IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"Design & Analysis Of Suspension System For TATA LPTA/Dumper"

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Abstract: "Design and Analysis of Suspension System for Military Vehicles" aims to enhance the performance, durability, and maneuverability of military vehicles by focusing on the critical component of suspension system. Military vehicles operate in diverse and challenging terrains, ranging from rough landscapes to combat zones, demanding robust and adaptable suspension systems. This research involves a comprehensive study of existing suspension technologies, materials, and Design methodologies, with a specific focus on their applicability to military vehicles. The research explores innovative design concepts that can withstand extreme conditions, improve off-road mobility, and provide enhanced crew comfort. The suspension system's role in ensuring the protection of Sensitive equipment and payload integrity during tactical operations is also a significant consideration. Finite Element Analysis (FEA) and computer-aided design tools will be employed to simulate and optimize various suspension configurations. This includes evaluating the system's response to dynamic loads, shocks, and vibrations encountered in military operations. The research will also consider the integration of adaptive suspension technologies to dynamically adjust the vehicle's height and stiffness based on the terrain and operational requirements. Furthermore, the research will delve into the utilization of advanced materials, such as composite materials and high-strength alloys, to reduce weight while maintaining structural integrity. The impact of weight reduction on fuel efficiency, transportability, and overall mission effectiveness will be thoroughly examined.

***Index Terms* -** Automotive, Mechanical Suspension, FEA Analysis of Suspension, Suspension System

I. INTRODUCTION

In an ever-evolving world where mobility, agility, and safety are paramount, the design and analysis of military troop carrier vehicles play a pivotal role in ensuring the readiness and effectiveness of armed forces. One critical component of these vehicles that often goes unnoticed but is absolutely in dispensable is the suspension system. We will delve into the key aspects of designing and analyzing the suspension system of the military vehicle, shedding light on its significance, challenges, and the engineering marvel that makes it a trusted asset in military fleets around the world.

The Main Objective of this project is:-

1. **Analysis of existing suspension system for the vehicle:**

This involves a comprehensive examination of the current suspension system used in military troop carrier vehicles. Engineers will assess its design, components, materials, performance under various conditions(such as different terrains and payloads), maintenance requirements, and any issues or weaknesses it may have encountered in real-world usage. This analysis serves as a foundation for identifying areas for improvement.

2. **Improvement in reliability of the suspension system:**

Building upon the analysis, the focus shifts to enhancing the reliability of the suspension system. This can involve redesigning certain components or subsystems to address identified weaknesses or failure points. For example, if a particular part is prone to premature wear or failure, engineers may explore stronger materials, better manufacturing processes, or alternative designs to increase durability and lifespan.

3. **Optimum design of the suspension system:**

Optimization aims to achieve the best balance of performance, cost, weight, and other factors critical to the suspension system's effectiveness. This stage often involves advanced modeling, simulation, and iterative design processes. Engineers may use computer-aided design (CAD) software and computational tools to explore various configurations, materials, and geometries, seeking to maximize performance while minimizing weight and complexity. Factors such as ride comfort, stability, maneuverability, and compatibility with other vehicle systems are carefully considered during this phase.

4. **Validation of the performance of the new suspension system:**

Once the improved suspension system design is finalized, it undergoes rigorous testing and validation to ensure it meets or exceeds the desired performance criteria. This includes both simulated tests in controlled environments (such as laboratories and test tracks) and real-world field tests under representative operating conditions. Data collected during testing is analyzed to verify that the new suspension system delivers the expected improvements in reliability, durability, ride quality, and overall performance.

Throughout the project, collaboration between engineers, designers, analysts, and military personnel is essential to ensure that the redesigned suspension system meets the specific operational requirements and mission objectives of military troop carrier vehicles. Additionally, considerations for ease of maintenance, repair ability, and compatibility with existing vehicle platforms are integrated into the design process to facilitate deployment and sustainment in the field. By addressing these objectives, the project aims to enhance the mobility, agility, and safety of military forces, ultimately contributing to their readiness and effectiveness in diverse operational environments.

II. RESEARCH METHODOLOGY

1. Literature Survey:

Understanding Existing Technologies: This involves a thorough review of existing literature, research papers, and patents related to suspension systems used in military vehicles as well as in other high-performance vehicles. By studying these sources, engineers gain insights into the latest advancements, materials, designs, and technologies being employed in suspension systems worldwide. Learn from Successes and Failures: Analyzing past projects and case studies helps identify both successful designs and failures encountered in suspension systems. Understanding what worked well and what didn't can provide valuable lessons for designing a more reliable, efficient, and effective suspension system for military troop carrier vehicles and commercial dumpers.

2. Specifying components of the suspension system:

Once the analysis is complete, engineers specify the individual components that make up the suspension system. This includes identifying and selecting components such as springs, shock absorbers, control arms, bushings, linkages, and stabilizer bars. Each component is chosen based on its intended function, compatibility with the vehicle's requirements, durability, weight, and cost considerations.

3. Design calculation for each component:

Design calculations involve determining the specifications and dimensions of each component based on engineering principles, vehicle dynamics, and performance requirements. For example, calculations may be performed to determine the spring rate, damping coefficient, stress levels, fatigue life, and other parameters for the springs and shock absorbers. These calculations ensure that each component is designed to withstand the forces and loads encountered during operation while maintaining optimal performance and safety.

4. Computer-aided design(CAD):

CAD software is used to create detailed 3D models of the suspension system components and their assemblies. Engineers can visualize the design, make adjustments as needed. This allows for iterative refinement of the design before physical prototypes are built, saving time and resources in the development process.

5. Material Selection:

Stress: The material should have high strength to withstand applied loads without failure. Steel, titanium, and composite materials are known for their high strength properties.

Strain: The material should exhibit minimal deformation under stress to maintain structural integrity. Steel and titanium typically have low strain rates, while composites can be engineered to have tailored strain properties.

Displacement: Depending on the application, displacement may need to be minimized to ensure stability and accuracy. Materials with high stiffness, such as steel and ceramics, tend to have low displacement under load.

Weight: Weight reduction may be crucial in applications where portability or fuel efficiency is essential. Lightweight materials like aluminium, titanium, and composites are favourable choices due to their high strength-to-weight ratios.

Deformation: The material should resist permanent deformation under load to maintain dimensional stability. Steel and titanium have good resistance to deformation, while composites can be designed to minimize deformation through fibre orientation and matrix selection.

6. Testing and Validation:

Once the design is finalized, prototypes of the suspension system are built and subjected to comprehensive testing and validation procedures. This includes both laboratory tests and field tests under simulated and real-world conditions. Testing may involve measuring parameters such as ride comfort, vehicle stability, handling, durability, and performance on different terrains. Data collected from testing is analyzed to verify that the suspension system meets the specified requirements and performs reliably under the intended operating conditions.

III. DESIGN CALCULATION FOR SEMI-ELLIPTICAL MULTI LEAF SPRING:

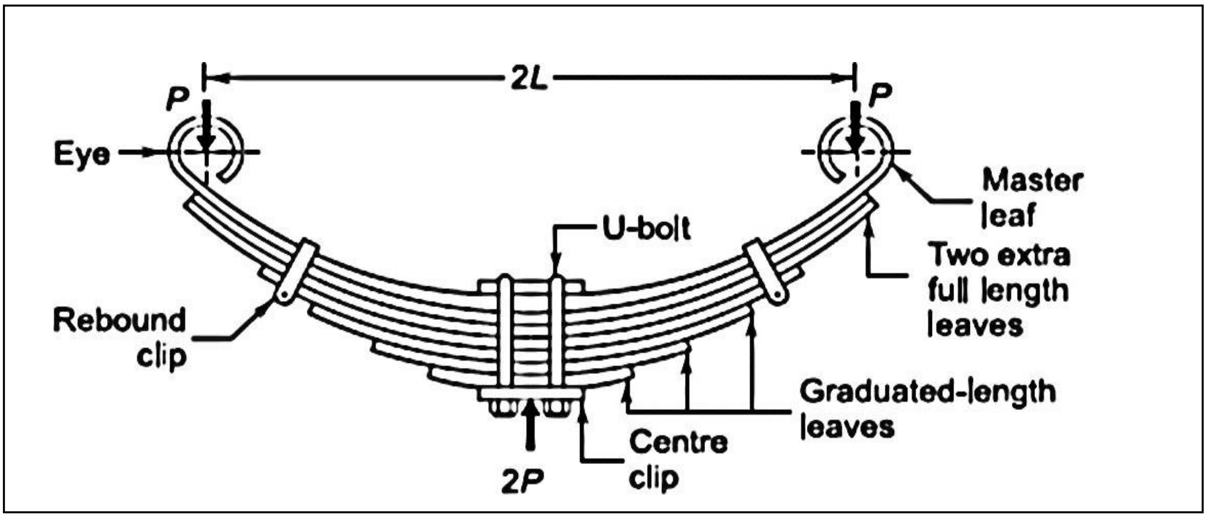

Fig1. Semi Elliptical leaf Spring

Fig2. Front leaf spring

Fig3. Rear leaf spring

LOAD ACTING ON THE VEHICLE:

- Vehicle gross weight: 7750(kg)

gross weight = curb weight (weight of the vehicle itself) + weight of the passenger, cargo, any accessories.

- Weight on each axle =7750/2= 3875 kg.
- Weight on each leaf spring =3875 / 2=1938 kg

=19011.78 newton

MATERIAL PROPERTIES:

- Material name : steel(50 cr 1v23)
- Composition of material:0.45%c, 0.1-0.3%si,0.6-0.9 mn ,0.9 -1.2%cr, 0.23%v.
- Yield strength:1800n/mm^2
- Factor of safety:1.5
- Allowable bending stress= (yield strength / fos)

  =(1800/ 1.5) =1200 n/mm^2.

DESIGN TERMINOLGIES:

nf = number of extra full-length leaves

ng =number of graduated-length leaves including master leaf n = total number of leaves

b=width of each leaf (mm)

t=thickness of each leaf(mm)

L=length of the cantilever or half the length of semi-elliptic spring(mm) P = force applied at the end of the spring (N)

Pf=portion of P taken by the extra full-length

PARABOLIC LEAF SPRING DESIGN:

Bending stress[for full loaded condition]:

=(6 pl) / (n b t^2)

=(6 *19011.78 * 800)/(12 *70 * 18^2)

=335.30n/mm^2 [design is safe]

SEMI-ELLIPTICAL LEAF SPRING DESIGN:

Bending stress [for full load condition] [main spring]

=(6 *14258.83 * 940)/(12 *80 * 18^2)

=258.55n/mm^2.

