



ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

*Development of Composite Materials for Rail Vehicle Body
by Using FEM*

**A Thesis Submitted to the Graduate School of Addis Ababa
University in Partial Fulfillment of the Requirements for the Degree
of Masters of Science**

In

**Mechanical Engineering (Railway Mechanical
Engineering)**

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Development of Composite Material for Rail Vehicle Body by Using FEM.

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Development of Composite Material for Rail Vehicle Body by Using FEM.

DECLARATION

I hereby declare that the work which is being presented in this thesis entitled “**Development of Composite Materials for Rail Vehicle Body by Using FEM**” is original work o has not been presented for a degree of any other university and all the resource of materials used for this thesis have been duly acknowledged.

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This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

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Abstract

This thesis work presents the development of composite materials for rail vehicle body by using FEM by considering steel material and bamboo fiber reinforced epoxy composite materials.

The Rail vehicle body of tram car model was used to develop the geometric model by Solid work R2017 modeling software. This 3D geometric model was imported to using ANSYS Workbench 15.0. The maximum operational load FEA was done after assigning displacement, load and boundary conditions. The equivalent stress and the displacement are noted and investigated to compare with the literatures revised. The result of this analysis shows that, the equivalent stress of bamboo fiber reinforced epoxy composite Rail vehicle body has the smaller value, as compared with the steel material. Based on these realities, it is recommended that bamboo fiber reinforced with epoxy composite materials are suitable for Rail vehicle body structural analysis.

Key words: Bamboo fiber, Epoxy, composite, door panel, structural analysis, displacement, vehicle

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LIST OF SYMBOLS

A = Area

L = Length

W = Width

Ms = Mass of the persons for standing.

M1 = Total mass [**In case of 6persons / m^2**]

M2 = Total mass [**In case of 8persons / m^2**]

L = Load

P = Pressure

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CHAPTER ONE

INTRODUCTION

Background

It is a natural phenomenon that human beings keep on moving here and there to perform their day to day activities within a given time range. And Rail vehicles are the dominant way of transportation system in many countries, including Ethiopia. Thus, researching on these area to design and provide a well improved, fast, economic and aesthetically attractive Rail vehicles is a crucial idea for the development of these countries by providing fast, effective and sufficient way of transportation. To address this aim a wise material improvement and design Excellency are crucial mechanisms. Materials for Rail Vehicle industries have been improved frequently starting from the very earlier one (wood) to the latest and most sophisticated modern materials.

The basic aim of developing new materials for Rail Vehicle application is to enhance vehicle efficiency by reducing the dead weight of the vehicle. Moreover their aesthetical appearance should be upgraded by researching materials for this application too. A number of researches have been demonstrated that composite materials are lightweight, fatigue resistant and easily molded to any shape, in other words, a seemingly attractive alternative to metallic materials. If the benefits of composite materials in terms of light weighting, durability, good aesthetical value, high specific energy absorption ability and ease of forming are to be exploited more widely by the Rail Vehicle industry, then there is a need to identify the critical technical barriers that must be overcome.[1, 9]

In order to conserve natural resources and economize energy, weight reduction has been the main focus of Rail Vehicle body designers and manufacturers in the present scenario. Weight reduction can be achieved primarily by the research of better material, design optimization and better manufacturing processes, [10]. Due to rise in demand of lightweight and more efficient vehicles and better mechanical performance of materials in Rail Vehicle applications, different material combinations such as composites, plastic and light weight metals are implemented on different structural parts of vehicles.

Composite materials have of high modulus to weight ratio and strength to weight ratio, excellent fatigue properties, and non-corroding behaviors.

Traditionally, the materials used in the construction of vehicle bodies are mainly various grades of steel and aluminum. Moreover, plastics and some synthetic materials mostly dominate the

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vehicle interior parts. The manufacturers meet the requirements of a particular crashworthiness standard and fuel efficiency by making the approximate design change in their vehicle structure and by introducing necessary structural components that satisfy the overall design objectives. [4] With the composite materials the designer can vary structural parameters, such as geometry and at the same time vary the material properties by changing the fiber orientation, fiber content. These properties of the composite materials create the positive environment in Vehicle industries, since they provide required strength for less weight when compared to steel and aluminum. [9, 10]

Composite Materials

The interest of a material with light weight and high performance is increasing in a dramatic way time to time. The improvement of the performance for a material is limited when there is only one composition. Therefore, there have to be a new material with high performance which constitutes two or more conventional materials.

Composite materials are engineering materials (engineered materials) in which two or more distinct materials are combined together but remain uniquely identifiable in the mixture, having strong fibers surrounded by a weaker matrix material to obtain better properties different from those of the individual components. The Reinforcing fibers provide the physical and mechanical properties; specifically to improve the physical and mechanical properties of the matrix and thus add strength and stiffness for the composite whereas the matrix serves to hold, protect and distribute the fibers, and also to transmit and distribute the load to the fibers. A collaboration between these two basic materials produce material properties that are not provided for each material element of origins. [11,12,13].

Overall, the properties of the composite material are determined by the properties of the fiber, the properties of the resin, the ratio of fiber to resin in the composite (Fiber Volume Fraction) and the geometry and orientation of the fibers in the composite.

Classification of composite materials

Different criteria's are taken in to account to classify Composite materials. The fiber arrangements and the types of matrix materials used in a composite can be considered.

i. Fiber arrangement

The fiber arrangement and its orientation within the composite is varying from one composite material to the other during manufacturing process. This variation helps the manufacturer to get a

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material with different properties. On the bases of fiber orientation and arrangement, composite materials can be classified as follows.

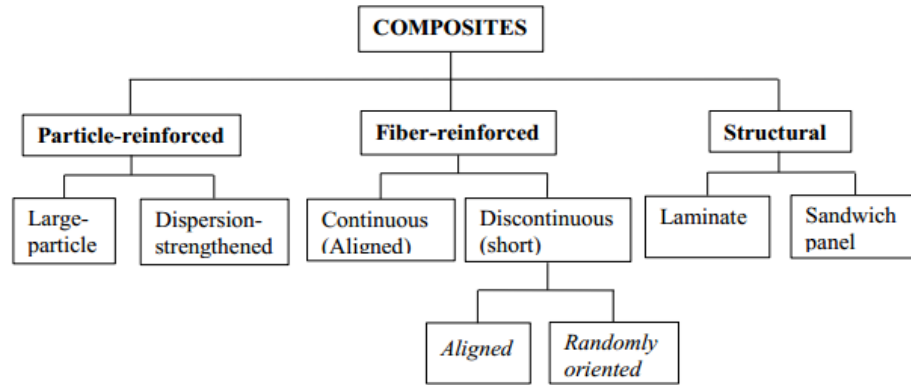


Figure 1: Composite materials classification based on fiber orientation [13]

A. Particle-reinforced composite

The role of reinforcement in composite materials is primarily to add mechanical properties to the material such as strength and stiffness. Thus, particles are used to increase the modulus of the matrix, to decrease the permeability of the matrix, or to decrease the ductility of the matrix. Particle reinforced composites support higher tensile, compressive and shear stresses. Particles used for reinforcing include: ceramics and glasses, metal particles, and amorphous materials. [13]

B. Fiber-reinforced composites

Fiber reinforced composites provide improved strength, fatigue resistance and strength to weight ratio over the constituent materials. Reinforcing fibers are responsible to increase the modulus of the matrix material in the composite. The strong covalent bonds along the fiber's length give them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved. [12, 13]

The arrangement or orientation of the fibers relative to one another, the fiber concentration, and the distribution all have a significant influence on the strength and other properties of fiber-reinforced composites. [13]

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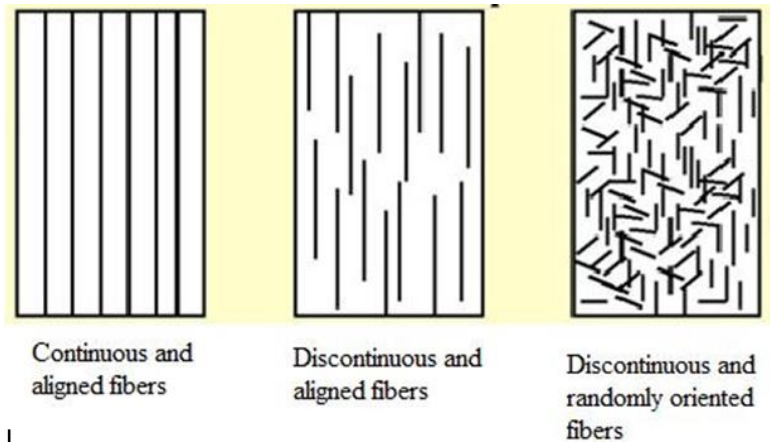


Figure 2: Fiber reinforced composites [13]

C. Structural composites

Composite Laminate

Laminates are sheet constructions which are made by stacking layers (also called plies or lamina) in a specified sequence. The one preimpregnated with partly cured resin) which are consolidated in an autoclave. A laminate may have more than 4 layers and the fiber orientation changes from layer to layer in a regular manner through the thickness of the laminate. The figure shown below describes how the laminate is formed from the ply or lamina [12, 15].

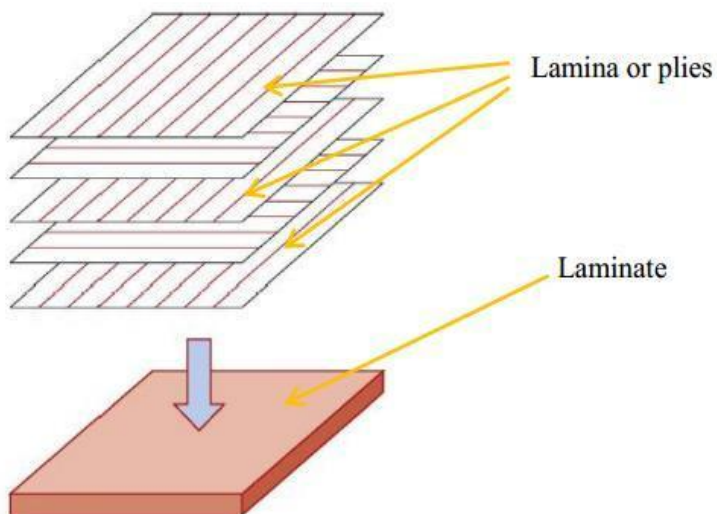


Figure 3: Composite laminate [15]

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Sandwich panels

These composite polymer matrixes have low density, honeycomb core as a reinforced bonded with the face sheet matrix by adhesive layers. Sandwich panels have the benefits of light weight, large bending stiffness and energy absorption. [12, 13]

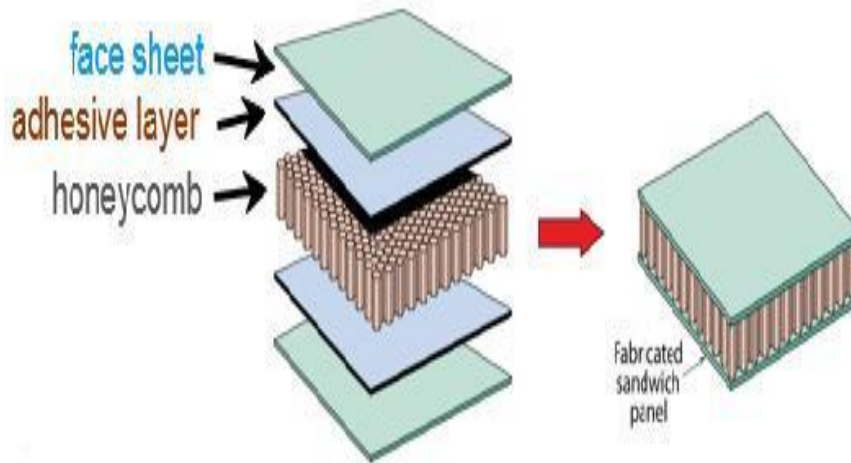


Figure 4: composite sandwich panel

ii. Matrix materials

Another way of classifying composite materials is focusing on the type of its matrix component of the composite. Based on this measurement, composite materials can be arranged as the following chart shown below.

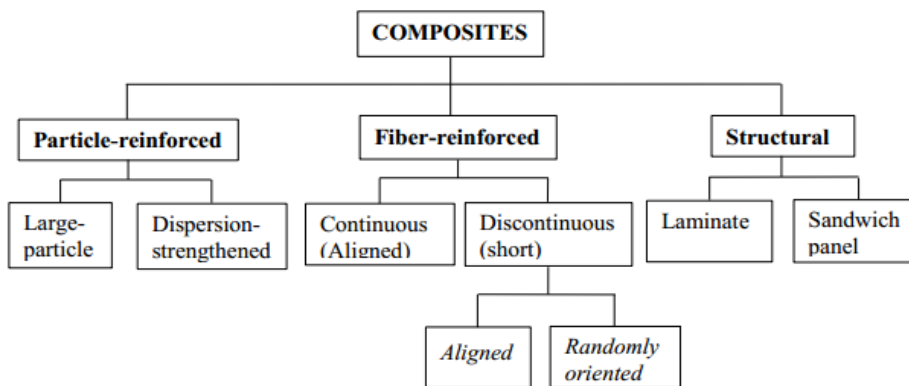


Figure 5: composite materials classification based on matrix type [15, 20]

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Here in this paper, we are interesting on the polymer matrix composite materials only. They are composed of long chain-like molecules consisting of many simple repeating units. The most commonly adopted polymer composites in more industries are thermosetting and thermoplastic polymer matrix composites. These fiber-reinforced polymer composites can be found in products that people interact with every day, including cars and sporting goods.

Thermoset polymers are polymers that are cured into a solid form and cannot be returned to their original uncured form. Composites made with thermoset matrices are strong and have very good fatigue strength. They are extremely brittle and have low impact-toughness making. They are commonly used for high-heat applications because the thermoplastics. Thermoset composites are generally cheaper and easier to produce because the liquid resin is very easy to work with. Thermoset composites are difficult to recycle because the thermoset cannot be remolded or reshaped; only the reinforcing fiber used can be reclaimed. [16]

Thermoplastic polymers are polymers that can be molded, melted, and remolded without altering its physical properties. Thermoplastic matrix composites are tougher and less brittle than thermoset, with very good impact resistance and damage tolerance.

Thermoplastic composites are less dense than thermosets making them a viable alternative for weight critical applications. The thermoplastic composites manufacturing process is more energy intensive due to the high temperatures and pressures needed to melt the plastic and impregnate fibers with the matrix. The energy required makes thermoplastic composites more costly than thermoset. These two similar materials have such different properties that both will continue to be used in different applications for very different reasons and the products of the future will likely be a combination of both [16].

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1.4. Problem statement

The structural analysis of railway car body is very complex due to its dynamic nature. The complexity of contact force developed in the wheel-rail interface strongly influences the dynamic nature of the vehicle. During the research and development of the new transportation solutions, the computational tools can be used to study problems related to the impact of car body loads, maintenance and operation of existing railway vehicles. In our country such modern rail vehicles are new technology so that the analysis will help to solve the problem and also becomes an input for the futures vehicles. In this paper the impacts of car body load on the strength of the material, components of the vehicle body, property of the material for vehicle body are considered.

Objective

1.4.1 General Objective:

The general objective of the proposed research is:

To do the Finite Element Analysis for Rail Vehicle body by considering steel and Bamboo Reinforced Epoxy Composite Material.

1.4.2 Specific objective:

The specific objectives are:

- To develop a suitable model of Rail Vehicle body structure by using SOLID WORK software.
- Determine the load and stress on the vehicle body,
- Static simulation car body using finite element method.
- Selecting of the appropriate materials to the car body based on its weight, cost, strength and availability.

1.4.3.Scope of the research

- In this specific research work, experimental investigations will not be conducted; instead a reasonable data that was already done by appropriate experiments will be taken.
- Construction of 3D model of Rail vehicle body using software SOLIDWORK.

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- Finite element model (meshing of geometry model).
- Finite element analysis using ANSYS software on static structural analysis.
- Interpreting of the result and conclusion.

1.5 Limitation of the research:-

- Some of the limitation that might be encountered when conducting the research includes. Ignoring the effect of other property like thermal analysis and vibration of at curve and being theoretical only without practical testing in the work shop. In general, this research may require ample time.

1.6. Methodology

- First of all a relevant data should be collected. Some crucial characteristics of bamboo fiber composite which was done by experimental investigation and the analysis of Rail Vehicle body on different materials are collected. Modeling of Rail Vehicle body has been developed by SOLID WORK modeling software.
- The Finite Element Method simulation and analysis were done by using the ANSYS analysis software.
- Finally, conclusion and recommendations for further researches are suggested based on the analysis outcomes.

1.7. Organization of the paper

This thesis is organized in to five chapters. In the first chapter background, statement of the problem, scope of the study, Limitation of the research, objectives and methodology of the study are discussed. In chapter two a literatures review related to the research have been investigated. The journals, articles and publications that are related to this research work are reviewed. In the third chapter, materials used, the conditions and the methods of analysis are stated. Modeling and FEM methods for static structural analysis have been discussed clearly. In chapter four the FEA results are displayed and an appropriate discussion is performed. The conclusions, recommendations and future work of the research are stated in the last chapter, chapter five.

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CHAPTER TWO

LITERATURE REVIEW

The design of Rail vehicle body has evolved from a simple, all steel structure that meets the basic requirement of strength and functionality, to the current day complex and efficient structure. Lightweight composite materials have been used to replace conventional one. This is because composite materials offer significant opportunities for enhancement of product performance in terms of strength, stiffness and energy absorption, combined with weight reduction & space saving. There are many journals, articles, thesis papers, books, conference and published study in the world related to Rail Vehicle body structure materials and their analysis. These previous works were trying to address different approaches to design and analyze the Rail Vehicle body parts by using different materials (conventional and composite).

Natural fibers have become popular reinforcement material for fiber reinforced polymer composite developments. The reinforcement can replace the conventional fiber, such as glass, aramid and carbon as an alternative material. [20]

The main advantageous of natural fibers include low cost, fairly good mechanical properties, high specific strength, non-abrasive, & eco-friendly. In spite of impressive specific mechanical properties, the main challenges associated with these reinforcements include severe moisture absorption, fire resistance, mechanical properties and durability, variability, and manufacturing/processing of natural fiber reinforced plastic composites. [30]

2.1. Bamboo Plant and its fiber

Bamboo, which is belonging to the family of the Bambusoideae, encompasses approximately 60–90 genera and 1100–1500 species. Bamboo mainly grows in tropical and sub-tropical regions of Asia, Latin America and Africa [17]

Bamboo, itself is very strong in its longitudinal direction due to strong fiber bundles penetration. The strength, however, decreases from the base to the top of the bamboo Culm [18].

