer combination was bonded with the help of Epoxy-LY556 and Hardener-HY951 by using hand layup method. In this work aluminium/glass/epoxy fiber metal laminate (FML) Specimen is Prepared by Single Layer GFRP, Double Layer GFRP and Triple Layer GFRP was prepared under ASTM E23 Standards. The impact behavior of an aluminium/glass/epoxy fiber metal laminate Specimens were tested in the Impact (Izod Test) testing machine then Experimental results were Obtained. The Experimental results obtained show that the increasing of GFRP layers will influences the impact strength of the composite. The Numerical simulation also done by using ANSYS Software with the help of ACP Pre post and Transient Structural Analysis Method. To validate the proposed numerical model, a comparative evaluation between the results obtained from the model and experimental once was carried out. The FML has been widely used in aerospace industries and wind turbine blade for their good strength with low density.

Keywords: FML, Aluminium, GFRP, Resin, Impact Strength, Numerical Analysis.

ABBREVIATIONS AND ACRONYMS

FML – Fiber Metal Laminate

GFRP – Glass Fiber Reinforced Polymer

PMC – Polymer Matrix Composites

ASTM – American Society for Testing and Materials ITM – Impact Testing Machine

UIS – Ultimate Impact Strength

1. INTRODUCTION

1.1 FIBER METAL LAMINATES

The composite materials are used in many engineering applications due to their excellent properties. The sandwich composite materials replace the metals owing to their excellent strength with low weight. Many of the literature deals with the combination of steel or aluminium reinforced with the Glass Fiber ReinforcedPolymers materials (GFRP). The carbon fiber finds application in aerospace and related fields. The cost of fabrication is reduced by using sandwich structures.

The aluminium and glass fiber are used in order to form a Fiber Metal Laminates (FMLs) and it has excellent qualities such as overall reduced weight,corrosion resistance and environment friendly. The aircraft materials are developed based on fiber metal laminates which needs the improved crack growth properties Competing materials like advanced aluminium alloys and fiber reinforced composites have potential to increase the cost effectiveness of the structure. Fiber metal laminates have hybrid composite structures based on thin sheets of metal alloys and plies of fiber reinforced polymeric materials. The concept is usually applied to aluminium with aramid and glass fibers, also it is applied to other constituents. Several articles have shown that, FMLs possess both the wonderful impact resistance characteristics of metals and the attractive mechanical properties of fiber reinforced composite materials Lightweight construction is an everlasting matter in the aviation of automotive industries. Efficient lightweight construction can be achieved by using appropriate materials with their particular merits each in parts with locally varying mechanical requirements. Therefore, an increasing use of material mix constructions is to be expected in the future. The combination of metallic components, which are reasonably reinforced in highly stressed areas by fiber reinforced polymers, suggests itself. However, the separate manufacturing of metallic components and a subsequent reinforcing of often complex components with fiber-reinforced polymers would not be affordable. Therefore, a procedure was developed, in which simple products made of metal and fiber-reinforced thermoplastics are formed in one shared step to a multi material part. The products are placed in the temperature controlled deep drawing tools andare formed together to one joined part. The challenge in this process consists mainly in the different forming characteristics of the components

1.2 OBJECTIVE OF PROJECT

- To develop fiber metal laminate material by using aluminum sheet reinforced with GFRP.
- To implement alternate material which have less weight and more stability.
- To propose this FML material for applications of aircraft, marine construction, automobiles, building structures.
- The FML material should manufacture by hand layup technique.
- The material strength should be tested experimentally.

1.3 CHARACTERISTICS OF FMLs MATERIAL

Almost any structural material which is available in the form of thin sheet may be used to form the faces of a sandwich panel. The properties of primary interest for the faces are, High stiffness giving high flexural rigidity, High tensile and compressive strength, Impact Resistance, Surface finish, Environmental resistance

The commonly used face materials can be divided into two main groups: metallic and nonmetallic materials. The former group contains steel, stainless steel and aluminum alloys. There is a vast variety of alloys with different strength properties whereas the stiffness variation is very limited. Later, the larger of two groups including materials such as plywood, cement, veneer, reinforced plastic and fiber composites

- High tensile and compressive strength
- Impact Resistance
- Surface finish
- Environmental resistance

1.4 BENEFITS OF FML MATERIAL

- FMLs provide multi-functionality for improved structural efficiency
- Efficient manufacture of difficult-to-process materials
- Unique combinations of metal/fabric/polymer possible

1.5 APPLICATIONS OF FML

Fiber Metal Laminates are used mostly in aircraft construction like fuselage design of Airbus A380, lower wing skin panels of previous Fokker 27 aircraft, and cargo door of Boeing C17. After successful implementation of FML technology in fuselage design in Airbus A380, researchers are making efforts to apply this FML technology in other structural parts of aircrafts like wings. FML manufacture will become less expensive,

- going forward, as GKN Aerospace's Fokker business continues work on an industrial automation project, with Airbus Premium Aerotec GmbH and Stelia Aerospace. Smart, automated and robotized production technology will enable higher-volume production rates and increase affordability for OEMs.

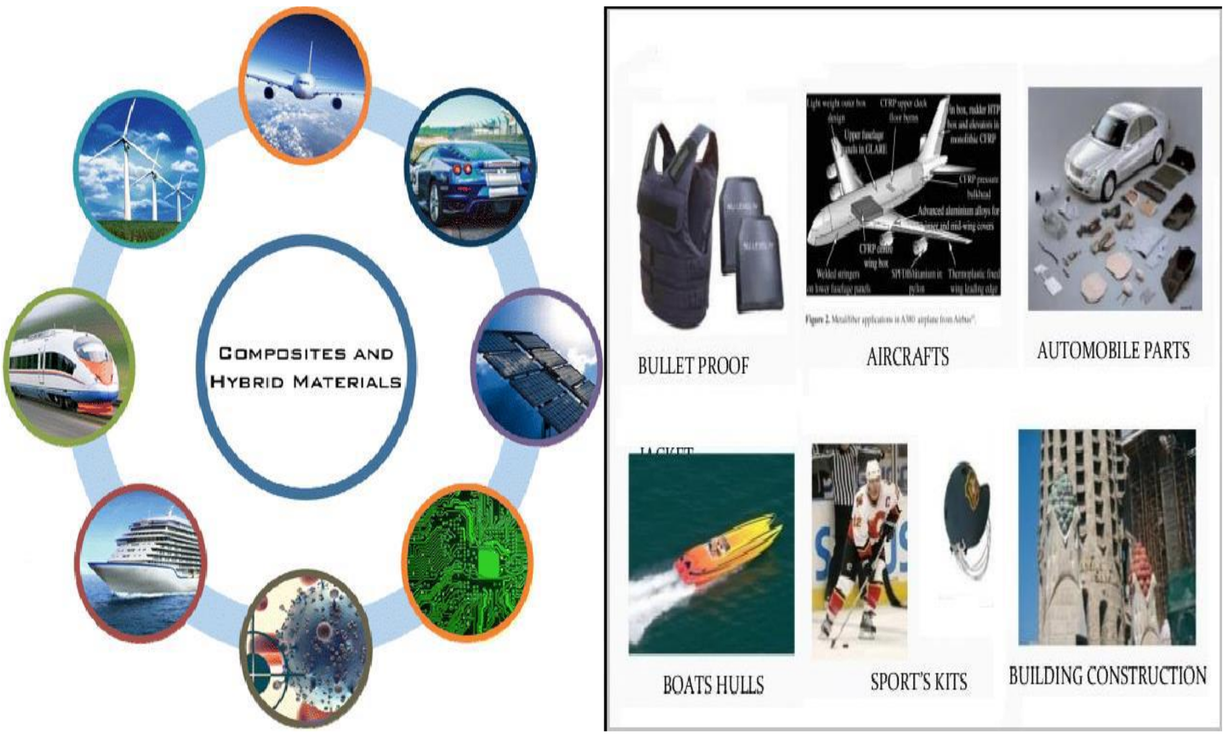

Fig.1. Application of FML

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www.ijprems.com
editor@ijprems.com
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2. MATERIAL SELECTION

Material selection refers to the process of choosing the most suitable material for a specific application or product design. It involves considering various factors such as mechanical properties, cost, availability, environmental impact, and manufacturing requirements.

