ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

E-Mail :
editor.ijasem@gmail.com
editor@ijasem.org

www.ijasem.org

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

Engineering Excellence: Complex Leaf Springs - Design, Modeling, and Static Investigation

Mr. J.STALIN DEVA PRINCE starlindevaprince@stellamaryscoe.edu.in
Mr. S.S.RAJKUMAR rajkumar@stellamaryscoe.edu.in
Mr.E.PRAKASH prakash@stellamaryscoe.edu.in
Dr. M.SIVA PRAKASH sivaprakash@stellamaryscoe.edu.in

Article Info

Received: 05-11-2022 **Revised: 08-12-2022** **Accepted: 14-01-2023**

Abstract

Leaf springs, a historical suspension component with roots dating back to the Middle Ages, have enjoyed widespread use. However, a contemporary shift towards composite materials as a substitute for traditional steel leaf springs is gaining momentum, particularly within commercial vehicle applications. The allure of composite materials lies in their superior strength-to-weight ratio, heightened durability, and the promise of weightreduction. This project seeks to delve into the repercussions of replacing steel leaf springs with their composite counterparts, focusing on critical aspects such as load-carrying capacity, stresses, stiffness, contact stiffness, andpotential weight savings. Design parameters take into account stress and deflection limitations. Employing SolidWorks and ANSYS software, the methodology entails modeling and analysis. A 3D model of a composite leaf spring undergoes static analysis, and these analytical findings are complemented by a comprehensive finite element analysis under full load conditions using ANSYS. Comparative assessment with experimental results validates the performance of the composite leaf spring. By judiciously selecting composite materials in adherence to predefined criteria and standards, this project aspires to establish the groundwork for the design of efficient and dependable leaf springs utilizing composite materials. The outcomes of this research will not only contribute to the ongoing evolution of composite material applications but will also foster innovation in the realm of automobile suspension systems. In essence, this project serves as a thorough exploration into the advantages and viability of incorporating composite materials in leaf springs. Armed with advanced modeling and analysis techniques, it provides valuable insights into the performance and potential of composite leaf springs, charting a course for the development of more efficient and sustainable suspension systems in the automotive industry.

1.INTRODUCTION

1.1 SPRINGS

A spring is a mechanical device made of an elastic but generally stiff substance, usually metal, bent or molded into a shape, notably a coil, that may be compressed or expanded and then returned to its original shape. By being compressed, springs may store energy. Although there are many distinct spring designs, the term is frequently used in dailyspeech to refer to coil springs. Spring steel is commonly used in the production of modern springs. The bow, which is usually fashioned of flexible yew wood and which, when drawn, stores energy to propel an arrow, is an example of a non-metallic spring. A standard spring that lacks stiffness variability features exerts an opposing force that is about proportionate to its change in length when compressed or stretched from its resting position (this approximation fails for bigger deflections).

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

A range of elastic materials, including spring steel, are used to make springs. Larger springs are constructed from annealed steel and hardened after manufacture, while smaller ones can be coiled from pre-hardened stock. Additionally, some non-ferrous metals are employed, such as low-resistance beryllium copper for springs conveying electric currentand phosphor bronze and titanium for parts needing corrosion resistance.

1.2 TYPES OF SPRINGS

1. Helical Springs: The helical springs are made up of wire coiled in the form of a helix and are primarily intended for compressive or tensile loads.
2. Conical and Volute Springs: The conical and volute springs are used in special applications where a telescoping spring or a spring with a spring rate that increases with the load is desired.
3. Leaf Springs: The leaf spring (also known as a flat spring or carriage spring) consists of several flat plates (known as leaves) of varying lengths held together by means of clamps and bolts. These are mostly used in automobiles.
4. Torsion Springs: These springs may be of the helical or spiral type. The helical type may be used only in applications where the load tends to wind up the spring and is used in various electrical mechanisms.
5. Disc or Belleville Springs: Thesesprings consist of a few conical discs held together against slipping by acentral bolt or tube.
6. Special Purpose Springs: These springs are air or liquid springs, rubber springs, ring springs, etc. The fluids (air or liquid) can behave as compression springs. These springs are used for special types of applications only.

1.3 LEAF SPRINGS

One of the earliest types of springing, originally known as a laminated or carriage spring butalso known as a semi-elliptical spring, elliptical spring, or cart spring, first appeared on carriages in France in the middle of the 17th century before spreading to England and Germany.