2.1.1. Bamboo Plants in Ethiopia

Ethiopia has the largest area of bamboo in Africa by constituting 67% of the total bamboo forest area

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of the continent and about 7% of the world total bamboo resource. The country has nearly 1 million hectares of bamboo reserves, yet the production and consumption of bamboo and bamboo products is very limited, and value addition is minimal due to poor processing technology. [19]

This large resource is dominated by the two indigenous bamboo species; the highland bamboo (*Yushania Alpina*) and the monotypic genus lowland bamboo (*Oxythenantera Abyssinica*), [19]. These resources are distributed in the highlands and lowlands of Ethiopia. Assosa, Injibara, Gimbi, Ambo, Gurage, Bale, Masha, Chenchu and Hagera-Selam are rich in naturally occurred and planted bamboo forests. The largest source of bamboo plant present in Assosa is lowland type which has solid Culm at maturing age. [19, 20, 31]

Although bamboo is not an integral part of the economy of Ethiopia, it plays a very important role socially, economically and ecologically in areas where it occurs naturally and where it is planted. It has been used in traditional way in the country side a little bit for the scaffolding, construction of houses, fuel, feed fodder, beehives, hats, mats, baskets, handicrafts, small furniture and other countless products. Recently, a market for bamboo culms and bamboo products has developed. [19, 20, 31]

2.1.2. Bamboo Fiber

Bamboo is an orthotropic material with high strength along axial and low strength transversal to its fibers. This is due to the longitudinally alignment of its fiber to its body while at the same time this is attributed by its poly-lamellate wall structure that consists of alternating broad and narrow layers with different fibrillary orientation. Furthermore, high cellulose and lignin content and relatively small micro-fibril angle of bamboo plant contribute to this high strength of bamboo fiber [21]. There is a variety between different culms on stiffness, strength and fracture toughness. The structure of bamboo itself is a composite material, consisting of long and aligned cellulose fibers immersed in a lignin matrix. That means, the Culm of a bamboo plant is a ligno-cellulosic natural functionally graded composite material. Fibers are densely located around the outer cortex and similarly on the top of the Culm. As a result when we examine bamboo timber; from inner to the outer and from the bottom Culm to the top, the mechanical strength of the bamboo is increased. [21, 22]

The chemical constituents of bamboo are primary cellulose, hemi-cellulose and lignin. The bamboo has 60% cellulose and a considerably high percentage of lignin (about 32%).

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Table 1: Composition of few commonly used natural fibers [24]

Fiber	Cellulose (wt %)	Hemi cellulose (wt %)	Lignin (wt %)	Pectin (wt%)	Moisture (wt %)	Waxes (wt %)
Cotton	85-90	5.7	-	0-1	7.85-8.5	0.6
Bamboo	60.8	0.5	32	-	-	-
Flax	71	18.6-20.6	2.3	2.2	8-12	1.7
Hemp	70-74	17.9-20.4	3.7-5.7	0.9	6.2-12	0.8
Jute	61.1-71.5	13.6-20.4	12-13	0.2	12.5-13.7	0.5
Kenaf	45-47	21.5	8-13	3-5	-	-
Sisal	66-78	10-14	10-14	10	10-22	2
Coir	32-43	0.15-0.25	40-45	3-4	8	
Banana	63-64	19	5	-	10-12	-

The bamboo fiber is often brittle compared with other natural fibers, because the fibers are covered with lignin. Therefore, a devised process should be adopted to extract the bamboo fibers for reinforcement of composite materials. [20].

The bamboo fiber length and fiber wall thickness is increase with increase of age of bamboo plant. Moreover, the strength of bamboo fiber increases with an increment of age. The optimum strength value occurs between 2.5 and 4 years. Then it became to decreases at a later age. However, as age increases the extraction of bamboo fiber from the Culm is more difficult. Thus, the good bamboo fiber with easy and minimum extraction cost will be got from the bamboo plant of age 2.5 to 4 years old. [17, 31]

Applications of bamboo fiber and its composites are roof construction, car dashboard, rope, making sheet, paint brush, upholstered furniture, geo-textile, bamboo cycle, computer hardware, bamboo decorative elements, etc. [22]

The bamboo fiber has a comparable property with that of glass fiber. More over the mechanical properties of bamboo fiber are comparable to the mechanical properties of the best among natural fibers. [20]

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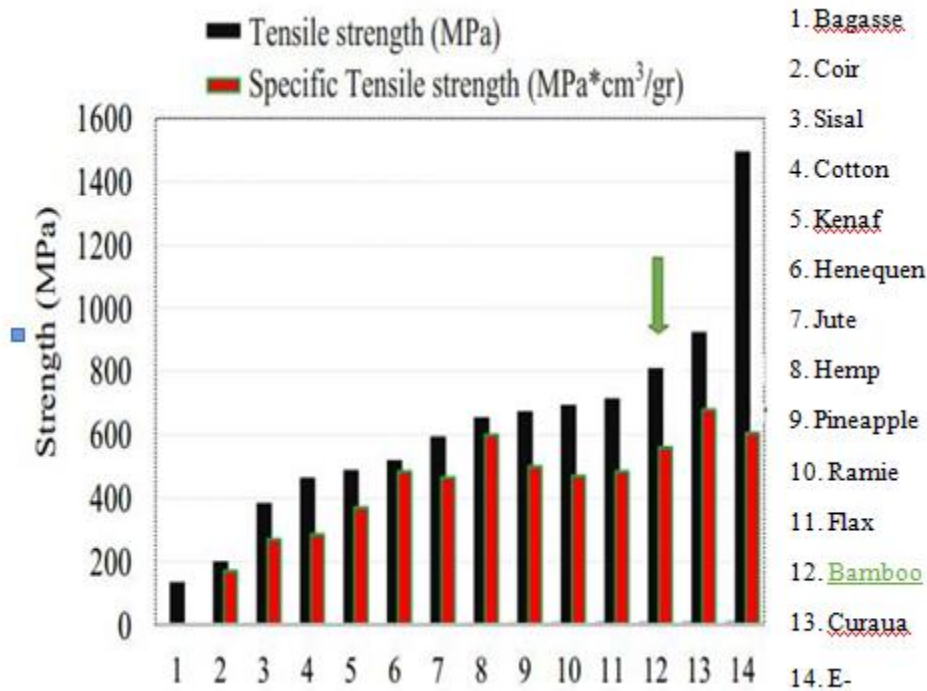


Figure 6: Comparison of Natural fibers strength and specific strength [20]

2.2. Thermosetting Polymer Matrix

Among different types of matrix materials, polymer matrices are the most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and they also have excellent room temperature properties when compared with others.

Polymer matrices can be either thermoplastic or thermoset according to the effect of heat on their properties. The thermoset polymer is frequently used as the matrix material due to some advantages it has over the thermoplastic one. The thermoset polymer matrix materials have overall, better economics and high temperature properties. Good mechanical, wetting and adhesion properties and easy to dispose are also the advantages of thermoset polymers.

The most commonly used thermoset resin materials are epoxy, vinyl ester, polyester and phenolic. Each resin has its own benefits and drawbacks to use as a matrix material.

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2.3. Previous Works

2.3.1. Sandwich structures in rail vehicles

In ground transportation sandwich structures can be found in cars, busses and trains. Since the 80s front cabs of locomotives have been built with sandwich technology because of its high strength and good impact and energy absorption properties. Some examples of this are the XPT locomotives in Australia, the ETR 500 locomotives in Italy, the French TGV and the Swiss locomotive 2000.

.The high specific bending stiffness of sandwich structures can with advantage is used in vehicles, provided that the structural behavior during a crash situation is well understood and possible to predict [12].

2.4.2 Korean Tilting Train Express, TTX

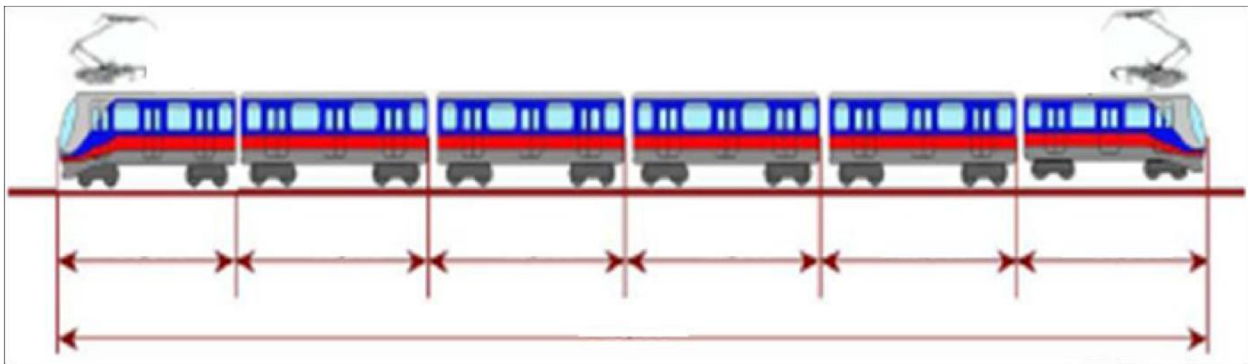


Figure 7: Vehicle configuration of TTX [7]

The sandwich structure elements consist of carbon fabric/epoxy prepregs for the faces and an aluminum honeycomb core. The entire car body is manufactured as one single structure. This was accomplished by means of large scale auto-clave. A large mold was built in which the outer face was firstly laid out. The outer face was then cured in the auto-clave. Secondly the inner frame and honeycomb core was placed on top of the outer skin. The core and skin was bonded by use of an adhesive film. After this step followed lay-up of the inner face. Lastly the entire structure was, after appropriate vacuum bagging, cured in the auto-clave. By constructing the entire car body as one structure weak links between panels is eliminated. The only remaining weak link is between the upper body and under frame [7]

The sandwich structure reduced the upper car body weight by 39% compared to a stainless steel

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car body. The total weight reduction, including under frame, was 28%.

2.5 past work

A number of researches were done on vehicle structural analysis and researches on sandwich materials strength test using simulation software and material labs .Some of the researches related to tram car and sandwich material are found below.

[17] Performed a multi-level approach on weight optimization for a “typical” rail vehicle body shell [7]. Initially the sandwich panel configuration was a 28mm thick polyurethane core with two 8mm thick face sheets of glass fiber reinforced epoxy composite plies giving a total of 16 plies and a lay-up of $[0^\circ/\pm 45^\circ/90^\circ]_S2$. Each ply was 1mm thick. This gave a total panel thickness of 44mm. The panels where supported by a frame of steel stiffeners. The car body was furthermore subjected to a longitudinal compressive force of 1500kN during the optimization.

[18] Investigates how various requirements, such as stiffness, strength, buckling, thickness and area density, influence the choice of load carrying sandwich panels for high-speed rail vehicles. Requirements on the load carrying structure are defined where after various sandwich alternatives are studied to match these requirements. Panels that first pass a general requirement evaluation are further studied by Finite Element Analysis (FEA).

[28] Performed Design and Testing of Sandwich Structures with Different Core Materials the purpose of the study was to design a light-weight sandwich panel for trailers. Strength calculations and selection of different materials were carried out in order to find a new solution for this specific application. 3D FEA was applied to virtually test the selected sandwich structure in real working conditions. Based on FEA results the Pareto optimality concept has been applied and optimal solutions determined.

[25] Studied how environmental ageing affects the structural integrity of the TTX car body [21], mainly by looking at how ageing effects influence the integrity of the composite skins. Tests showed severe decrease in stiffness and strength for the graphite/epoxy specimens except for the transverse tensile stiffness which showed an 8% increase over time due to post-curing effects.

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The transverse compressive stiffness and transverse tensile strength showed the largest decay over time, -17.5% and -27.74% respectively. The shear strength on the other hand remained relatively constant. By using an electron microscope the authors showed that the decay in strength and stiffness was most likely due to loss of matrix material from the surface of the composite specimens. FE analysis was performed on the car body, with both non-degraded and degraded mechanical properties. Interestingly the maximum stress levels in the composite structure with degraded properties were lower than in the case of non-degraded. The stress levels in the under frame slightly increased but were well within safety values. However, after degradation the car body's maximum deflection under vertical load had increased by about 8%, exceeding the prescribed limit.

Performed an optimization investigation on a rail vehicle with acoustic and mechanical constraints. The lowest natural frequency constraint was set to 9.5Hz and the car body was subjected to a compressive coupler load of 2000kN. Buckling of the floor was designated the most critical failure mode, why local and global buckling stresses of the floor sandwich panels where used as constraints during calculations. The sandwich panels where constructed of quasi-isotropic carbon fiber reinforced polymer laminates with a foam core. Face and core thickness as well as core density was used as design variables in the floor and mechanical properties of the core. For the roof and side walls the core thickness and density was kept constant while the face thickness was the only design variable. An additional acoustic constraint on the sound reduction index was used on the floor.

[23] Developed an expert system to calculate the optimum stiffness design of composite laminates for a train car body by varying the stacking sequence. Optimal stiffness was achieved by quasi-isotropic stacking with design rules such as: avoid grouping of 90° plies, shield primary load carrying plies and do not differ ply angles between adjacent plies more than 45°. These design rules minimized the objective function for most loading situations, however, several other combinations showed good results with a lower number of plies compared to the quasi-isotropic stacking. During uniaxial loading cross-ply stacking was the stacking sequence that, not surprisingly, minimized the objective function.

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[10] Performed experimental Test on Sandwich Panel Composite Material. Bending test, tensile test is performed on sandwich panel composite material. Two type of inner core structure is considered for sandwich panel composite material, without hexagonal composite material, and with hexagonal composite material. And it is observed that with hexagonal composite material weight saving is 39% compared with without hexagonal composite material. From tensile test and bending test of composite material, tensile strength and bending strength capacity of with hexagonal composite material is less compare to without hexagonal composite material, but it can be negligible. Hence sandwich panel composite material (with hexagonal structure) is acceptable in Automobile, Aerospace, and Marine engineering.

[28] This paper presents a combined Finite element modeling and experimental analysis of Carbon fiber composite sandwich panel. The emphasis of this study is on evaluation of deflection, bending stress and shear stress response under static four point bending condition. The 2D and 3D FE model predictions correlate with experimental results of Sandwich specimen. Predicted deflection in this study is success fully matching the response of CFC sandwich panels. The 3D FE model under static loading condition is closely matching with experimental deflection. It is found that the maximum percentage error is only 11.27%. Thus, in this study can be used with confidence in design analysis of the CFC sandwich panels.

[19] Performed Finite Element Analysis of Loading Area Effect on Sandwich Panel behaviors beyond the Yield Limit. The investigation is accomplished in sight of the core material nonlinearity and the geometric nonlinearity of the whole panel. High tech software 'I-DEAS' (Integrated Design Engineer Analysis software) is utilized to carry out the investigation. It is proved that the load carrying capacity of sandwich panel can be improved by loading the panel beyond the core yield limit. This load is going to be transmitted to the face sheet. Increasing the stiffness of the core material to a certain extent leads to face sheet yielding before the core material. It is proved that increasing core stiffness increases the load carrying capacity of the sandwich panel. Loading area plays good roll in the load carrying capacity of sandwich panel. Distributing loads over large area of panel surface leads to higher load carrying capacity.

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[27]The three point bending test is conducted theoretically on aluminum, titanium and high tensile steel honeycomb sandwich panels and it is observed that titanium alloy has more strength to weight ratio. From the crushing tests on the aluminum honeycomb sandwich panel specimens under lateral crushing loads varying the cell thickness and height of the honeycomb core, it is seen that the core height is not an influential parameter on the crushing behavior of the honeycomb core. However the wall thickness of a honeycomb core cell is a critical variable affecting the crushing strength of the sandwich panels subject to lateral pressure loads.

2.6. Mechanical characterization of bamboo fiber reinforced composites

S. A. H. Roslan et.al. [21] Conducted a review on the natural fiber composites based on bamboo fibers. This paper is to review on the properties of bamboo reinforced composites from numerous characterization studies of bamboo that are available in the literatures. The review is based on characterization studies on several types of bamboo reinforced composites such as laminated bamboo fiber reinforced composite, randomly oriented bamboo reinforced composite, hybrid fiber reinforced composite, bamboo fiber reinforced bio-composite and bamboo fiber sandwiched structure composite. It can be said that the laminated bamboo composite in general gives higher mechanical properties compare to other structural forms of bamboo composite. Even though bamboo bio-composite in general provides low mechanical properties, the properly design unidirectional bamboo bio-composite can also have high mechanical properties that are as good as the laminated bamboo reinforced composite.

S. sreeni vasul u et.al. [22] performed the research on Mechanical properties evaluation of bamboo fiber reinforced composite materials. The research has attempted to explore the potential utilization of short bamboo fiber reinforced polyester composites with different weighting compositions, see the table below.

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Table 2: Designation and weighting of Composites [22]

Samples	Compositions
PB-1	Polyester + bamboo Fiber (15 wt %)
PB-2	Polyester + bamboo Fiber (30 wt %)
PB-3	Polyester + bamboo Fiber (45 wt %)
PBA-1	Polyester + bamboo Fiber (45 wt %) + Alumina (0 wt %)
PBA-2	Polyester + bamboo Fiber (45 wt %) + Alumina (5 wt %)
PBA-3	Polyester + bamboo Fiber (45 wt %) + Alumina (10 wt %)

It has been evaluated the Mechanical properties such as Tensile strength, and Flexural strength of short bamboo fiber reinforced polyester composites material.

Table 3: Mechanical properties of bamboo fiber reinforced polyester composites

Composites	Tensile strength (MPa)	Flexural strength (MPa)
PB-1	7.241	29.381
PB-2	8.587	38.989
PB-3	15.601	26.226
PBA-1	17.883	38.109
PBA-2	16.861	45.848
PBA-3	18.767	28.448

The results of this research has been shown that, the mechanical properties of short bamboo fiber reinforced polyester composite material are greatly influenced by the fiber volume fraction and the filler content.

Syed Altaf Hussain et.al., [23] conducted a research titled as Mechanical properties of short bamboo fiber reinforced polyester composites filled with alumina particulate. It was about the evaluation of mechanical properties namely, Tensile strength and Flexural strength, of short bamboo fiber reinforced polyester composites filled with alumina particulates. Specimens were prepared by hand lay-up technique and are cut as per ASTM standards to perform the test. The experimental result reveals that the mechanical properties of the composite material were highly influenced by the fiber volume fraction (fiber loading). Addition of alumina (Al_2O_3) particulate

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at various proportions as filler material the mechanical properties i.e., Tensile strength and flexural strength are distinctly improved.

Table 4: Designation and composition of Composites [23]

Samples	Compositions
PB-1	Polyester + Bamboo Fiber (15 wt. %)
PB-2	Polyester + Bamboo Fiber (30 wt. %)
PB-3	Polyester + Bamboo Fiber (45 wt. %)
PBA-1	Polyester + Bamboo Fiber (45 wt. %) + Alumina (5 wt.%)
PBA-2	Polyester + Bamboo Fiber (45 wt.%) + Alumina (10 wt.%)
PBA-3	Polyester + Bamboo Fiber (45 wt.%) + Alumina (15 wt.%)

The test results are summarized according to the following graphical expressions.

