EXPERIMENTAL INVESTIGATION OF GLASS FIBER REINFORCED POLYMER (GFRP) COMPOSITE LAMINATES

[1]A.Karthick, [2]Karthik Prabu B, [3]Johnson V, [4]Karthik Praveen, [5]Kiran P

[1]Assistant Professor, [2,3,4,5]UG Students
Department of Mechanical Engineering
Adithya Institute of Technology, Coimbatore

***ABSTRACT*: The laminated composite materials usage is increasing in all sort of engineering application due to high specific strength and stiffness. Fibre reinforced composite materials are selected for weight critical applications. The component such structures invariably experiences various types of constant and variable tensile, impact properties. Thus, safe operation of the structures for the required technical life time demands that such composite material, in addition to their good static mechanical properties need to possess relatively high tensile durability.**

This journal is having the aim to compute the tensile and impact life of glass fiber reinforced polymer and the replacement of steel car door with the investigated glass fiber composite material. For this work, , unidirectional mat glass fiber and epoxy resin have been used. The testing specimen based on the ASTM standard has been fabricated by hand lay-up method. The ultimate strength and impact strength of the GFRP composite laminates have been obtained by conducting tensile and charpy impact on the fabricated specimen using computerized UTM and impact test machine. The investigated material is applied for the replacement of steel car door on observing under FEA analysis. Therefore the experimental investigation is carried out and the steel car door has been replaced with composite glass fiber material on considering various factors.

***Keywords*: Fibre reinforced composite materials, steel car door, epoxy resin, unidirectional mat glass fiber, etc**

INTRODUCTION

Fibre Reinforced Polymer (FRP) composites are widely used in ship hull, airframe, and wind –turbine structural applications due to their high specific strength and stiffness. The components in such structure invariably experience various types of constant and variable amplitude tensile loads in service. Thus, safe operation of the structure for the required technical life time demands that such composite materials, in addition to their good static mechanical properties, need to possess relatively high tensile durability, impact and fracture toughness.

The majority of engineering composite materials in service consist of continuous fibres of glass, or carbon, reinforcing an epoxy polymeric matrix. The epoxy, when polymerized, is an amorphous and a highly cross-linked material. This microstructure of the epoxy polymer results in many useful properties such as high modulus and failure strength, low creep, etc., but also leads to an undesirable property in that it is relatively brittle. These adverse fracture properties may obviously also affect the overall tensile and fracture performance of the FRP composites.

The tensile failure in laminated composite materials is a very common failure mode in most of the FRP components. As reinforced polymers used in weight critical applications. Often over designed to compensate tensile failure lead to the increase in weight which in turn hampers the objective of designer. In this connection the investigation on tensile failure behaviour of laminate to be used in the component is very important.

UNIDIRECTIONAL GLASS FIBER MAT

A unidirectional (UD) fabric is one in which the majority of fibres run in one direction only. A small amount of fibre or other material may run in other directions with the main intention being to hold the primary fibres in position, although the other fibres may also offer some structural properties. Some weavers of 0/90° fabrics term a fabric with only 75% of its weight in one direction as a unidirectional, whilst for others the unidirectional designation only applies to those fabrics with more than 90% of the fibre weight in one direction. Unidirectional usually have their primary fibres in the 0° direction (along the roll - a warp UD) but can also have them at 90° to the roll length (a weft UD).

True unidirectional fabrics offer the ability to place fibre in the component exactly where it is required, and in the optimum quantity (no more or less than required). As well as this, UD fibres are straight and uncrippled. This results in the highest possible fibre properties from a fabric in composite component construction. For mechanical properties, unidirectional fabrics can only be improved on by prepreg unidirectional tape, where there is no secondary material at all holding the unidirectional fibres in place. In these prepreg products only the resin system holds the fibres in place.

Table 1 Properties of E-Glass Fiber

Properties	Values
Density (g/cm^3)	2.54
Tensile modulus (GPa)	72.4
Tensile strength (GPa)	3.45
Poisson's ratio	0.2

THERMOSET MATRIX (EPOXY)

Starting materials for epoxy matrix are low-molecular weight organic liquid resins containing a number of epoxide groups, which are three-member rings of one oxygen atom and two carbon atoms. The Epoxy molecular structure is shown in Figure 1.

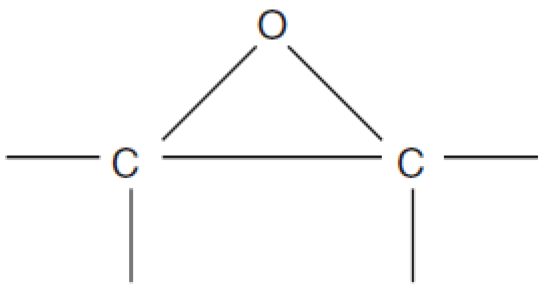

Figure 1 Epoxy Molecular Structure

A common starting material is di-glycidyl ether of biphenyl A (DGEBA), which contains two epoxide groups, one at each end of the molecule other ingredients that may be mixed with the starting liquid are diluents to reduce its viscosity and flexibilizers to improve the impact strength of the cured epoxy matrix. The polymerization (curing) reaction to transform the liquid resin to the solid state is initiated by adding small amounts of a reactive curing agent just before incorporating fibers into the liquid mix. One such curing agent is di-ethylene tri-amine (DETA). Hydrogen atoms in the amine (NH_2) groups of a DETA molecule react with the epoxide groups of DGEB. As the react ion continues, DGEBA molecules form cross-links with each other and a three-dimensional network structure is slowly formed. The resulting material is a solid epoxy polymer. The properties of Epoxy resin is shown in Table 2.

Table 2 Properties of Epoxy Resin

Properties	Values
Density (g/cm^3)	1.2-1.3
Tensile modulus (GPa)	2.75-4.10
Tensile strength (MPa)	55-130
Cure shrinkage (%)	1-5
Poisson's ratio	0.2-0.33

FABRICATION

HAND LAYUP TECHNIQUE

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mould surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mould plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats is cut as per the mould size and placed at the surface of mould after Perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mould.

The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mould plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mould is opened and the developed composite part is taken out and further processed.

The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirement is less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, daises board, deck etc.

LITERATURE REVIEW

The following literatures have been reviewed to study about composite materials and fatigue life of GFRP composite laminates.

V. K. Srivastava (2012) This explains the sandwich structures are made of cross-plied E-glass fibre reinforced plastic (GFRP) composite faces with polyurethane foam core. GFRP composites are used to combine the upper face and the lower face through the core in stitched sandwich structures. Three impact conditions are considered, such as the Izod impact, Charpy impact and weight drop impact. The results show that weight drop impact energy is higher than the Izod and Charpy impact energy, whereas dynamic fracture toughness of charpy impact energy is more than the Izod and weight drop impact energy due to geometry of impactor and specimen.