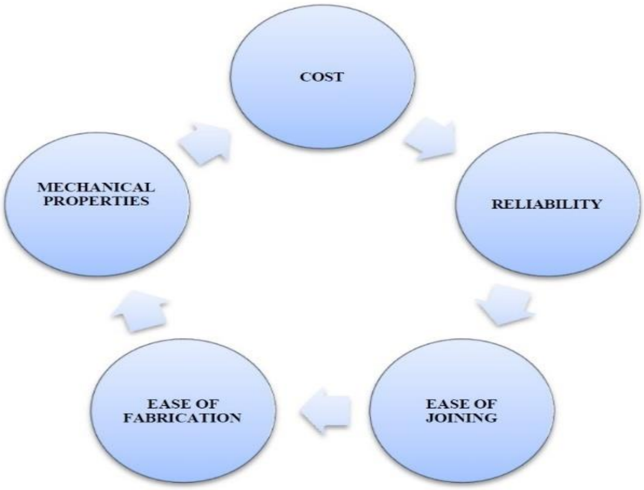

Fig 2. Engineering Factors of Material Selection

In this project, the suitable raw material is selected based on the engineering factor is shown in fig 3.1

2.1.1 Fiber Metal Laminates

Fiber Metal Laminate (FML) composed of several very thin layers of metal (usually aluminium) interspersed with layers of Glass-fiber Pre-preg, bonded together with a matrix such as epoxy. The Uni-directional pre-preg layers may be aligned in different directions to suit predicted stress conditions.

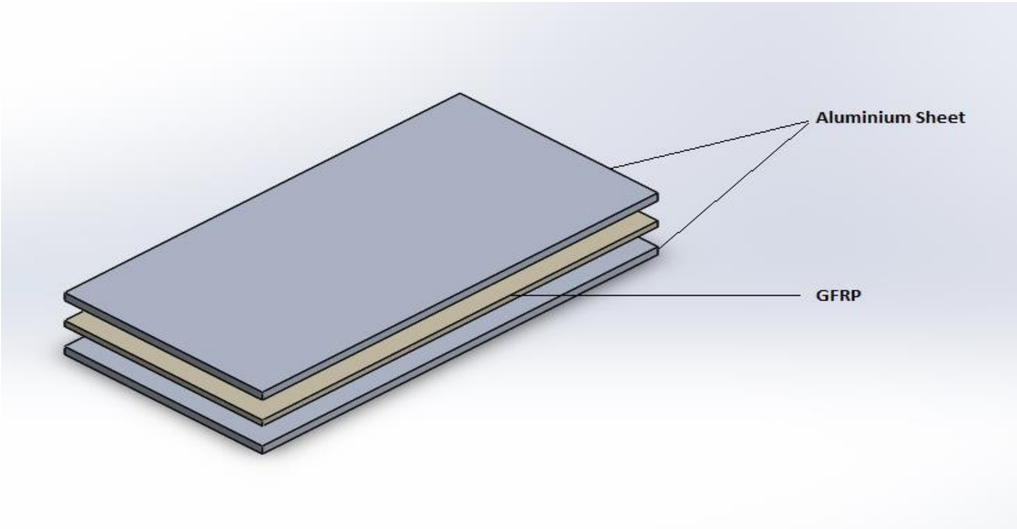

Fig.3 - Illustration of Fiber Metal Laminates

2.2 ADVANTAGES

The major advantages over conventional aluminium are:

Better damage tolerance

Better corrosion resistance

Better fire resistance

Lower specific weigh

2.3 6061 ALUMINIUM ALLOY

6061 is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties, exhibits good weld ability, good formability, and is very commonly used in forging. 6061 is an alloy used in the production of extrusion long constant cross section structural shapes produced by pushing metal through a shaped die. 6061 is an alloy that is suitable for deep drawing. This particular alloy is suitable for open die forgings. Automotive parts, ATV parts, and industrial parts are just some of the uses as a forging. Aluminium 6061 can be forged into flat or round bars, rings, blocks, discs and blanks, hollows, and spindles. 6061 can be forged into special and custom shapes other colors. It can be etched to a matte finish, polished to a sparkling brightness or textured to resemble wood and painted.

Fig 4 – Aluminium Sheet

2.3.1 Properties of 6061 Aluminium Alloy

Physical Property

Density (ρ) =2.70 g/cm3

Mechanical Properties

Young's modulus (E) = 68.9 GPa Tensile strength (σt) = 124–290 MPa Elongation (ε) at break = 12–25% Poisson's ratio (ν) = 0.33

Thermal Properties

Melting temperature (Tm) =585 °C (1,085 °F) Linear thermal expansion coefficient (α) =2.32×10−5 Specific heat capacity (c) =897

Table. 1 Chemical composition 6061 aluminium alloy

Material	Minimum (%)	Maximum (%)
Silicon	0.4	0.8
Iron	-	0.7
Copper	0.15	0.4
Manganese	0	0.15
Magnesium	0.8	1.2
Chromium	0.04	0.35
Zinc	-	0.25
Titanium	-	0.15
Aluminium	95.85	98.56

2.4 GLASS FIBER

Glass fiber (or glass fiber) is a material consisting of numerous extremely fine fibers of glass. Glass fiber is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes.

2.4.1 Properties of Glass Fiber

Glass fibers are useful because of their high ratio of surface area to weight. However, the increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity of the order of 0.05 W/m K. The strength of glass is usually tested and reported for "virgin" or pristine fibers those which have just been manufactured. The freshest, thinnest fibers are the strongest because the thinner fibers are more ductile. The more the surface is scratched, the less the resulting tenacity. Because glass has an amorphous structure, its properties are the same along the **fiber** and across the fiber. Humidity is an important factor in the tensile strength.

Table. 2 Properties of glass fiber reinforced polymer

Tensile strength (MPa)	3445
Compressive strength (MPa)	1080
Density (g/cm^3)	2.58
Thermal expansion(µm/m°C)	5
Softening T(°C)	846

2.5. GLASS FIBER REINFORCED POLYMER

Fiber Reinforced Polymers (FRP) is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass. The resin epoxy is molded with glass fiber in order to produce Glass Fiber Reinforced Polymers (GFRP) with a desired shape. It is also called Fiber Reinforced Polymer. Fiberglass Reinforced Polymers, FRP, is an excellent choice of material for the construction of chemical storage tanks, piping systems, apparatus and other types of industrial process equipment. The FRP material properties beat many conventional materials, such as steel when it comes to chemical and corrosion resistance.