[helper spring]:

=(6 *4752.95 * 710)/ (7 * 80 *18^2)

=111.59n/mm^2 [design is safe]

IV. CATIA MODEL AND ANSYS ANALYSIS:

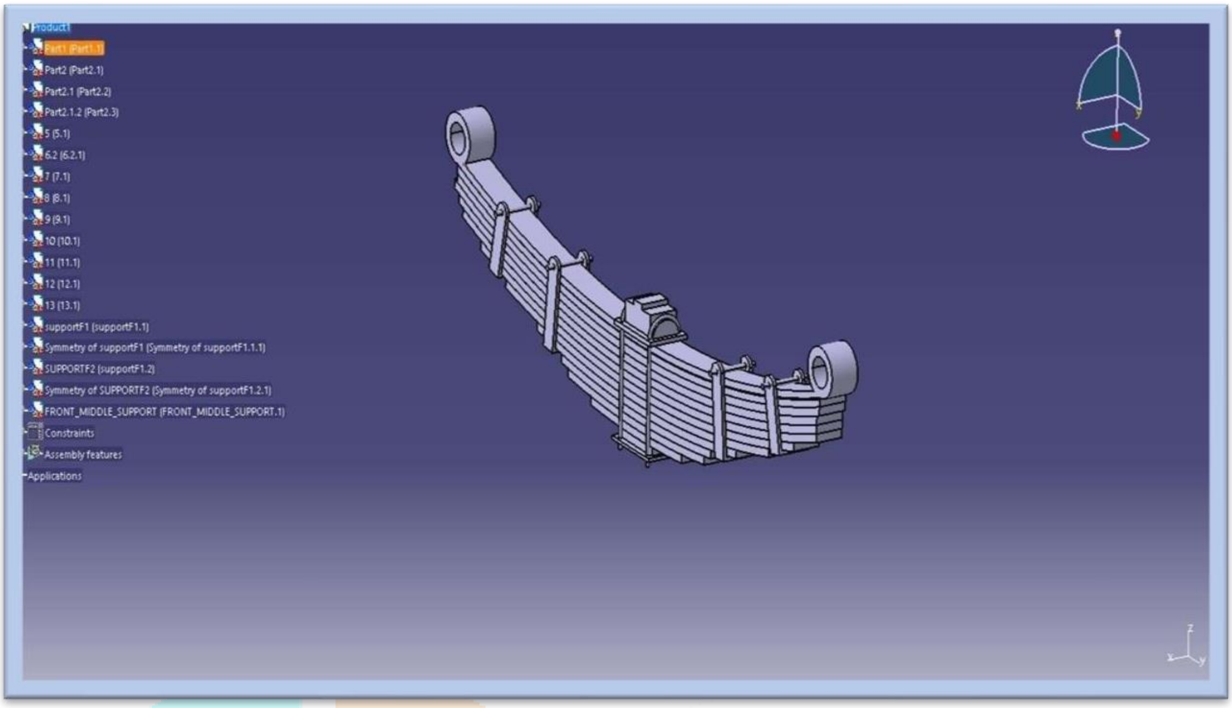

Fig.4 Front leaf spring CATIA model

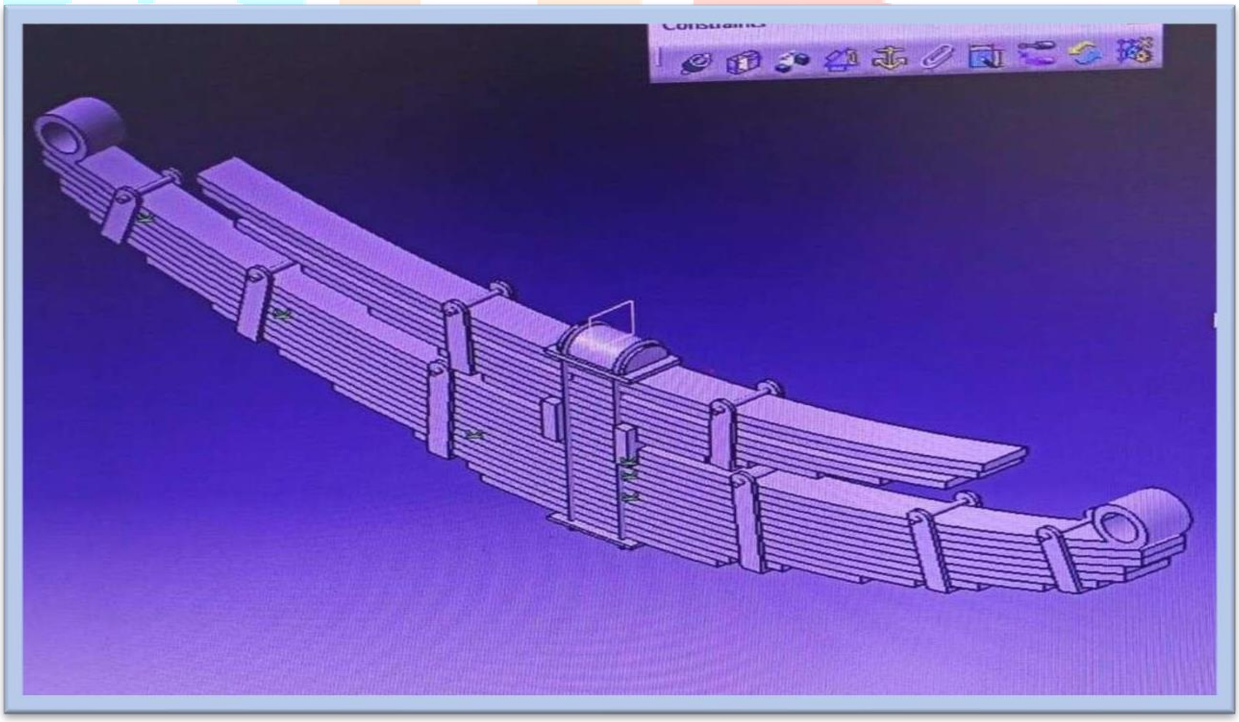

Fig.5 Rear leaf spring CATIA model

MESHED MODEL OF LEAF SPRING:

In ANSYS, meshing is a crucial step in setting up a finite element analysis (FEA) simulation. Here's how meshing is typically used with step-by-step explanations within ANSYS:

- **Geometry Import and Clean-up:** Start by importing the geometry of the structure or component into ANSYS Workbench or Mechanical. You can import CAD models from various formats such as IGES, STEP, or native CAD formats. Perform any necessary geometry clean- up, such as repairing gaps, removing small features, or simplifying complex details to ensure a smooth meshing process.

- **Pre-processing Setup:** Define the analysis type and any specific analysis steps required for your simulation, such as static structural, transient dynamics, or thermal analysis. This step is performed in the ANSYS Workbench environment. Specify material properties, boundary conditions, loads, and other relevant parameters required for the analysis.

- **Mesh Generation:** Launch the ANSYS Meshing tool from the Workbench environment. In ANSYS Meshing, import the geometry from the project schematic or directly from CAD if it's not already imported. Define the meshing settings, including element types (tetrahedral, hexahedral, etc.), element size, and mesh controls for capturing geometric details or areas of interest. Generate the mesh using automatic meshing algorithms or manually by specifying mesh sizes and controls on specific surfaces or volumes.

- **Mesh Quality Checking and Refinement:** After mesh generation, evaluate the quality of the mesh using ANSYS Meshing tools. Check for element quality metrics such as aspect ratio, skewness, and element size deviation. Refine the mesh as needed to improve the quality and capture fine geometric details or regions with high stress gradients. ANSYS provides various mesh refinement techniques such as local mesh controls, sizing functions, and adaptive meshing.

- **Boundary Conditions Application:** Once the mesh is generated and checked, return to the ANSYS Workbench environment to apply boundary conditions and loads to the model. Define constraints, forces, displacements, temperatures, and any other boundary conditions required for the analysis.