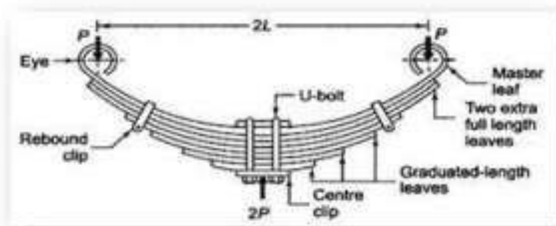
Flat plates are used to create leaf springs. The benefit of a leaf spring over a helical spring is that the spring's ends can be directed along a predetermined path while it deflects, acting as both a structural member and an energy absorber. As a result, in addition to shocks, leaf springs may also support lateral loads, brake torque, driving torque, etc.

A leaf spring is an energy-absorbing device (also known as flat springs). It is a type of suspension spring that consists of several layers or leaves of metal strips bound together, known for strength, load-carrying capacity, and durability. The leaves are stacked on top of each other and secured with clamps or fasteners. The master leaf is the thickest leaf, forms the center of spring, and provides primary support. Graduated leaves, or smaller leaves, are called secondary and helper leaves; these are placed below the master leaf, which assists in load distribution and flexibility.

The arched shape of the leaf spring allows it to flex and absorb shocks and vibrations from the road surface, providing a smoother ride. A leaf spring is a thin piece of spring steel with a rectangular cross section that is formed like an arc. In its most typical shape, the arc's center serves as the site for the axle, while the loops generated at either end serve as points of attachment to the car's chassis. Several leaves layered on top of each other in various layers, frequently with increasingly shorter leaves, can be used to create a leaf spring for very large

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT
ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

vehicles. Although the interleaf friction dampens the motion of the suspension, it is poorly managed and causes stiction. Mono-leaf springs have been adopted by several manufacturers as a result.



1.1 COMPOSITE MATERIALS

Materials that are composed of two or more distinct constituent materials with different physical or chemical properties. The two main components of a composite material are the matrix and reinforcements. Composite materials contain 80% matrix and 20% reinforcement.

Matrix: sets up the part geometrically, gives cohesion to the material, is usually flexible and not very resistant, and transmits efforts from one fiber to another. It surrounds and supports the reinforcement material, which provides composites with their mechanical properties. It holds the reinforcement material in place and transfers stress.

Reinforcement provides rigidity and resistance. It is responsible for adding strength and stiffness to composites. It provides length, shape, and orientation to the composites.

Fig. 1.11: TYPES OF MATRIX AND REINFORCEMENTS

- **Composite Leaf Springs**

Due to the significant benefits of composites, such as their high specific modulus, high specific strain energy density, low weight, unmatched corrosion resistance, better internal damping, and longer life, their demand has increased in comparison to metallic materials in the automotive industry. These qualities allow for the direct replacement of conventional components or the integration of conventional and composite components into a single component or structure when employed in automobile structures. The automotive industry is quite concerned about replacing one of the most important parts of an automobile, the leaf spring, with a composite leaf spring. Though numerous studies focusing on the use of composites for leaf springs have recently been done, Metal leaf springs have been strengthened for decades to accommodate unsprang weight. As a result, the use of composite materials in the fabrication of leaf springs allowed for the reduction of unsprang weight and the provision of a smooth ride because composite materials had higher specific strengths, longer lives, and lower weights than metallic materials.

Fig. 1.12: COMPOSITE MATERIAL LEAF SPRING

1.2 USES OF COMPOSITE LEAF SPRINGS

- Composite leaf springs are used in the automotive, railway, aerospace, and renewable energy industries.
- They offer weight reduction, improved performance, and enhanced durability.
- Composite leaf springs contribute to fuel efficiency, reduced emissions, and increased payload capacity.
- They provide design flexibility and customization options.
- The use of composite materials aligns with sustainability goals.
- Ongoing research and development will further enhance their performance and reliability.