Fig.5

2.5.1 Types of GFRP

The two types of glass fibers commonly used in the fiber-reinforced plastics:

- E-glass
- Sglas.s
- Other
- A-glass
- E-CR-glass
- C-glass
- D-glass
- R-glass

- The basic commercial form of continuous glass fibers: Strand, which is a collection of parallel filaments numbering 204 or more other forms of glass fibers are:
- Roving
- Chopped Strands
- Woven roving or woven cloth

2.5.2 Properties of Glass Fiber Reinforced Polymer

- GFRP has a very high strength to weight ratio.
- Low weights of 2 to 4 lbs per square foot means faster installation, less structural framing, and lower shipping costs.
- Resists salt water, chemicals, and the environment - unaffected by acid rain, salts, and most chemicals.
- Domes and cupolas are resined together to form a one-piece, watertight structure.
- Virtually any shape or form can be molded.
- Research shows no loss of laminate properties after 30 years.
- Stromberg GFRP stood up to category 5 hurricane Floyd with no damage, while nearby structures was destroyed.

2.5.3 Advantages and Limitations

FRP allows the alignment of the glass fibers of thermoplastics to suit specific design programs. Specifying the orientation of reinforcing fibers can increase the strength and resistance to deformation of the polymer. Glass reinforced polymers are strongest and

- most resistive to deforming forces when the polymers fibers are parallel to the force being exerted, and are weakest when the fibers are perpendicular. Thus, this ability is at once either an advantage or a limitation depending on the context of use.

2.6 RESIN

Among them epoxies are one of the most common and widely used thermosets today in structural and specialty composites applications. Due to their high strength and rigidity (because of high degree of crosslinking), epoxy thermoset resins are adaptable to nearly any application.

- The term "epoxy", "epoxy resin", or "epoxide" (Europe), α-epoxy, 1,2-epoxy etc. refers to a broad group of reactive compounds that are characterized by the presence of anoxirane or epoxy ring. This is represented by a three-member ring containing an oxygen atom that is bonded with two carbon atoms already united in some other way.
- The three primary classes of epoxies used in composite applications are:
- Phenolic glycidyl ethers
- Aromatic glycidyl amines and
- Cycloaliphatic
- Further epoxy resins can be combined with varied curing agents, modifiers to achieve the properties required for a specific application.

2.6.1 Properties of Epoxy Resin

- High strength
- Low Shrinkage
- Excellent adhesion to various substrates
- Effective electrical insulation Chemical
- Solvent resistance, and Low cost
- Low toxicity

Epoxy resin is also used to modify several polymers such as polyurethane or unsaturated polyesters to enhance their physical and chemical attributes.

For thermosetting epoxies:

- The tensile strength ranges from 90 to 120 MPa
- A tensile modulus ranging from 3100 to 3800 MPa
- Glass transition temperatures (Tg) that range from 150 to 220◦C

2.6.2 Epoxy LY556

- The Epoxy Resin LY 556 is extensively used as a reinforcing material due to its medium viscosity and chemicals resistivity. Property of this resin can easily be modified within wide limits with the use of fillers and hardeners. The composition of this resin is based on Bisphenol-A which makes it suitable for high-performance FRP composite applications such as pultrusion, pressure molding, filament winding and so on. Epoxy resin is known for exceptional mechanical, good fiber impregnation and thermal & dynamic properties. Also, the Epoxy Resin LY556 is having a low tendency to crystallize, that's why it is preferred for aircraft and aerospace adhesives.

2.7. Hardener HY951

- 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.

Table 3 : Chemical Properties of Hardener HY951

1.	Viscosity at 25°C	10-20 mPa*s
2.	Specific Gravity at 25°C	0.98 g/cm³
3.	Appearance	Clear liquid
4.	Flash point	110°C
5.	Mix ratio	10:1

Fig. 6- Epoxy Resin and Hardener

3. MANUFACTURING PROCESS

Laser ablation, hydrothermal, sputtering, pyrolysis, sol-gel, and ball milling are among the many techniques that can be used to synthesize aluminum oxide nanoparticles. One technique that's most commonly utilized in the production of nanoparticles, is laser ablation as they can be made in liquid, vacuum, or gas. High purity and rapid processes are some of the numerous benefits that this technique provides in comparison to the other methods.

3.1 Advantages

- High Thermal barrier properties as well as being super hydrophobic
- Durability, fire retardancy, Stiffness, Thermal fatigue resistance, Fracture toughness, Creep resistance and Wear resistance
- Chemically stable
- Anti-corrosive
- Mechanical strength enhancement
- Electrical insulating

4. FINITE ELEMENT SIMULATION

4.1 ANSYS SOFTWARE

- Ansys develops and markets engineering simulation software for use across the product life cycle. Ansys Mechanical finite element analysis software is used to simulate computer models of structures, electronics, or machine components for analyzing strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. Most Ansys simulations are performed using the Ansys Workbench system, which is one of the company's main products.

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4.2. ANSYS WORK

- In Engineering data, we have to add the material properties. In that, there are some standard properties of materials is already available in data source. Using the data source, we can take the properties of a material which we need. In our test, we have selected some materials namely Aluminium 6061, GFRP, epoxy resin, Nanocomposite. For the selected material we have added the material properties like tensile strength, density young's modulus, etc. Similarly, we have taken the data for epoxy resin from the data source which is available in software. Create a geometry using the given dimensions. The top layer and bottom layer of that sheet have Aluminium and at the center we are placing a GFRP. Both the materials are attached using the epoxy resin.

4.3 ANSYS COMPOSITE PREPOST

Composites materials combine two or more layered materials, each with different properties. The material can provide flexibility, so the process for manufacturing products with complex shapes is easier if they are made of composites materials. This simplified model was created in ANSYS Workbench with the help of ANSYS Composite PrePost and the impact simulation is conducted by ANSYS Transient structural. Initially designing and modeling of fiber metal laminate were conducted in ANSYS with a Composite Prep Post. Aluminium alloy was selected to form the fiber metal laminate then glass fiber is arranged on the inner surface of the aluminium sheet metal. Glass fiber is arranged as a unidirectional orientation.