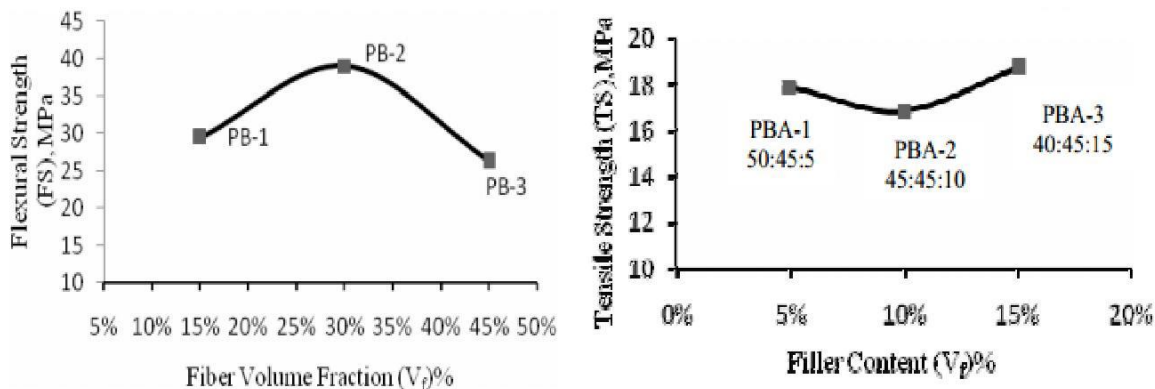


Figure 8: Variation of mechanical properties with respect to the filler content (fiber volume fraction) a. flexural strength, b. tensile strength,

Subhash Kumar Gupta, Prof. Sandhyarani Biswas [24] A study on mechanical behavior of bamboo fiber based polymer composites. It has been investigate the mechanical behavior of short bamboo fiber reinforced epoxy based composites. Bamboo fibers with different length and contents are reinforced in epoxy resin to fabricate composite materials.

The effect of fiber length and content on the mechanical behavior of the composites was studied under this research work.

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Table 5: Composition and designation of fiber reinforced composites [24]

Composite	Composition
C-1	Epoxy (90 wt.%) + short bamboo fiber of length 4mm (10 wt.%)
C-2	Epoxy (80 wt.%) + short bamboo fiber of length 4mm (20 wt.%)
C-3	Epoxy (70 wt.%) + short bamboo fiber of length 4mm (30 wt.%)
C-4	Epoxy (90 wt.%) + short bamboo fiber of length 7mm (10 wt.%)
C-5	Epoxy (80 wt.%) + short bamboo fiber of length 7mm (20 wt.%)
C-6	Epoxy (70 wt.%) + short bamboo fiber of length 7mm (30 wt.%)
C-7	Epoxy (90 wt.%) + short bamboo fiber of length 10mm (10 wt.%)
C-8	Epoxy (80 wt.%) + short bamboo fiber of length 10mm (20 wt.%)
C-9	Epoxy (70 wt.%) + short bamboo fiber of length 10mm (30 wt.%)

The study tried to verify the mechanical properties of bamboo reinforced epoxy based composites such as tensile strength, flexural strength, with their varying composition are explained below.

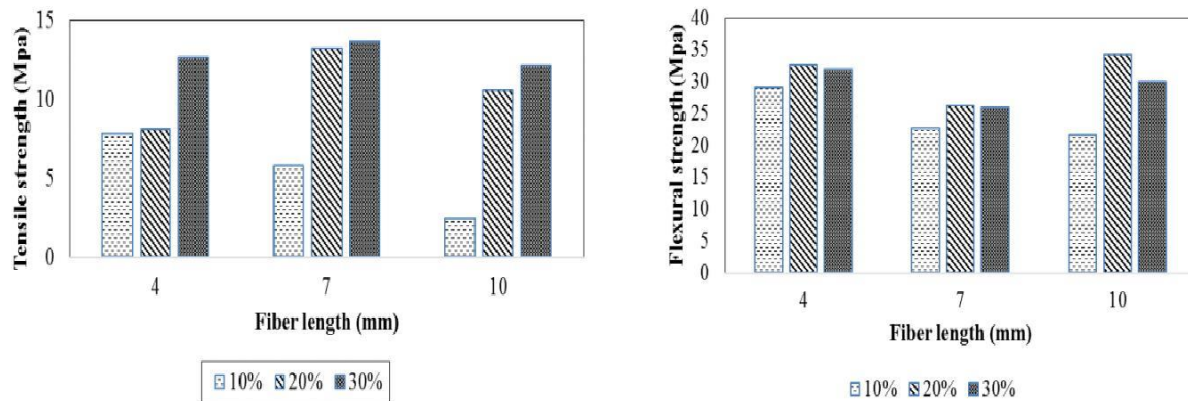


Figure 9: Effect of fiber parameters on the mechanical property of composite: A. tensile strength, B. flexural strength [24]

D. Dash et.al. [25]; Conducted the mechanical characterization of Natural Fiber Reinforced Composites (NFRC) consisting of epoxy resin reinforced with jute fiber and bamboo fiber. Hand lay-up technique was used for fabrication of the composite specimens. The effect of fiber orientation (0 /90, 15 /-75, 30 /-60, and 45 /-45) was analyzed and it shows that the fiber orientation of 0 /90 provides higher strength and stiffness than other fiber orientations used in this work.

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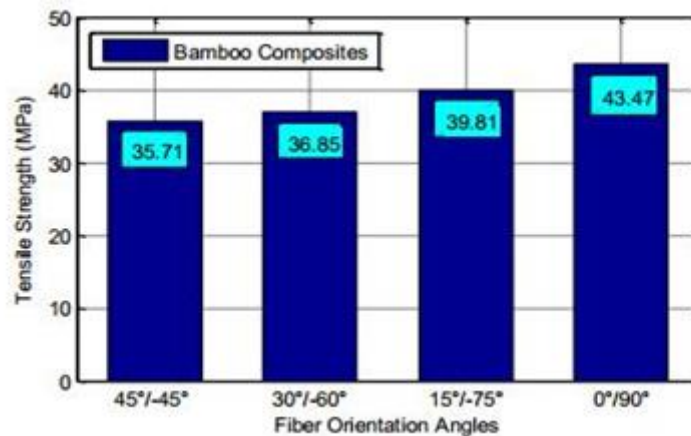


Figure 10: Effect of Fiber Orientation on Tensile Strength of Bamboo Composites. [25]

The natural fiber reinforced composite can be used in places where light load application is important and the economics of natural fiber composite materials is more beneficial as compared to E-glass fiber composites.

Dheeraj Kumar (Asstt. Prof.) [26] Characterization of tensile properties of treated bamboo natural fiber polymer composite. The paper tried to show the practical observation which includes characterization of mechanical properties of potential bamboo fiber. The fabrications of the samples were made by hand lay-up technique.

Table 6: Sample Composition

Designation	Composition	No. of Samples
B	Pure Epoxy	5+5+5 = 15
B1	Epoxy (95%) + Bamboo Fiber (5%)	5+5+5 = 15
B2	Epoxy (90%) + Bamboo Fiber (10%)	5+5+5 = 15
B3	Epoxy (80%) + Bamboo Fiber (20%)	5+5+5 = 15
B4	Epoxy (75%) + Bamboo Fiber (25%)	5+5+5 = 15
B5	Epoxy (70%) + Bamboo Fiber (30%)	5+5+5 = 15

The Result shows the variation in tensile strength in respect with the variation in fiber content (%). The tensile strength of bamboo-epoxy composite increases to the certain level of fiber loading and then starts decreasing on further fiber loading.

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Table 7: Tensile strength of bamboo fiber polymer composite with random orientation [26]

Designation	Fiber Content (%)	Orientation (Degree)	Tensile Strength (MPa)
B	0	-	18.16
B1	5	Random	26.22
B2	10	Random	37.98
B3	20	Random	45.28
B4	25	Random	53.61
B5	30	Random	46.91

The result shows that the tensile strength of bamboo-epoxy composite increases to the certain level of fiber loading and then starts decreasing on further fiber loading. The maximum value of tensile strength is obtained at 25wt% of fiber loading

Vivek Kumar, Sanat Mohanty [27] Researched on High Performance Moldable Bamboo Fiber-Epoxy Composites. For development of the composites, woven bamboo mats were used where the bamboo was stripped into narrow strips, about 4.25mm wide and about 0.5 mm in thickness.

The composites contained between 30-40 wt.% fibers, although up to 60 wt. % fiber can be used. Fillers such as carbon black and fly ash can also be added to these composites. The composites exhibit tensile strengths of 140MPa, flexural strengths of 160 MPa and notched Charpy Impact strengths of 60 kJ/m². These composites were molded into auto body parts (dashboard, doors, and panels) and are under test with an auto-rickshaw manufacturer

Fekadu Tarekegne and Philip Conze [19] Researched on the study of Ethiopia high land bamboo composite for structural materials. The main objective of the study was to introduce the industrial application of bamboo to bamboo sectors of the country by investigate the performance of bamboo fiber composite. The experimental analysis was carried out by using a short bamboo fiber reinforced epoxy composite (with bamboo fiber content of 25 wt. %) to evaluate its mechanical properties. The fiber was extracted from a two years old highland bamboo (bamboo from Injibara). These experimental results were summarized by the following table, (Table 2.9)

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Table 8: Mechanical properties of bamboo fiber reinforced epoxy composites [19]

Mechanical Properties	Values	Tests Standards
Tensile Strength	187.73MPa	ASTM D638
Flexural Strength	190.32MPa	ASTM D790
Compressive Strength	114.13MPa	ASTM D695
Shear Strength	18.18MPa	ASTM D638
Water Absorption	2-3%	24 hour submersion
Young's Modulus	3852	-
Shear Modulus	1580	-

From these results the researchers concluded that the analyzed BFREC material has an attractive Mechanical properties which can replace the current structural materials. The research was commissioned by Fortune Enterprise P.L.C collaborated with GTZ on a public private partnership project (PPP). The PPP has the objective of establishing a sustainable production of high value composite bamboo materials, and promote industrial production.

Generally to summarize this chapter, several experimental investigations were done to characterize the mechanical properties of the bamboo fiber reinforced composite materials. As we have seen from the above reviewed literatures, the bamboo fiber reinforced composites have mechanical properties comparable to currently used engineering plastics and are appropriate for application in vehicle body parts.

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CHAPTER THREE

MATERIALS, METHODS AND CONDITIONS

3.1. Materials

As we have seen from different literatures (previous chapter), bamboo fiber has better mechanical properties as compared with other natural fibers. Therefore, using this plant fiber as reinforcement in composite materials for different structural components by replacing the currently used conventional materials will have a competence advantages.

In this analysis the bamboo fiber/epoxy composite materials with a considerable composition are used as the materials of a Rail Vehicle body structure.

Bamboo Fiber

From the fact that, the availability of large amount of bamboo plant resources in Ethiopia attracts for the relying on this plant for different studies in the past. Especially the highland bamboo (Yushania Alpina) species is given more focus from the researchers and it is suitable for different applications.

Epoxy Resin

The choice of a resin system for the use of most composite structural component depends on a number of its characteristics, such as: adhesive properties, mechanical properties, and degradation from water ingress.

The most commonly used thermoset resins are epoxy, vinyl ester, polyester and phenolic. Among these thermoset matrix materials, the epoxy resins are being widely used for many advanced composites due to their valuable advantages such as excellent adhesion to wide variety of fibers, good performance at elevated temperatures and better mechanical and electrical properties. In addition to that they have low shrinkage upon curing and good chemical resistance. It has very low viscosity, long average pot life at room temperature, consistent performance and d contain any hazardous dilutes or extenders.

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Moreover, epoxies generally out-perform most other thermosetting resins in terms of mechanical properties and resistance to environmental degradation, (has superior tensile strength, bond strength, adhesive characteristics, fatigue resistance and resistance to water degradation).

Mechanical Characterization of BFREC

The mechanical properties of most reinforcing fibers are considerably higher than those of the resin systems. Therefore; the fiber/resin composite properties are dominated by the contribution of the fiber to the composite. The main factors that govern the fiber's contribution are the basic mechanical properties of the fiber itself, the surface interaction of fiber and resin (the 'interface'), the amount of fiber in the composite ('Fiber Volume Fraction') and the orientation of the fibers in the composite.

Mechanical properties of a designed bamboo composite depend on how bamboo fibers are extracted from the bamboo trees, the form of bamboo fibers and eventually the types of bamboo composites, the treatments on the fibers and the polymers and the fabrication process used to produce the composite. [21]

The fiber length, diameter, orientation, amount and properties of the constituents (fiber and matrix materials), and the bonding between them have also the effect on the composite properties. Fiber dimensions are characterized by the aspect ratio (their fiber length and diameter ratio, l/d , where l is the fiber length and d is the fiber diameter). The strength improves when the aspect ratio is large. Fibers often fracture because of surface imperfections. Making the diameter small reduces its surface area, which has fewer flaws.

Long fibers are preferred because the ends of the fiber carry less of the load. Thus the longer the fiber, the fewer the ends and the higher the load carrying capacity of the fiber reinforced composites.

Epoxy has low strength. It doesn't support any load. So, the main purpose of epoxy is to transfer loads to the fiber. As a result, the length and orientation/ angle of the fibers in the composite determine the strength of the composite materials.

More over the manufacturing methods used to produce the final product is very important as it dictates the type of properties as well as the quality of the product.

Development of Composite Material for Rail Vehicle Body by Using FEM.



Figure 11: Forms of bamboo being used as composite reinforcement (a) long fibers (b) flake (c) short fibers (d) sliver (e) strips and (f) powder. [21].

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According to AALRT take as the no of passenger at the peak hour which is 8 persons per meter square and According to EN 12663 standard average passenger's weight is 68 kg.

3.2. Numerical Analysis of Rail vehicle body

Table 3.1 Technical Specification for passenger Rail vehicle

s.n	Basic technical parameter	Parameter value
1	Track gauge	1435 mm
2	Minimum radius of vertical curve	1000 m
3	Minimum radius of horizontal curve	25 m
4	Axle load	
5	Maximum gradient	50
6	Rated voltage	DC 750V
7	Train length	28800 mm
8	Maximum width	2650 mm
9	Height	3610 mm
10	Floor level to rail level at low-floor area	380 mm
11	Floor level to rail level at high-floor area	655 mm
12	Center-to-center distance between both bogies	10400 mm
13	Axle distance of the motor unit	1900 mm
14	Axle distance of the trailer unit	1800 mm
15	Clear height in passenger compartment at low-floor area	2255 mm
16	Clear height in passenger compartment at high-floor area	1980 mm

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3.3. Load condition

According to Addis Ababa city tram take as the no of passenger at the peak hour which is 8 persons per meter square and According to EN 12663 standard average passenger's weight is 60 kg.

The occupied area of standing person is 6 persons\m² for rated passenger capacity, or 8 persons\m² for over crowded capacity and the average weight of the passenger is 60kg\person.

$$M_1 = \text{person on seat} + \text{person standing for 6 person}\backslash\text{m}^2$$

Therefore,

$$\text{One passenger weight} = 60\text{kg}$$

$$\text{The Train} = 65 \text{ seat}\backslash\text{chair}$$

$$\text{Person for seat} = 65 \times 60 = 3900\text{kg}$$

$$\text{The mass of the seat} = \underline{\underline{3900\text{kg}}}$$

Person for standing,

The person for standing is 6 persons for 1m²

$$\text{Area} = \text{Length} \times \text{Width}$$

$$A = L \times W$$

$$= 28.800\text{m} \times 2.650\text{m}$$

$$= \underline{\underline{76.32 \text{ m}^2}}$$

$$\frac{6 \text{ persons}}{1 \text{ m}^2} \times 76.32\text{m}^2$$

Therefore, $76.32 \times 6 = \mathbf{458 \text{ persons}}$ → *the persons for standing.*

The mass of the person for standing is calculated by:

$$M_s = 458 \times 60\text{kg} = \underline{\underline{27480\text{kg}}}$$

Development of Composite Material for Rail Vehicle Body by Using FEM.

- In case of 6persons /m² the total mass is calculated as follows

$$\begin{aligned}M_1 &= \text{Persons on seat} + \text{persons for standing} \\ &= 3900\text{kg} + 27480\text{kg} \\ &= \underline{\underline{31380\text{kg}}}\end{aligned}$$

- In case of 8persons /m² the total mass is calculated as follows

The number of person for standing is:

$$= \frac{8\text{persons} \times 458\text{persons}}{6\text{persons}} = \mathbf{611} \text{ persons for standing}$$

The mass of the person for standing is

$$\begin{aligned}M_s &= 611 \times 60\text{kg} \\ &= \underline{\underline{36660\text{kg}}}\end{aligned}$$

M₂ = person for seat + person standing for 8person/m²

$$= 3900 \text{ kg} + 36660 \text{ kg} = \underline{\underline{40560\text{kg}}}$$

Therefore the total Load is calculated by two conditions.

$$\begin{aligned}\text{Load}_1 &= m_1 \times g \\ &= 31380\text{kg} \times 9.81\text{m/s}^2 \\ &= \underline{\underline{307837.8 \text{ N}}}\end{aligned}$$

$$\begin{aligned}\text{Load}_2 &= m_2 \times g \\ &= 40560\text{kg} \times 9.81\text{m/s}^2 \\ &= \underline{\underline{397893.6 \text{ N}}}\end{aligned}$$

From these we can calculate the total pressure applied on the vehicle body structure.

$$P_1 = \frac{F_1}{A} = \frac{307837.8\text{N}}{76.32\text{m}^2} = \underline{\underline{4033.51 \text{ Pa}}}$$

$$P_2 = \frac{F_2}{A} = \frac{397893.6\text{N}}{76.32\text{m}^2} = \underline{\underline{5213.5 \text{ Pa}}}$$

The specific material property of the selected bamboo fiber reinforced epoxy composite

Development of Composite Material for Rail Vehicle Body by Using FEM.

material is stated in the table below.

Table 9: mechanical properties of Bamboo fiber reinforced epoxy composite [19]

Material Property	Values
Density (ρ)	1120 kg/m ³
Tensile Strength	187.73MPa
Flexural Strength	190.32MPa
Compressive Strength	114.13MPa
Shear Strength	81.18MPa
Young's Modulus	3852
Shear Modulus	1580

Table 10: load condition stated under EN 12663 for P-V type locomotive

Load	description	value
tensile load at coupling area	50KN tensile load in both direction	A value of 25 KN at each buffer
Compressive force at buffers	200KN compression force in both direction	A value of 100000N at each buffer
Turning right	0.15*gross vehicle weight in Y direction	0.15 *9.81 =1.4715m/s ²
Turning left	0.15* gross vehicle weight in Y direction	0.15*9.81 =1.4715 m/s ²
Maximum operating load	1.3*gross vehicle weight in Z-direction	1.3* 9.81 =12.753m/s ²

From the European standard In order to calculate the forces on the equipment attachments during operation of the vehicle, the masses of the components shall be multiplied by the specified accelerations in x, y and z direction.