S. Kocaoz, V.A. Samaranayake, A. Nanni (2005) This states the tensile strength by Four selected types of glass FRP (GFRP) bars with the same diameter were tested. In total, 32 bars from the same manufacturer were investigated. Instead of a polymeric resin-based anchor, a steel pipe filled with expansive cementitious grout was used as the end restrained. An experiment based on a randomized complete block design was carried out to obtain data for statistical analysis. The analysis was carried out using a commercially available data analysis software program. And denotes the tensile characteristics of GFRP rod.

Kalidass R, Balaji S (2014) This explains the tensile life of environmental treatment on glass fiber. There have been several efforts made by researchers in the last few years to establish the much needed correlation between the mechanical properties of the material and the moist environment or similar hydrothermal conditions, subjected to thermal shocks, spikes, ambient & sub ambient temperatures. But most research has been on the mechanical aspects rather than the physical & chemical interface and how this brings change in the internal mechanical properties and affects a variety of other morphological changes. The focus of our research has been to understand the physical changes that take place at the bonding interface between the fibers and the matrix, as it is of prime importance due to its link to the stress transfer, distribution of load and it also governs the damage accumulation & propagation. This has wide significance in aerospace applications, because the aircraft components are exposed to harsh moist environment.

A. R. Maligno, N. A. Warrior, A. C. Long (2008) This journal provides knowledge on finite element analysis by following conditional approach. Residual stress has been determined by considering two contributions: volume shrinkage of matrix resin from the crosslink polymerization during isothermal curing and thermal contraction of both resin and fibre as a result of cooling from the curing temperature to room temperature. To examine the effect of residual stress on failure, a study based on different failure criteria and a stiffness degradation technique has been used for damage analysis of the RVE subjected to mechanical loading after curing for a range of fibre volume fractions. Predicted damage initiation and evolution are clearly influenced by the presence of residual stress.

JatothPrudhvi Raj Naik, B.Mahasenadhipathi Rao &B.ShivaSambi Reddy (2015) This journal provides idea about investigation of mechanical, chemical and thermal properties of GFRP rotor blades which are used in cooling towers. These blades are manufactured by pressure bag moulding process by using suitable mould. Before installation (Delivery), the blade must be tested for mechanical, chemical, thermal and other properties. For this testing, GFRP laminate is made by hand layup technique. Epoxy resin is used as matrix in manufacturing of the GFRP laminate.

SunithBabu L, H. K. Shivanand (2014) This explains the impact investigation of composite by the following methodology such that The behavior of E-glass/epoxy and carbon fiber laminated composite plates has been experimentally studied under impact of steel projectile at low velocities. The results were obtained using a drop weight impact machine and presented for cross-ply laminates [0 - 90] combination. The time history of the impact process such as the load, energy, velocity for both laminates is determined for a target square plate of 2mm thickness and deflection due to an impact force acting at the centre.

S. Prabhakaran, K. Chinnarasu, M. Senthil Kumar (2012) This provides the factors considered for the replacement of steel car bumper on composite car bumper by the following The best way to increase the fuel efficiency without sacrificing safety is to employ fiber reinforced composite materials in the cars. Bumper is the one of the part having more weight. In this paper the existing steel bumper is replaced with composite bumper. In this work the design and fabrication of composite bumper made up of glass fiber reinforced polymer is carried out by which weight of the bumper can be reduced. Fabrication of composite bumper is carried out by hand layup process by using E- Glass/ Epoxy bidirectional laminates. Composite bumper is analysed and Charpy impact tests are carried out. Compared to steel bumper, the composite bumper is found to have 64% higher factor of safety and 80% less in cost.

Dong-Woo Seo, Ki-Tae Park, Young-Jun You, Ji-Hyun Hwang (2014) This helps to know the tensile characteristics of hybrid composite fiber on different observational conditions This uses the concept of material hybridization to increase elastic modulus to be used in concrete structures, especially for marine and port concrete structures. The effect of hybridization on tensile properties of FRP Hybrid Bars was evaluated by comparing the results of tensile test with those of non-hybrid FRP bars. The results of this study indicated that the elastic modulus of the hybrid GFRP bar was increased by up to approximately 5 to 204 percent by the material hybridization.

AditiKaul Shah, Sandeep K. Sodhi (2009) This journal provides the knowledge and methodology carried out on composition of different types of resin and hybrid glass fiber. The tensile life is meant for investigation for the better strength characteristics. The tensile strength of the hybrid GFRP composites was improved with the increase in concentration of abrasive content. Composites of different compositions with three different abrasive particles i.e. Al_2O_3, SiC, and TiO_2 are made with varying weight percentage from 2, 4 and 6gm each. The maximum Tensile strength i.e. 77.14 MPa is observed for composites reinforced with 2 gm of Al2O3, 4 gm of SiC and 4 gm of TiO2 in epoxy.

From the literatures reviewed, an attempt is made in this work to predict the tensile and impact life of GFRP composite laminate by experimentally.

RESEARCH GAP AND SCOPE OF WORK

From the detailed literature review it is observed that, most of the researchers have developed FE based models to predict tensile damage in carbon fiber epoxy, glass fiber epoxy, and E-glass polyurethane and validated by experimentation. Laminates and four points bent specimens have been used to predict tensile life of the composite materials. Stiffness degrading, and stress analysis have been identified from tensile model and tensile testing.The impact life of the specimen is also found by doing charpy impact testing. In this study, an attempt is made to predict the tensile and impact life of unidirectional mat glass fiber/Epoxy composite laminates by conducting experiments.

METHODOLOGY

This journal is concerned with tensile life of the GFRP composite laminates. It also involved characterization of the materials. The tensile life prediction of the composite laminates involves the following procedure and is represented as in Figure 3.

- Selecting the fiber and matrix.
- Fabricating the specimens as per standards using Hand lay-up technique.
- Conducting tensile test on fabricated specimen.
- Finally, generate the tensile and impact report, alsoobtained tensile life of composite laminates.

The detailed methodology flow chart is shown in figure 3.1.

Selection of fibre, resin, and hardener

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Fabrication of the GFRP composite laminate using Hand lay-up technique

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Conducting tensile test on fabricated specimen

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Conducting impact test on fabricated specimens using impact testing machine

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Prediction of tensile life and impact strength

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Fabrication of composite car door using Hand lay-up method

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FEA analysis of car door

Figure 3 Flow Chart of Methodology

EVALUATION OF MATERIAL PROPERTIES

FIBER CONTENT AND DENSITY

One of the primary factors that determine the properties of composite is the relative proportion of fiber and the matrix. The relative proportion can be expressed in terms of weight or volume fractions. Weight fractions are easier to obtain during manufacture or by an experimental method after manufacture. Volume fractions on the other hand are more convenient for theoretical calculations. Hence, it is desirable to determine expression for conversion between weight and volume fraction.