CHAPTER2
LITERATURESURVEY

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

JOURNAL NAME	AUTHOR NAME	YEAR	FINDINGS
DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING	• Prasanna Nagarai • Srikanth • Tarun	SEPTEMBER 2020	Depicts about the design constraints focused on stress and deflection.
DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING	• Y. N. V. Santhosh Kumar • M. Vimal Teja	JANUARY 2018	Discusses the replacement of steel leaf springs with fiberglass composite leaf springs in the automotive industry.
DESIGN AND ANALYSIS OF LEAF SPRING USINGCOMPOSITE MATERIALS	• Ganesh R. Chavhan • Pawan V. Chilbule	MAY 2018	Highlights the importance of weight reduction in automobiles for fuel efficiency and emission regulations, focusing on the potential of composite materials.
MODELING AND FINITE ELEMENT ANALYSIS OF LEAF SPRING	• Sarika S. Tade • M. J. Shaikh	NOVEMBER 2018	The study includes modification considerations for weight reduction and cost savings.
DESIGN, ANALYSIS AND COMPARISON BETWEEN THE CONVENTIONAL MATERIALS WITH COMPOSITE MATERIAL OF THE LEAF SPRINGS	• Durari Ashok Kumar • Abdul Kalam	JULY 2016	Highlights the analysis and comparison of a composite leaf spring made of E-Glass Epoxy with a steel leaf spring.
SIMULATION AND ANALYSIS OF HEAVY VEHICLES COMPOSITE LEAF SPRING	• J.Hameed Hussain • C.M. Meenakshi	JANUARY 2017	It discusses the modeling and analysis using different materials using CATIA and ANSYS software.

CHAPTER-3
OBJECTIVES AND METHODOLOGY

3.1 PROBLEM STATEMENT

- Weight Reduction: The weight of leaf springs can be effectively reduced while maintaining their load-carrying capacity and stiffness.
- Material Selection: Which composite materials are suitable for leaf spring applications, considering factors such as strength, stiffness, fatigue resistance,and cost?
- Design Optimization: Considerations of design parameters and geometric configurations that maximize the performance of composite leaf springs.

3.2 OBJECTIVES

- To design a comprehensive composite leaf spring considering load requirements, size constraints, and manufacturing feasibility.
- To create an accurate 3D model with precise dimensions and material properties.
- perform static analysis to assess load-carrying capacity and structural integrity under different conditions.
- To ensure stress distribution and deflection meet design criteria and performance requirements.
- To compare static analysis results with traditional steel leaf springs to determine the advantages of composites.
- To optimize design parameters (fiber orientation, layer thickness, stacking sequence) for improved performanceand weight reduction.

3.3 METHODOLOGY

- A flow chart is drawn in the figure, which explains the layout of the project work.
- The main aim of this project is to reduce the weight of the leaf spring using composite materials without decreasing the quality of the vehicle or its reliability.
- A composite leaf spring is designed considering the load requirements, size constraints, and manufacturing feasibility.

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT
ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

- Later, a 3D model is created withprecise dimensions and material properties.
- Composite materials are selected, and then analysis is done.
- Later, static analysis is done on the 3D model created to assess load-carrying capacity and structural integrity under different conditions.
- Finally, the results obtained using different composite materials are compared and then discussed to choose the most suitable material among them.

3.3.1 PROJECT FLOW CHART

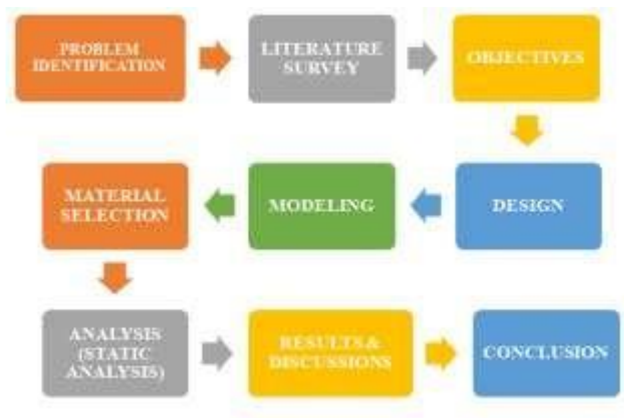


Fig. 3.1: SEQUENCE OF THE WORK

CHAPTER-4
DESIGNING OF CAD MODEL

4.1 DESIGNING OF LEAF SPRING

❖ TATA 407 Light Gold Truck

- Gross Vehicle Weight (GVW) = 4450 kg
- Kerb weight of the vehicle = 2200 kg

➢ Properties of Leaf Spring used: -

PROPERTIES	VALUES
Overall Length of Span/Spring ($2L1$)	1220mm
Camber	80mm
Width of the Plate (b)	70mm
Thickness of the Plate (t)	12mm
Width of Band (l)	105mm
Inside diameter of the Eye (d)	40mm
Number of full-length Leaves (nf)	2
Number of gradual length Leaves (ng)	8

TABLE 4.1: PROPERTIES OF LEAF SPRING OF TATA 407 LIGHT GOLD TRUCK

Minimum Load:
Both Rear Leaf Springs combined = 0.6 x 2200 = 1320 kg
For single Rear Leaf Spring = 1320 / 2 = 660 kg = 6475 N