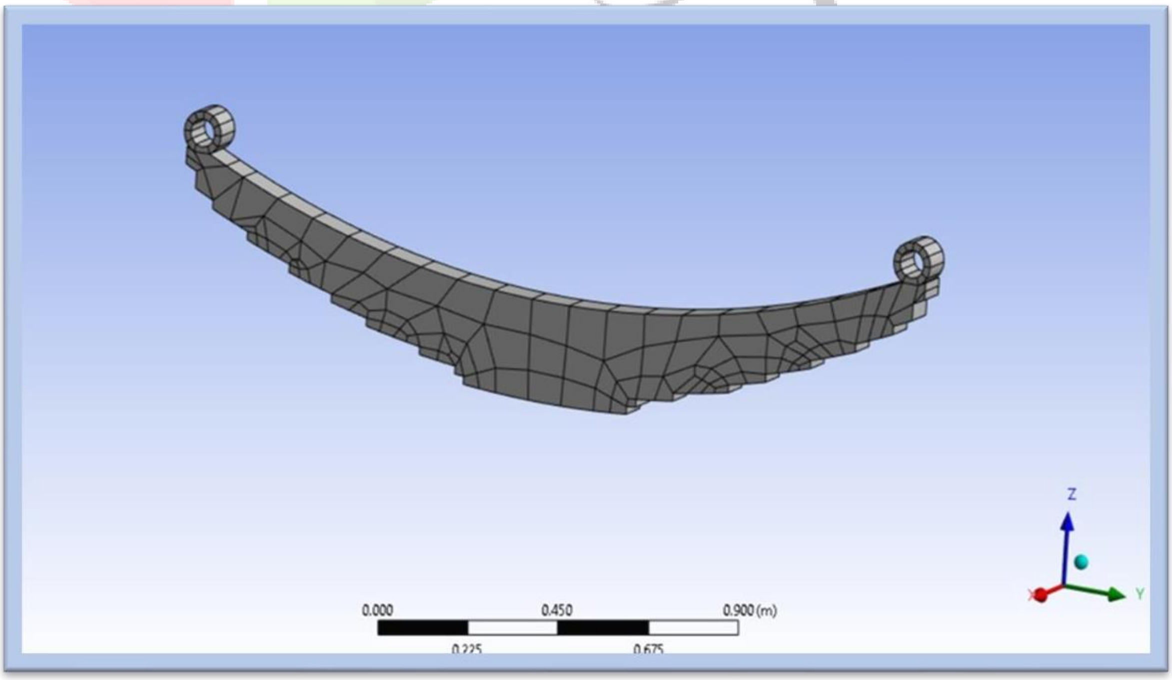

Fig.6 Meshing of leaf spring

BOUNDARY CONDITIONS AND FORCE DIRECTION IN ANSYS ANALYSIS

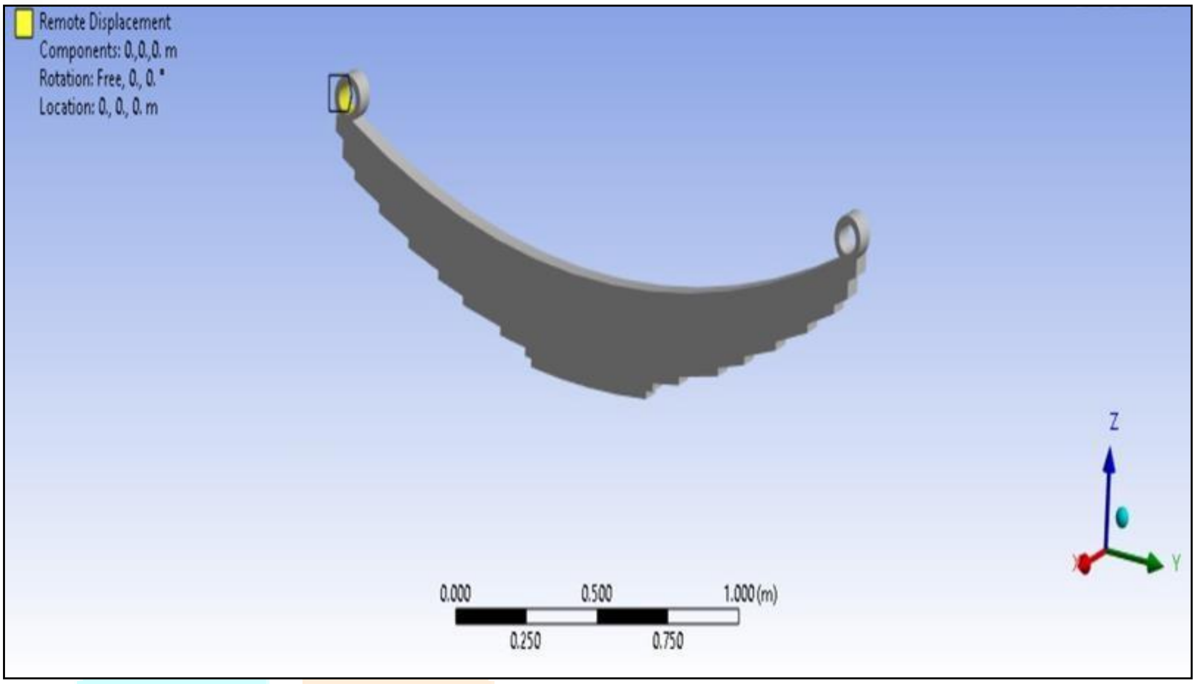

Fig.7 Remote displacement 1

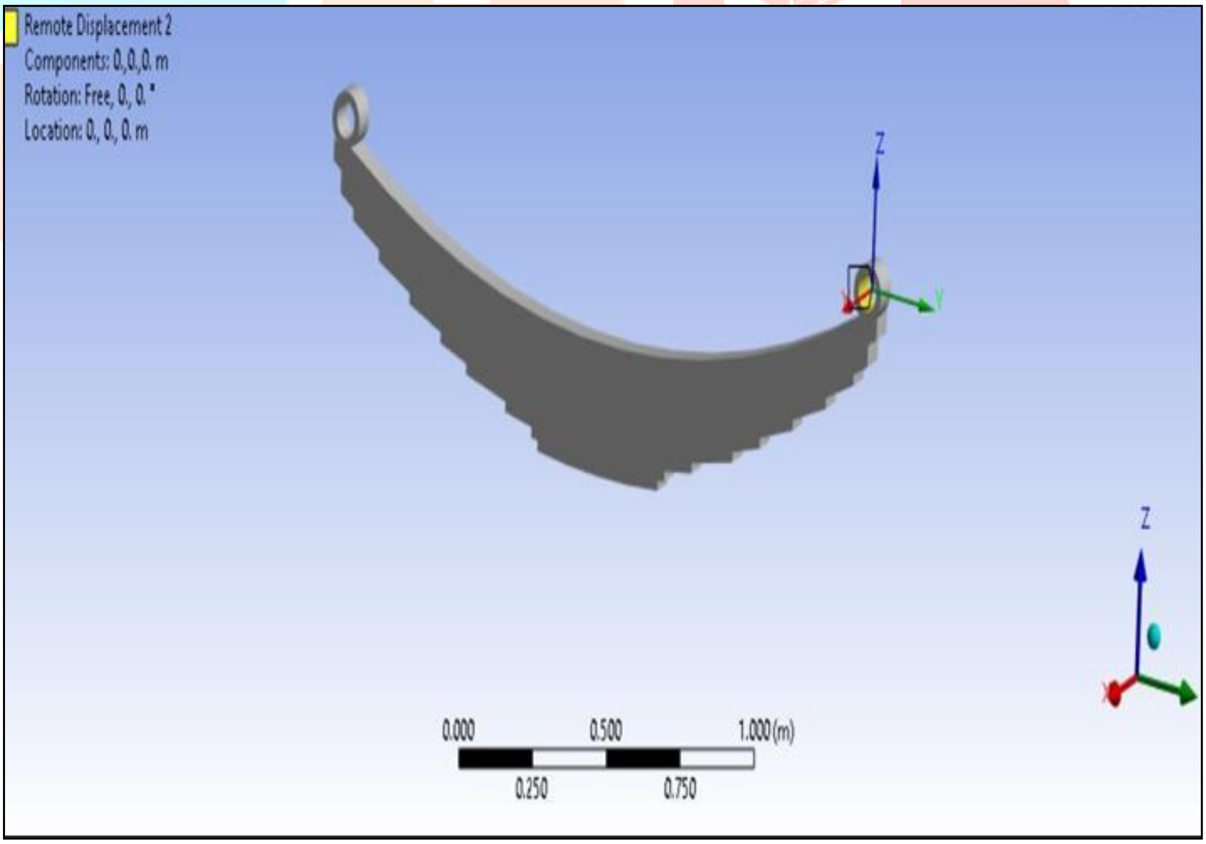

Fig.8 Remote displacement 2

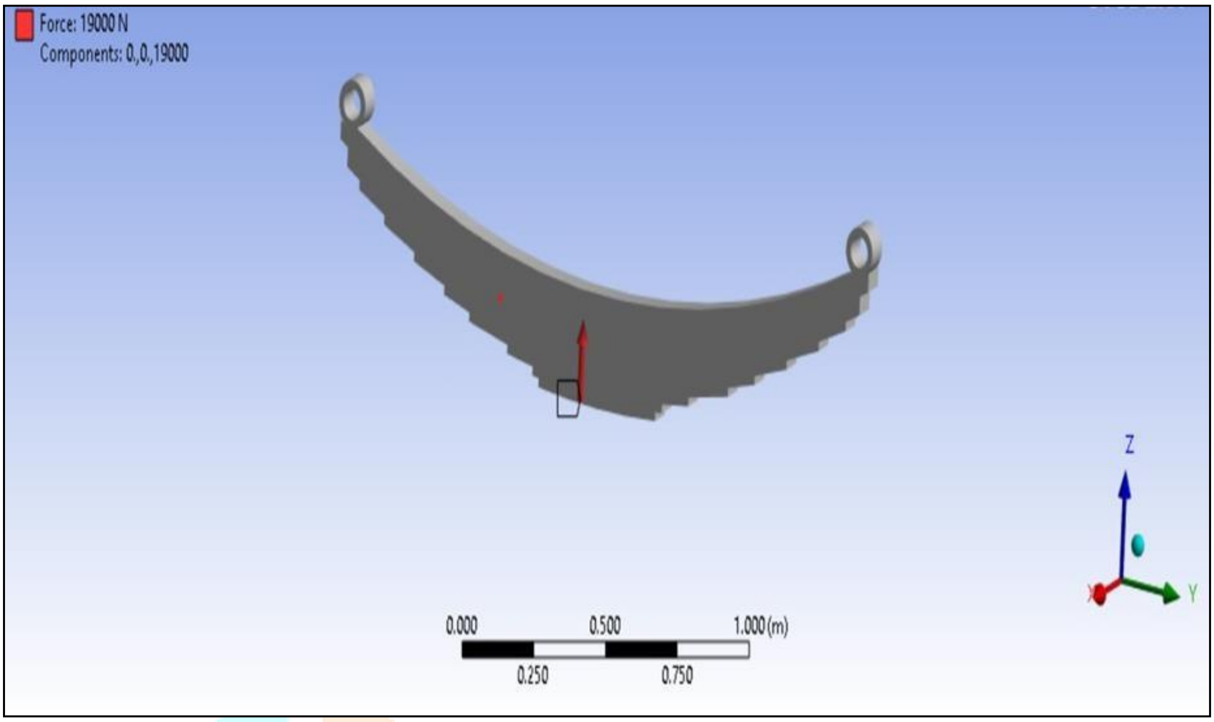

Fig.9 Force direction

ANSYS ANALYSIS RESULTS:

(EQUIVALENT STRESS)

In structural analysis, the equivalent stress is a derived quantity used to simplify the interpretation of complex stress states in a material or structure. Interpretation of complex stress states, assess the safety and durability of structures, and guide design decisions to ensure structural integrity and performance. This analysis is done for all the materials which we selected.

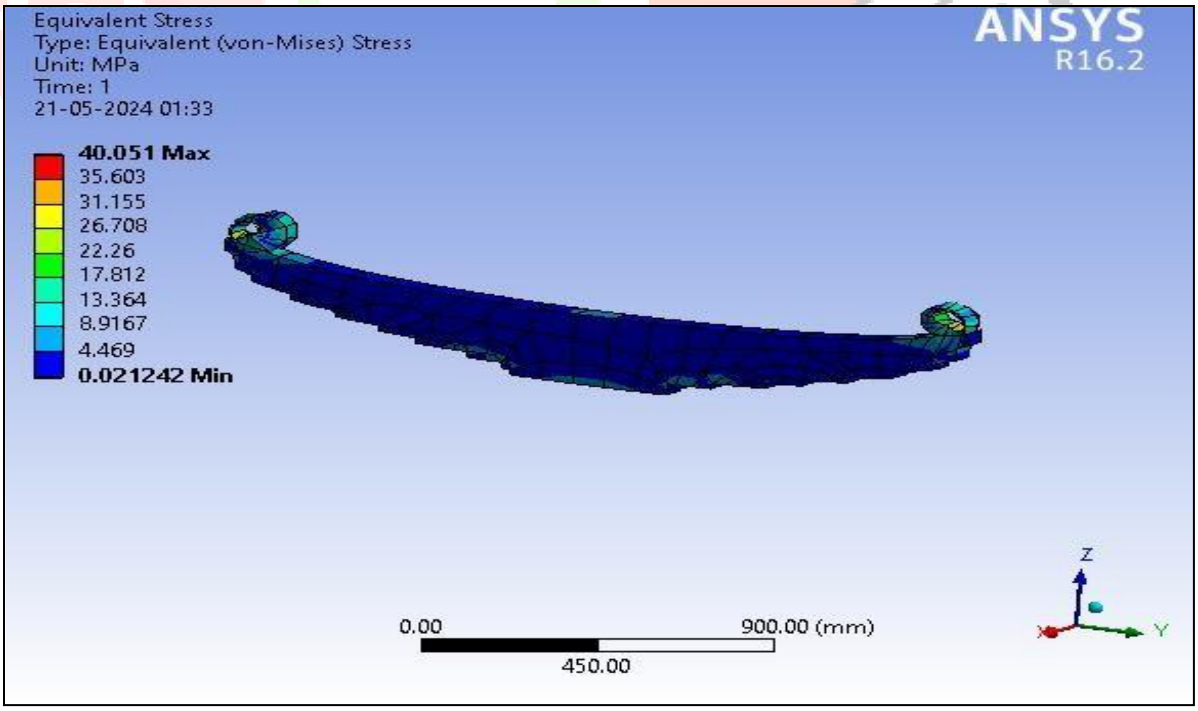

Fig.10 Equivalent Stress (steel)

