Design And Analysis of Composite Leaf Spring

Mr. J B Gosavi[1], Prof. N S Biradar[2]
[1]Dept of Mechanical Engineering
[2]HOD, Dept of Mechanical Engineering
[1, 2] JSPM'S Imperial College of Engineering & Research, Pune, India

Abstract- *Composites are possible replacements for the metals, which have the same strength but less weight. They have higher strength-weight ratio. Among the various types of composites, fiber-reinforced polymeric composites are now utilized in different types of applications due to their low cost of production and simplicity in fabrication. They have high levels of specific strengths, but their fields of application are restricted due to higher production cost. Nowadays, the main focus of automobile industry is weight reduction. This is done because of good characteristics of composite materials such as damping quality, corrosion resistance and high ratio of strength to weight etc. Mostly, the composites are preferred as the materials in place of conventional metallic leaf springs due to their reduction in weight of about 70% and improved performance etc., and this facilitates the growth of fuel efficiency and riding qualities. This study is the design and experimental analysis of composite leaf spring for passenger cars. In this study comparative analysis done for three composite materials like kelvar/epoxy e-glass/epoxy and silicon manganese steel.*

Keywords- Composite Leaf spring, E-Glass/Epoxy,Silicon manganese steel, ANSYS

I. INTRODUCTION

This work discusses the design and experimental analysis of a composite leaf spring built from composite materials. The primary objective is to compare the load-bearing capability, stiffness, and weight savings of composite leaf springs and steel leaf springs. The design limitations are strain plus deflection The measurements of a light commercial existing traditional steel leaf spring vehicle were taken into account for this study. Fabrication of a conventional composite multi-leaf spring utilizing E-Glass/Epoxy unidirectional laminates with same dimensions. Static examination of a 2D model ANSYS 10 has also been used to simulate and compare typical leaf springs. experimental findings. The 3-D model of a composite multileaf spring was subjected to ANSYS finite element analysis with a full load, and the results were compared with experimental data (B, 2020). The suspension system is a crucial component for providing vehicle frames with strength and protection. However, the suspension system is the focus of manufacturer efforts to reduce the load of an automobile by reducing suspension weight. 15-20 percent of unsprang weight is accounted for by suspension system weight. weight. Moreover, automotive suspension systems are undergoing development. routinely to offer impact protection, prevent chassis distortion, and damage (Tariq, 2020). Leaf springs and helical springs are essential components of a vehicle's suspension system, however due to their superior ability to absorb shock loads, leaf springs are utilized more commonly than helical springs. In order to reduce the weight of automobiles, the leaf spring suspension systems are crucial components. As a result, fuel efficiency and riding quality improve. The design of leaf springs is simple and inexpensive, which is one of their advantages. However, different types of leaf springs are utilized in automobiles based on their gross vehicle weight (Tariq, 2020). The shape of several varieties of leaf springs differentiates them from one another. The standard leaf spring and the parabolic leaf spring have a different amount of leaves stacked. However, the standard leaf spring requires more leaves than the parabolic leaf spring. This is because the geometry of the parabola provides uniform stress distribution (Muaz, 2020).

1.1 Leaf Spring

Originally referred to as a laminated or carriage spring, a leaf spring is a typical kind of spring used for the suspension of wheeled vehicles. This is also one of The first kinds of springing date back to the Middle Ages. times. Occasionally called a semi-elliptical spring or cart spring, it resembles a skinny spring. arc-shaped length of rectangular-section spring steel. The arc's center specifies the position for the axle, whereas tie holes referred to as eyes are located on either connecting to the vehicle body end for very weighty Multiple leaves may be used to construct a leaf spring for automobiles. layered on top of one another in many layers, often with shorter and shorter leaves (Kumar Y. N., 2013).

In addition to springing, leaf springs may also provide locating and, to a lesser degree, dampening duties. A leaf spring may be either directly or indirectly coupled to the frame. or immediately linked to one end, often the front, with The other end was linked through a shackle and a short chain. swinging arm. The shackle adopts the inclination of the the ability of a leaf spring to expand when compressed, and for gentler springiness (Santhosh, 2013).

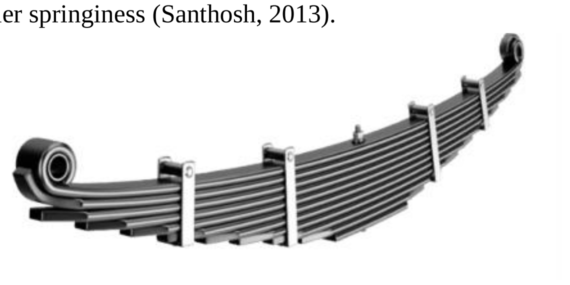


Fig.1.1 Leaf Spring

1.1.1Semi-elliptical Springs

Typically, semi-elliptical springs are used in all vehicles. Particularly on the front and rear axles of trucks, semi-elliptical springs are used.