Maximum Load:
Both Rear Leaf Springs combined = 0.6 x 4450 = 2670 kg
For single Rear Leaf Spring = 2670/2 = 1335kg = 13100 N

4.1.1 THEORETICAL CALCULATIONS

➢ $IneffectiveLength = \frac{2 \times l}{3} = 70\ mm$

➢ $EffectiveLength\ (2L) = 2L1 - \frac{2 \times l}{3} = 1150\ mm$

➢ $Length\ of\ MasterLeaf = 1220\ mm$

➢ $Length\ of\ 9th\ Leaf = \frac{\quad}{n-1}\ x$ (N−1) + $IneffectiveLength$

$= 1220\ mm$

- *[Here N = total number of leaves (i.e., 10)*
- *n = number of the leaf]*

➢ $Length\ of\ 8th\ Leaf = 1092.2\ mm$

➢ $Length\ of\ 7th\ Leaf = 964.4\ mm$

➢ $Length\ of\ 6th\ Leaf = 836.6\ mm$

➢ $Length\ of\ 5th\ Leaf = 708.8\ mm$

➢ $Length\ of\ 4th\ Leaf = 581.1\ mm$

➢ $Length\ of\ 3rd\ Leaf = 453.3\ mm$

➢ $Length\ of\ 2nd\ Leaf = 325.5\ mm$

➢ $Length\ of\ SmallestLeaf = 197.7\ mm$

CHAPTER-5

MATERIAL SELECTION

5.1 SELECTION OF MATERIALS FOR LEAF SPRING

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

Composite materials offer a promising solution by combining weight reduction with improved mechanical properties. Leaf springs offer weight reduction potential without sacrificing performance in vehicle suspension systems. Composite materials possess a high strength-to-weight ratio and effective energy storage properties.

5.1.1 ARAMID FIBER REINFORCED POLYMER

Aramid fiber was the first organic fiber used as reinforcement in advanced composites with a high enough tensile modulus and strength. On an equal-weight basis, they have much better mechanical properties than steel and glass fibers. Aramid fibers are inherently heat- and flame-resistant, which maintain these properties at high temperatures.

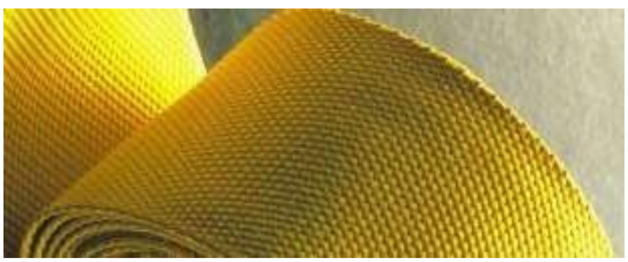


Fig.5.1: ARAMID FIBER REINFORCED POLYMER

5.1.2 BASSALT FIBER REINFORCED POLYMER

Basalt-reinforced composites are recently developed materials. These mineral amorphous fibers are a valid alternative to carbon fibers for their lower cost and to glass fibers for their strength. The first trials to produce basalt fibers (BF) date back to 1923 in the US (Paul Dhé patent, as cited in [2]); after World War II, research was developed in the US, Europe, and the Soviet Union to get the fibers extruded and study their first applications in military and aerospace fields.

Fig. 5.1.2: BASALT FIBER REINFORCED POLYMER

5.1.3 CARBON FIBER REINFORCED POLYMER

Carbon fiber-reinforced plastics, also known as carbon fiber, carbon composite, or just carbon, are extremely strong and light fiber-reinforced plastics that contain carbon fibers. CFRPs can be expensive to produce but are commonly used wherever a high strength-to-weightratio and stiffness (rigidity) are required, such as in aerospace, superstructures of ships, automotive, civil engineering, sports equipment, and an increasing number of consumer and technical applications. The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester, or nylon, are sometimes used.

Fig. 5.3: CARBON-FIBER REINFORCED POLYMER

5.1.4 **Glass(fiber) Reinforced plastic** (GRP) is a composite material that consists of a polymer matrix and glass fibers. The polymer matrix is usually an epoxy, vinyl ester, or polyester thermosetting resin. The resin brings environmental and chemical resistance to the product, is the binder for the fibers in the structural laminate, and defines the form of a GRP part.