X- Longitudinal

direction Y- Lateral

direction

Z -vertical direction

Vertical load (F_z) is the load uniformly distributed over the floor of the car

Development of Composite Material for Rail Vehicle Body by Using FEM.

$$\text{body } F_z = 1.3 * (m_1 + m_4)$$

m_1 the design mass of the vehicle in working order according to EN15663 without bogie mass. And m_4 the mass of exceptional pay load.

3.4 FE Analysis method of steel tram car

As stated earlier, to build the model of the AALRT drawn in SOLIDWORKS 2017.

Data of AALRT.

Length=28800mm

Width=26500mm

Height between under frame to car top=3610 mm

3.4.1 Define material property

Properties of material under study

Material is structural Steel according to EN 10025:2004 standard

Table 11: Material property of steel frame

	S235J2/d0001	S355J2
Min yield stress limit	235	355
Tensile strength	510	630
Impact strength (KV-J)	20	20
Modules of elasticity	210GPa	
Poisons ratio	0.3	
Density	7850kg/m ³	

3.4.2 Mesh generation

The model consisted of 187499 elements and 377287 nodes and the mesh with coarse sizing was selected and at different location an average element size between 10mm up to 20 mm and the face material sized element size of 10mm.

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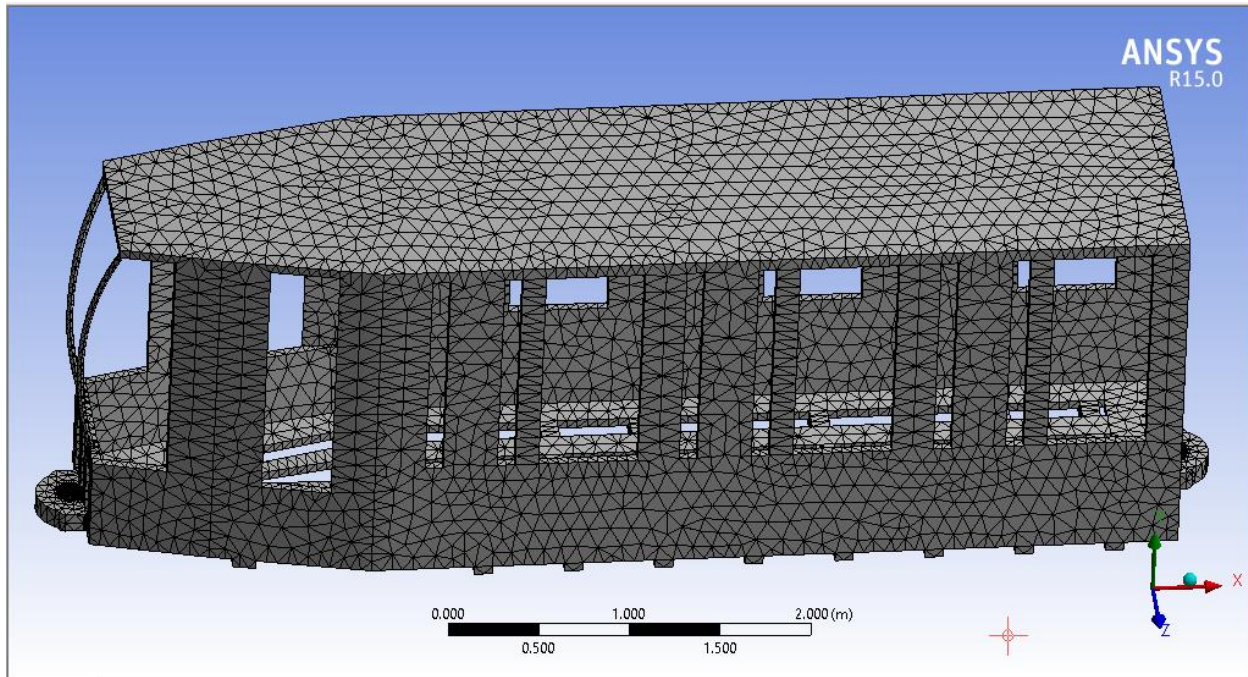


Figure 12: Meshing of steel vehicle body

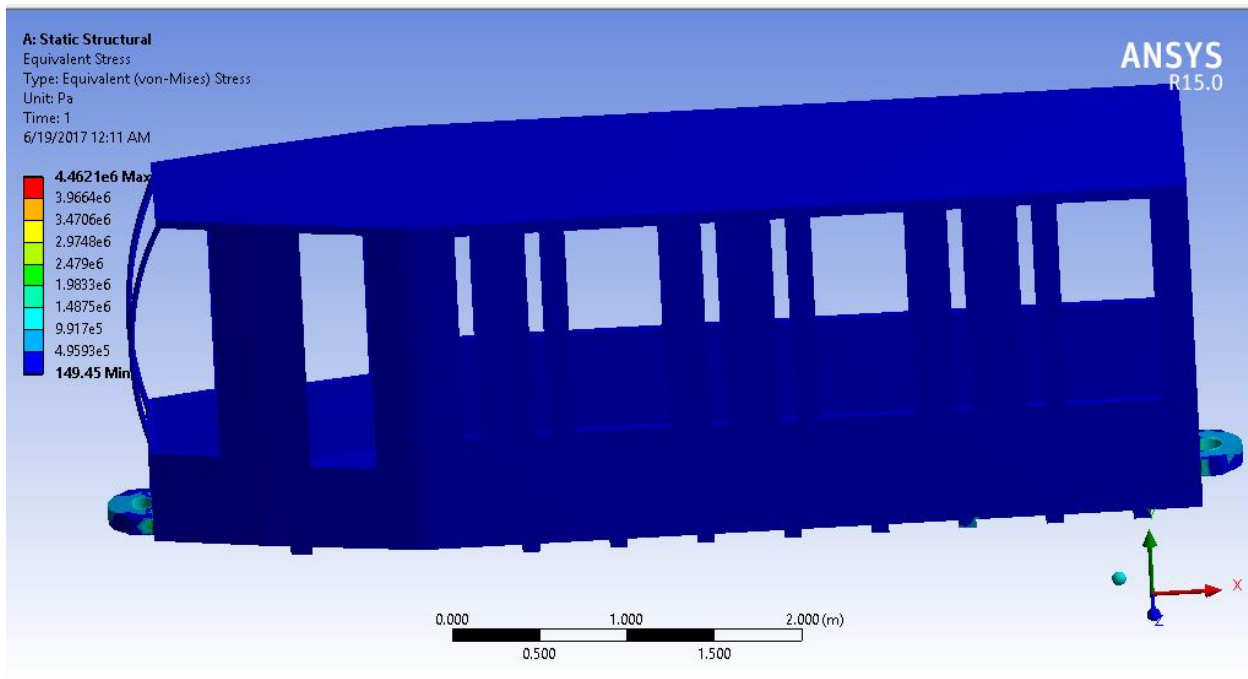


Figure 13: Tensile force at buffer

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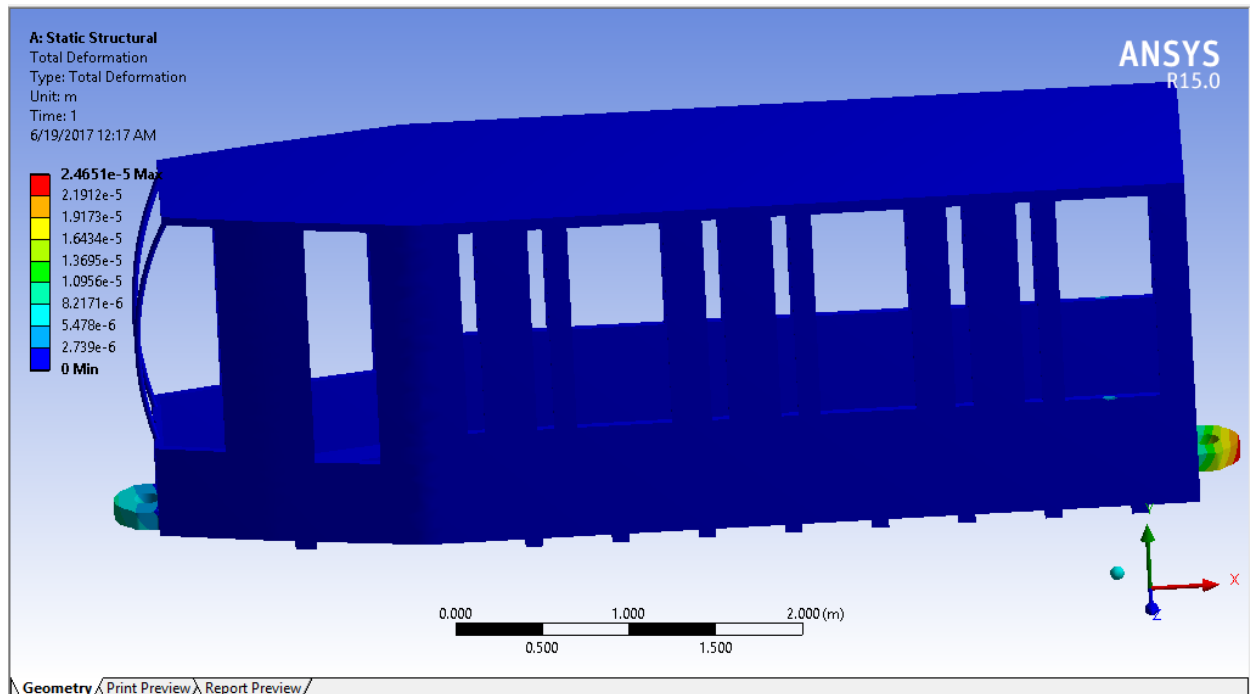


Figure 14: Total deformation due to tensile force

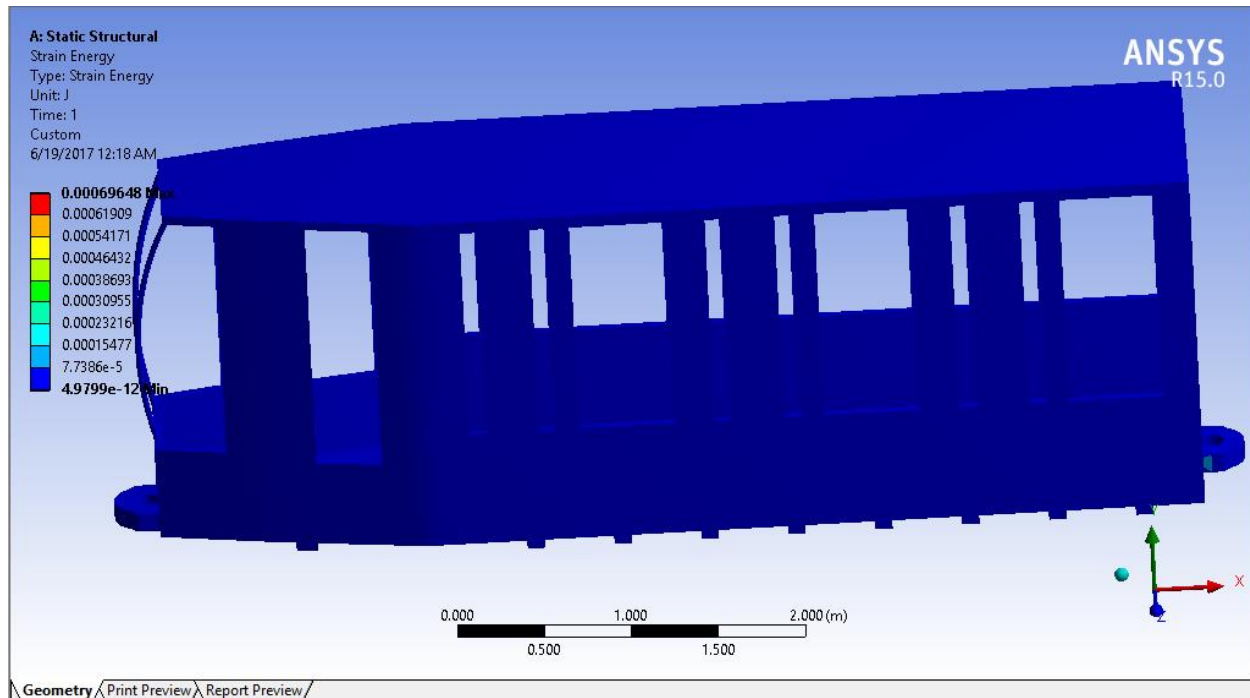


Figure 15: Strain energy due to tensile force at buffer

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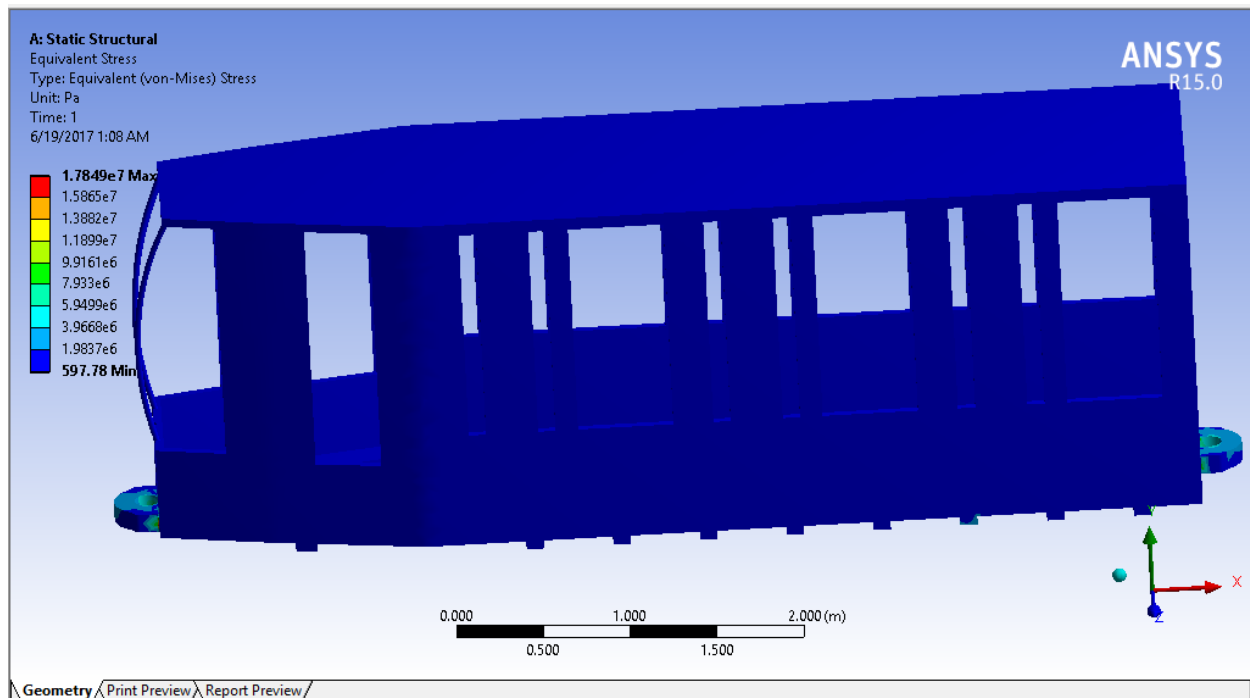


Figure 16: Compression force at buffer

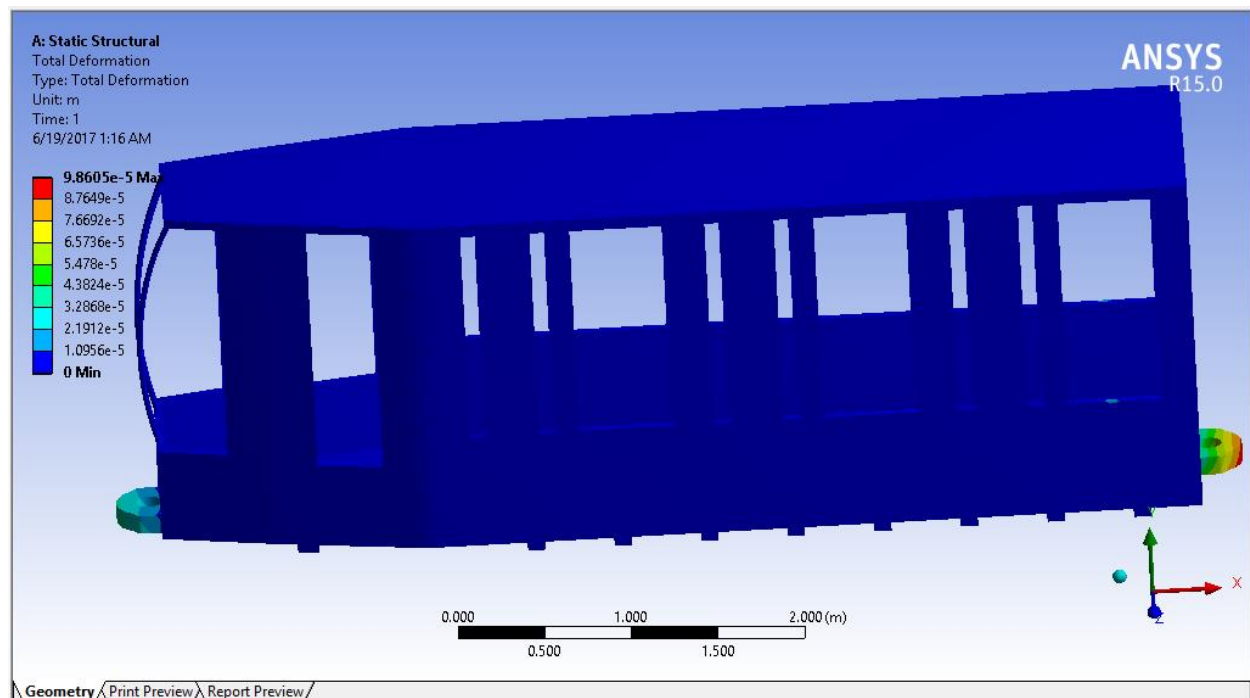


Figure 17: Total deformation due to Compression force.