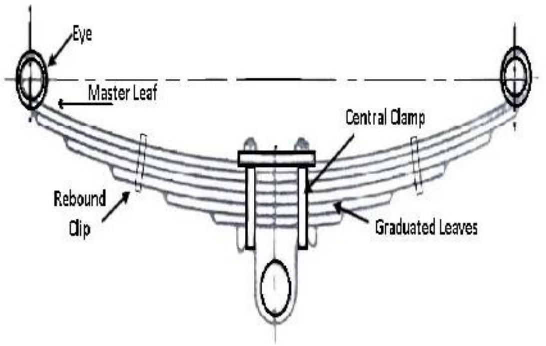


Fig.1.1.1 Semi-elliptical Springs

But in automobiles, they are only installed on the rear axle, whereas independent suspension is used on the front axle. Semi-elliptical springs are more affordable and need less maintenance. They extend the range of spring motion and are very durable.

1.1.2 Helper Spring

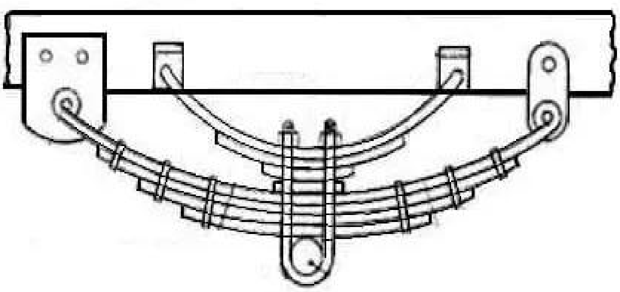


Fig 1.1.2 Helper Spring

A helper spring is identical to a semi-elliptical spring, except the ends' eyes. To handle the hefty weight, the rear axle of the truck is outfitted with the vehicle's primary springs. When the vehicle is substantially loaded, the ends of the assist spring will contact the frame-mounted brackets.

1.1.3 Coil Springs

Coil springs are made of spring steel. These characteristics are specified by the independent suspension system (M, 2021). In addition to offering a broad range of spring rates, they may be installed in any limited place. In comparison to leaf springs, they weigh just half as much for the same function (M, 2021).

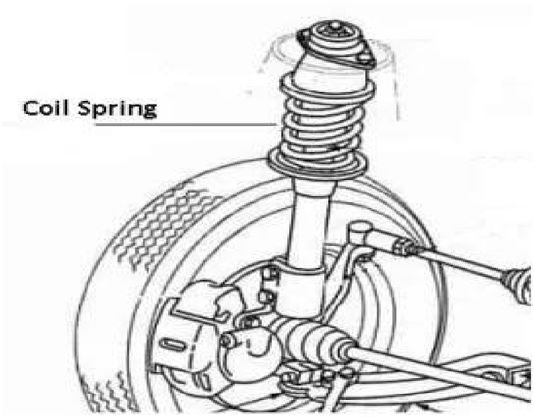


Fig 1.1.3 Coil Springs

They can also store twice as much energy per unit volume as leaf springs, although anti-roll bars or radius roads are required to manage acceleration, braking, and cornering. The coil spring is seated in pan-shaped brackets or spring seats connected to the rear axles. Similarly, spring seats integrated into the frame are utilized to compress springs against them (Saif, 2021).

The suspension may also be employed with torque tube or torque rod drive. In terms of energy storage, or the amount of energy stored in a spring of a given weight, coil and torsion bar springs are superior than leaf springs (Saif, 2021).

1.1.4 Torsion Spring

In addition, a torsion spring is used in an independent suspension system. A torsion suspension spring has a rod that absorbs shear forces while functioning under torsion (M, 2021).

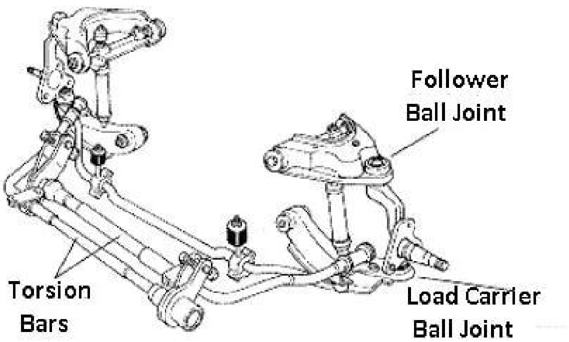


Fig 1.1.4 Torsion Spring (Saif, 2021).