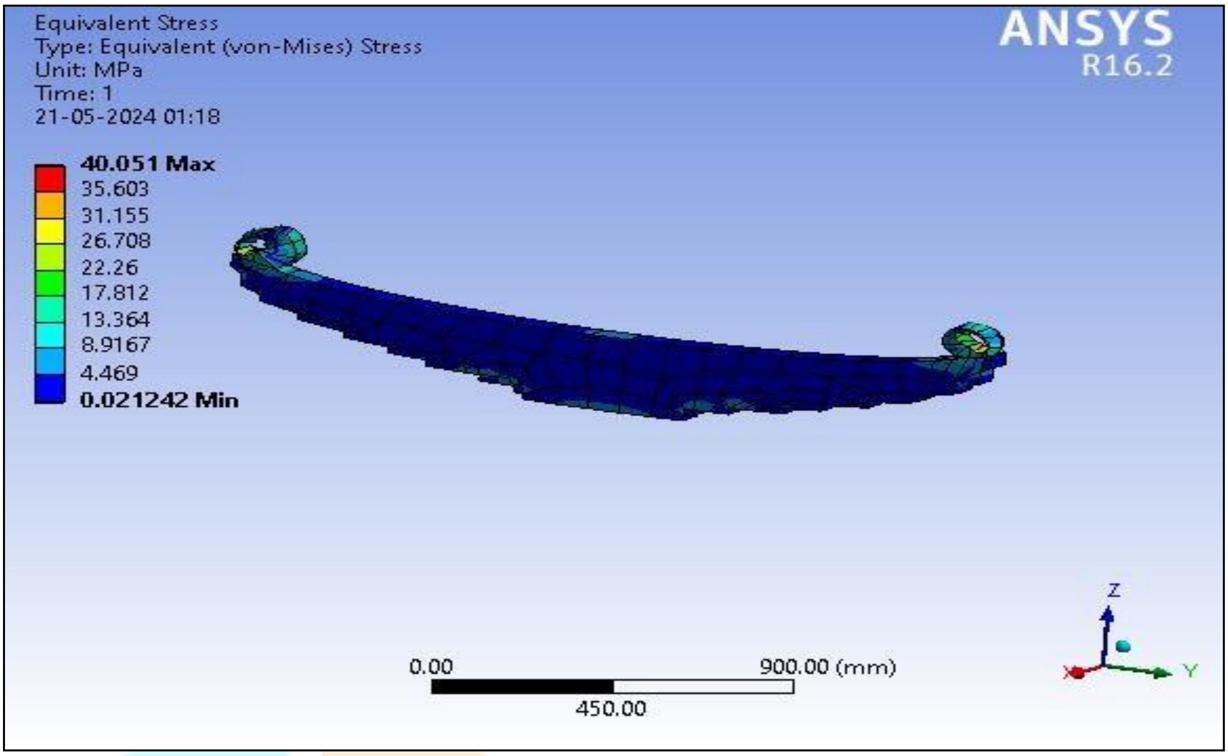

Fig.11 Equivalent Stress (E Glass/ Epoxy)

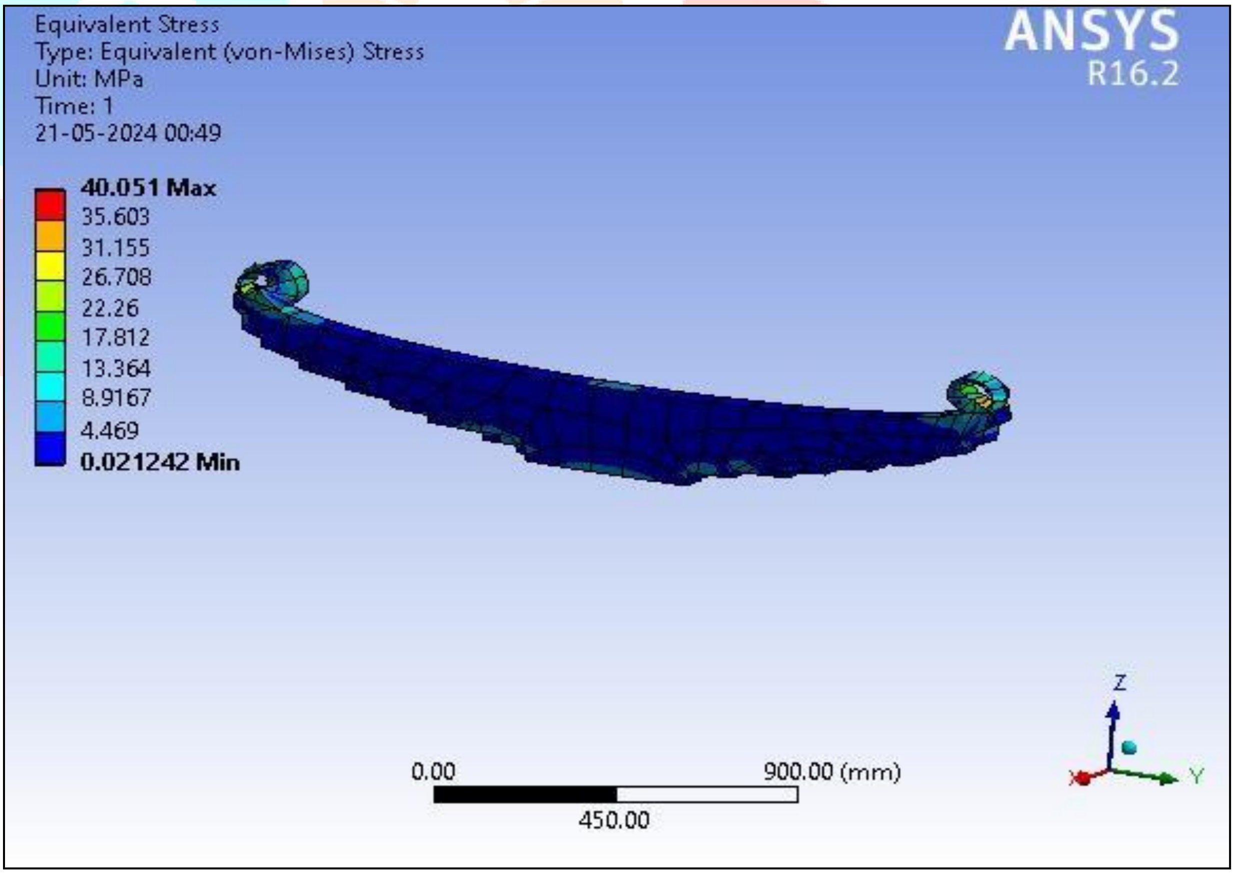

Fig.12 Equivalent Stress(Carbon Epoxy)

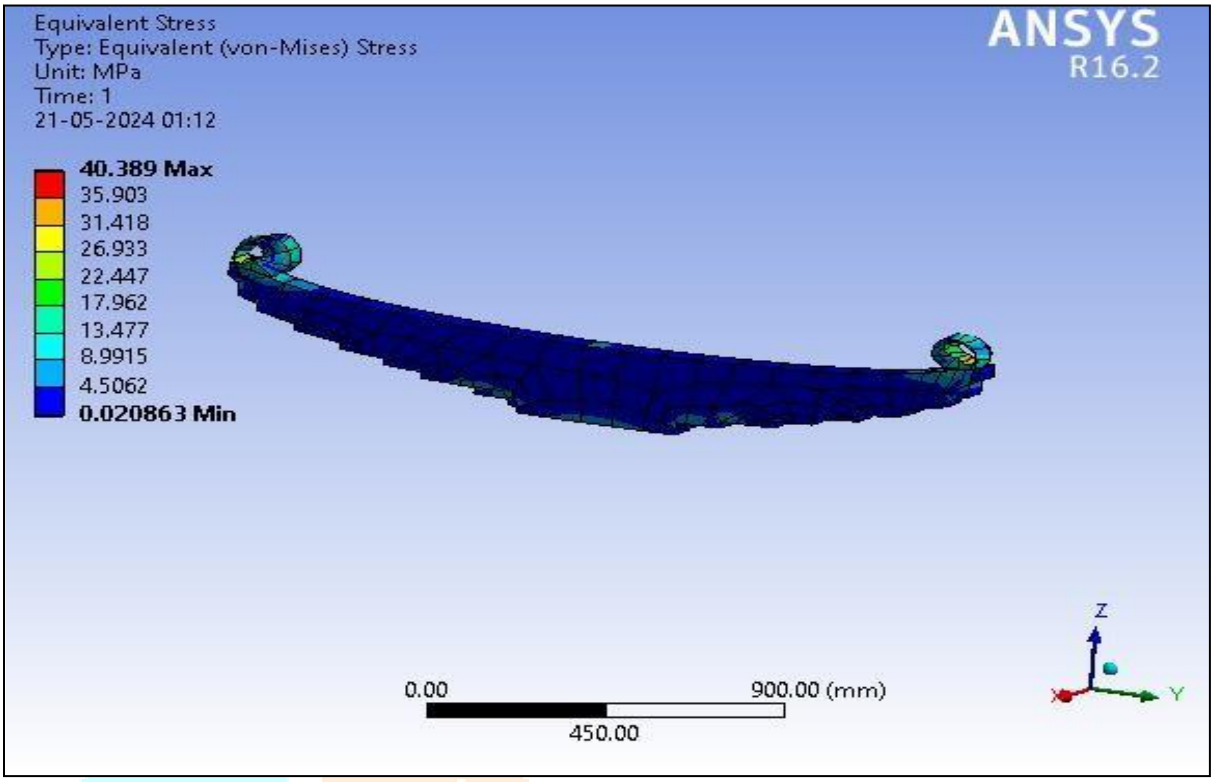

Fig.13 Equivalent Stress(Graphite Epoxy)

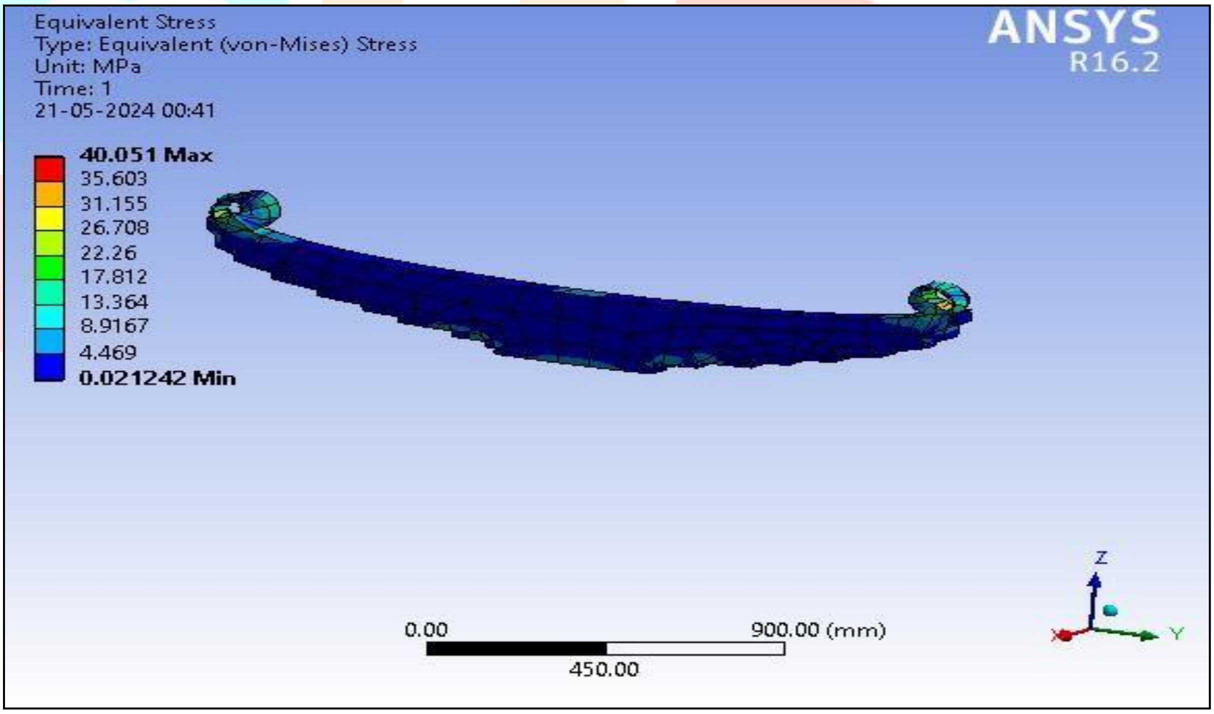

Fig.14 Equivalent Stress(Bamboo Polyester)

(EQUIVALENTELASTIC STRAIN)

Equivalent elastic strain in ANSYS analysis results provides valuable insights into the deformation behaviour of structures, helps assess safety margins, guides design optimization efforts, and supports fatigue life predictions, ultimately contributing to the development of robust and reliable engineering solutions. This analysis is done for all the materials which we selected.