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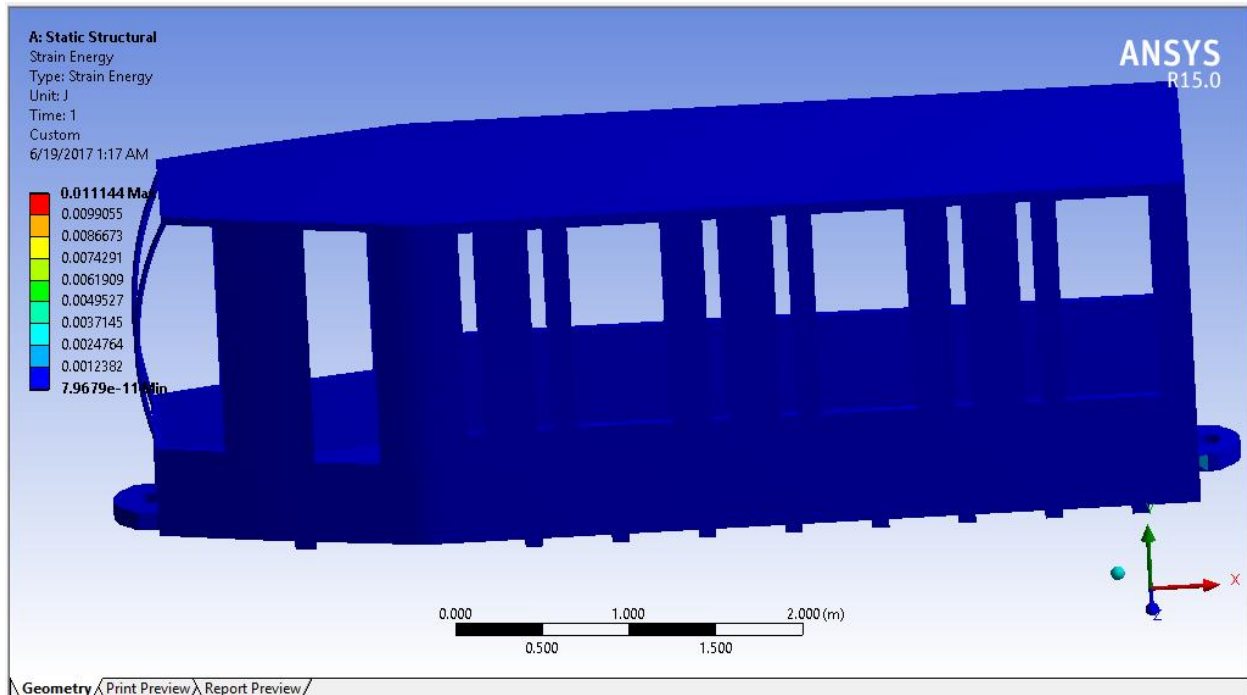


Figure 18: Strain energy due to compression force at buffer

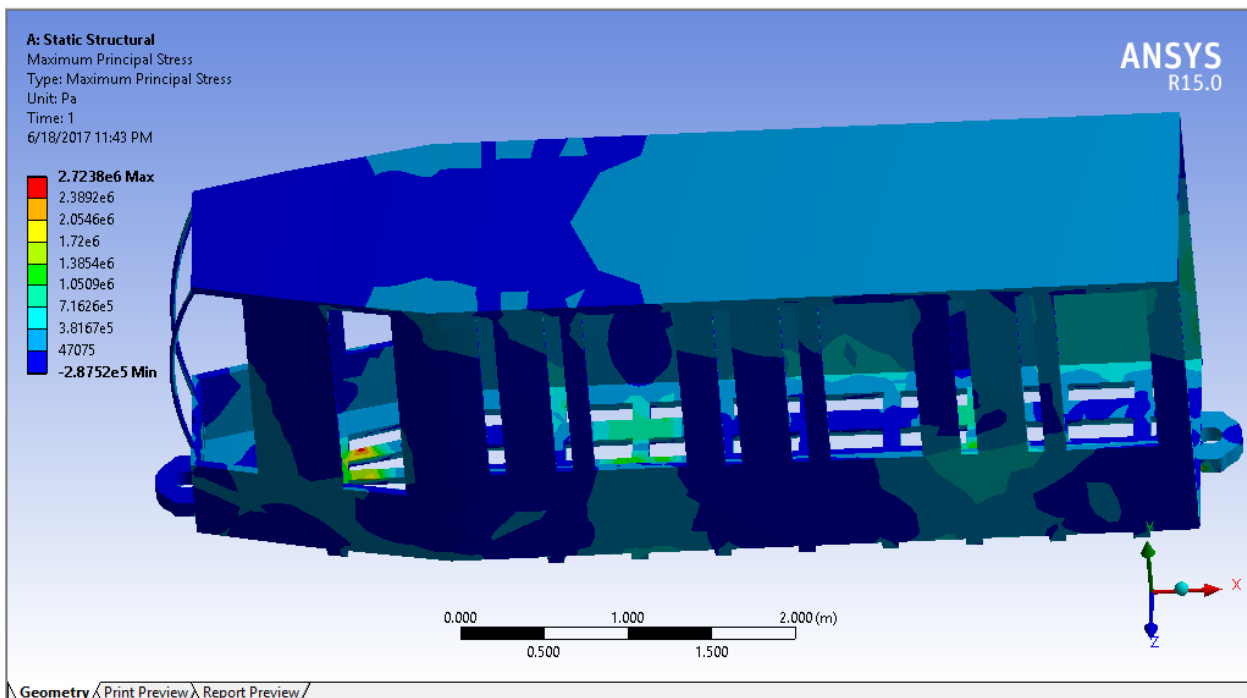


Figure 19: Maximum operating load.

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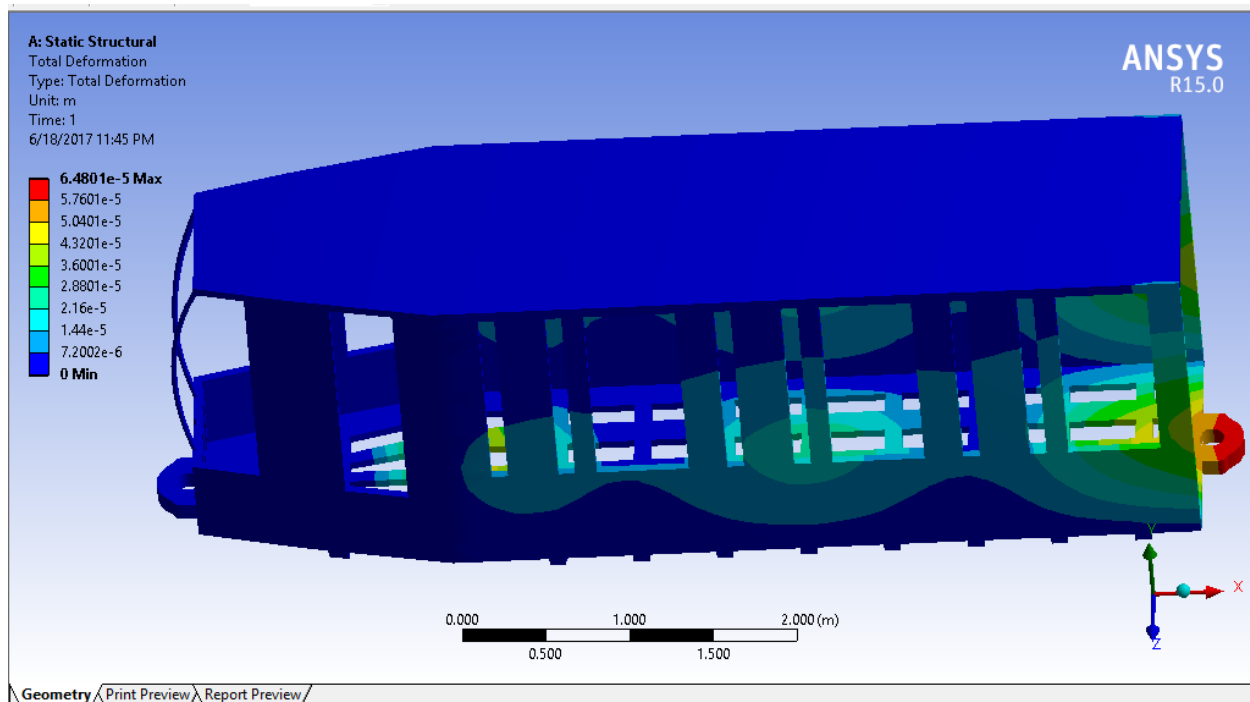


Figure 20: Total deformation due to operating load.

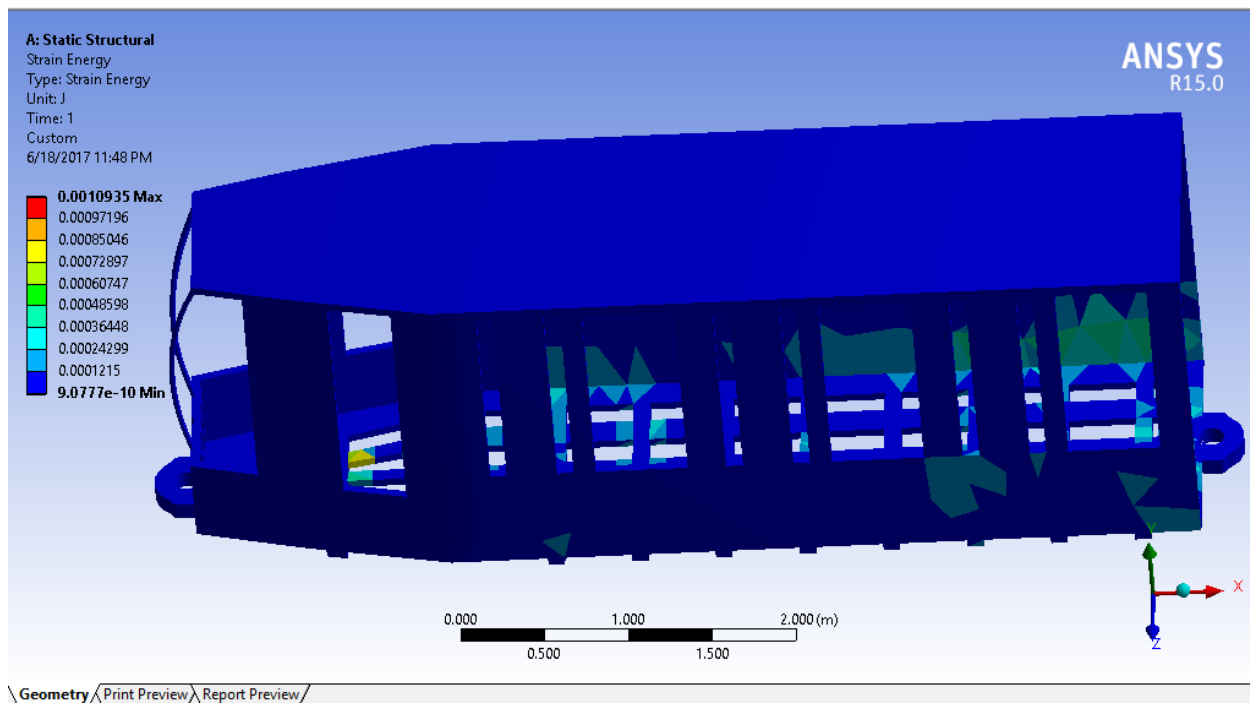


Figure 21: Strain energy due to operating load

Development of Composite Material for Rail Vehicle Body by Using FEM.

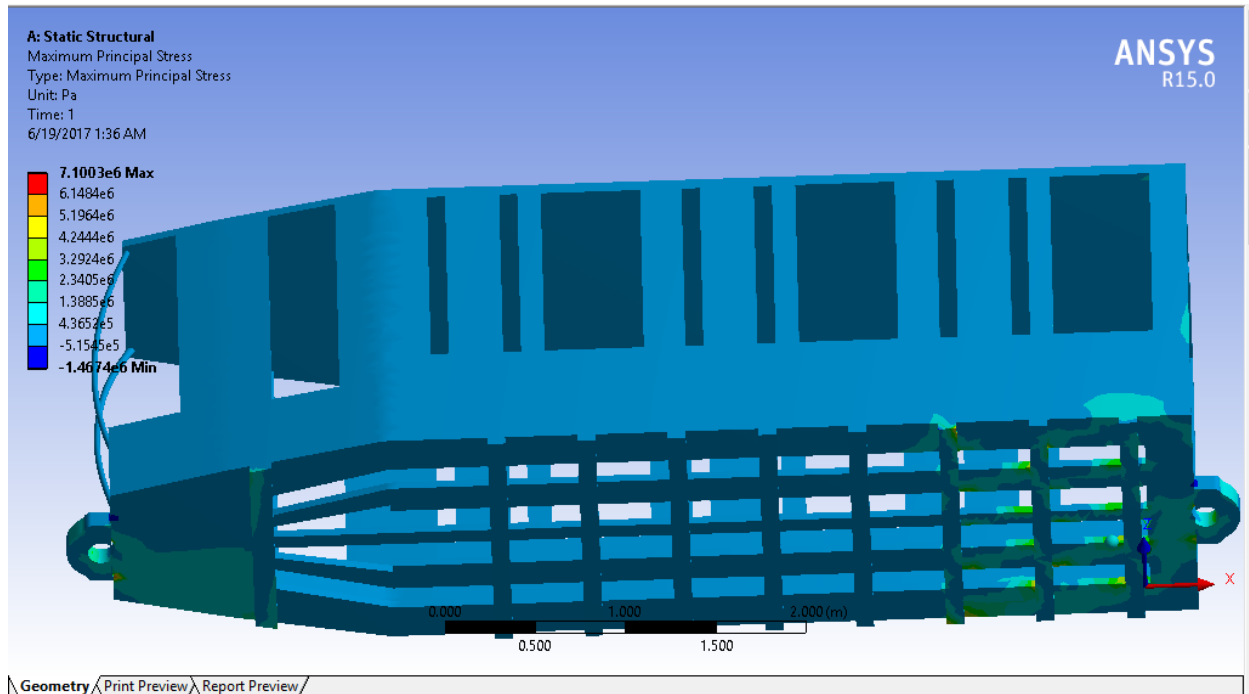


Figure 22: Maximum principal stress due to right turn

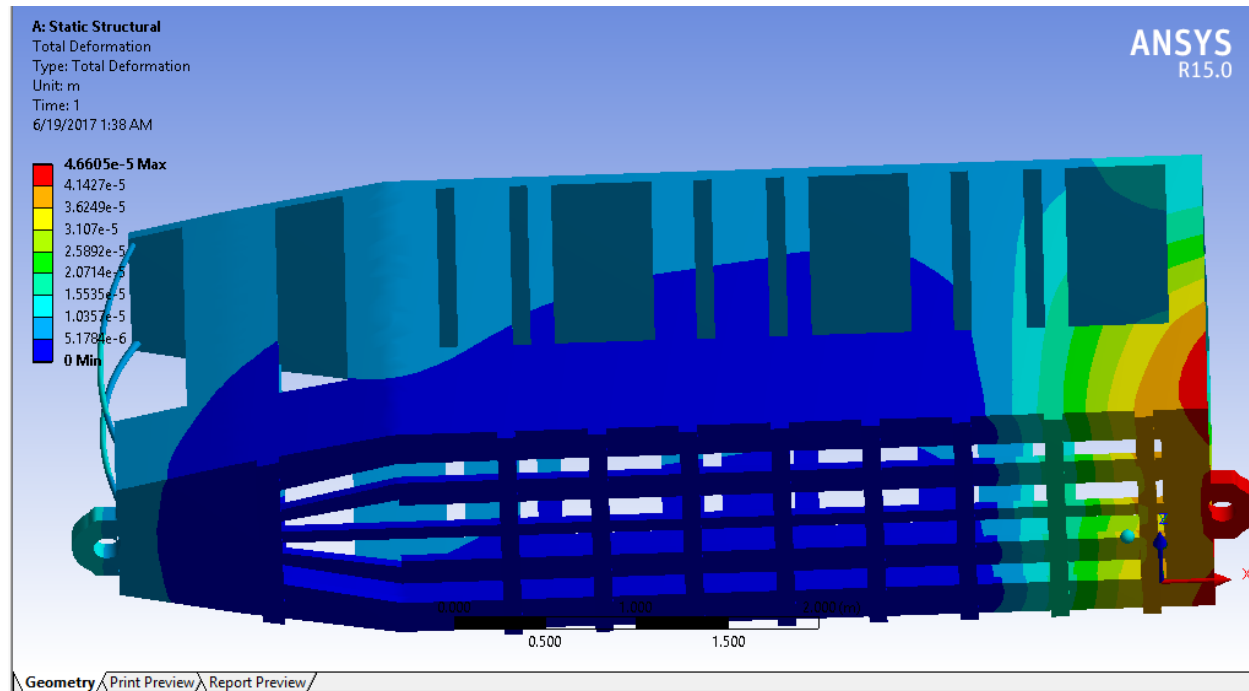


Figure 23: Total deformation due to right turn

Development of Composite Material for Rail Vehicle Body by Using FEM.