One end of the bar is attached to the frame, while the other end is attached to the wheel arm and supported by a bearing. The wheel arm's end is attached to the wheel hub. When the wheel encounters a bump, it begins to vibrate up and down, causing the torsion bar's torque to operate as a spring (Saif, 2021).

1.1.5 Design of Leaf Spring

As it is commonly known that springs are intended to collect and store energy before releasing it slowly, the connection of the particular strain energy may be represented. Ability to storing and absorbing a larger quantity of strain energy guarantees the comfortable suspension system.

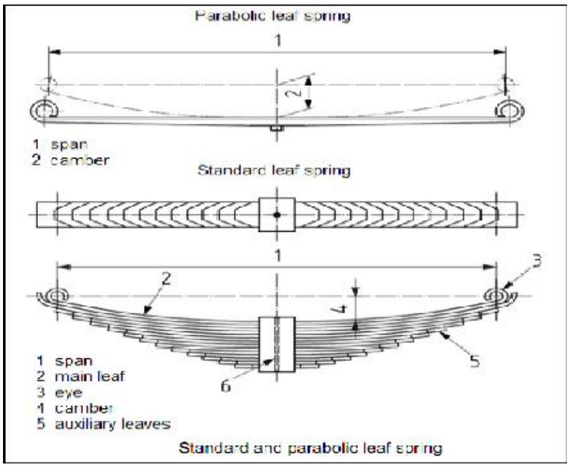


Fig 1.1.5 Standard and Parabolic Leaf Spring

1.2 Composite Leaf Spring

A leaf spring is a typical kind of spring used in the suspension of wheeled vehicles. It is one of the earliest kinds of springing, going back to the Middle Ages, and was once known as a laminated or carriage spring. It is also known as a semi-elliptical spring or cart spring.

A leaf spring is a thin, arc-shaped piece of spring steel with a rectangular cross-section. The arc's center offers a position for the axle, with tie-down holes at either end for attachment to the vehicle body (Patel, 2017). For very large vehicles, a leaf spring may be constructed from many leaves piled on top of one another, often with increasingly shorter leaves. In addition to springing, leaf springs may also provide locating and, to a lesser degree, dampening duties. Although the interleaf friction offers a dampening effect, it is poorly managed and causes station in the suspension's motion. Consequently, some manufacturers have used single-leaf springs (Kanitkar, 2017). Either both ends of a leaf spring are fastened directly to the frame or just one end, often the front, is attached directly to the frame through a shackle, a short swinging arm. The shackle absorbs the leaf spring's inclination to lengthen when squeezed, resulting in a gentler springiness. Some springs had a concave end, known as a spoon end (now seldom used), to carry a swiveling element.

1.3Model to Predict the Stiffness of Composite Leaf Springs

The primary distinction between fiber-reinforced composites and conventional metals is that the former are regarded anisotropic while the latter are isotropic. Therefore, the orientation of the fiber plies must be taken into account while designing the composite leaf spring body. In particular, fewer fiber ply orientations may facilitate simplification The design and production work under the stipulation of according to the design specifications (SHI, 2021). In addition, composite leaf Springs must withstand many forms of external loads. by vertical loads for the course of their service life in light of the reality that leaf springs are exposed to transverse stresses (along the length of the spring) (GAO, 2021). Herein, breadth direction (such as the condition of a car's turn) is discussed. We regard the spring's composite body to include of Single layers alternately stacked in the + and configurations (is the angle between the fiber ply direction and the layer direction). direction circumferential of the leaf spring) (LIU, 2021).

Statement of the Problem

The purpose of this research is to create and test a composite leaf spring for passenger cars. In this section, we examined at static and dynamic analysis. The primary objective of this research is to consider an automobile leaf spring model of Tata Sumo car and to design and study composite leaf springs for Tata Sumo car. This research included a comparative investigation of three composite materials: kelvar/epoxy, e-glass/epoxy, and silicon manganese steel. In this research, we compare the composite materials E-glass Epoxy. Kevlar Epoxy, and Silicon manganese steel for composite leaf springs.