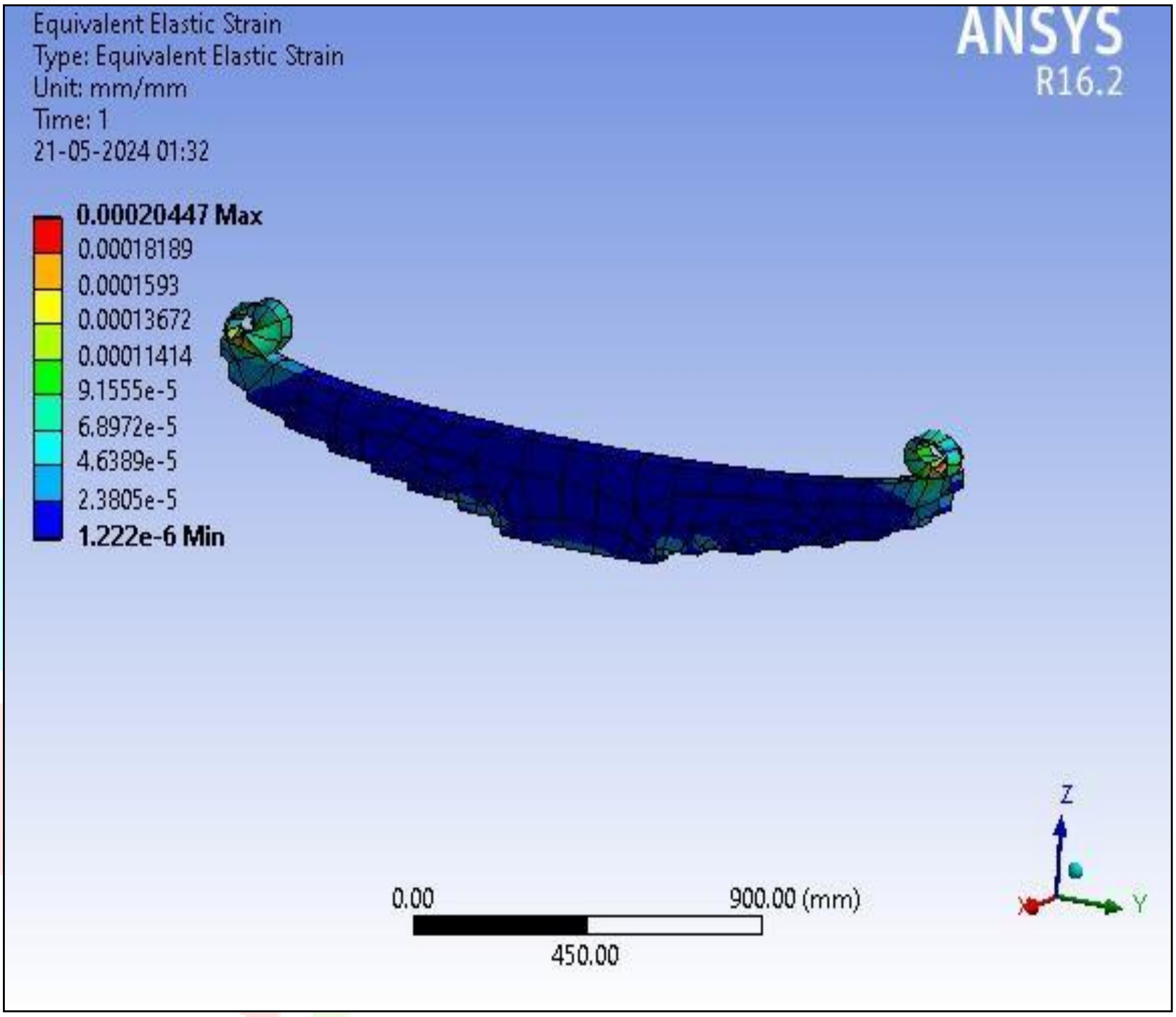

Fig.15 Equivalent elastic strain (Steel)

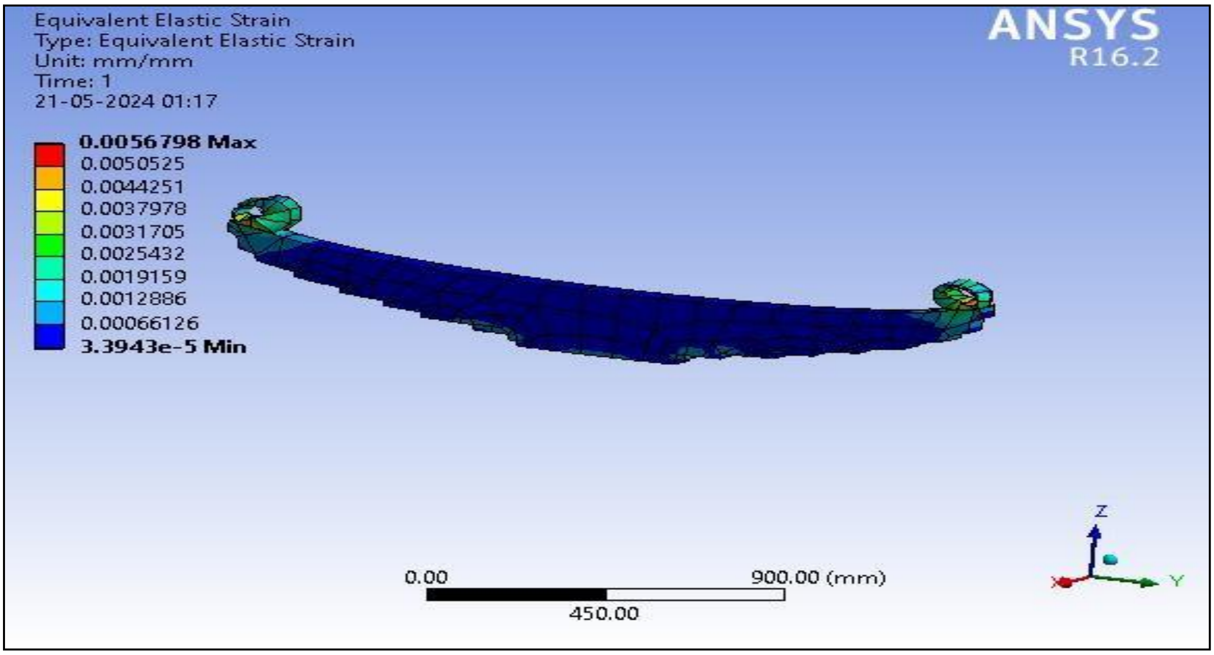

Fig.16 Equivalent elastic strain (E-Glass / Epoxy)

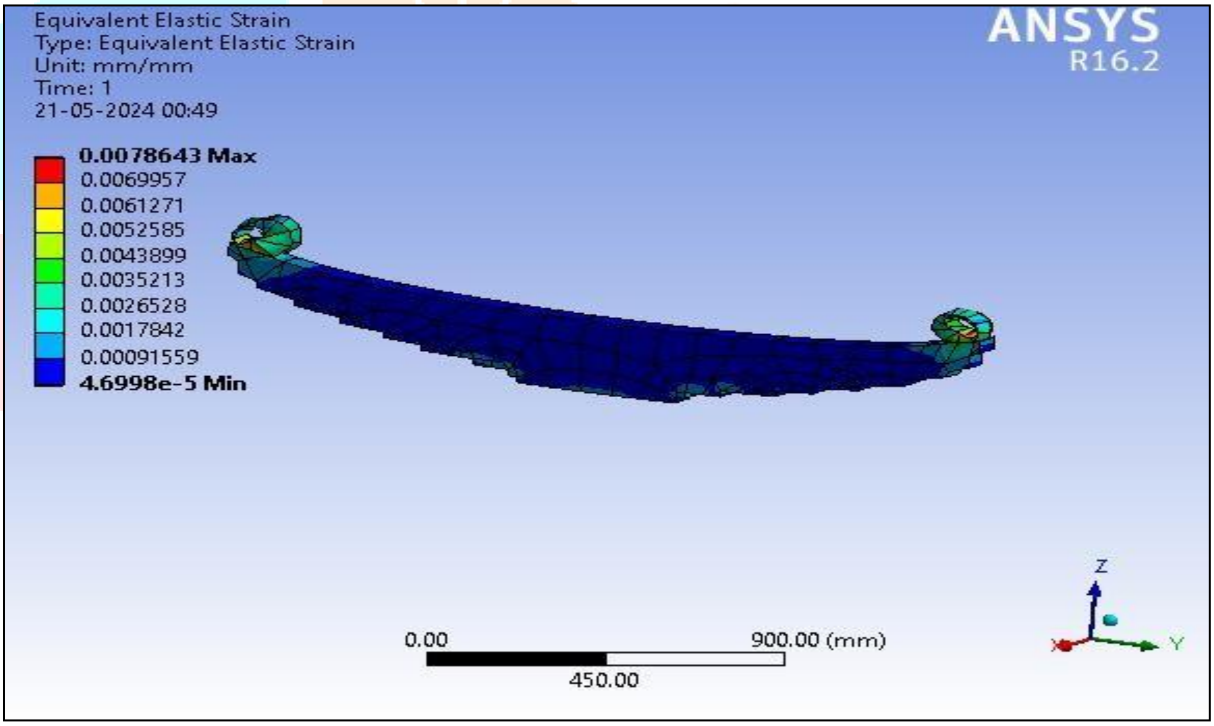

Fig.17 Equivalent elastic strain (Carbon Epoxy)