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT
ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

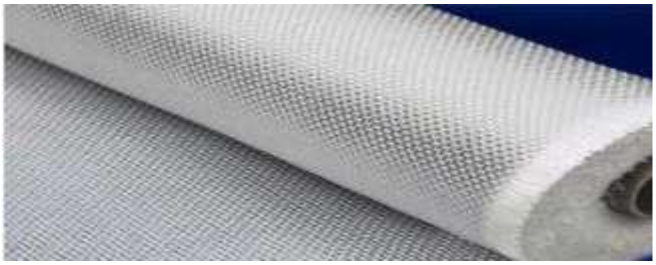


Fig. 5.4: GLASS FIBER REINFORCED POLYMER

5.1.5 NATURAL FIBER REINFORCED POLYMER

Natural fiber polymer composites (NFPC) are a composite material consisting of a polymer matrix embedded with high-strength natural fibers, like jute, oil palm, sisal, kenaf, and flax. Usually, polymers can be categorized into two categories: thermoplastics and thermosets. The structure of thermoplastic matrix materials consists of one- or two-dimensional molecules, so these polymers tend to become softer at a raised heat range and roll back their properties throughout cooling.

Fig. 5.5: NATURAL FIBER REINFORCED POLYMER

5.2 PROPERTIES OF MATERIALS USED

MATERIAL	PROPERTIES
ARAMID FIBER REINFORCED POLYMER	**High Impact Resistance, Good Heat Resistance, Lower StiffnessCompared to Carbon**
BASALT FIBER REINFORCED POLYMER	**Similar To Glass in Terms of Strength but With Better TemperatureResistance**
CARBON FIBER REINFORCED POLYMER	**High Strength, High Stiffness, Low Weight**
GLASS FIBER REINFORCED POLYMER	**Moderate Strength, Good Corrosion Resistance, Cost Effective**
NATURAL FIBER REINFORCED POLYMER	**Renewable Source, Lower Strength Compared to SyntheticFibers, Cost Effective.**

TABLE 5.1: PROPERTIES OF MATERIALS USED

MATERIAL	DENSITY (kg/m^3)	YOUNGS MODULUS (Pa)	POISSONS RATIO
ARAMID FIBER REINFORCED POLYMER	1700	1.4e+11	0.3
BASALT FIBER REINFORCED POLYMER	2200	1.2e+11	0.3
CARBON FIBER REINFORCED POLYMER	1900	3e+11	0.3
GLASS FIBER REINFORCED POLYMER	2000	7e+10	0.3
NATURAL FIBER REINFORCED POLYMER	1600	1e+10	0.4

TABLE 5.2: PHYSICAL PROPERTIES OF MATERIALS USED

CAD MODELING

A three-dimensional solid model of TATA 407 Leaf Spring was modelled in the CAD Software SOLIDWORKS.

CREATING PARTS

Each Leaf of the Leaf Spring is constructed in SOLIDWORKS as a separate part. So, with SOLIDWORKS, creating a model typically begins with 2D sketches. Geometry elements including points, lines, arcs, conics, and splines are present in the sketch. To specify the size and placement of the geometry, dimensions are added to the sketch. Attributes like tangency, parallelism, perpendicularity, and concentricity are defined using relations.

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

Fig. 6.1: MASTER LEAF

Fig. 6.2: 9th LEAF

Fig.6.3: 8th LEAF

Fig. 6.4: 7th LEAF

Fig. 6.5: 6th LEAF

Fig. 6.6: 5th LEAF

Fig. 6.7: 4th LEAF

Fig. 6.8: 3rd LEAF

Fig. 6.9: 2nd LEAF

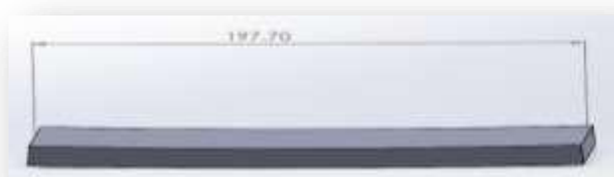


Fig. 6.10: 1st LEAF (SMALLEST LEAF)

MERGING THE LEAF SPRING

Once each leaf was completed the other leaf was merged to it in

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

the SolidWorks part modeling itself. Using convert entities and 3-point arc the curve was made, giving smart dimensions to make the curve created constraint and then extruded using extruded boss base, and selecting midplane.