4.4 ANSYS SCHEMATIC WORK

- The analysis of Impact strength is done through the ANSYS workbench software. This software package is based on the finite element analysis and basic steps involved in this are as follows
- Pre processing
- Solution Phase
- Post processing

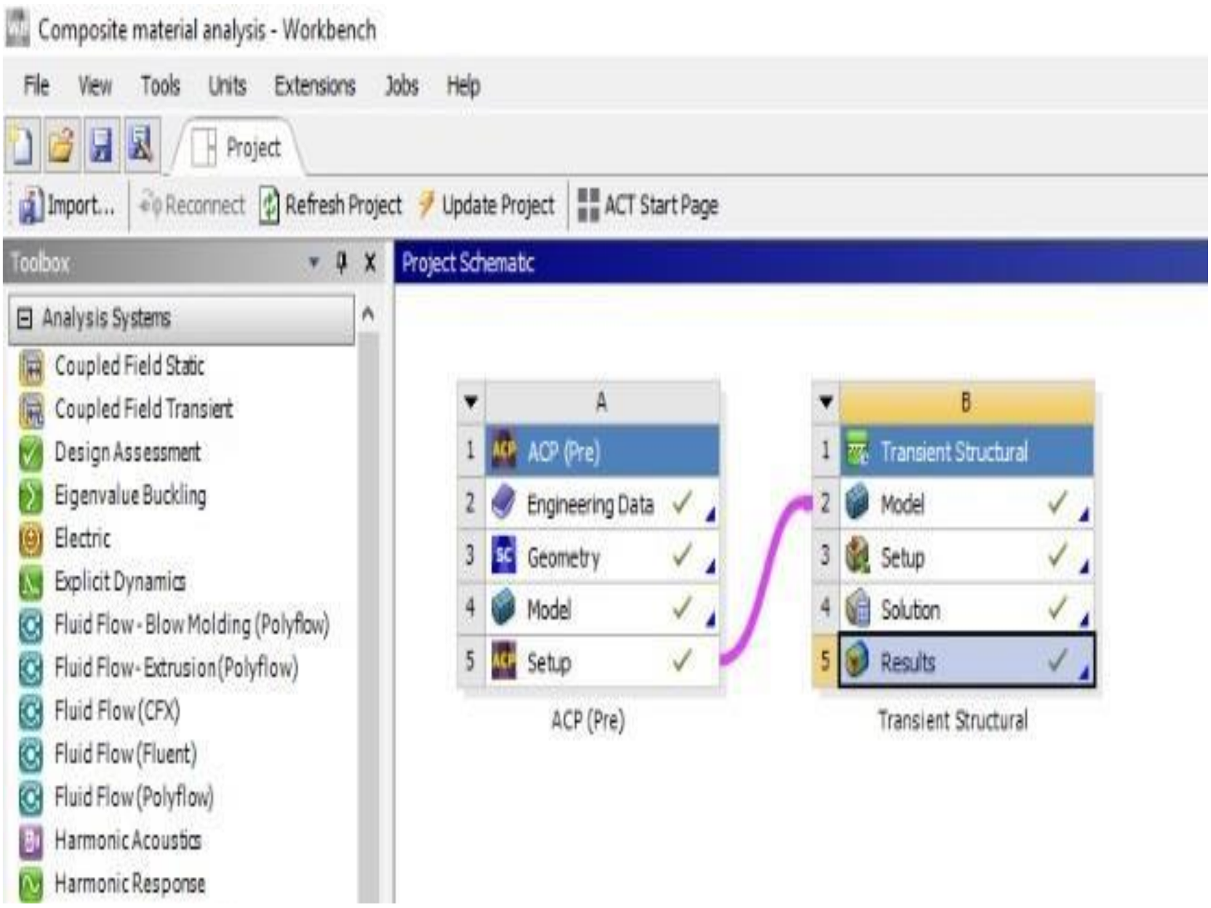

Fig 7 - Project Schematic View

4.5 Engineering Data

Start from ANSYS 16.2, select the component system – open the engineering data- select the filter engineering data - click here to the new material-add the name AL 6061- enter the properties value with help of tool box. The properties value given table. Insert epoxy e - glass material for engineering data source.

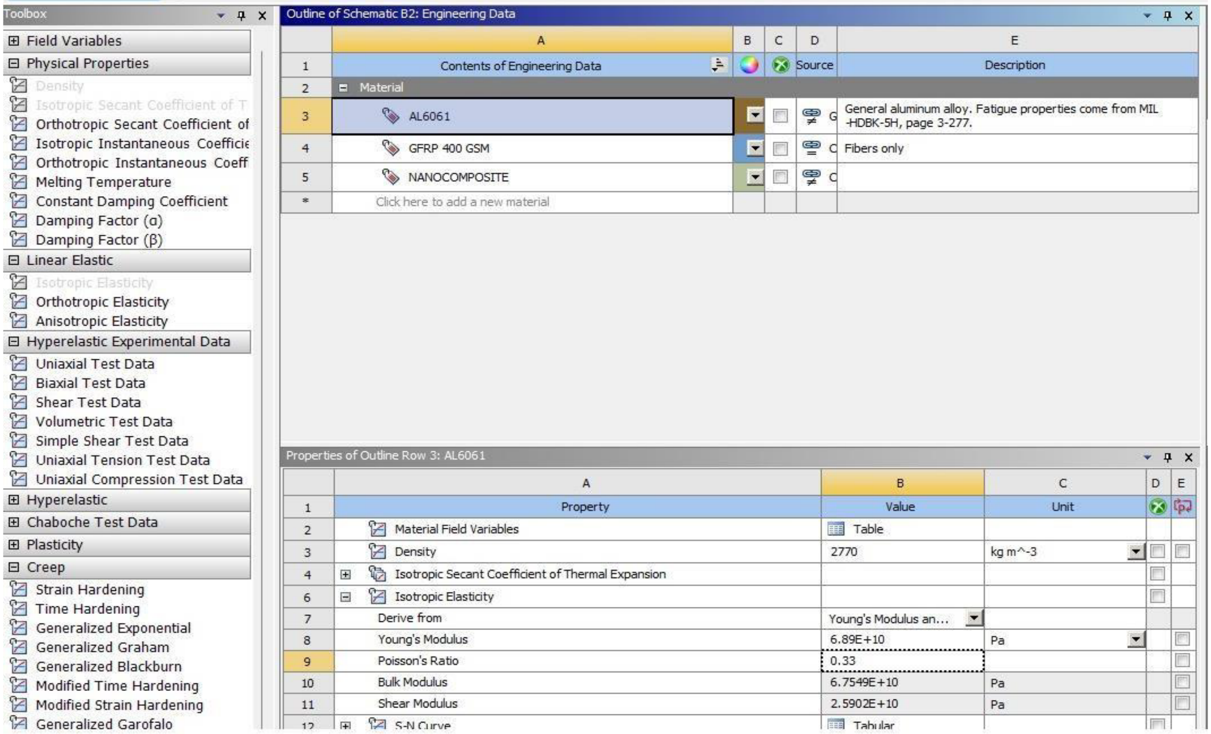

Fig 8 – Al 6061 Engineering Data

Table.4

Density	2770kg m^{-3}
Young's Modulus	6.89E+10 pa
Poisson's Ratio	0.33
Bulk Modulus	6.7549E+10 pa
Shear Modulus	2.5902E+10 pa
Specific Heat	875 J Kg^{-1} C^{-1}
Coefficient Of Thermal Expansion	2.36E-05 C^{-1}
Reference Temperature	22^{0} C