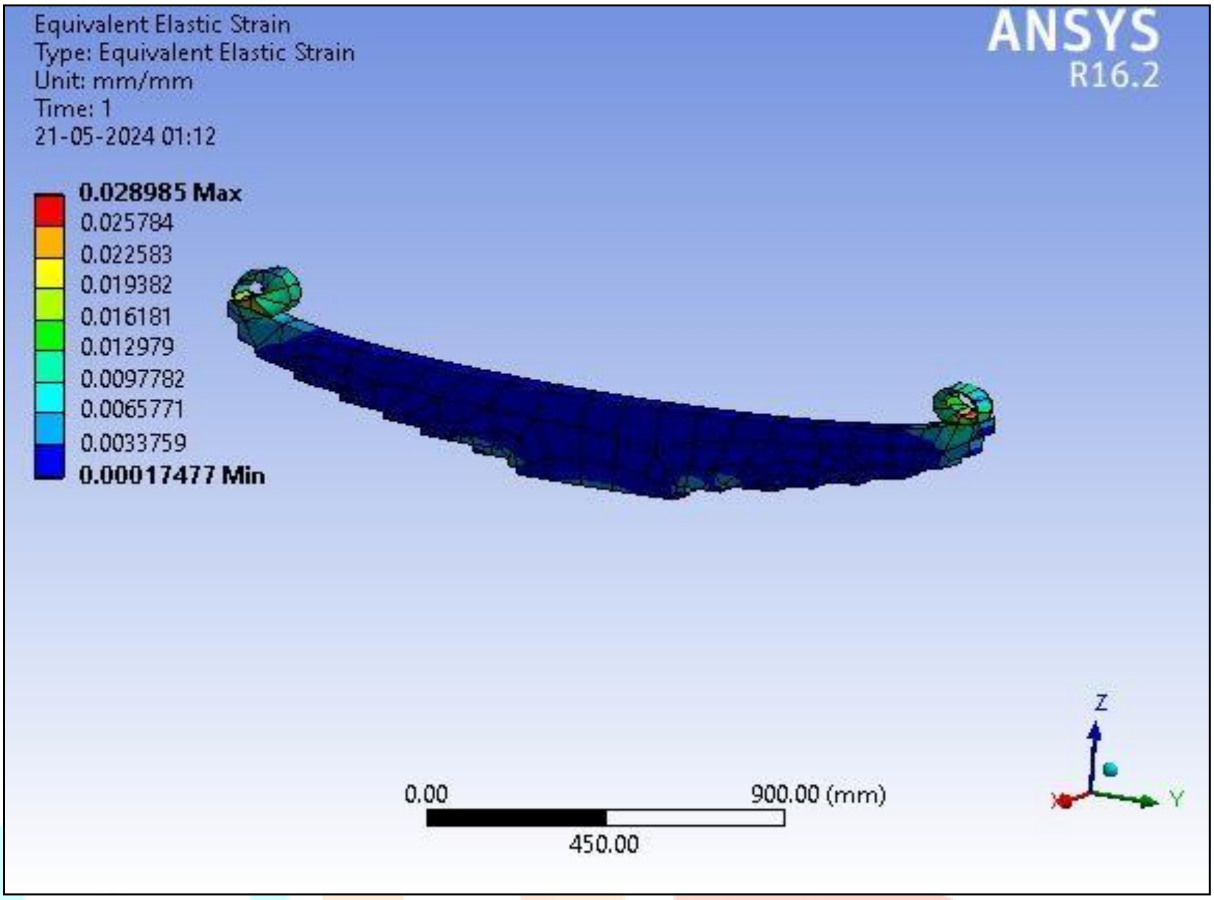

Fig.18 Equivalent elastic strain (Graphite Epoxy)

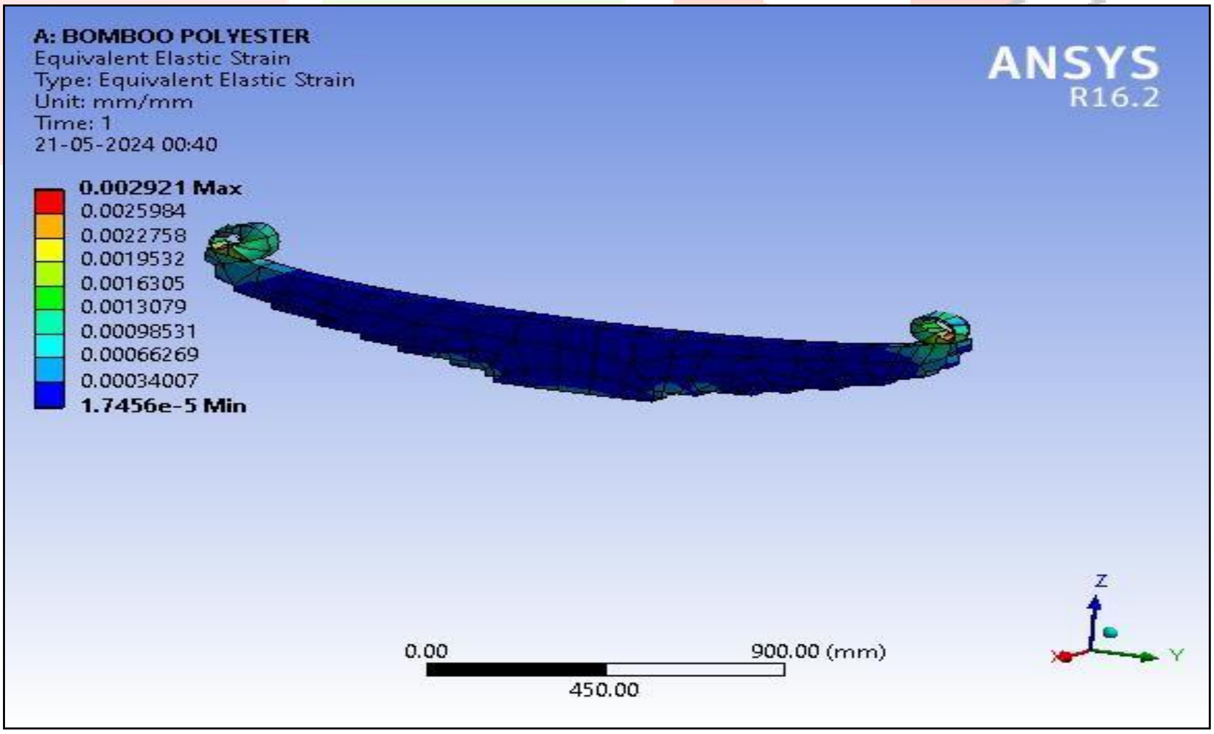

Fig.19 Equivalent elastic strain (Bamboo Polyester)

(TOTAL DEFORMATION)

Total deformation is a post-processing tool used to visualize the cumulative deformation experienced by a structure under load. It shows the overall displacement of each point in the structure from its original position. Optimize the behavior of structures under different loading conditions. This analysis is done for all the materials which we selected.

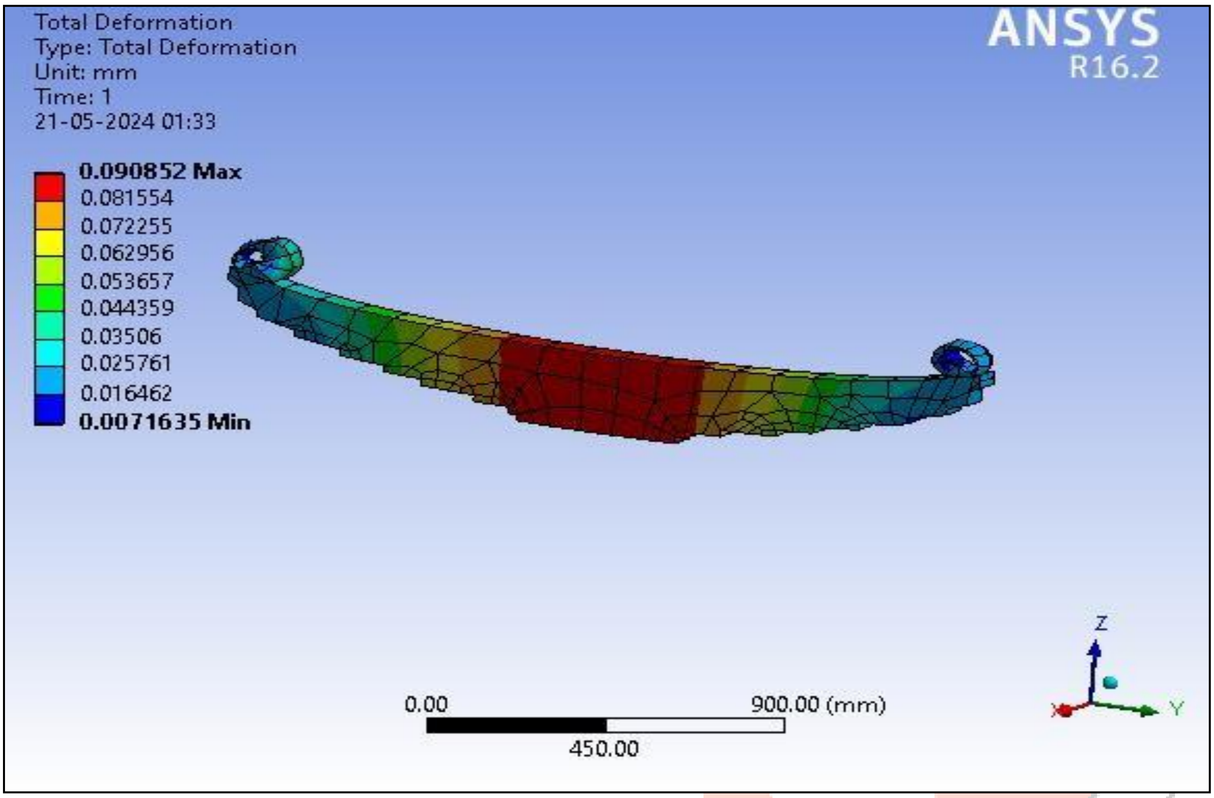

Fig.20 Total deformation (Steel)

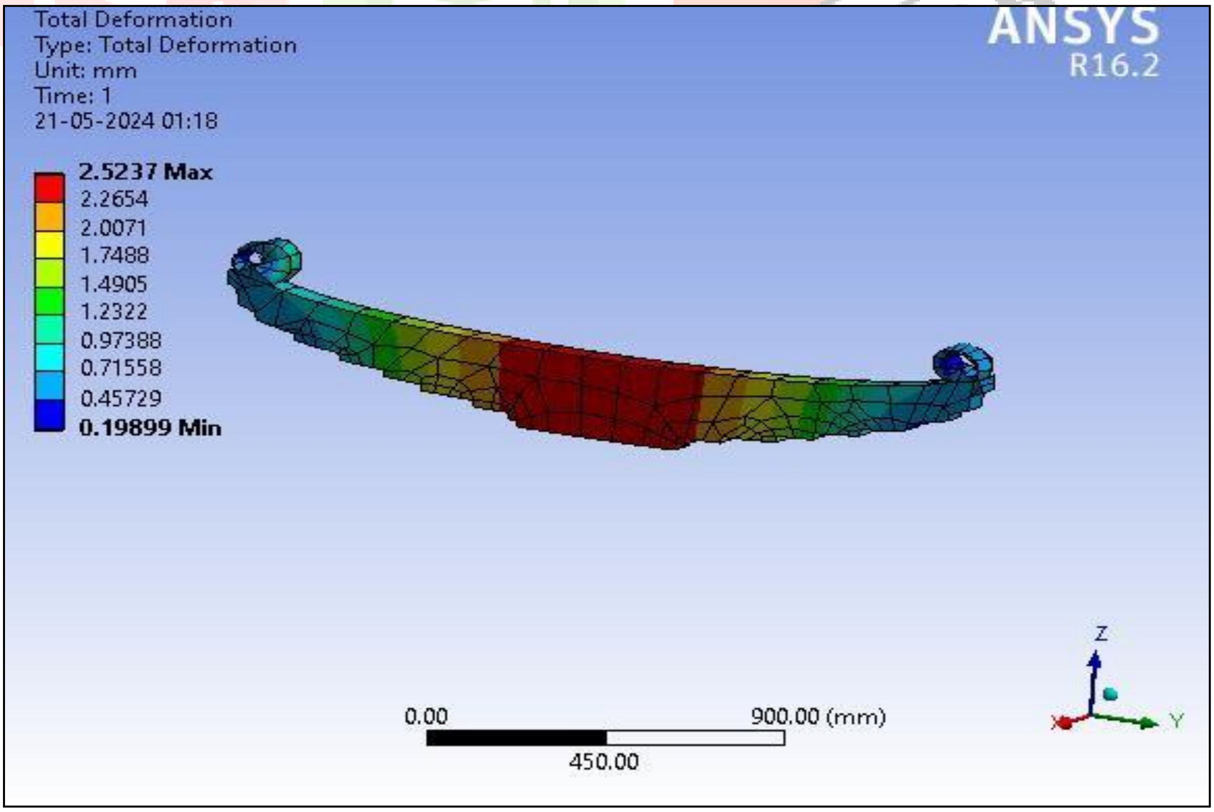

Fig.21 Total deformation (EGlass / Epoxy)