Fig. 6.11: SEMI-ELLIPTICAL MULTI LEAF SPRING

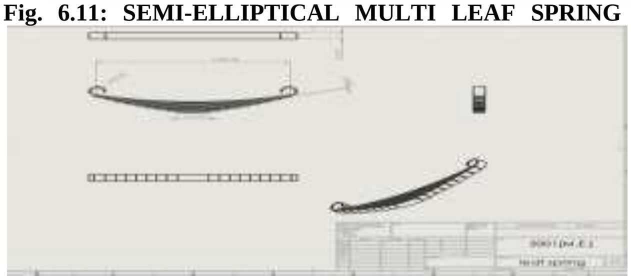


Fig. 6.12: DRAWING SHEET OF LEAF SPRING

FINITE ELEMENT ANALYSIS

7.1 STATIC STRUCTURAL ANALYSIS

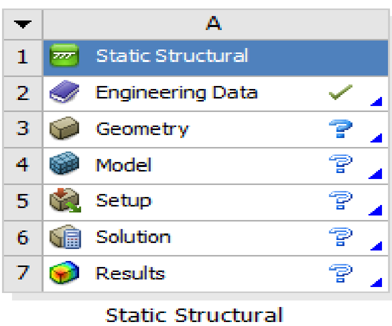


Fig. 7.1: STATIC STRUCTURAL

7.1.1 IMPORTED GEOMETRY

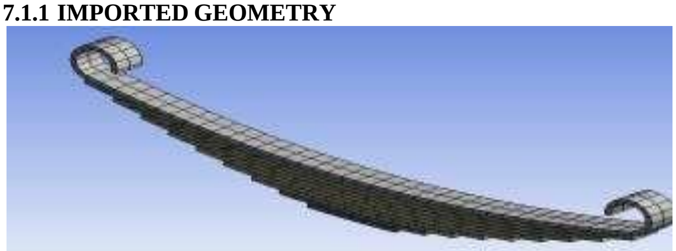


Fig. 7.2: IMPORTED GEOMETRY WITH MESH APPLIED

7.1.2 MESHING

Mesh sizing- Coarse
Element type- Rectangle
No. of Elements- 416
No. of Nodes- 4047

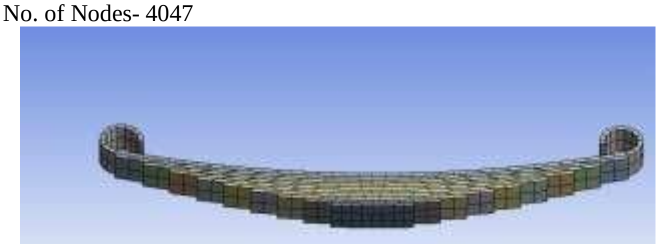


Fig.7.3: MESH

7.1.3 BOUNDARY CONDITIONS

- FORCE
- DISPLACEMENT
- REMOTE DISPLACEMENT

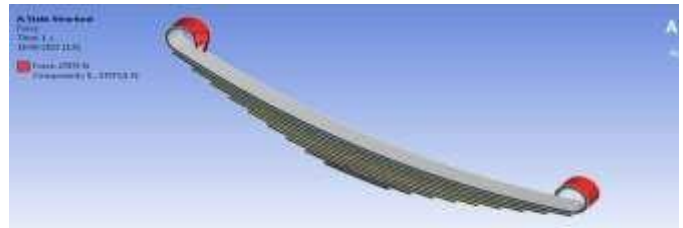


Fig. 7.4: FORCE

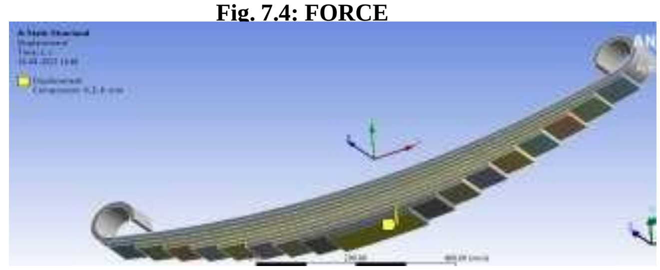


Fig. 7.5: DISPLACEMENT

Fig. 7.6: REMOTE DISPLACEMENT-1

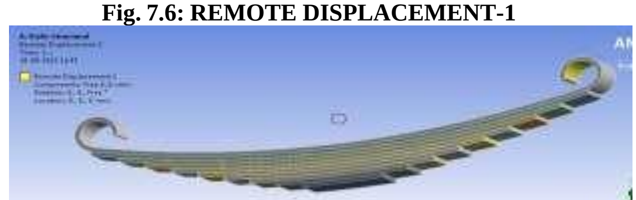


Fig. 7.7: REMOTE DISPLACEMENT-2

7.2 ANALYSIS OF LEAF SPRING WITH DIFFERENT COMPOSITE MATERIALS

After the geometry is imported and boundary conditions are applied, analysis is done on the geometry. Different materials are added to the engineering data library and then after boundary conditions are given the material is applied to the leaf spring and then solved.