Theoretical calculations for strength, modulus, and other properties of a fiber reinforced composite are based on the fiber volume fraction in the material. Experimentally, it is easier to determine the fiber weight fraction w_f, from which the fiber volume fraction v_f and composite density ρ_c can be calculated from Equation (4.1) and (4.2.)

$$v_f = \frac{w_f/\rho_f}{(w_f/\rho_f)+(w_m+\rho_m)} \quad (1)$$

$$\rho_c = \frac{1}{(w_f/\rho_f)+(\frac{w_m}{\rho_m})} \quad (2)$$

Where,

w_f = Fiber weight fraction
w_m = Matrix weight fraction
ρ_f = Fiber density, in g/cm^3
ρ_m = Matrix density, in g/cm^3

In terms of volume fractions, the composite density ρ_c can be written as

$$\rho_c = \rho_f v_f + \rho_m v_m \quad (3)$$

Where,
v_f Is the fiber volume fraction
v_m Is the matrix volume fraction
From these values obtained by using Equations (1) to (2), volume fraction of the fiber and matrix is calculated.

MATERIAL PROPERTIES

The E-Glass chopped strand mat fiber/Epoxy composite properties are determined by using the following formulae. The composition of the test specimen was taken 60% weight fraction of the fiber and 40% weight fraction of matrix.

PROPERTY OF FIBER

Density of E-Glass fiber ($\frac{g}{cm^3}$)=2.54$\frac{g}{cm^3}$
Young's modulus of fiber (GPa) = 70 Gpa
Poisson's ratio of fiber = 0.2(v_f)
Weight of fiber (g) = 77 g

PROPERTY OF MATRIX

Density of E-Glass matrix ($\frac{g}{cm^3}$)=2$\frac{g}{cm^3}$
Young's modulus of matrix (GPa) = 4 Gpa
Poisson's ratio of matrix = 0.265(v_f)
Weight of matrix (g) = 51.33 g

VOLUME FRACTION OF FIBER AND MATRIX

Volume of fiber (V_f) $= \frac{\text{Weight (W)}}{\text{Density }(\rho)}$
$=30.31 cm^3$

Volume of matrix (V_m) $= \frac{\text{Weight (W)}}{\text{Density }(\rho)}$
$= 42.775 cm^3$

Volume of composite (V_c) $= (V_f + V_m)$
$= 73.085\ cm^3$

Volume fraction of fiber (V_f) $= \frac{V_f}{V_c}$
$=0.414$

Volume fraction of matrix (V_m) $= \frac{V_m}{V_c}$
$= 0.585$

Young's modulus (E)
$E_{xx}=E_f V_f + E_m V_m$
$= (70\times0.414) + (4\times0.585)$
$=31.32$ Gpa

$E_{YY} = (E_f E_m) \div (E_f V_m + E_m V_f)$
$= (70\times4)\div(70\times0.585) + (4\times0.414)$
$=6.571$ Gpa

$E_{YY}=E_{ZZ}$

Poisson's Ratio (v)
$v_{XY}= (v_f V_f + v_m V_m)$
$= (0.2\times0.414) + (0.265\times0.585)$
$= 0.237$

$v_{YX}= (E_{YY}\div E_{XX}) \times v_{XY}$
$= (6.571\div31.32) \times 0.237$

= 0.49

$\nu_{XY}=\nu_{YX}$

The calculated material properties are based on the rule of mixture formula.

FABRICATION OF SPECIMENS

In this chapter, the step by step procedures for fabrication of specimens are explained.

RAW MATERIALS OF COMPOSITE PLATES

To predict the fatigue life of GFRP specimens should be fabricated for the standard dimensions. To fabricate the composite specimen following, the raw materials are used.

- Unidirectional glass fiber mat (320 GSM) as reinforcement of the composite.
- Epoxy resin (LY556) as matrix of the material.
- Hardener (HY951) as curing agent.
- Wax as mould release agent.

STANDARD DIMENSIONS OF SPECIMEN

In the course of operation or use, all the structures are subjected to the action of external forces, which create stresses that inevitably cause deformation. To keep these stresses, and, consequently deformation within permissible limits it is necessary to select suitable materials for the Components of various designs and to apply the most effective heat treatment. i.e. a Comprehensive knowledge of the chief characteristics of the semi-finished metal products & finished metal articles (such as strength, ductility, toughness etc.) are essential for the purpose.

For this reason the specification of metals, used in the manufacture of various products and structure, are based on the results of mechanical tests. The mechanical tests conducted on the specially prepared specimens (test pieces) of standard form and size on special machines to obtain the strength, ductility and toughness characteristics of the metal.#

TENSILE TEST SPECIMEN ASTM D3039

ASTM D3039 is used to prepare tensile test specimen as shown in Figure 4.1.

Figure 2 Tensile Test Specimen

Gauge length L_2	= 150 mm
Tab length L_1	= 50 mm
Width (w)	= 25 mm
Thickness of plate (t)	= 3 mm
Thickness of plate with tab (T)	= 6 mm

CHARPY IMPACT TEST SPECIMEN ASTM E23

ASTM E23 is used to prepare impact test specimen as shown in Figure

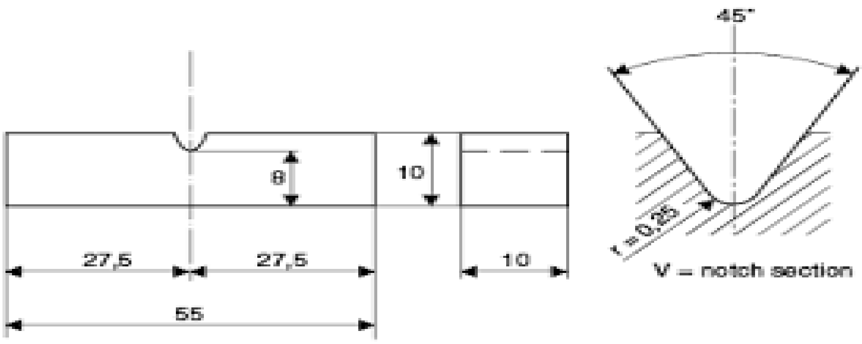


Figure 3CharpyimpactTest Specimen

Gauge length (l) = 55 mm
Width (w) = 10 mm
Thickness of piece (t) = 6 mm

HAND LAY-UP METHOD

Hand lay-up technique is the simplest method of composite processing. The step by step procedure in hand lay-up technique is as follows,