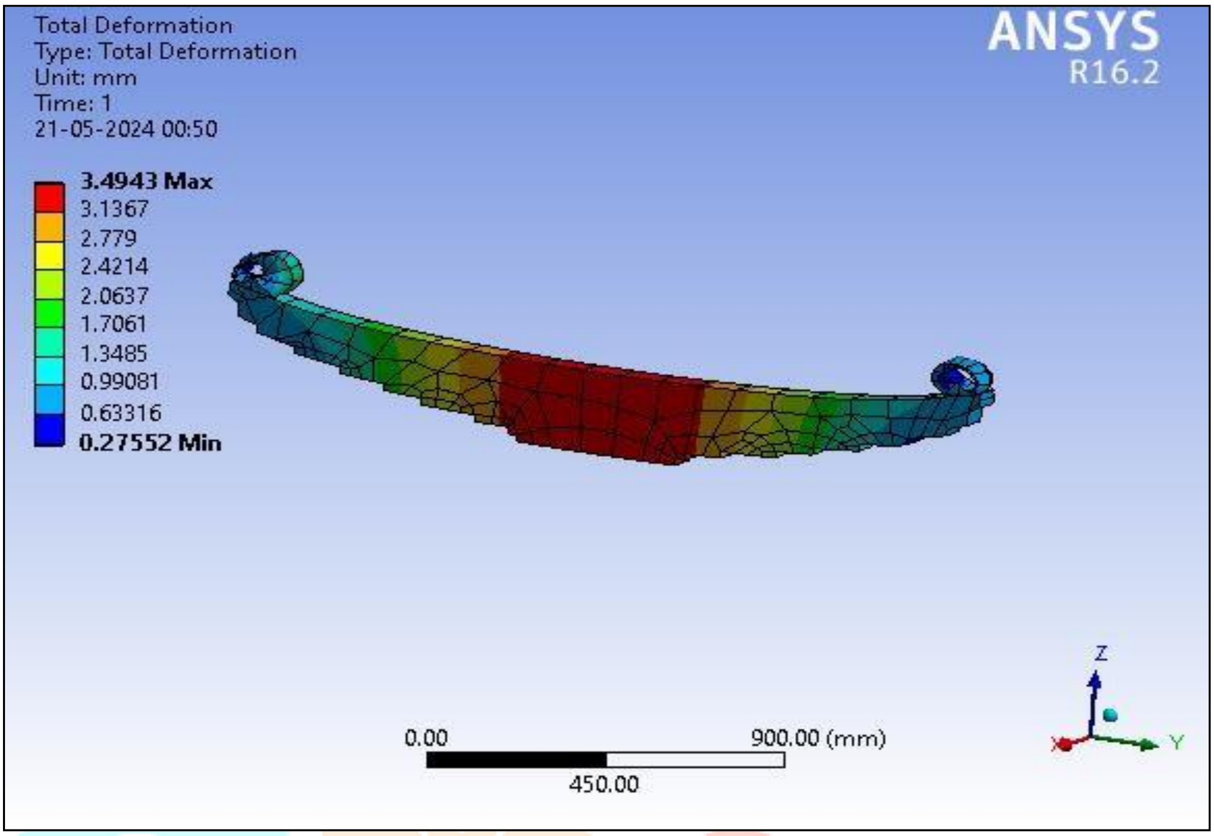

Fig.22 Total deformation(Carbon Epoxy)

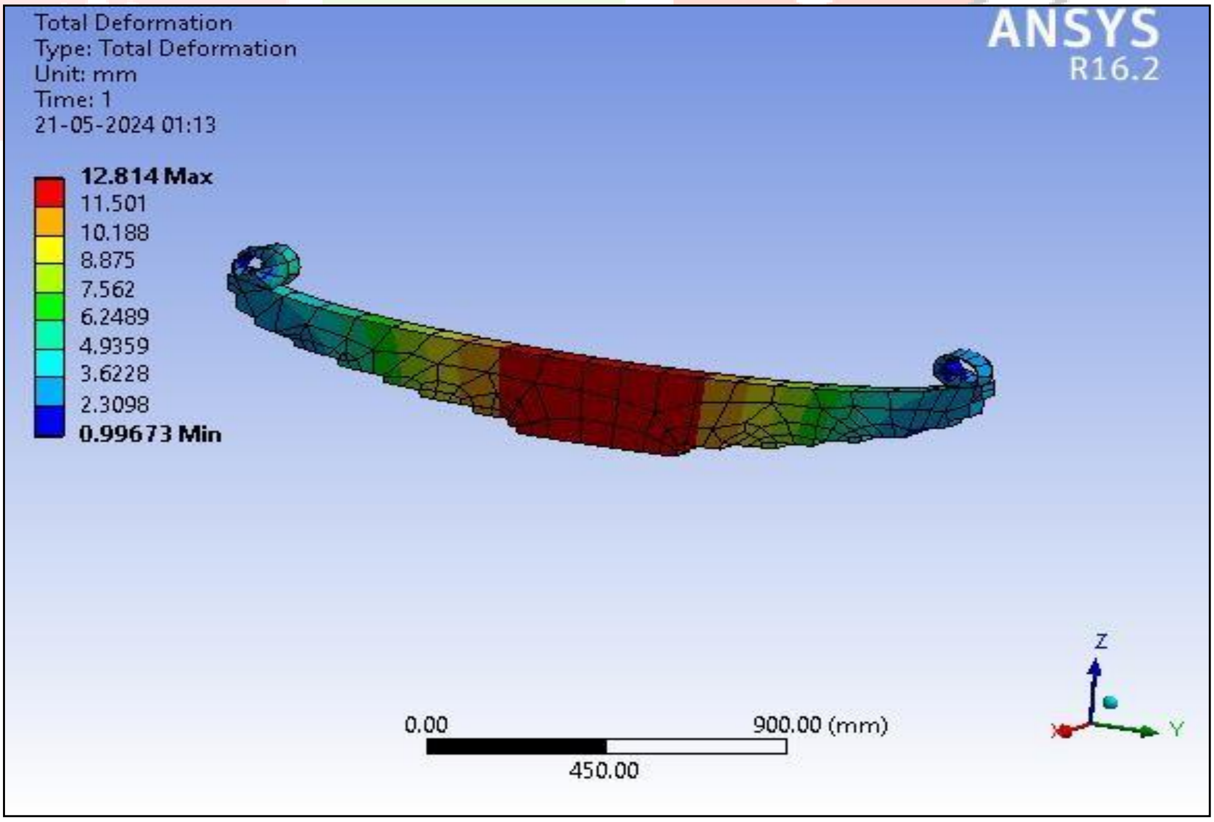

Fig.23 Total deformation (Graphite Epoxy)

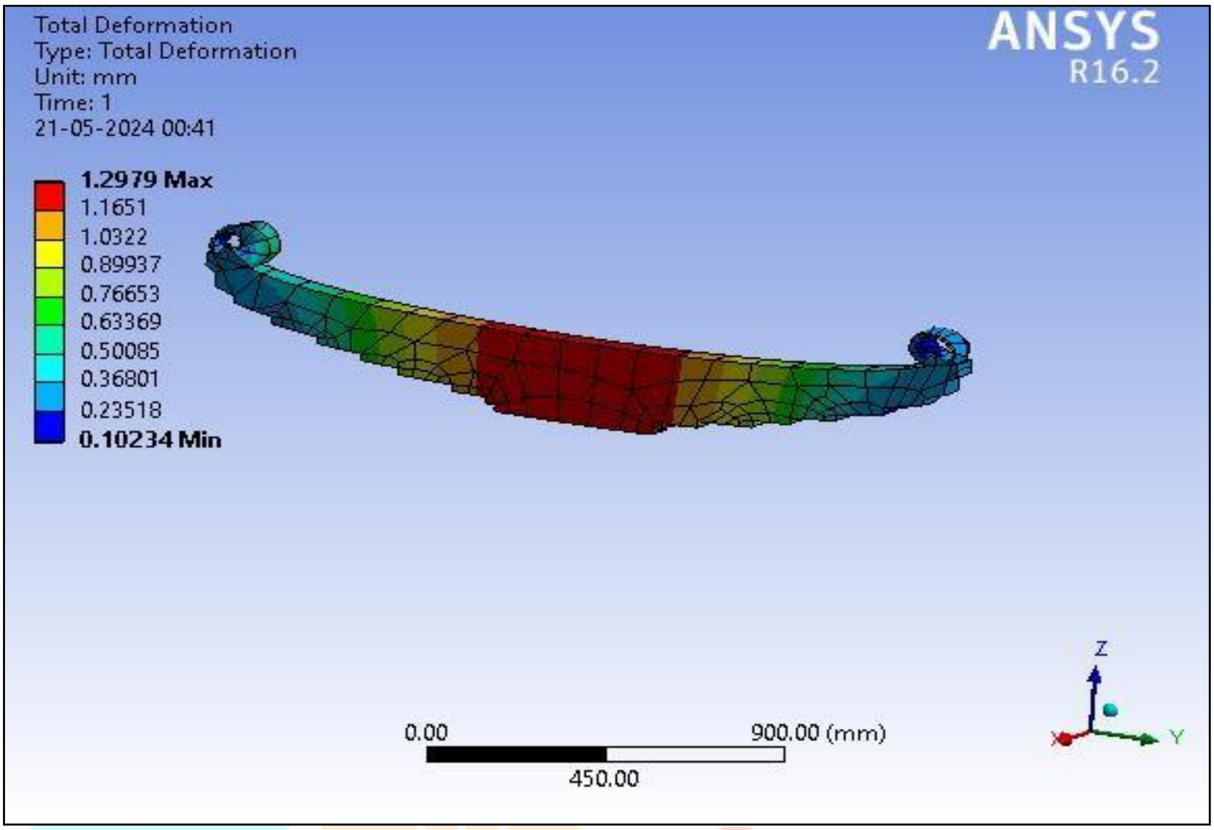

Fig.24 Total deformation (Bamboo Polyester)

V. COMPARISON OF COMPOSITE MATERIAL LEAF SPRING AND CONVENTIONAL STEEL LEAF SPRING:

No	Material Name	Stress (MPa)	Strain	Displacement(mm)	Mass(Kg)
1	Steel	40.051	0.0002	0.0908	223.43
2	E-Glass/Epoxy	40.051	0.0056	2.5237	72.294
3	Carbon Epoxy	40.051	0.0078	3.4943	64.04

4	Graphite Epoxy	40.389	0.0289	12.814	56.697
5	Bamboo Polyester	40.051	0.0029	1.2979	22.77

Table 1. Materials Comparison

VI. FATIGUE ANALYSIS:

Leaf spring is one component in vehicles that used to reduce the vibrations caused by force due to the presence of load. Some cases that occur in vehicles are related to load. This condition can affect fatigue life of steel leaf springs. One method that used to determine the fatigue life is a high fatigue cycle which can be simulated using the finite element method.