4.6 GFRP Engineering Data

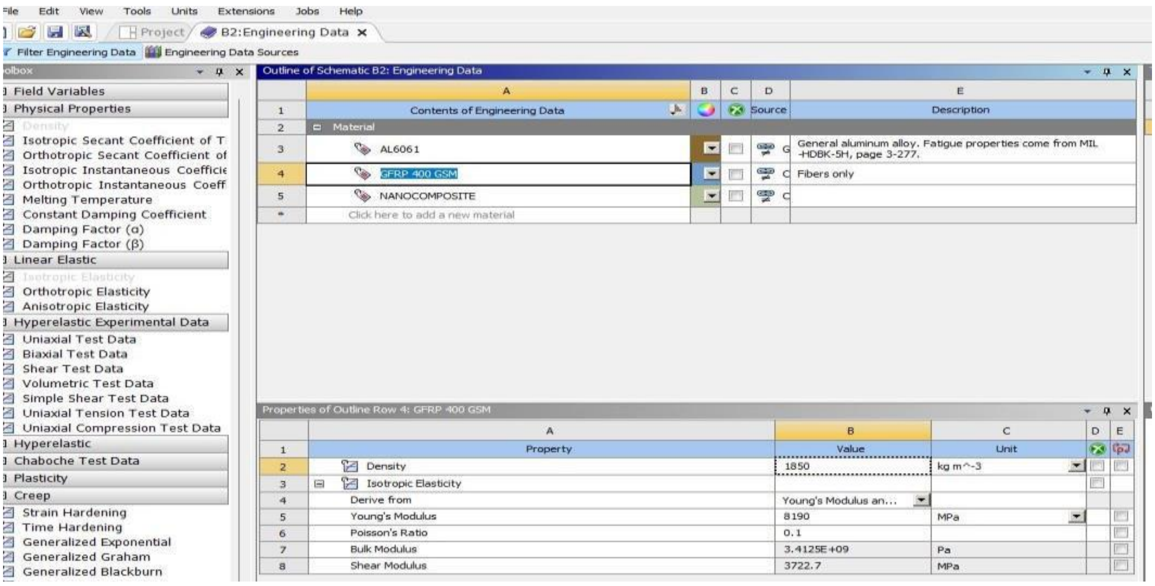

Fig.9

Table.5

Density	1850 Kg m^{-3}
Young's Modulus	8190 Mpa
Poisson's Ratio	0.1
Bulk Modulus	3.4125E+09 pa
Shear Modulus	3722.7 Mpa
Tensile Yeild Strength	1600 Mpa
Isotropic Thermal Conductivity	0.0004 W mm^{-1} K^{-1}
Specific Heat	1610j kg^{-1} k^{-1}

4.7 IMPACT SIMULATION

4.7.1 Impactor Design

In the numerical analysis, the static indentation test and drop weight impact test are replicated as close as possible in the virtual domain but without incurring high computational expenses. The commercial FE computer software was employed for this purpose. The following points are valid for both static and impact analyses. As the thickness-to-span ratio for the sandwich plate is high, transverse shear deformation is expected to be significant. Elements in the core must include the effect of transverse shear deformation. In addition, membrane strains and large rotations must be accounted for, as large deformation effects are expected. The impactor/indentor was modelled as a rigid body using four- noded linear tetrahedron continuum elements, and its motion was governed by the rigid body reference node. The impactor/ indentor had a Young's modulus of 200 GPa, with a Poisson's ratio of 0.3. In the impact analysis, the 13 mm diameter steel spherical impactor had a density of 2.25 106 kg/m3 to reflect its actual 36.

mass in the experiment, which was 2.65 kg in all impact simulations. The impactor was also constrained to move only in the out-of-plane direction (i.e. Z-direction) of the plate. To reduce the runtime, all simulations commenced with the impactor situated just 0.1 mm above the sandwich plate. However, for the static analysis, gravitational load and initial velocity were not assigned. Instead, only a download displacement load in the Z-direction was prescribed on the indentor's reference node to simulate the static indentation test.

4.8.1 Geometry – Design Modeler

Open the geometry component tool -select the xz plane-click the look at face tool using the sketching tool -create the rectangle-select the dimensions tool –length (55mm) width (13mm)-using extrude tool- select the material type-add material-thickness for 3mm.

Geometry Dimensions Specimen

Length 55mm

Width 13mm

Thickness 3mm

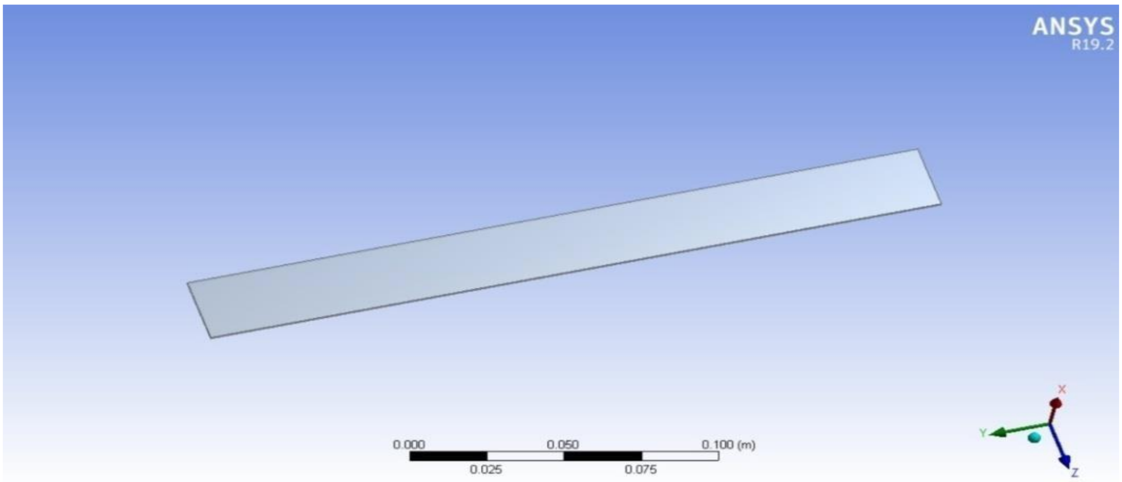

Fig 10 - FML Sheet

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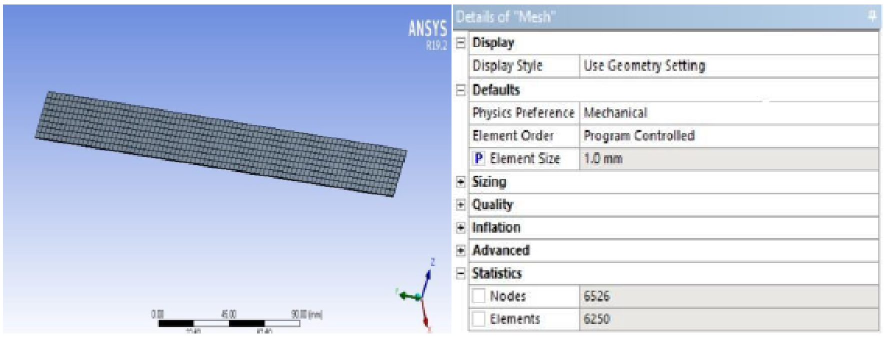


Fig 4.5 -Mesh

4.6.3 Defining Loads and Boundary Condition Fixed Support

In this, the movement of the one face of the FML will be arrested in all the three dimensions.