- Thin plastic sheets are used at the top and bottom of the mould plate to get good surface finish of the product.
- Reinforcement in the form of chopped strand mats (320 GSM) are cut as per the 200×150 size and placed at the surface of mould after Plastic sheet. Then thermosetting polymer (EPOXY LY556) in liquid form is mixed thoroughly in 10:1 proportion with a prescribed hardener HY951 (curing agent) and poured onto the surface of mat already placed in the mould.
- The polymer is uniformly spread with the help of brush.
- Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present.
- The process is repeated for each layer of polymer and mat, till the 7 layers are stacked.
- After placing the plastic sheet the pressure is applied. The time of curing is 24 hours.
- A layer is finally placed on top of the laminates and squeezed properly with roller so as to remove the entrapped air and obtain the void free and smooth surface. The composite laminate is allowed to cure at room temperature for twenty four hours.
- After curing Plastic sheet is removed from both sides of the laminate.
- Specimens are cut from the fabricated laminates to over dimension (about 3-5 mm on each side) using abrasive cut-off wheel mounted with water cooled cutting saw.
- Specimens are placed in between the wooden backing plates of same dimension and then machined together to the required dimension by a cutting machine. Backing plates are used to avoid edge delamination.

FABRICATED TEST SPECIMENS

In order to predict fatigue life of chopped strand mat fiber tensile and impact test specimens are fabricated as shown in Figure 4.

Figure 4 Fabricated Tensile Test Specimen

Figure 5 Fabricated Impact Test Specimen

END TAB PREPARATION

When performing quasi-static tests on fiber reinforced materials, the use of end tabs is often necessary to prevent clamp failure. For preparing end tabs standards are also available. Summarized, a continuous glass fiber reinforced polymer with [+45°/-45°] ns laminate configuration should be used, the length should be 50 mm and width 25 mm. when gripping the specimen, the grips should overhang the bevelled portion of the tab by approximately 10 to 15 mm.

Figure 6 Fabricated End Tab

GFRP tabs of ± 45 degree sequences and required dimension are bonded to the test specimen using AV138/HV998 adhesive system. Before bonding the tabs, bonding surface of the tabs and specimen are roughened using 200-grit sandpaper and then cleaned with isopropyl alcohol. The fabricated end tab is shown in above Figure 6.

EXPERIMENTAL INVESTIGATION

In this work, the Tensile and Fatigue test were carried out. The procedures of Tensile and Fatigue tests explained below.

TENSILE TEST

Tensile test is a widely performed test to determine several mechanical properties of material that are important in design. In this test, a standard specimen is subjected to gradually increasing uniaxial tensile load until it fractures. Then the tensile strength is taken as initial load to fatigue test.

The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics.

TENSILE TESTING MACHINE

The tensile test machine is shown in Figure 7 and machine specifications are given below.

Figure 7 Tensile Testing Machine used for testing

Name	: Servo Controlled Universal Testing Machine
Model	: UNITK-94100
Load range	: 0 to 100 KN
Max. cross head speed	: 0.5 - 250 mm/min

TESTING PROCEDURE

- Measure the original length of the specimen. The length may either be length of gauge section which is marked on the specimen or the total length of the specimen.
- Insert the specimen into grips of the test machine.
- Begin the load application and record load versus displacement data
- Take reading more frequently as yield point is approached
- Continue the test till fracture occurs
- Measure the final length of the specimen by joining the two broken halves of the specimen together.

TENSILE TEST SPECIMENS

The tensile test specimens before and after tensile test specimens are shown in Figure 7 and Figure 8 respectively.

Figure 8 Specimen Before the Tensile Test

Figure 9 Specimen After the Tensile test

TENSILE TEST RESULTS

The tensile test is carried out for three specimes, its average value is taken. The tensile test results for three specimens are summarized in the Table 2

Table:2 Tensile test results

Specimen no.	Ultimate strength (MPa)	Maximum load (KN)
1	406.11	62.24

CHARPY IMPACT TEST

This impact test shows the relationship of ductile to brittle transition in absorbed energy at a series of temperatures. Since iron and all other body-centred cubic metals undergo a transition from ductile behaviour at higher temperatures to brittle behaviour at lower temperatures, this test is required today for a number of important steel products including steel hull plate for ships, nuclear plant pressure vessels, forgings.

The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. From these measurements the following properties can also be determined were impact strength of the composite material.

IMPACT TESTING MACHINE

The impact test machine is shown in Figure 10 and machine specifications are given below.

Figure 10 Impact Testing Machine

TESTING PROCEDURE

- Measure the original length of the specimen. The length may either be length of gauge section which is marked on the specimen or the total length of the specimen.
- Insert the specimen into slots of the test machine.
- Begin the load application and record load accurately
- Take reading suddenly when the load is released from the head.
- Observe the test specimen for complete break.
- Apply external brake till the load pendulum stops.
- Now check the broken test specimen

IMPACT TEST SPECIMENS

The impact test specimens before and after impact test specimens are shown in Figure 11 and Figure 12 respectively.


Figure 11 Specimen Before Impact Test

Figure 12 Specimen After Impact Test

FABRICATION OF COMPOSITE CAR DOOR

ADVANTAGES OF COMPOSITE CAR DOORS

- 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.
- Composites offer excellent resistance to corrosion, chemical attack, and outdoor weathering; however, some chemicals aredamagingto composites (e.g.,paint stripper),and new types of paint and stripper are being developed to deal with this. Some thermoplastics are not very fesist to some solvents. Check data sheets for each type.
- Thermoplastic resin composites are much tougher than thermosets and offer fast processing times and good environmental performance, except against certain solvents in some cases. Again, check each material and its response to each solvent likely to be encountered.
- No health hazards.
- More closely match fiber performance.
- Good fire/smoke performance (interiors and fuel tanks and engine parts)
- Future possibility of resin transfer moulding (RTM) around reinforcing fiber or use in conventional application mode (i.e., pre-preg stacking). Single crystal growth versions could be used for engine parts

MOULD FOR CAR DOOR

The mould for manufacturing of car door is prepared using the other grade of glass fiber named to be E-glass roving along with mats of chopped strand mat with higher thickness. Whereas the mould is directly taken from the original door with the tolerance .The preparation of mould also includes the hand lay-up method,with the usage of colour pigment in order to have the difference of mould and the composite car door. Where in order to reduce the cost for making the mould the general resin were used as a matrix along with roving mat glass fiber.Therefore the bellow given images shows the mould prepared for car door.