RESULTS:

Fatigue Life:

The fatigue life of a leaf spring refers to the number of cycles or the duration it can endure repetitive loading and unloading before failing.

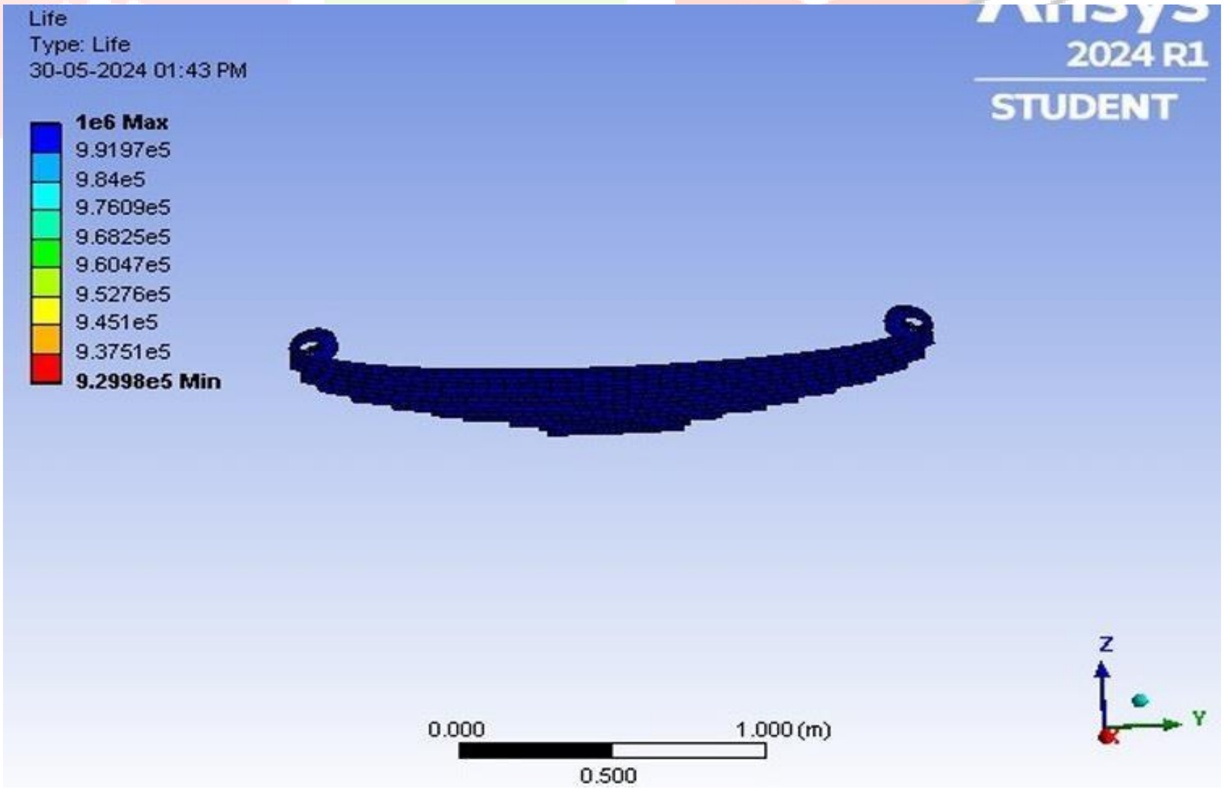

Fig.25 Fatigue Life of Leaf spring

FATIGUE SENSITIVITY:

Fatigue sensitivity represents the variation of fatigue results as a function of loading at critical locations in the leaf spring.

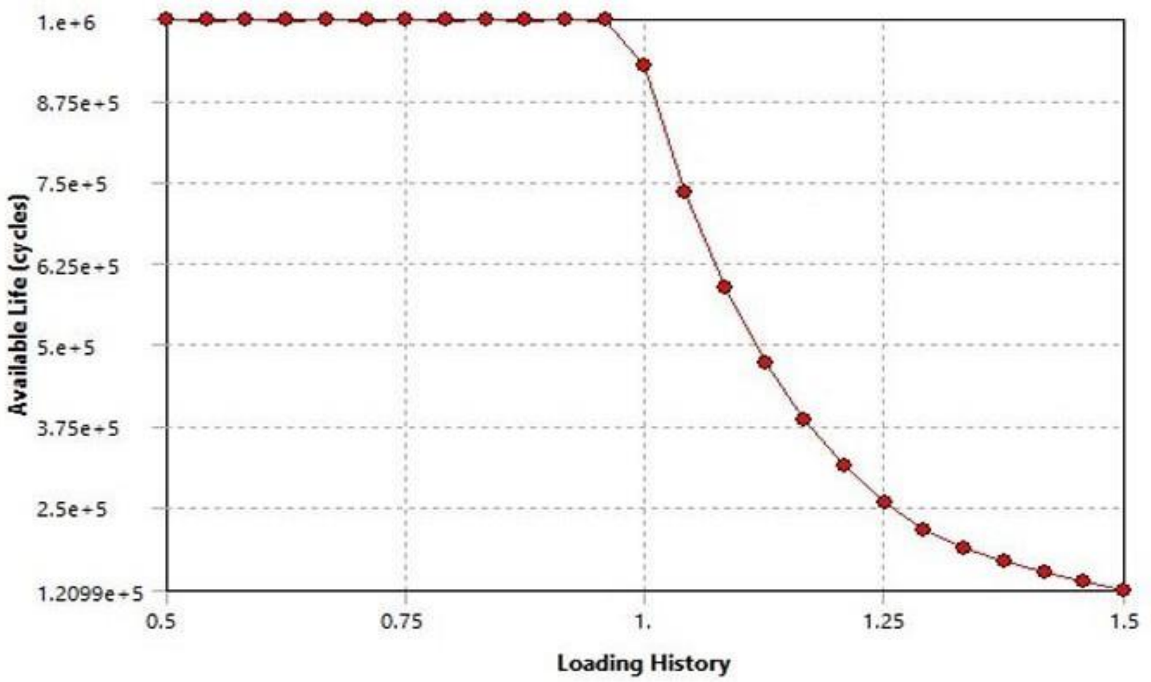

Fig.26 Fatigue Sensitivity of steel

VII. COST ANALYSIS:

No	Material Name	Cost(per kg)
1	Steel	Rs. 60 to 80
2	E-Glass/ Epoxy	Rs. 300 to 800
3	Carbon Epoxy	Rs. 2000 to 5000
4	Graphite Epoxy	Rs. 2000 to 10000
5	Bamboo Polyester	Rs. 200 to 600

Table2. Cost Analysis

VIII. RESULT AND DISSUSION:

- All the composite materials performed better than the conventional steel leaf in terms of weight and strength.
- Graphite epoxy shows the maximum displacement i.e.,12.814 mm.
- Bamboo polyester having the lowest mass value(22.77 kg).
- Bamboo polyester is also cost effective among all composite materials.

IX. CONCLUSION:

In our pursuit to enhance the vehicle's suspension system, we embarked on a systematic journey focused on four key objectives : analysing the existing system, improving reliability, designing an optimum solution, and validating its performance. Through meticulous analysis, we unearthed valuable insights into the strengths and weaknesses of the current setup. By implementing targeted enhancements and rigorous testing protocols, we fortified the system's reliability, ensuring consistent performance under diverse conditions. Leveraging advanced design methodologies, we design an optimized suspension system that strikes a harmonious balance between ride comfort, handling, durability, and cost-effectiveness. Through exhaustive validation analysis, we unequivocally demonstrated the superiority of the redesigned system, surpassing performance targets and delivering unparalleled ride quality, stability, and longevity compared to its predecessor.

X. FUTURE SCOPE:

Thermal Analysis:-

Thermal analysis of a suspension system involves studying how heat affects the components and performance of the suspension. This analysis is crucial because various factors, such as friction, braking, and road conditions, can generate heat within the suspension system, potentially impacting its reliability and performance.

- **Identifying Heat Sources**: The first step is to identify the sources of heat within the suspension system. These may include friction between moving parts, heat generated during braking, or heat transfer from the engine or exhaust system.
- **Modelling Heat Generation:** Engineers use mathematical models and simulations to predict how much heat each source will generate under different operating conditions. This helps in understanding the magnitude of thermal effects on the components.
- **Heat Transfer Analysis**: Once the heat sources are identified and modeled, the next step is to analyse how heat transfers within the suspension system. This involves studying factors such as conduction, convection, and radiation to determine how heat moves through various components.
- **Temperature Distribution:** Thermal analysis also helps in predicting the temperature distribution within the suspension system. This includes identifying areas of high

temperature, which may indicate potential overheating issues, and areas of low temperature, which may affect lubrication or material properties.

- **Material Selection and Design Optimization:** Based on the thermal analysis results, engineers can select appropriate materials and optimize the design of suspension components to withstand the expected temperature variations. This may involve incorporating heat-resistant materials, improving thermal insulation, or redesigning components to enhance heat dissipation.
- **Performance Evaluation:** Finally, engineers validate the thermal performance of the suspension system through testing and analysis under real-world conditions. This ensures that the system operates within safe temperature limits and maintains its performance and reliability over time.

Modal Analysis:-

Modal analysis of a suspension system involves studying its natural frequencies and mode shapes. Essentially, it's about understanding how the suspension system vibrates and moves in response to different forces or inputs.

- **Model Creation:** Engineers first create a mathematical or computer-based model of the suspension system. This model includes all the components of the suspension, such as springs, dampers, control arms, and other structural elements.
- **Eigen value Analysis:** Using the model, engineers perform an eigenvalue analysis to determine the natural frequencies of the system. These frequencies represent the rates at which the suspension system naturally vibrates or oscillates when subjected to external forces or disturbances.
- **Mode Shapes:** Along with natural frequencies, modal analysis also reveals mode shapes. These are the patterns of motion or deformation exhibited by the suspension system at each natural frequency. Mode shapes provide insights into how different parts of the system move relative to each other and can help identify potential issues or areas for improvement.
- **Frequency Response Analysis:** Engineers may also conduct frequency response analysis to understand how the suspension system responds to specific input frequencies. This analysis helps evaluate the system's performance under different driving conditions and road surfaces.

- **Optimization:** Based on the results of modal analysis, engineers can optimize the design of the suspension system to minimize unwanted vibrations, improve ride comfort, and enhance vehicle handling. This may involve adjusting component stiffness, damping characteristics, or overall geometry to achieve desired performance goals.

- **Validation:** Finally, engineers validate the modal analysis results through physical testing, such as laboratory experiments or on-road measurements. This ensures that the predicted natural frequencies and mode shapes accurately represent the behavior of the actual suspension system.