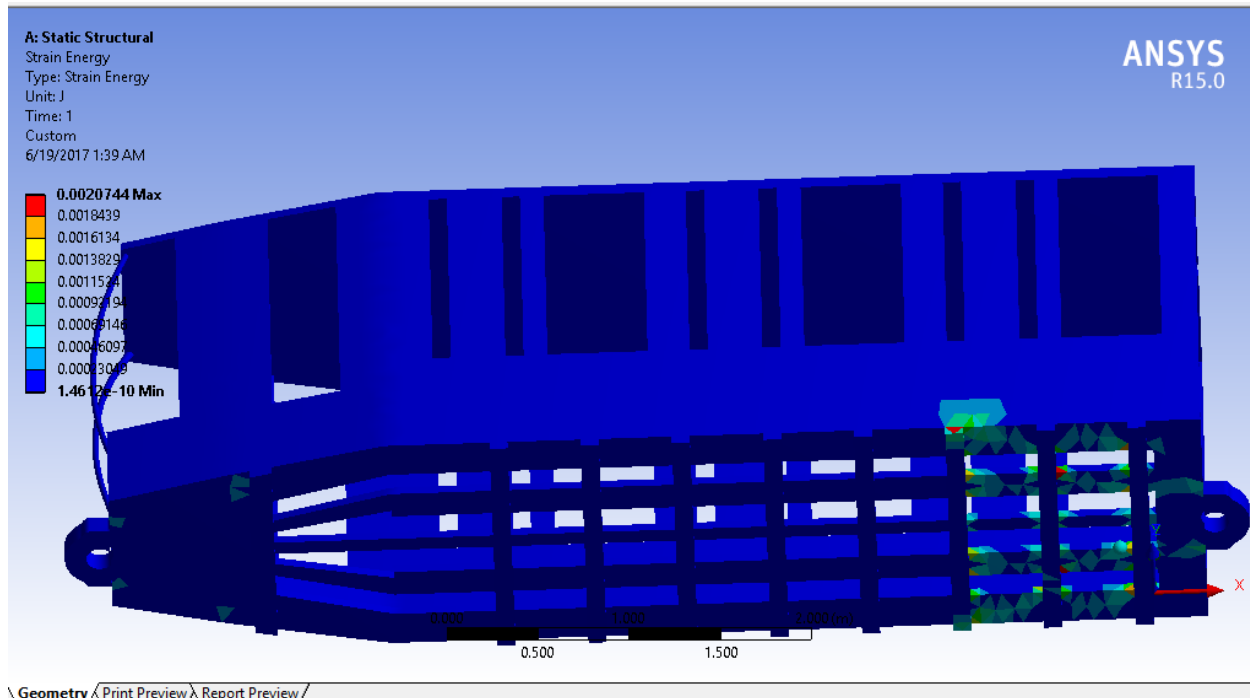


Figure 24: Strain energy due to right turn

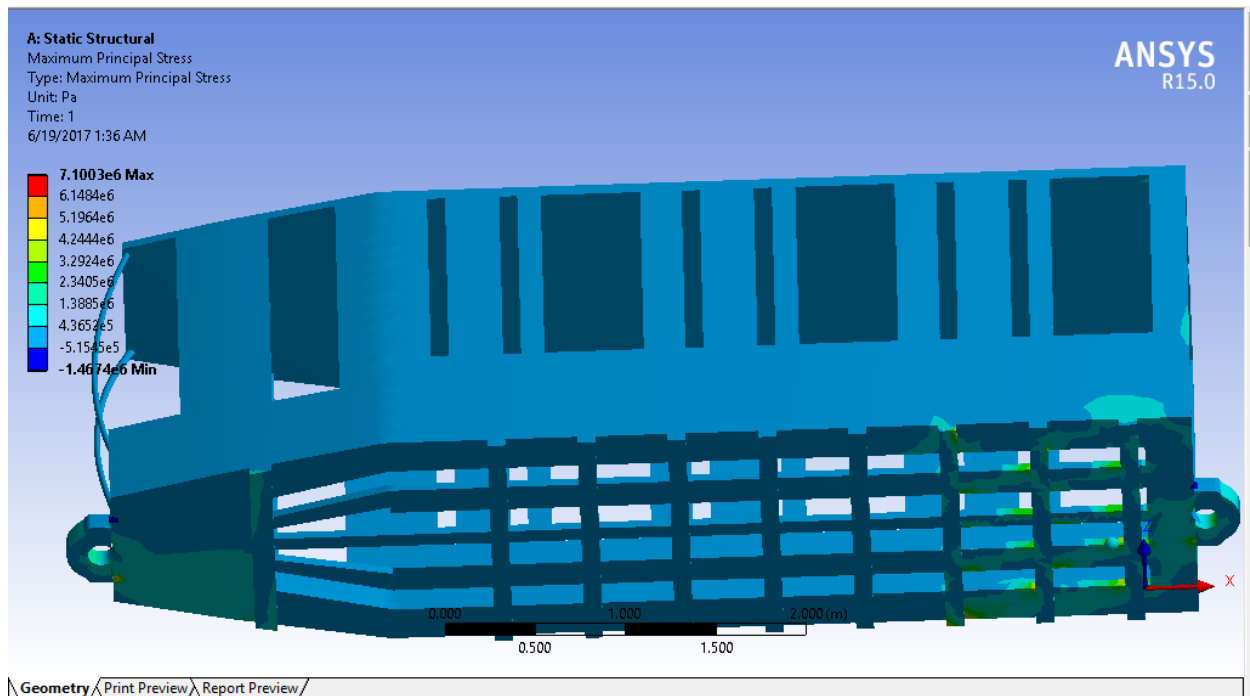


Figure 25: Maximum principal stress due to left turn

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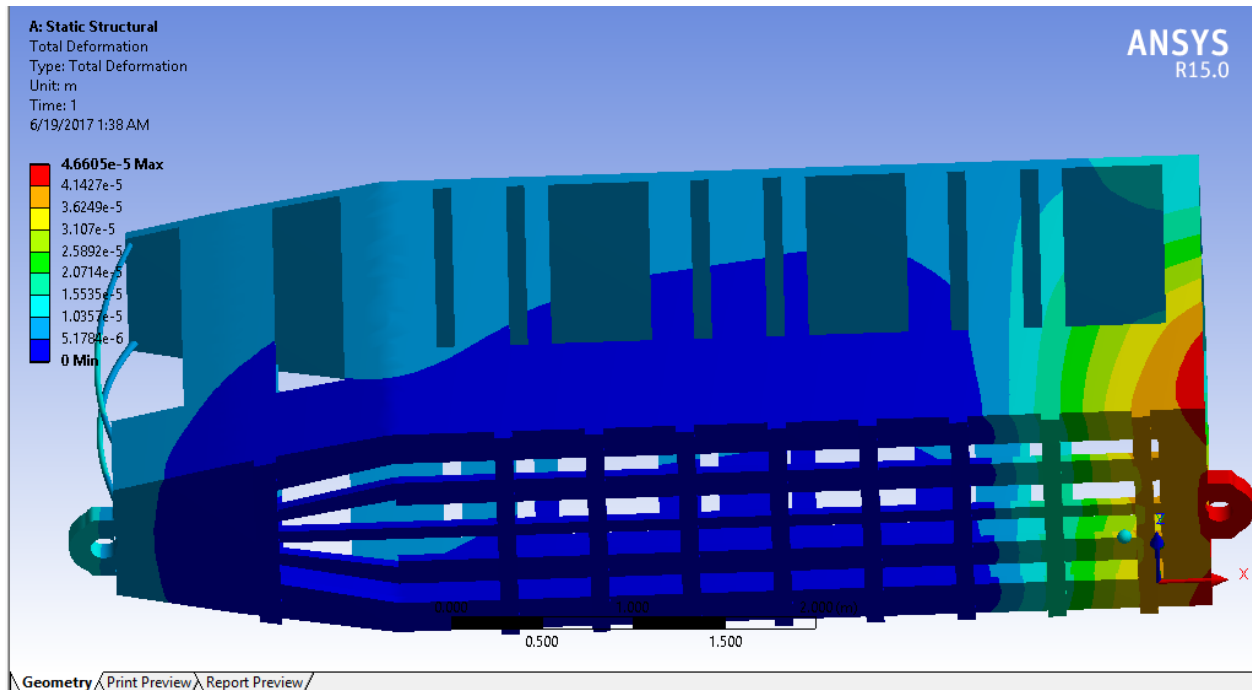


Figure 26: Total deformation due to left turn.

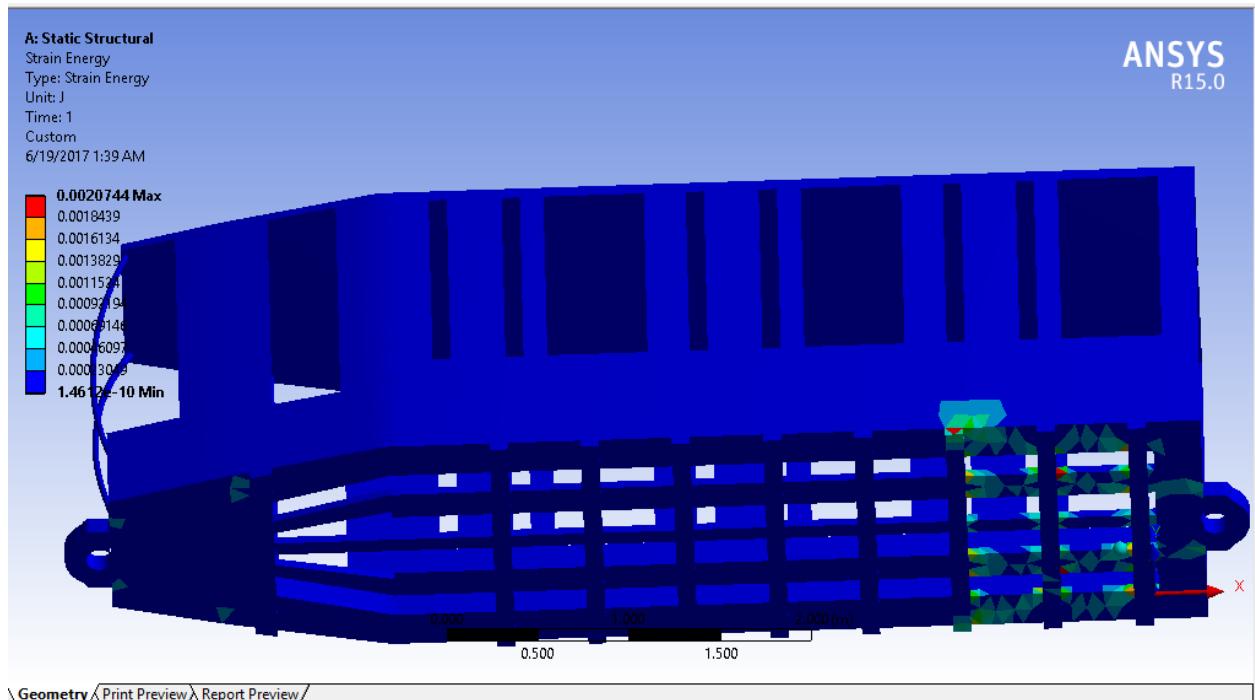


Figure 27: Strain energy due to left turn

Development of Composite Material for Rail Vehicle Body by Using FEM.

3.5. FE Analysis method of Bamboo fiber reinforced epoxy composite tram car

The specific material property of the selected bamboo fiber reinforced epoxy composite material is stated in the table below.

Table 12: mechanical properties of Bamboo fiber reinforced epoxy composite [19]

Material Property	Values
Density (ρ)	1120 kg/m ³
Tensile Strength	187.73MPa
Flexural Strength	190.32MPa
Compressive Strength	114.13MPa
Shear Strength	81.18MPa
Young's Modulus	3852
Shear Modulus	1580

3.4.3 Mesh generation

The model consisted of 187499 elements and 377287 nodes and the mesh with coarse sizing was selected and at different location an average element size between 10mm up to 20 mm and the face material sized element size of 10mm.

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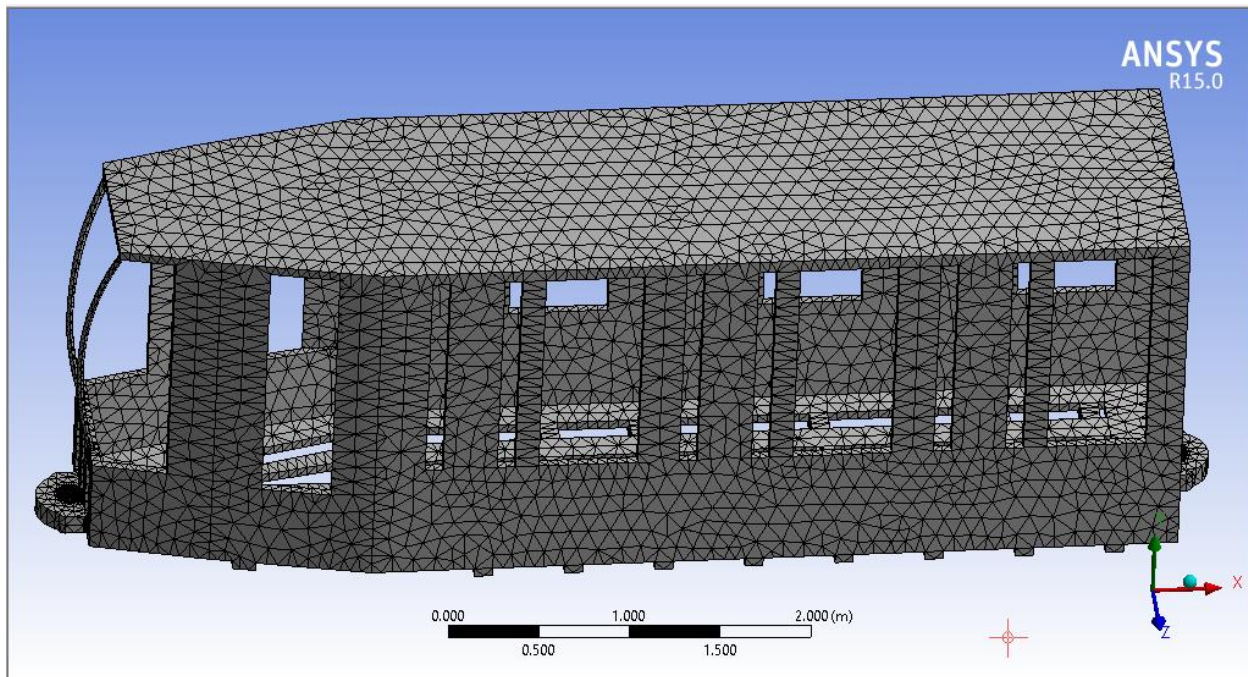


Figure 28: Meshing of bamboo fiber reinforced epoxy composite vehicle body

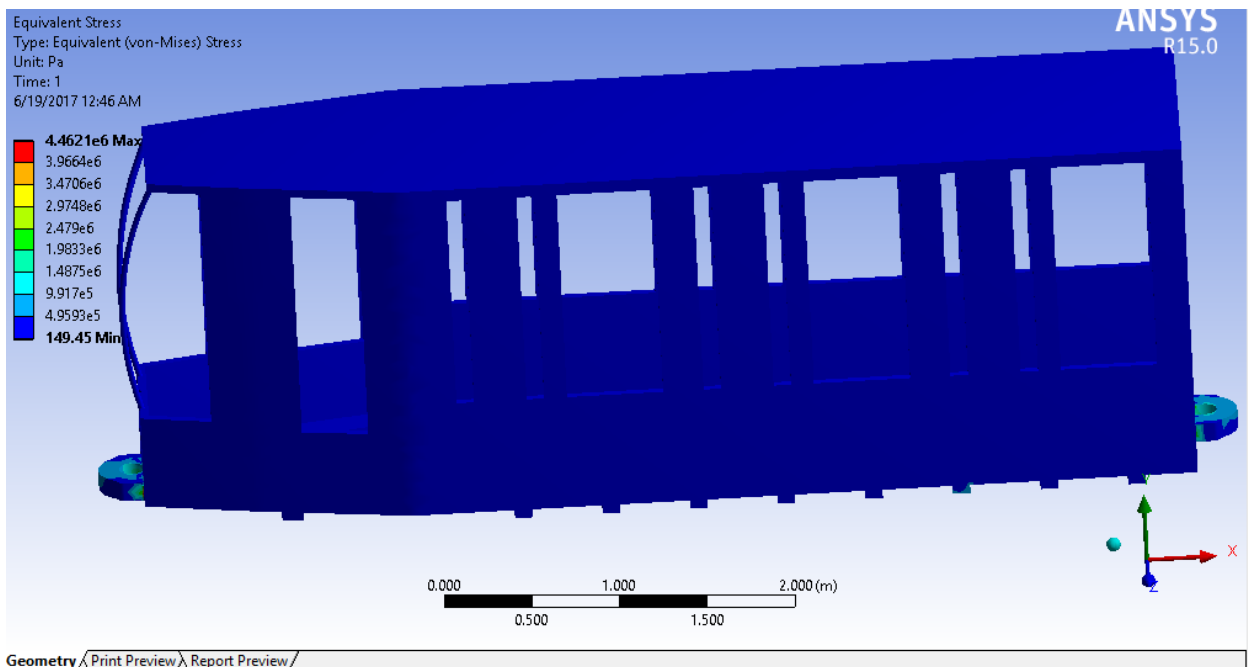


Figure 29: Tensile force at buffer

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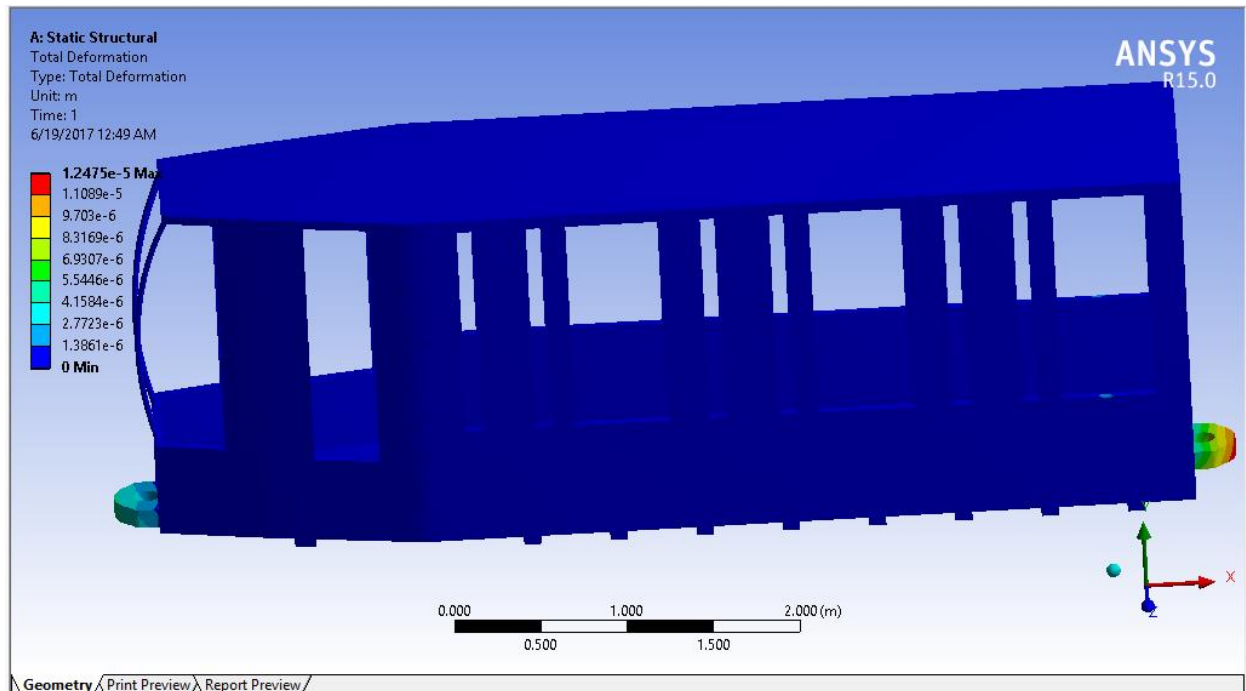


Figure 30: Total deformation due to tensile force.