II. LITERATURE REVIEW

2.1 Mawiz Muaz Tariq, et.al (2020) Conducted study on, "Composite Leaf Spring Design and Analysis" I investigated the usage of composites materials for lightweight automotive leaf springs in this project. For this reason, I picked the leaf springs of a Tata Sumo motor automobile. The fundamental goal of this study is to create optimal geometry for lightweight leaf spring that can sustain external stresses without failing. The leaf spring was analytically and numerically analyzed under static stresses. The numerical stress & deflection values were confirmed by analytical analysis, & optimization was carried out based on the findings of static stresses analysis to minimize the weight of a composites leaf spring without losing its strength. A dynamic study was also performed to determine a maximum number of failures cycle under dynamics load. Furthermore, stresses were evaluated against each dynamic load. Kevlar/epoxy & E-glass/epoxy composites were used to make these leaf springs. The stress & deflection values produced from analytic & numerical calculations for composites leaf springs was compared & found to be consistent. The optimization findings indicated a linear connection between width & length, and also width & length from eye to an axle seat. A proposed optimization method is effective for minimizing spring weight. The modal analysis, on the other hand, demonstrated that the composites leaf spring used to have a higher natural frequency than that of the steel leaf springs.

2.2 Kumarasubramanian Ramar, et.al (2020) Conducted study on, "Design & Analysis of an Aramid Fiber Composite Leaf Spring" This article analyzes the effectiveness of composite leaf springs that are suitable for use in vehicles. It has been established that such cost & weight of a leaf spring may be reduced by using composite fibers. The assemblage This is an aramid fiber, which is well-known because its strong tensile strength, great heating resistance, low abrasion, & light weight. reduced weight ratio The leaf spring has been studied and constructed. The specimens are created in compliance with ASTM specifications. Standards & testing were carried out. A leaf spring was a kind of suspensions spring that was often employed to absorb vibration induced by vehicle motion. as a result of a vehicle's loads or road conditions Because of its remarkable strength-to-weight ratio, the automobile industry has expressed greater concern over the replacement of metal leaf springs built of composites material.

2.3 Nishant Varma, et.al (2020) Conducted study on, "Design and evaluation of a composite monoleaf springs for passenger vehicles" This study's objective is to assess the appropriateness of an hybrid composites spring consisting of carbon fibers and flax fibers, which serve as the primary & secondary reinforcement, etc. It was established that the intrinsic frequency of composites leaf spring was 93% more than that of steel. In addition, the addition of flax layer among the carbon fibers increased the security factor. as a consequence of its superior dampening properties, it absorbs both strain and energy. A suspension leaf spring was one of a most essential component that improve the ride quality of a vehicle. This was designed can absorb, store, & release energy. A large reduction in unsprung Generally, weight was added to improve ride quality and comfort. A metallic leaf spring would be replaced with such a composite spring as a simple and practical means of achieving this objective. At addition to weight reduction, the composites leaf spring has other benefits, including a high strengths ratio & excellent fatigue resistance. storage capacity of elastic tensions energy in this research, an automobile-applicable steel mono leaf springs were created. The passenger car reference is assessed and compared with composites mono leaf design.

2.4 T.G. Loganathan, et.al (2019) Conducted study on, "Finite element study of flexural and fatigue properties of a composite leaf spring" The current study presents the results of a FE Analysis on flexural fatigue life & damage in both materials. Several plies orientations are being investigated in order to enhance the fatigue life for composite materials. The automotive and aerospace sectors have a propensity to qualify a better alternative material with higher specific strengths, low weight, & excellent durability in order to minimize fuel consumption & increase efficiency. The leaf spring in a car is indeed the component that promotes vehicle dynamics &, hence, travel comfort. giving the necessary stiffness This paper focuses on the material examination of a vehicle's leaf spring. Replace SAE 5160 (chromium steel) with CFRP (Carbon Reinforced Polymer). Composite) could provide significant strength, weight saving with lower fuel use, and improved vehicle performance.

2.5 Dr. Sheharyar Malik, et.al (2013) Conducted study on, "Comparative Stress Analysis of Composites Leaf Springs" The goal of this study is to compare steel & composites leaf spring, with latter exhibiting the same geometrical features as steel leaf springs. Validation is carried out by modeling leaf springs using ANSYS & compared the results to analytical ones. The results showed that the tension in a composites leaf spring are 64.8 % less than in a steel leaf springs. geometrical characteristics Analytical findings reveal that the measures for deflections are also in great agreement with those for composite leaf springs, with a reduction of 51.3 %. The proposed Methodology allows us to reduce the weight for leaf spring by 74.39 % while maintaining strength. lowering allowable stresses and thereby increasing a material's strain energy Spring leaves Automobile manufacturers are focusing on weight reduction in order to save natural resources and improve fuel efficiency; automobiles use more than half of a world's resources. Because weight contributes significantly both to fuel use & emissions, lowering it quickly reduces both. enhancements to fuel efficiency A leaf spring is one of the major competitors for the Despites various shocks, decreasing a vehicle's weight does not reduce its worth. Absorbent devices are now available on on market.