The different composite materials which I used in this project are:

- Aramid Fiber Reinforced Polymer (AFRP)
- Basalt Fiber Reinforced Polymer (BFRP)
- Carbon Fiber Reinforced Polymer (CFRP)
- Glass Fiber Reinforced Polymer (GFRP)
- Natural Fiber Reinforced Polymer (NFRP)

For static structural analysis in this project the composite leaf spring is given the following:

- TOTAL DEFORMATION
- EQUIVALENT STRESS
- EQUIVALENT-ELASTIC STRAIN

7.2.1 ARAMID FIBER REINFORCED POLYMER [AFRP]

Fig. 7.8: TOTAL DEFORMATION OF AFRP

Fig. 7.9: EQUIVALENT STRESS OF AFRP

Fig. 7.10: EQUIVALENT-ELASTIC STRAIN OF AFRP

7.2.2 BASALT FIBER REINFORCED POLYMER [BFRP]

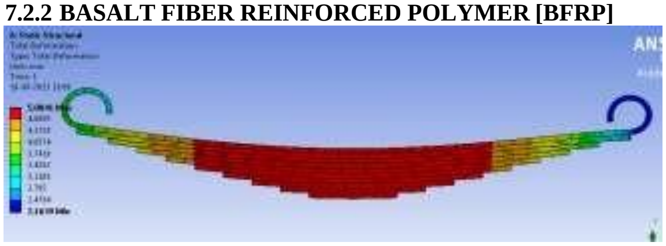


Fig. 7.11: TOTAL DEFORMATION OF BFRP

Fig. 7.12: EQUIVALENT STRESS OF BFRP

Fig. 7.13: EQUIVALENT-ELASTIC STRAIN OF BFRP

7.2.3 CARBON FIBER REINFORCED POLYMER

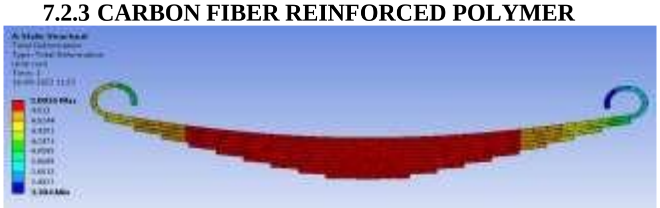


Fig. 7.14: TOTAL DEFORMATION OF CFRP

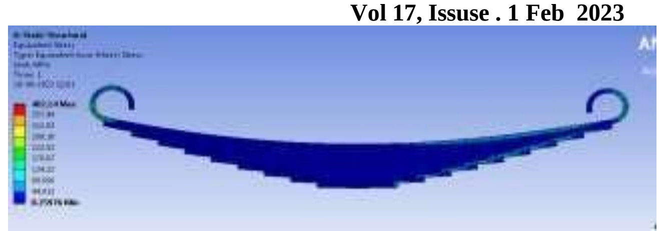


Fig. 7.15: EQUIVALENT STRESS OF CFRP

Fig. 7.16: EQUIVALENT-ELASTIC STRAIN OF CFRP

7.2.4 GLASS FIBER REINFORCED POLYMER

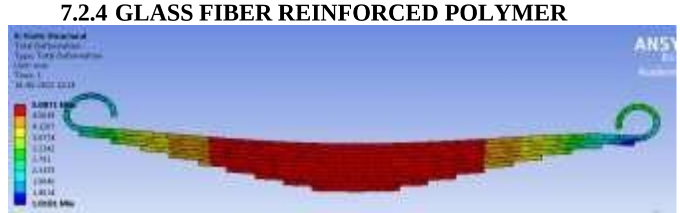


Fig. 7.17: TOTAL DEFORMATION OF GFRP

Fig. 7.18: EQUIVALENT STRESS OF GFRP

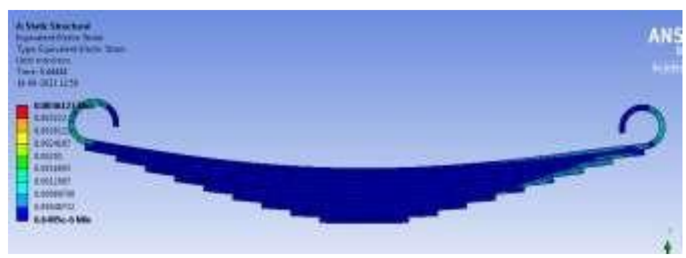


Fig. 7.19: EQUIVALENT-ELASTIC STRAIN OF GFRP

7.2.5 NATURAL FIBER REINFORCED POLYMER

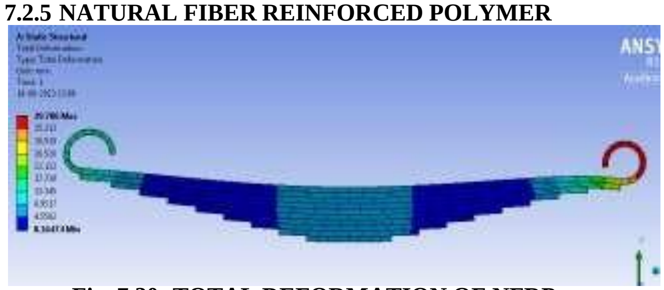


Fig. 7.20: TOTAL DEFORMATION OF NFRP

Fig. 7.21: EQUIVALENT STRESS OF NFRP

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 17, Issuse . 1 Feb 2023

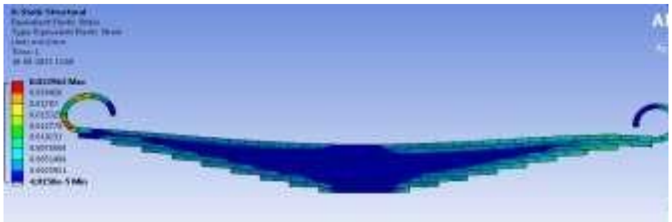


Fig. 7.22: EQUIVALENT-ELASTIC STRAIN OF NFRP

RESULTS & DISCUSSIONS

8.1 ANALYSIS OF COMPOSITE LEAF SPRING

Results obtained by Static Structural Analysis of Leaf spring for different Composite Materials are:

MATERIAL	TOTAL DEFORMATION		EQUIVALENT STRESS		EQUIVALENT ELASTIC STRAIN	
	MAX (mm)	MIN (mm)	MAX (MPa)	MIN (MPa)	MAX	MIN