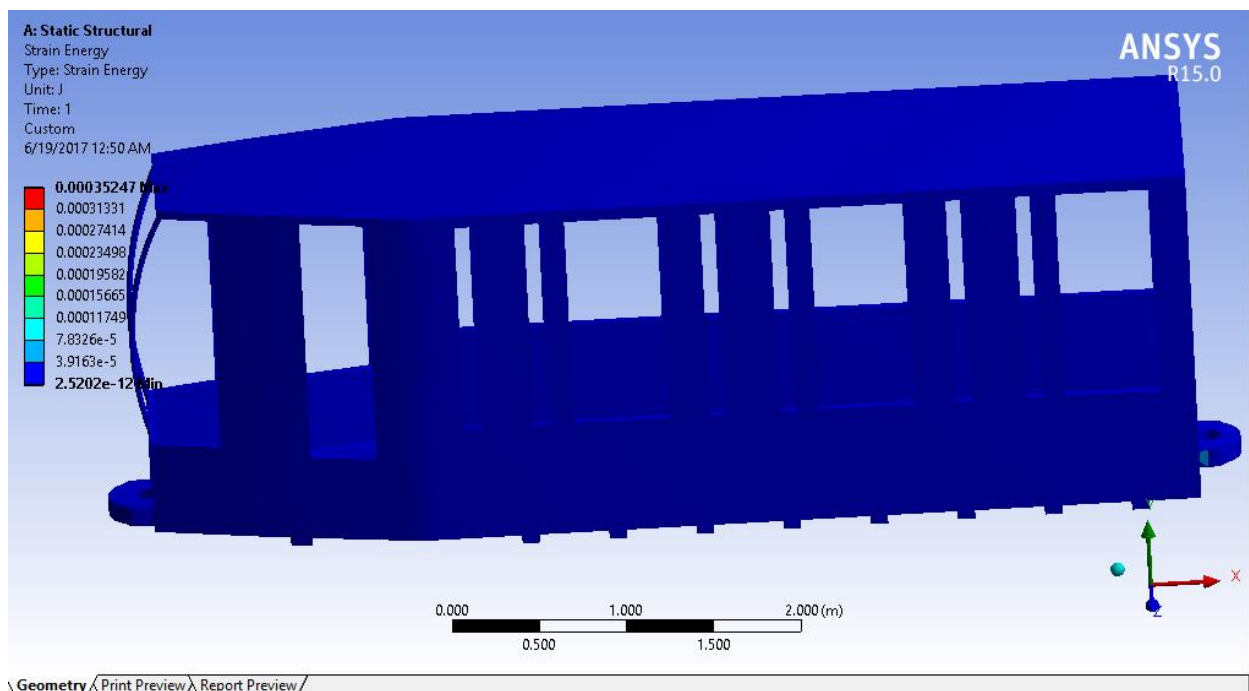


Figure 31: Strain energy due to tensile force.

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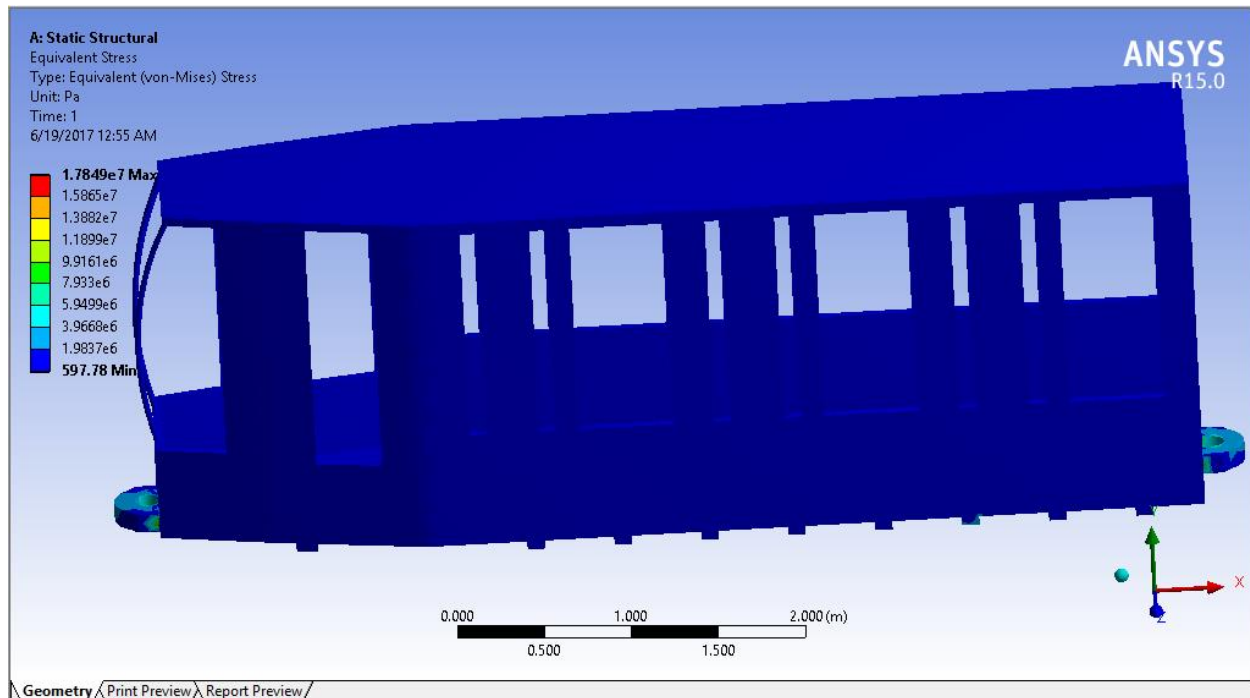


Figure 32: Compressive force at buffer

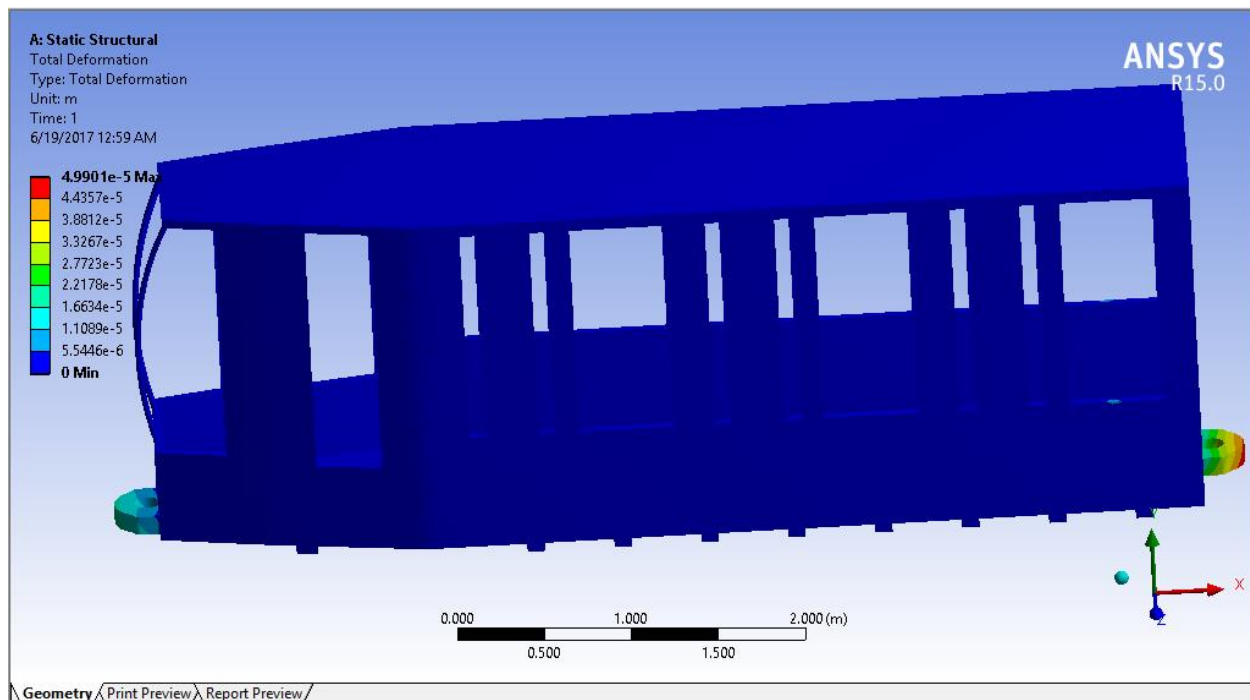


Figure 33: Total deformation due to compressive force.

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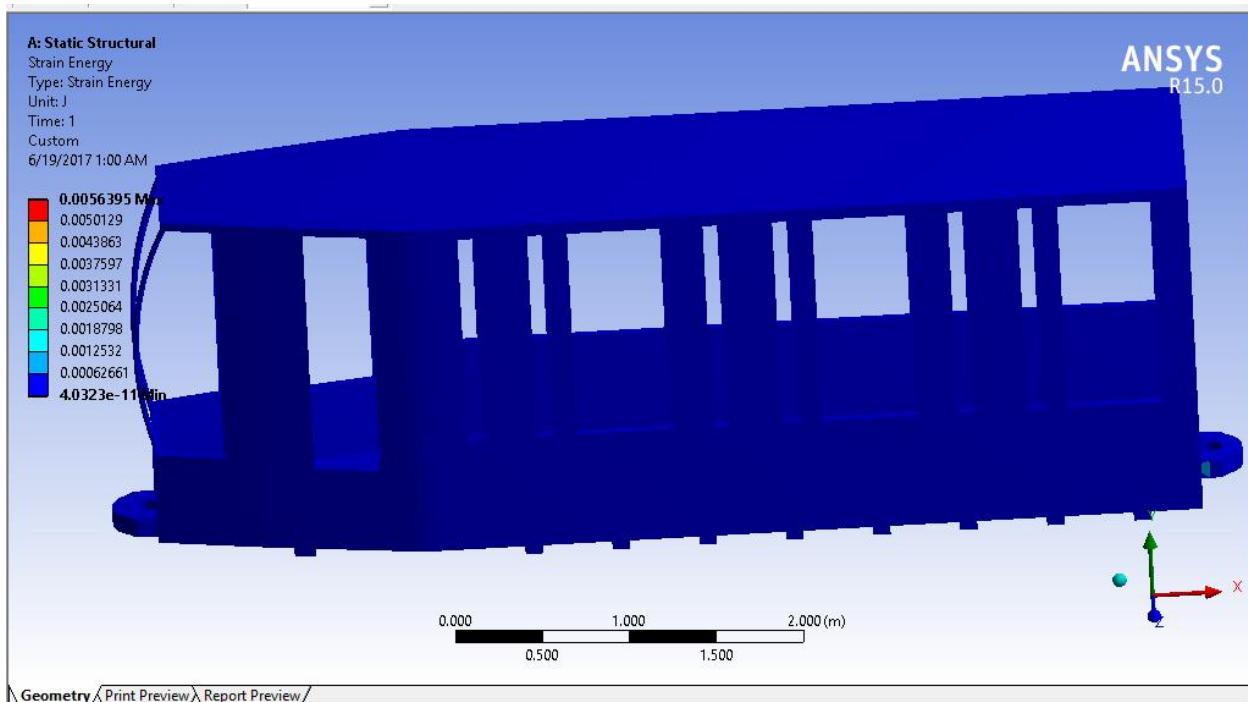


Figure 34:

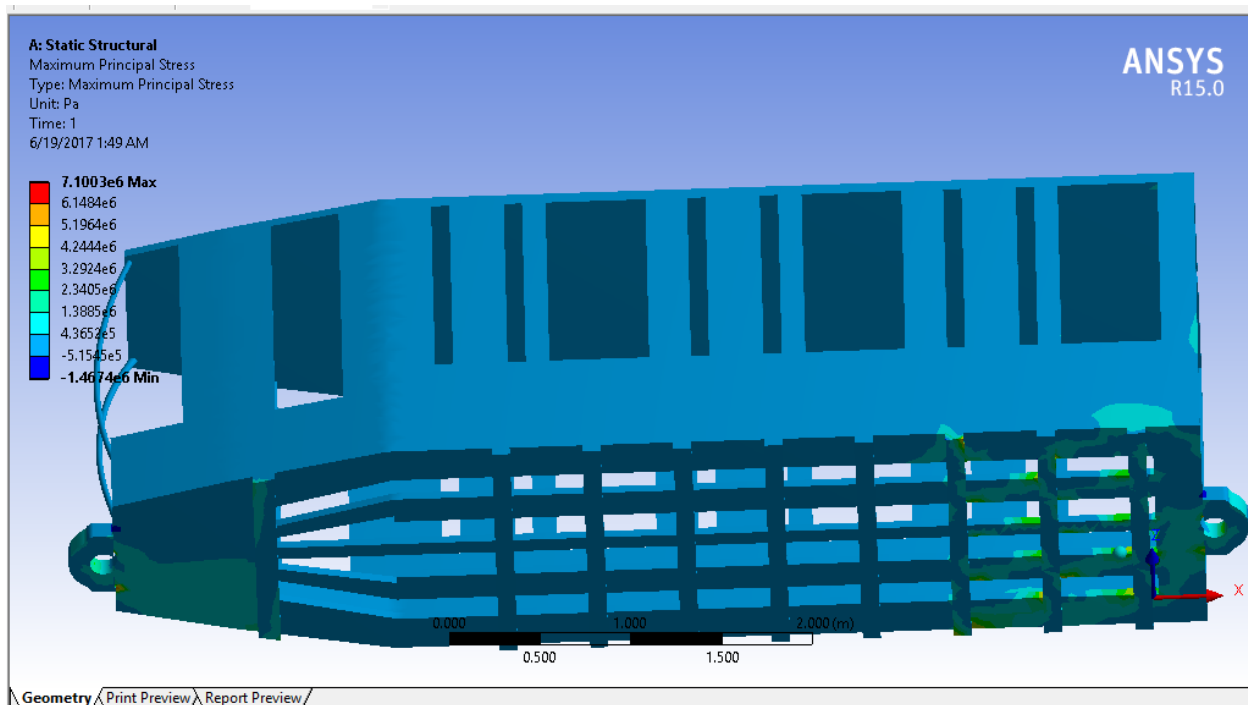


Figure 35: Maximum principal stress due to right turn

Development of Composite Material for Rail Vehicle Body by Using FEM.

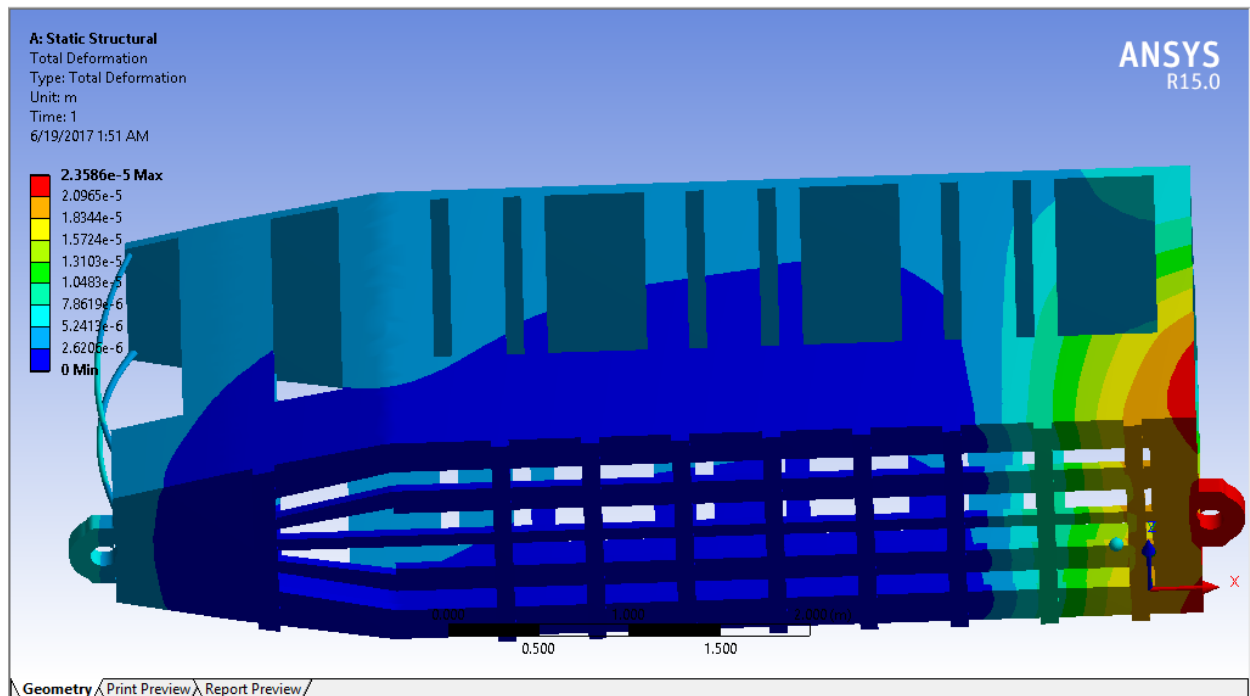


Figure 36: Maximum deformation due to right turn.

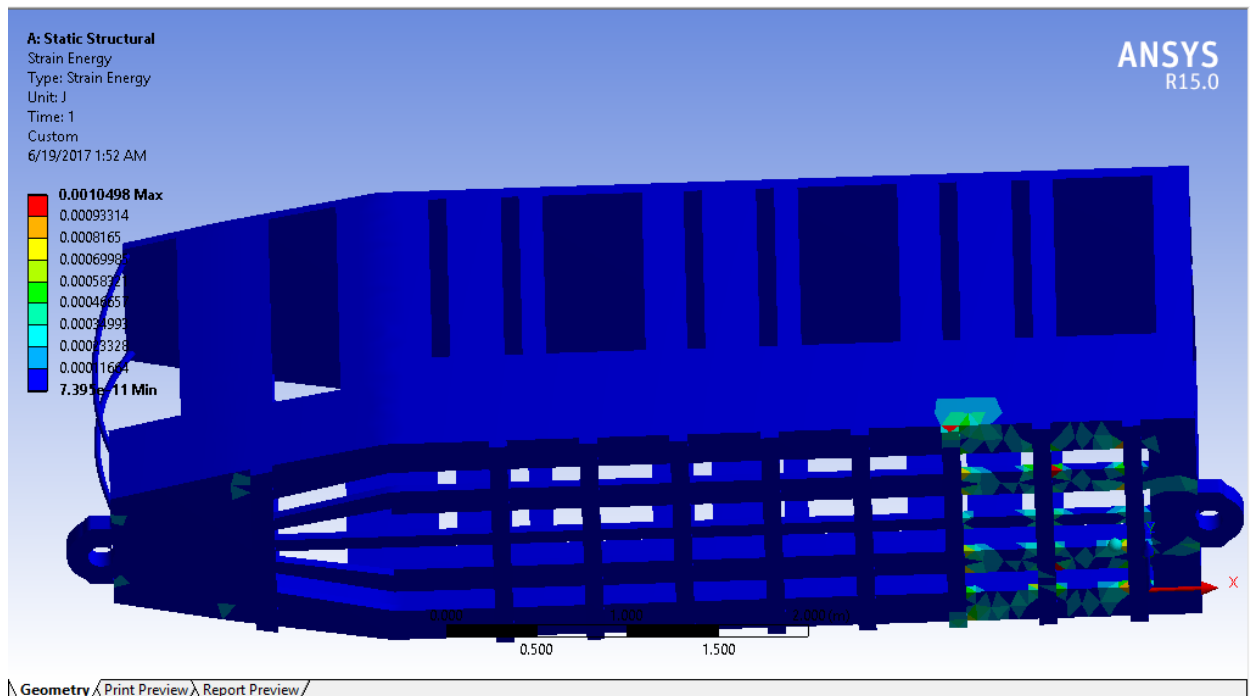


Figure 37: Strain energy due to right turn.