Figure 13Mould for car door

FABRICATION OF CAR DOOR

The car door is made as such the of preparation of mould but here the unidirectional glass fiber mat is used with epoxy resin for good strength and effective physical properties .Here also the procedure of hand lay-up method is involved with certain changes such that , they mentioned below as follow,

1. The first step includes applying mug in the corners and nooks in order to avoid the air holes for better composition.
2. Later a thin layer of wax coating is given to the mould with hands.
3. A thin layer of releasing agent PVA(polyvinyl alcohol) is applied over the wax coating.
4. Now the resin is applied on the surface as left to cool for few minutes and a layer of e-glass unidirectional mat is spread out and again resin is applied.
5. This is repeated till the required thickness is obtained.
6. Then the mould is closed with the female part of mould and screwed at the corners for better shape and after two days (48 hours) of cooling at the room temperature the car door is removed from the mould.
7. After that the moulded door may have edges with unfinished fiber looking out, so they are cleared by using the hand grinding machine.
8. Thus, the finished car door is shown in the figure as followed along the process involved.

Figure 14 Fabrication of car door

Figure 15 Patching of car door

Figure 16 Fabricated of car door

DESIGN AND ANALYSIS OF COMPOSITE CAR DOOR

Surface modelling of car door

The surface modelling is carried out using the solid works software with respective tools and the designed car door is shown below in different views.