ARAMID FIBER REINFORCED POLYMER	5.0035	2.4213	294.57	0.27722	0.0021151	$3.4903e^{-6}$
BASALT FIBER REINFORCED POLYMER	5.0041	2.1639	281.7	0.28341	0.0023629	$3.9951e^{-6}$
CARBON FIBER REINFORCED POLYMER	**5.0016**	**3.304**	**402.14**	**0.25977**	**0.0013467**	**$2.0678e^{-6}$**
GLASS FIBER REINFORCED POLYMER	5.0071	1.0181	251.19	0.30169	0.0036127	$6.6485e^{-6}$
NATURAL FIBER REINFORCED POLYMER	39.706	0.16474	227.54	0.31743	0.022962	$4.9158e^{-6}$

CONCLUSION

Utilizing composite materials in leaf springs presents a diverse array of mechanical properties that can be customized to specific applications. The study investigates five distinct compositematerials: glass fiber reinforced polymer (GFRP), carbon fiber reinforced polymer (CFRP), natural fiber reinforced polymer (NFRP), aramid fiber reinforced polymer (AFRP), and basalt fiber reinforced polymer (BFRP), each exhibiting unique characteristics. Notably, carbon fiber-reinforced polymer (CFRP) emerges as the most resilient, displaying minimal deformation compared to other materials due to its high stiffness and strength. The high stress observed in CFRP further underscores its strength and stiffness, as materials with elevated stiffness resist deformation and maintain their shape under applied loads. Consequently, the comprehensive analysis positions carbon fiber-reinforced polymer as the most suitable choice among the investigated materials for optimizing leaf spring performance.

REFERENCES

- A textbook of Machine Design; R.S. Khurmi; J.K. Gupta.
- Design & Analysis of composite Leaf Springs for Light Vehicles; Pankaj Saini, Ashish Goel, Dushyant Kumar.
- Design & Analysis of composite Leaf Springs for Light Weight Vehicles; D. Lydia; C. Venkata Siva Murali.
- Design & Modeling of Leaf Springs Using Composite materials for Tata Gold light weight truck.
- Z. Wu et al.Tensile fatigue behaviour of FRP and hybrid FRP sheets
- Simulation & analysis of heavy vehicles composite leaf spring; J. Hameed Hussain, C.M. Meenakshi