Development of Composite Material for Rail Vehicle Body by Using FEM.

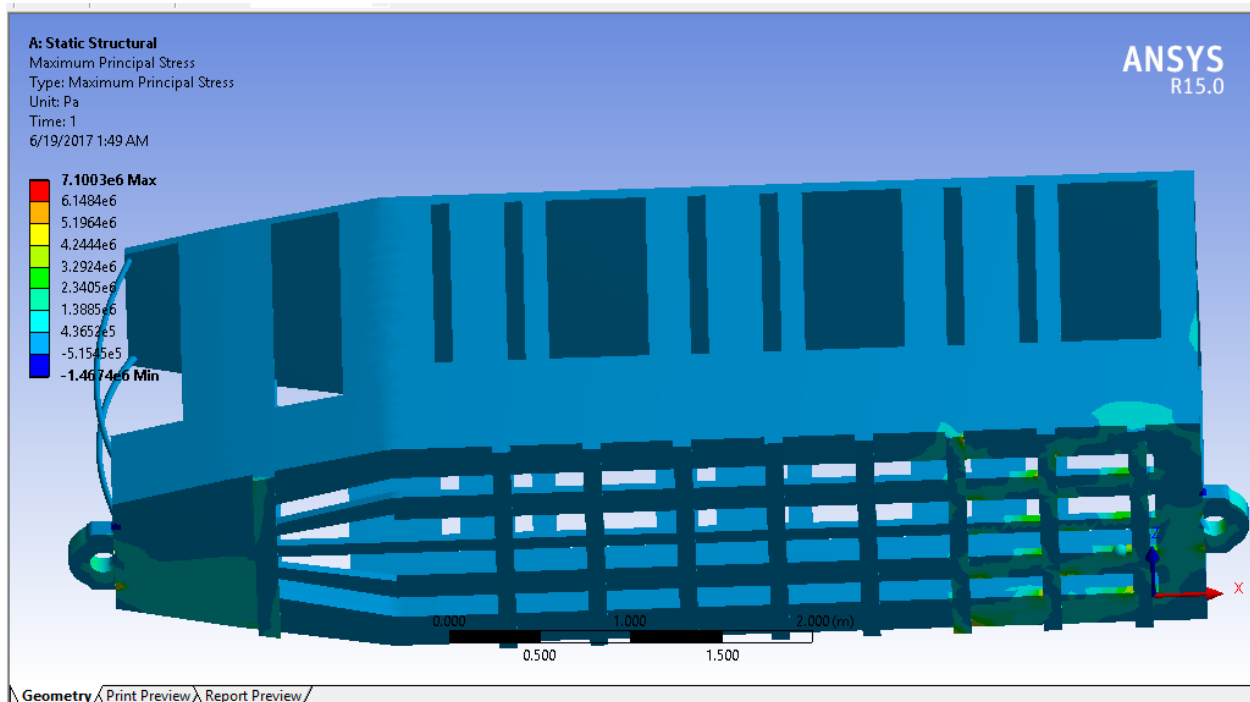


Figure 38: Maximum principal stress due to left turn

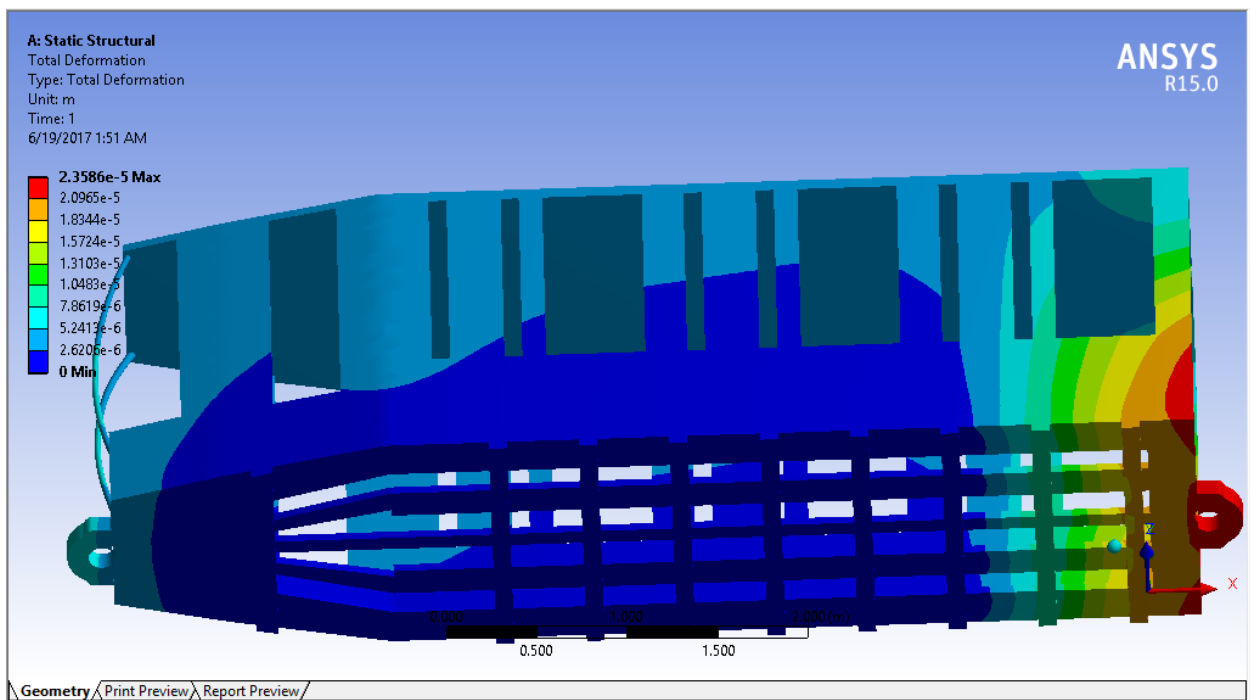


Figure 39: Maximum deformation due to left turn

Development of Composite Material for Rail Vehicle Body by Using FEM.

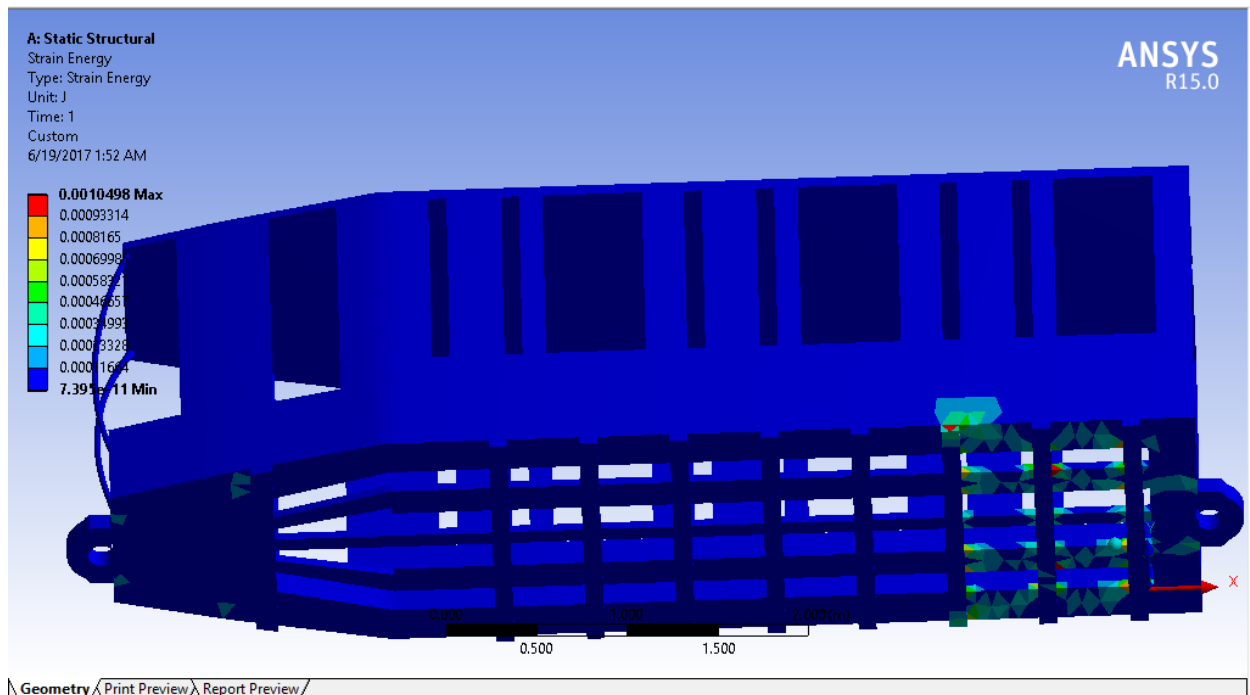


Figure 40: Strain energy due to left turn.

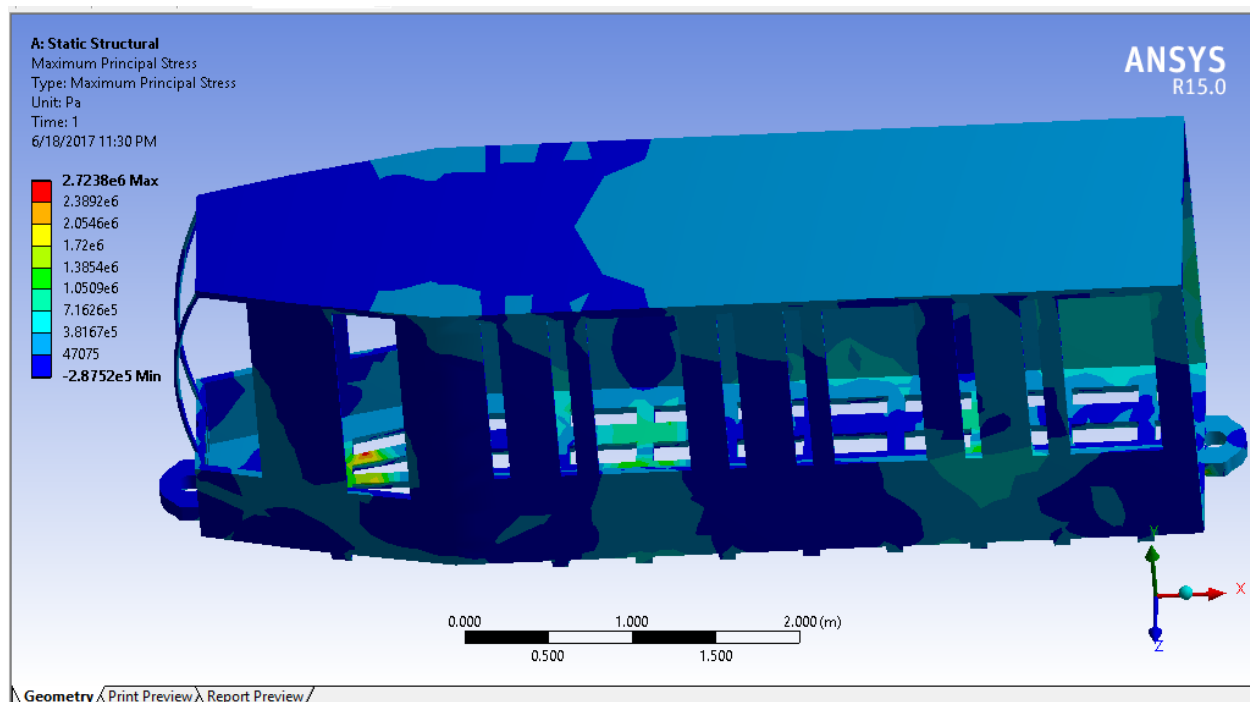


Figure 41: Maximum operational load.

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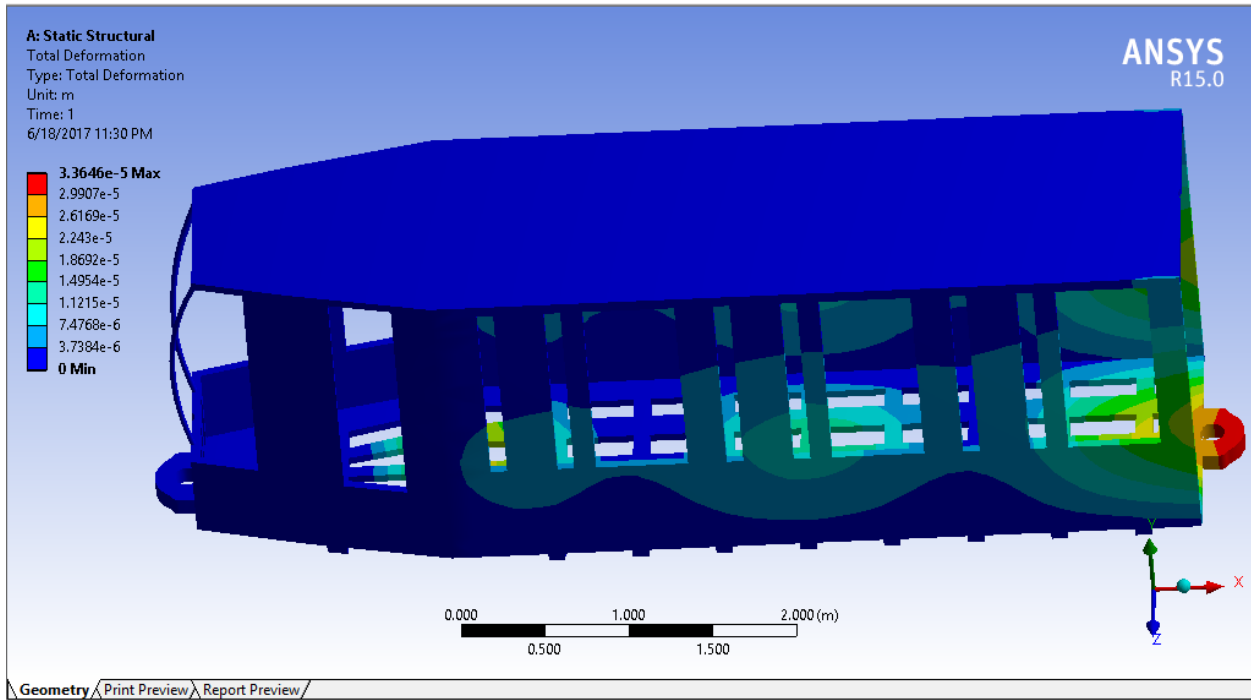


Figure 42: Maximum deformation due to operational load.

Development of Composite Material for Rail Vehicle Body by Using FEM.

CHAPTER FOUR

4. Result and discussion

4.1 Result

The results from solid work modeling of the tram car using steel and Bamboo fiber reinforced epoxy composite material has been studied in solid work are presented. The purpose of the modeling is to verifying the vehicle body with the standard and the testing are based on proven experience supported by the evaluation of experimental data and published information. The stress analyzed under five different load condition stated under table 3.3. The goal of stress analysis and the deformation presented in this section is to investigate the maximum stress area and verified with the standard and parameterized study of change of stress with both material. The solid work result described in table form found below.

Load condition	Steel material	Bamboo fiber reinforced epoxy composite
Due to operation load	2.7238MPa	1.6234MPa
Due to tensile force at the buffer	4.4621MPa	3.8201MPa
Due to compression force at the buffer	17.849MPa	15.461MPa
Due to left turn	7.1003MPa	5.301MPa
Due to right turn	7.1003MPa	5.301MPa

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Table 13: Total deformation

Load condition	Steel material	Bamboo fiber reinforced epoxy composite
Due to operation load	0.000064081	0.000033646
Due to tensile force at the buffer	0.000024651	0.00012475
Due to compression force at the buffer	0.000098605	0.000049901
Due to left turn	0.000041427	0.000023586
Due to right turn	0.000041427	0.000023586

Table 14: Maximum principal stress values

The advantage of Bamboo fiber reinforced epoxy composite material is not only weight reduction but also remove the manufacturing complexity of the steel vehicle due to its parts used. Due to a compression force of 200KN force applied on both side the maximum principal stress of steel material is 17.849MPa and using Bamboo fiber reinforced epoxy composite its value is 15.461MPa.

Due to a tensile force of 50KN force applied on both side the maximum principal stress of steel material is 2.7238MPa and using 1.6234MPa. Due to acceleration force in the lateral direction and vertical direction the variation of 2.4MPa and 1.12MPa.

The maximum principal stress due to compression force applied on tram car using Bamboo fiber reinforced epoxy composite result .To reduce the variation add steel or other stiffener on the material or Increasing either the core or the face material thickness further reduced the maximum stress value.

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CHAPTER FIVE

5. Conclusion and future work

The purpose of this thesis was the structure analysis of the tram car by using Solid work analysis methods and also parameterized study was done by varying the material using steel and Bamboo fiber reinforced epoxy composite

5.1 conclusions

From the analysis of vehicle body using steel and Bamboo fiber reinforced epoxy composite material maximum stress found on the two ends of buffer when subjected to tensile and compression load. The tram car maximum deformation and maximum stress found on the End walls and side walls connections area, the vertical support at the door area and the two end window corner.

From the analysis verify that no significant permanent deformation is present after removal of the maximum loads. To reduces the deflection further change the structure with higher yield strength material in higher stress area. Bamboo fiber reinforced epoxy composite has advantages due to its light weight and it has direct or indirect advantage on the railway infrastructure.

5.2 RECOMMENDATIONS

The rail vehicle body shall be designed as stiff as possible to resist the incoming compressive, vertical, quasi static, vibration stress and as the same time provide comfort to the passenger on board.

The Appropriate material must be selected for rail vehicle body to reduce the weight and increase the strength of rail vehicle body and improve the comfort of the passenger. However, this passenger rail vehicle structure is made out of steel of different profile that is believed to be available on the market with low cost. Even thought, it increases the dead load, operational cost, and efficiency of passenger rail vehicle. It is recommended to use more strong and lightweight structures which area esthetically, structurally, and operationally viable.

The conditions that are taken into account to increase the car body stiffness and to increase the natural frequency the car body.

Development of Composite Material for Rail Vehicle Body by Using FEM.

- Make the car body as short as possible. However, this conflicts with the desire to maximize the number of passengers in relation to the number of bogies.
- The sheet metal which is covered on the structure should be included in the finite element analysis in order to find a more refined result.
- Use stiffer car body materials or design resulting in high car body stiffness. This is, however contradictory with the requirement of lightweight car bodies.

5.3. Future work

- modal frequency analysis of tram car using lightweight material
- Fatigue strength analysis of the tram vehicle on the articulation joints between vehicle bodies.
- Induced loading resulting from vertical, lateral and twist irregularities of the track on the vehicle body.
- aerodynamic loads arise a trains passing at high speed;

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