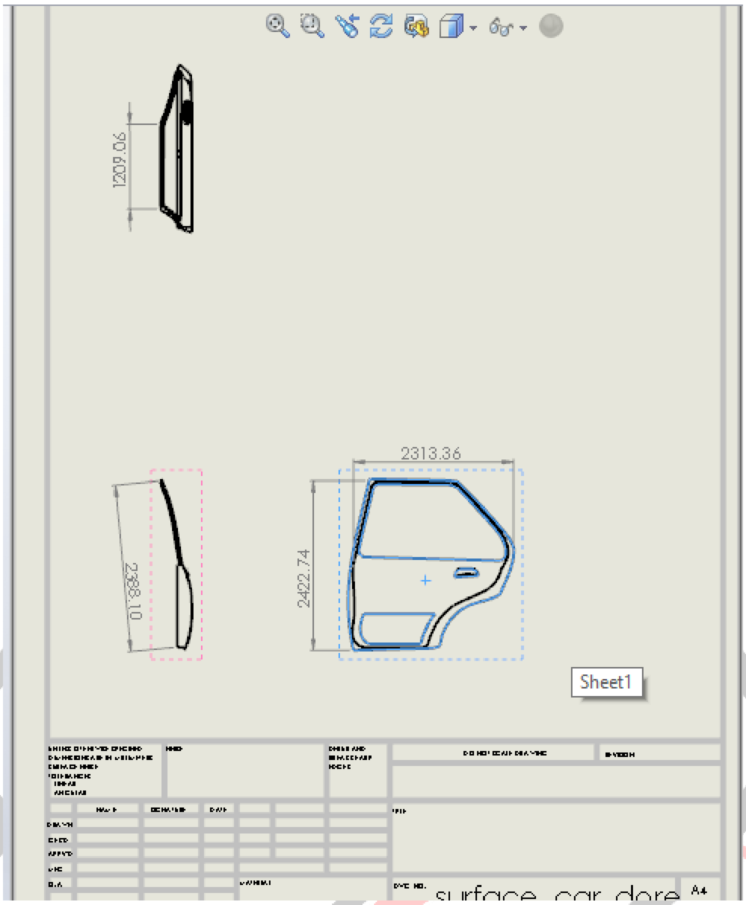


Figure 17 Dimension of car door

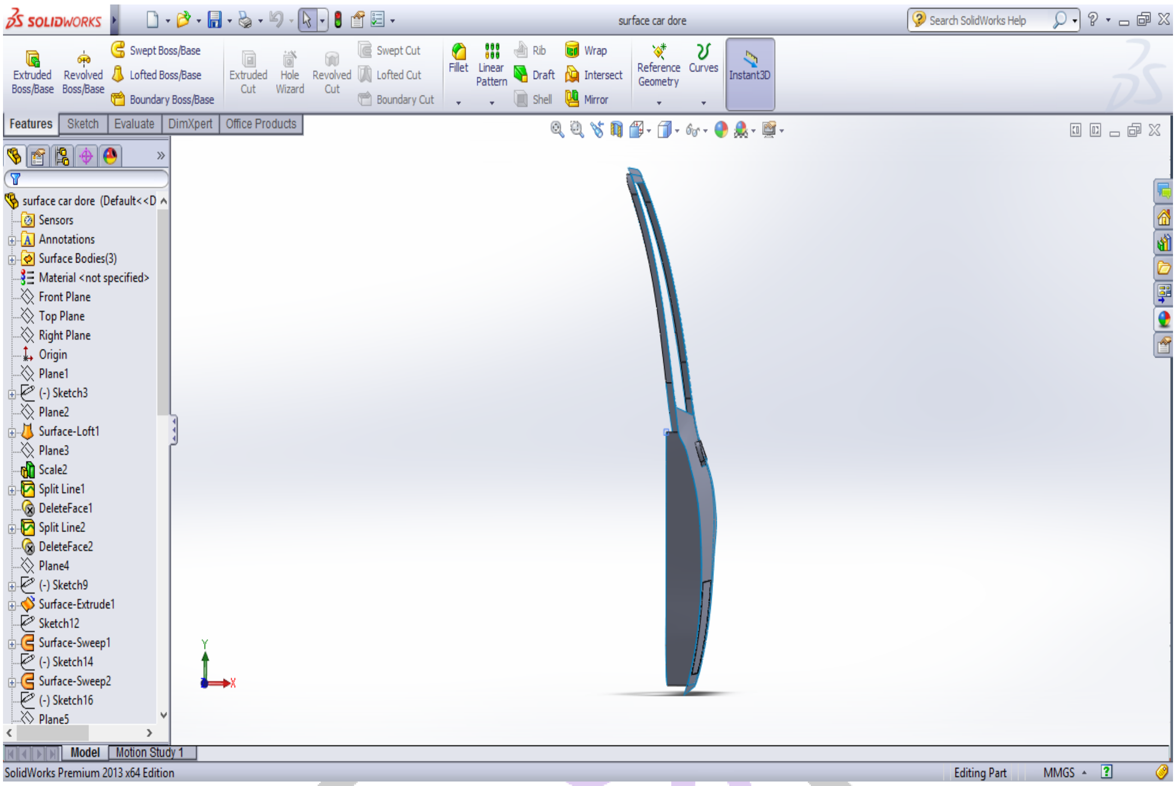


Figure 17 Side view of car door model

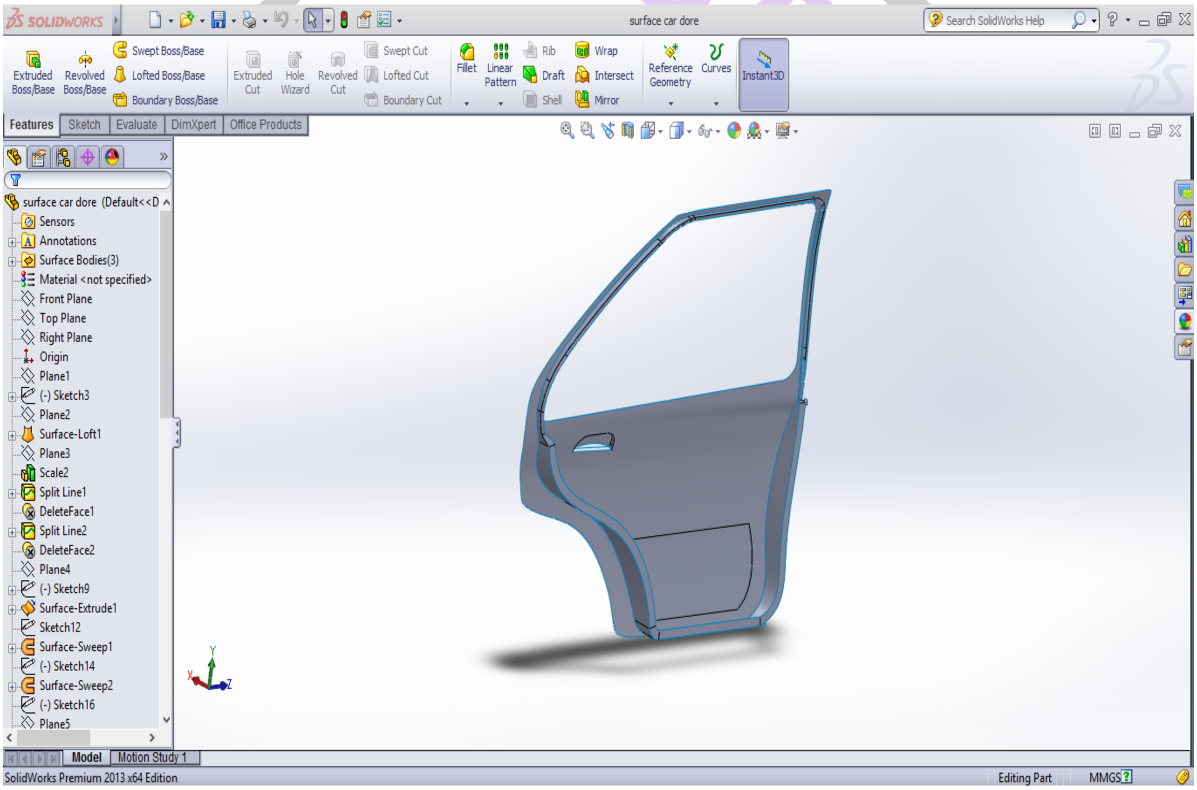


Figure 18 Isometric view of car door model

ANALYSIS OF CAR DOOR MODEL

The designed car door is involved for ansys process using solid works simulation software with the load calculated below.

Force (F) = m×a

Where,

m = mass of the vehicle crashed on the door (1554kg)