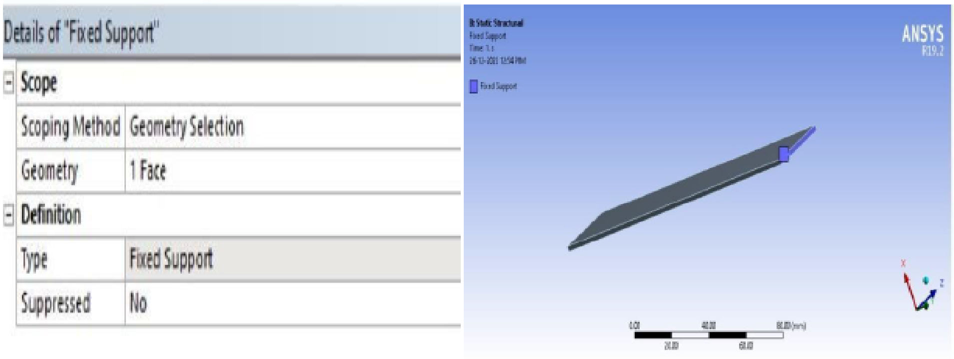


Fig 11 - Details of Fixed Support

4.6.4 Force

In this the movement of one face is arrested in X, Y direction and the load direction is applied in Z direction. In this step the force of required magnitude is applied in the position we want to applying the load. After applying load direction of load applied is determined by using selection of direction plane.

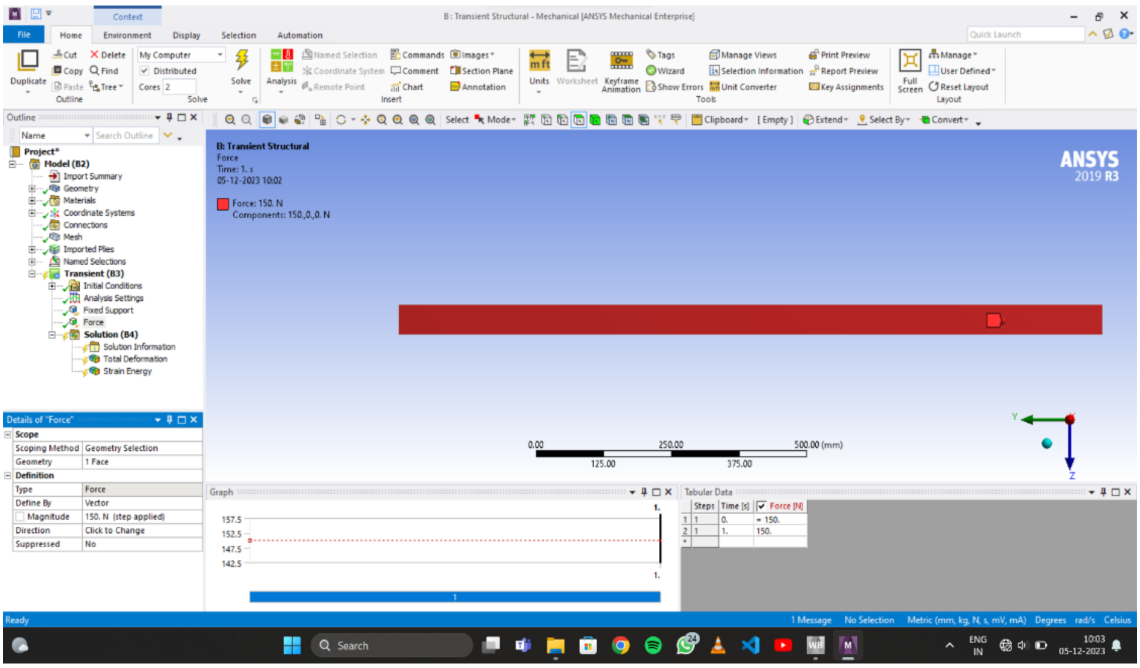


Fig.12

4.6.5 Solution Process

Select the solution option and right click to insert total strain energy in the insert menu option. Select the solution option and right click to solve. Then the overall dialogue box will appear. After the completion of solution result will be viewed.

4.6.6 Post Processing

In this phase of the analysis, results are viewed and plotted. It includes plotting of contours, vector display, deformed shape and tabulating of results obtained at nodes. To visualize the results are interested in, add the following items to the solution total deformation and equivalent (von misses) stress. Right click on solution and evaluate the results.

4.6.7 Results Obtained

Select the solution – right click – insert – Energy – Strain - equivalent von mises strain -evaluate all results. **Visualizing Strain: Equivalent (Von-Mises)**

4.6.7.1 Single Layer

After the post processing the result of fiber metal laminates with single layer was obtained. In this single layer the minimum strain energy obtained is **0.23733 J** and the maximum strain energy obtained in the numerical analysis is 1.4062 J.

Table.6

Model (B2) > Transient (B3) > Solution (B4) > Results

Object Name	*Total Deformation*	*Strain Energy*
State	Solve Failed	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Definition		
Type	Total Deformation	Strain Energy
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Results		
Minimum	0. m	0.23733 J
Maximum	0.35741 m	1.4062 J
Average	9.6932e-002 m	
Minimum Occurs On	SolidModel.1	
Maximum Occurs On	SolidModel.1	
Total		17.701 J
Information		
Time	1. s	
Load Step	1	
Substep	999999	
Iteration Number	22	

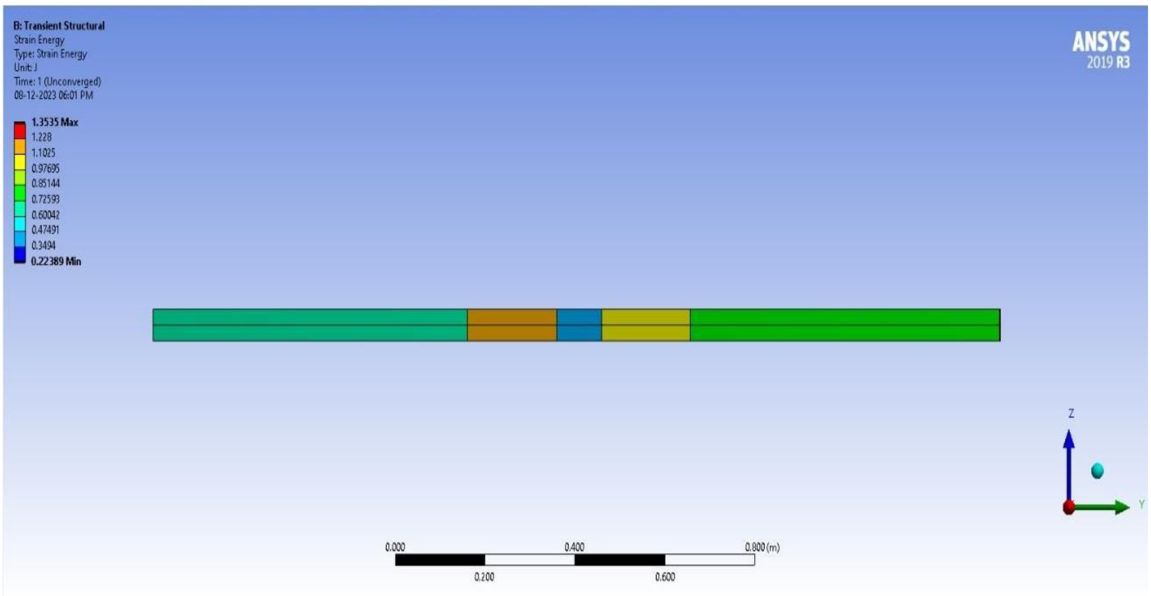


Fig 13 – Strain Energy – Single Layer

4.6.7.2 Double Layer

After the post processing the result of fiber metal laminates with single layer was obtained. In this single layer the minimum strain energy obtained is 3.4881e-0.03 J and the maximum strain energy obtained in the numerical analysis is 2.9079 J.