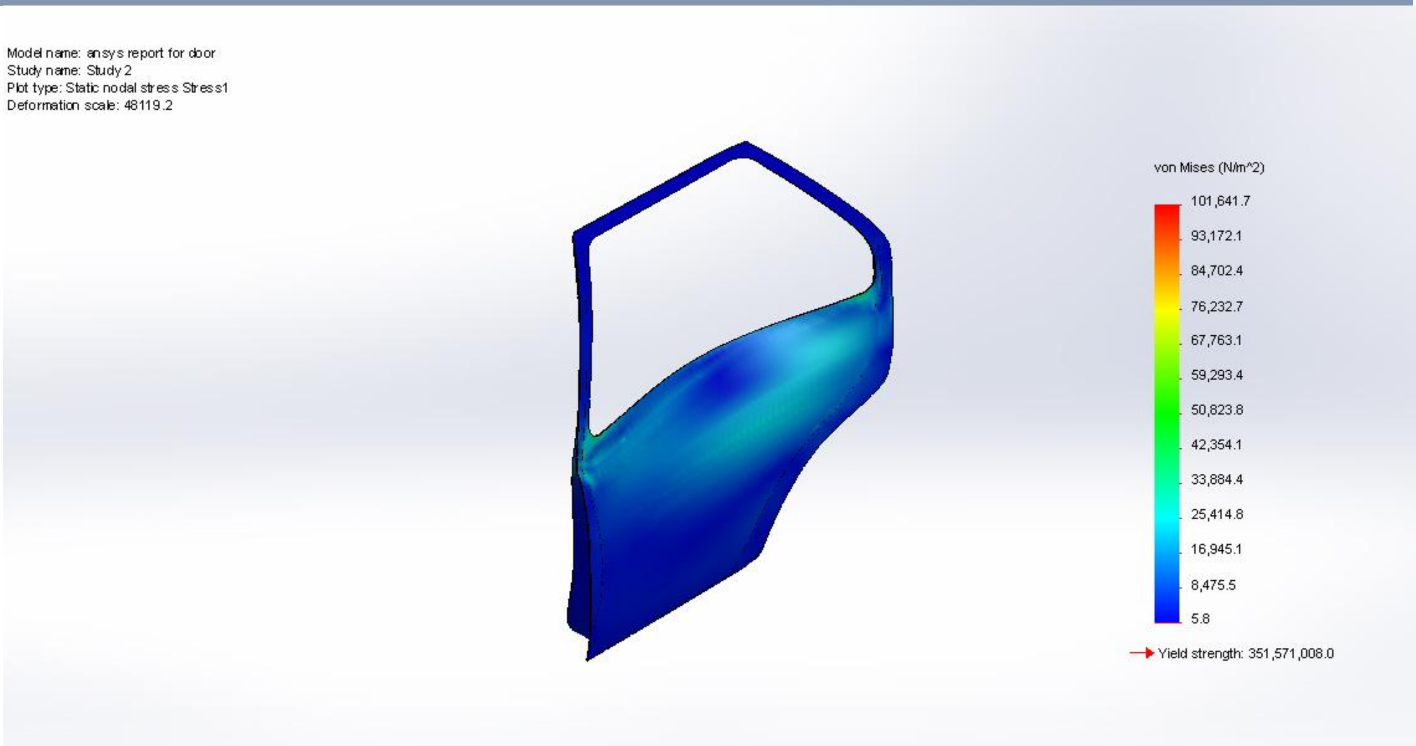
a = acceleration due to gravity (m /sec^2)

a = (u -v) / t

Where,

V = Final velocity after collapsing (m/sec)
u = Initial velocity before collapsing (m/sec)
u = 8km/hr
= 2.22 m/s (taken from NHTSA)
t = time taken for collapsing (sec)
a = (2.22-0) / 0.1
= 22.22 m/sec^2
Force (F)= 1554 x 22.222 = 34529.88 N
Pressure (P) = F/A
F = force acting on the door
= 34529.88 N
A = front area cross section
= 2422 x 2313
= 560208 mm^2
P = 34529.88 /560208
= 0.63 N/mm