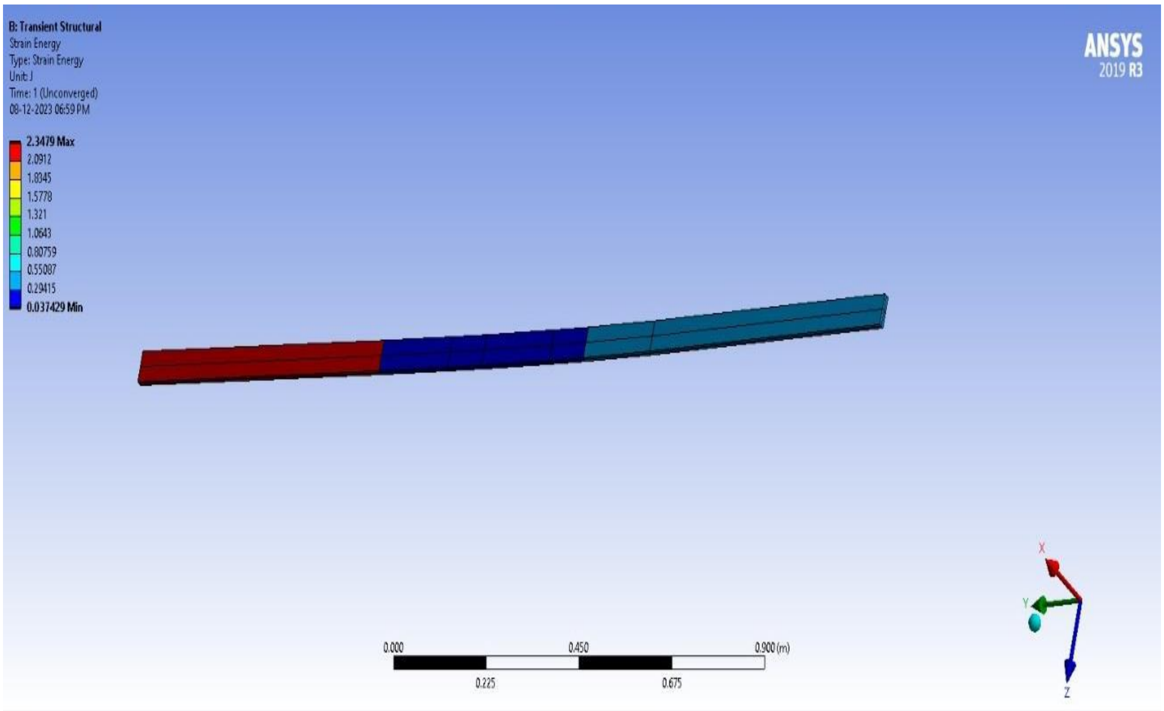


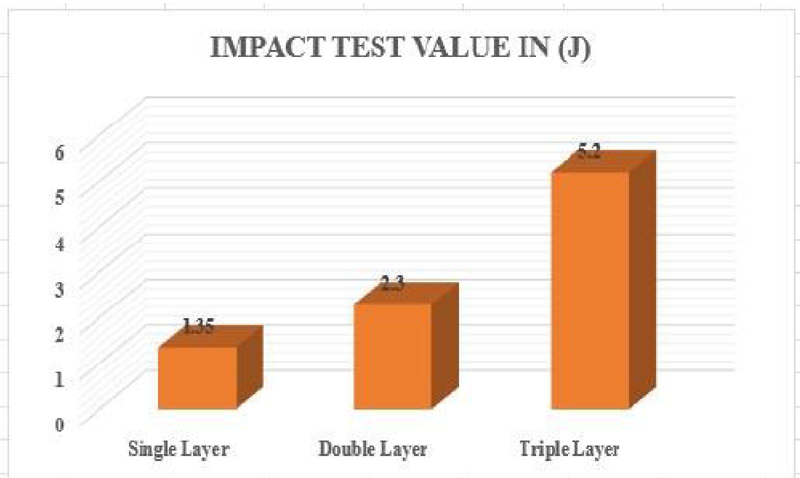
Fig.14. Printing of Products

4.7 NUMERICAL RESULT

Finally, all the three combinations of fiber metal laminates with numerical result were tabulated and compare the all the three results. To validate the effect of increasing of GFRP Layers in the fiber metal laminates with the help of graphical representation drawned by number of layers and strain energy in J.

Table 4.3 Numerical Result

Description	Strain Energy in J
Single Layer	1.35
Double Layer	2.39
Triple Layer	5.27



5. PREPARATION OF FIBER METAL LAMINATES

5.2 OPEN MOLD LAMINATING

As the name implies, open mold laminating of Fiber Reinforced Plastics is achieved utilizing a single "open" top or bottom semi-rigid concave or convex mold. The desired "finished side" of the part dictates the orientation of the mold. In starting the manufacturing process, the mold is cleaned and prepped with a release agent. If a cosmetic surface finish is required, the mold surface is covered with a gel coat and allowed time to cure.

The methods of open mold fabrications:

- Hand lay-up
- Spray-up
- Tap Lay-up
- Filament Winding
- Autoclave Method

5.2.1 Hand Lay-Up

In the hand lay-up process, the laminate structure, commonly a single continuous strand glass mat, a woven glass mat or an advanced composite mat is manually "hand- laid" in the mold. The catalyzed thermoset resin is introduced, and the materials are 44

- formed to fit the mold surface using a "roll-out" process, as well as a number of specialized laminating tools. Additional layers of reinforced mat can be added to key structural points to enhance rigidity and performance. The Hand lay-up process is most effective when molding complex surfaces, and is commonly used in the transportation,

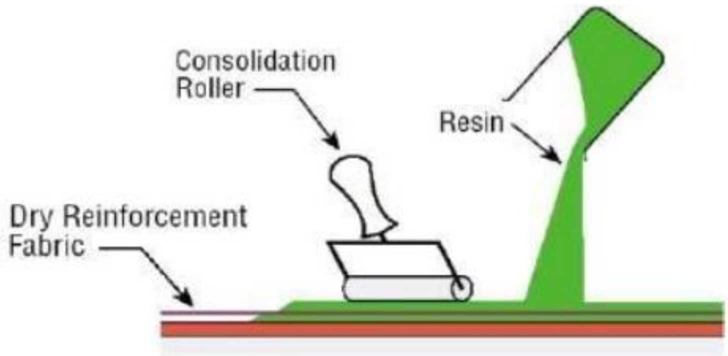


Fig 5.1 Hand - up Method

Fig 5.2 - Preparation of Fiber Metal Laminate

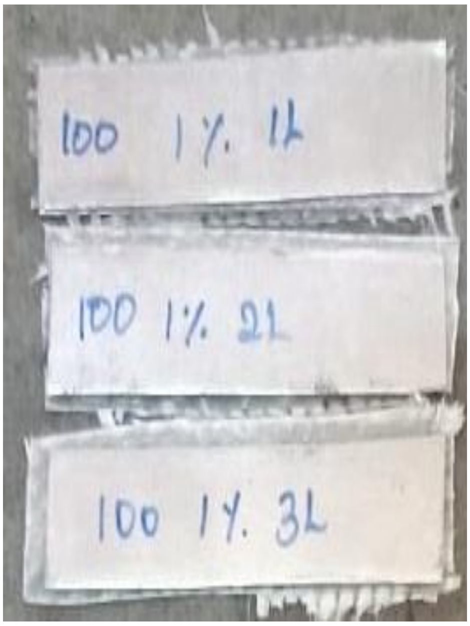
6.1 IMPACT STRENGTH

- The Izod test is a standardized test procedure used to determine the impact resistance of a material. It is commonly employed for testing the impact strength of plastics. The test involves striking a notched sample with a pendulum and measuring the energy absorbed by the sample during fracture