Name	Type	Min	Max
Stress1	VON: Von Mises Stress	4.10602 N/m^2 Node: 8814	8134.1 N/m^2 Node: 19978

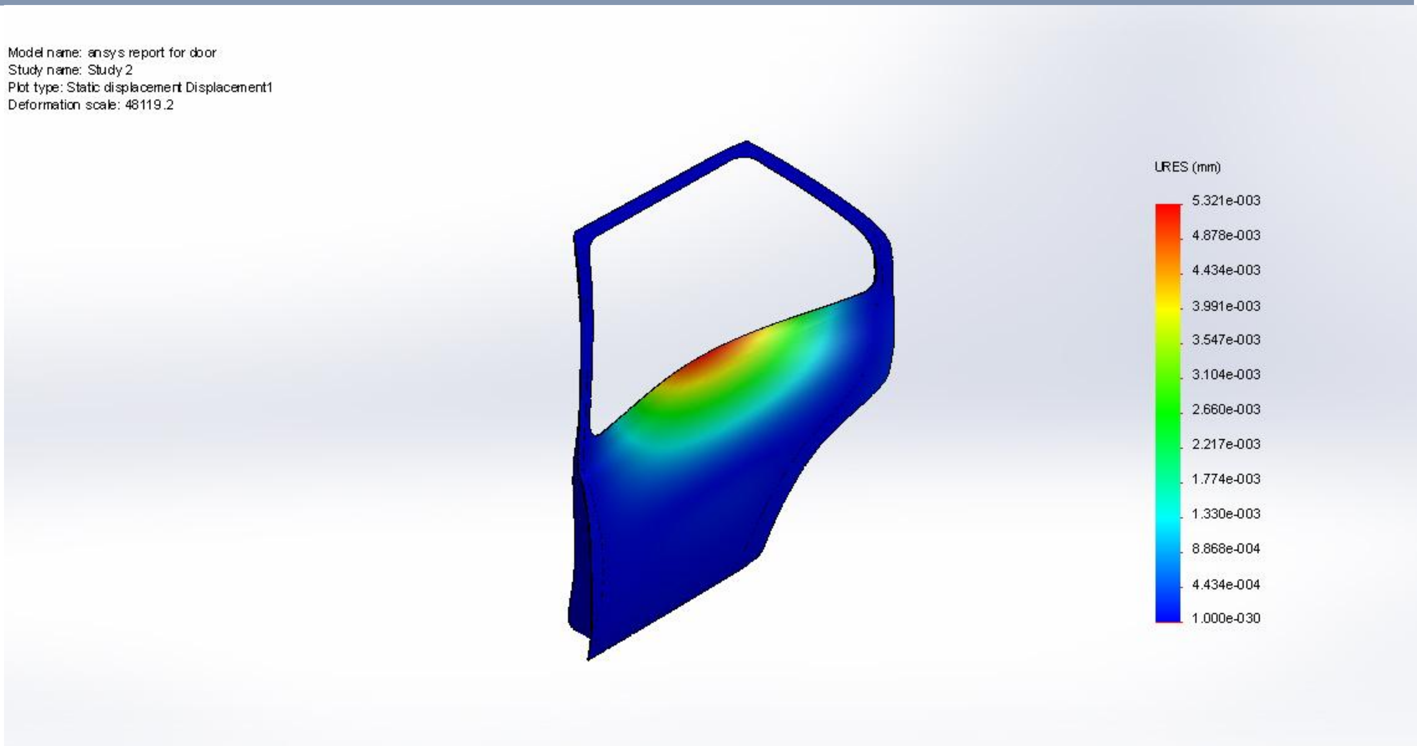


ansys report for door-Study 2-Stress-Stress1

Figure 19 Stress analysis of steel model

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.00532096 mm Node: 1171

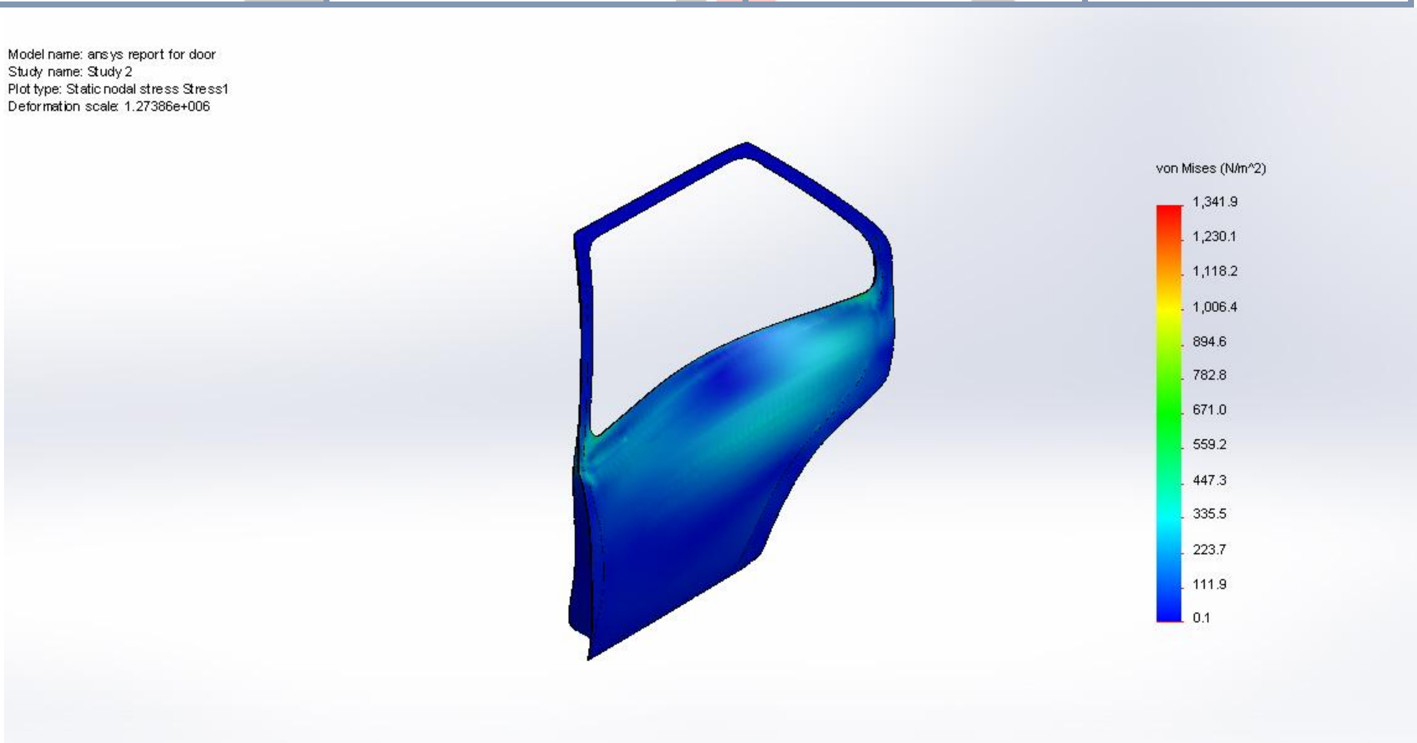
Name	Type	Min	Max



ansys report for door-Study 2-Displacement-Displacement1

Figure 20 Displacement of steel model

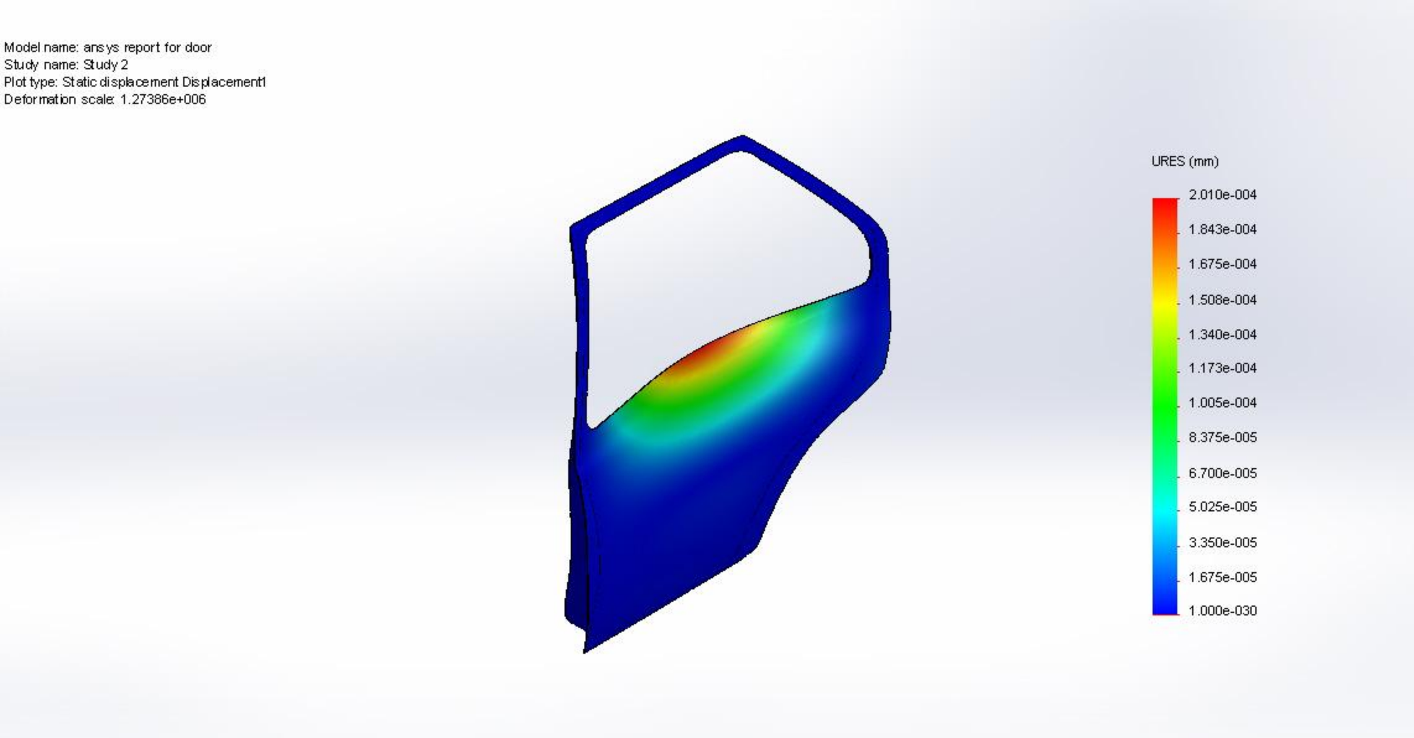
Name	Type	Min	Max
Stress1	VON: Von Mises Stress	5.0747658 N/m^2 Node: 8814	10164.07 N/m^2 Node: 19978



ansys report for door-Study 2-Stress-Stress1

Figure 21 Stress analysis of composite model

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 1	0.000201011 mm Node: 1171



ansys report for door-Study 2-Displacement-Displacement1

Figure 22 Displacement of composite model

RESULTS COMPARISON

Table 3 Comparison of properties

PROPERTIES	STEEL CAR DOOR	COMPOSITE CAR DOOR
Weight	14kg	5.2kg
Cost	Approx. 12000-18000	6500
Young's modulus	2×10^5	76×10^3
Ultimate tensile load	47.06KN	62.24KN
Ultimate tensile strength	330.04Mpa	406.11Mpa
Impact value	210J	290J
Impact energy	4.375J/mm^2	6.041J/mm^2
Corrosion	Will Occur	Will not occur

CONCLUSION

The unidirectional strand mat Glass fiber/ Epoxy composite specimens have been fabricated based on the ASTM D3039 for tensile test and ASTM E23 for Impact test using Hand lay-up technique. The material properties Young's modulus, Poisson's ratio are computed for the fabricated specimens using rule of mixture formulae. The ultimate strength and yield strength of the material is determined by conducting tensile test on the fabricated specimen. Then the impact test were carried out by experimentally and these experimental data were validated numerically using ANSYS software. The predicted tensile life using ANSYS has good agreement with experimental evaluation. It is also observed that the stress ratio had a strong influence on the fatigue life of composites. The present tensile test can be useful to characterize the effect of various parameters on the tensile behaviour of fiber reinforced plastic composites. There are several advantages as compared with composite materials on steel. Therefore the normal car door can be replaced with composite doors.

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