Fig 6.1 - ITM for Izod Test

6.2.1 Testing of Specimen

The entire Izod test will focus on the gauge length, while one end of the shoulders will be firmly gripped by the Impact tester machine. These machines hold your specimen with the use of grips or crossheads that firmly hold one end. One grip keeps the material in place, while the other grip will pull until it eventually breaks



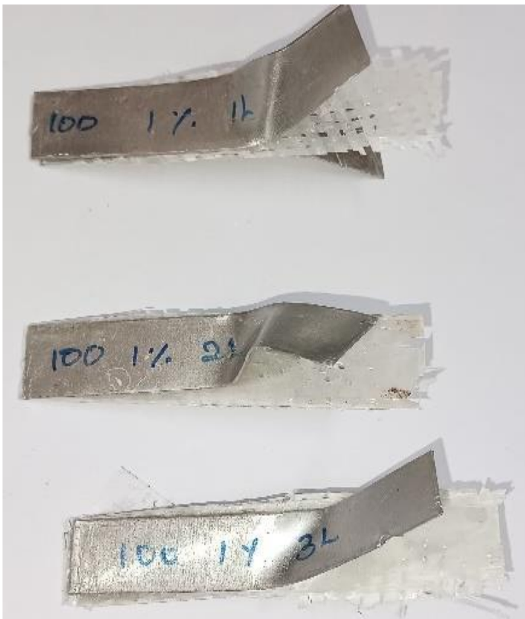


Fig 6.2 - Before Load **Fig 6.3** - After Load

6.3 EXPERIMENTAL RESULT

The Experiment was conducted in the impact testing machine the experimental result of fiber metal laminates with various layers namely Single, Double and Trible layer GFRP was obtained. The fiber metal laminates with single layer GFRP have 1 J of strain energy and double layer GFRP have 2.1 J strain energy and also fiber metal laminates with triple layer GFRP have strain energy of 3.3 J.

Finally, all the three combinations of fiber metal laminates with experimental result were tabulated and compare the all the three results. To validate the effect of increasing of GFRP Layers in the fiber metal laminates with the help of graphical representation drawned by number of layers and strain energy in J

Description	IMPACT TEST VALUE IN (J)
Single Layer	1
Double Layer	2.1
Triple Layer	3.3

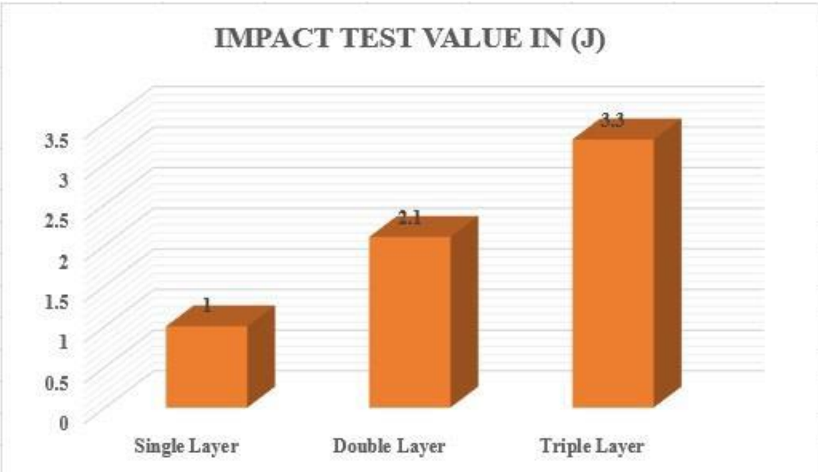
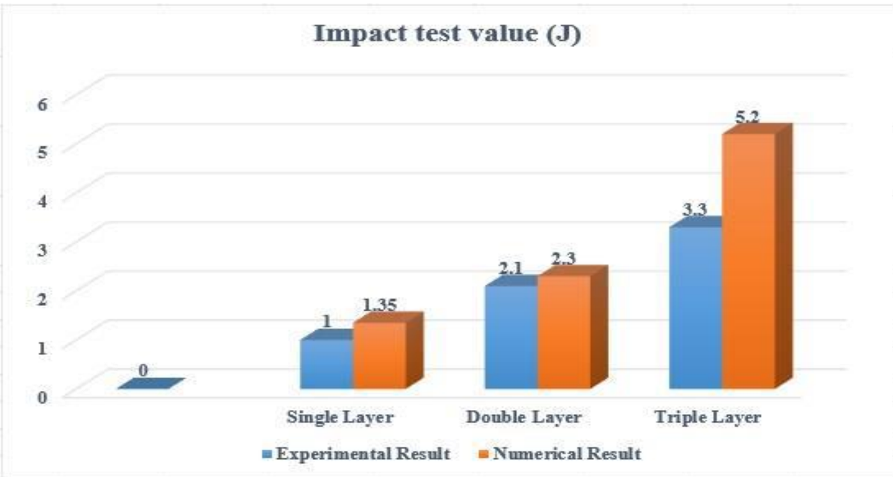


Fig.6.4 Experimental Result

6. RESULT AND DISCUSSION

In this study Impact test values in (J) vs. Number of layers was recorded in impact tests for FML laminates in comparison with relationships obtained from numerical and experimental analyses. Generally, Impact test values in (J) vs. Number of layers determined for tested fibre metal laminates experimentally and numerical analyses shows to their similar nature. These observations relate to FML laminates with single layer GFRP 1J of impact energy obtained in experimental result and 1.35J is obtained in Numerical result. FML with double layer GFRP 2.1J of impact energy is obtained in experimental result and 2.3J is obtained in numerical result and also FML with triple layer GFRP 3.3J of impact energy obtained in experimental result and 5.2J is obtained in Numerical result.



7. CONCLUSION

The present work describes about the impact characterization of FML in both numerical and experimental analyses. In our work fiber metal laminates are made with Aluminium-6061, Glass fiber with single layer, double layer and Triple layer combination was bonded with the help of Epoxy-LY556 and Hardener-HY951 by using hand layup method. From the numerical and experimental analyses, the fiber metal laminates with single layer GFRP 1J of Impact energy obtained in experimental analysis and 1.35J is obtained in Numerical analysis. FML with double layer GFRP 2.1J of impact energy is obtained in experimental analysis and 2.3J is obtained in numerical analysis and also FML with triple layer GFRP 3.3J of impact energy obtained in experimental analysis and 5.2J is obtained in Numerical analysis. From the above result will clearly identify the effect of Impact energy will increases while increasing the GFRP layers into the fibre metal laminates. Finally, we observed and conclude that both experimental and numerical results give approximately equal Impact strength. Thus, it can be concluded that the obtained composites will acts as a low cost, lightweight composites to be used for various purpose, on account of their better mechanical and physical characterization.

8. REFERENCES

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