2.6 Rama Krishna Reddy Guduru, et.al (2020) Conducted study on, "Development of a composite mono leaf springs and investigation of its mechanical characteristics" The mechanical characteristics of several composite materials were studied in this research in order to select the best composite for the construction of a mono composites leaf springs. Unique experimental experiments were used to determine the weight, stiffness, & load-carrying capability of the produced leaf spring in a whole. The experiment findings show a weight drop of 69.4 % & 75 percent, respectively, with the use of glass fiber epoxy & carbon fiber. Due to its great strength & low weight, the automotive industry is presently focusing on composites, lightweight material as an alternative for traditional steel. The major goal of this research is to create a mono composite leaf springs to replace the usual multi-leaf spring in automobiles. The composites material has several benefits, including an high energy-to-weight ratio, easy availability, simple & trouble-free manufacturing procedures, and improved thermal and mechanical properties. The kind of material, production procedures, and fiber orientation all influence the mechanical qualities of a leaf spring. Some composite materials having higher stiffness & pressure rate than metal, & a strength of a composite material is also affected by its geometry and form.

2.7 helong liu, et.al (2021) Conducted study on, “Composite Leaf Springs Stiffness Predictions & Analysis" This paper presents an explicitly theoretical model for forecasting stiffness that use the energy conservation rule that takes into consideration an anisotropic of composites & the unique structure of a leaf spring. The obtained findings are comparable to the finites element technique & the basalt/epoxy sample benches test results. Furthermore, the investigation of the influence of key design factors on stiffness yields recommendations for Composites leaf spring with matching rigidity. Gradually raising the thickness of a composites leaf spring effects its rigidity as a critical parameter reflecting bearing capacity, and strength is directly connected to leaf spring dependability. The impact of the relevant variables was studied to use the Tasi-Wu strength failures criteria. The impact of design parameters just on strength ratio of a composite leaf spring was investigated under the constraints of stiffness. When the stiffness of a composite leaf spring stays constant, increasing its breadth improves its bear capacity. needs to stay inside an certain range In the field of lightweight car components, composite leaf springs is indeed a significant use of composite. Stiffness, as a critical property of composites leaf springs, is closely related to vehicle handling stability & ride comfort.

III. METHODOLOGY

3.1 Introduction

The automobile industry has a special interest in the replacement of the conventional leaf spring with composite leaf spring to get better performance with less weight. This thesis deals with the design and analysis of composite leaf spring. Automobile industries are so concerned with reducing weight for fuel saving that they are now focusing on innovations without sacrificing driving comforts. Mostly, they are concentrating on composite materials for corrosion resistance, damping quality and high strength to weight ratio, besides easier maintenance. Application of composite materials in place of steel leaf springs will not only meet the stiffness requirement but also cater to the need for damping of the drive system, facilitating better vehicle dynamics.

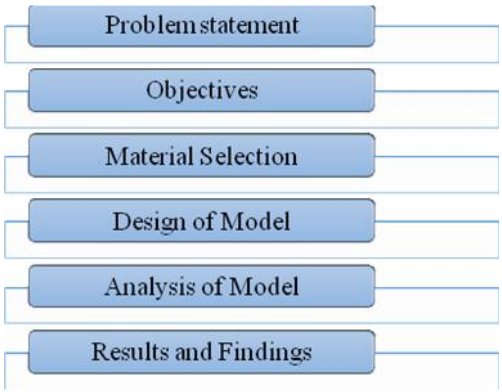


Fig 3. 1 Flowchart

3.2 Properties of Materials

Mechanical properties of composite materials A composite material incorporates high strength, high modulus fibers in a matrix (polymer, metal, or ceramic). The fibers may be oriented in a manner to give varying in-plane properties (longitudinal, transverse-stress, strain, and modulus of elasticity).

Composites are extremely versatile products - their benefits being:

High Strength to Weight Ratio

Fiber composites are extremely strong for their weight. By refining the laminate many characteristics can be enhanced. A common laminate of say 3mm Chopped strand mat, is quite flexible compared to say a 3 mm ply. However, it will bend a long way more than the ply before yielding. Stiffness should not be confused with Strength. A carbon fiber laminate on the other hand, will have a stiffness of many times that of mild steel of the same thickness, increased ultimate strength, yet only be less than 1/4 of its weight.

Lightweight

A standard Fiberglass laminate has a specific gravity in the region of 1.5, compared to Alloy of 2.7 or steel of 7.8. When you then start looking at Carbon laminates, strengths can be many times that of steel, but only a fraction of the weight.

A DVD case lid was produced using carbon fiber to reduce the case's overall weight so that it could be carried as cabin baggage whilst traveling, and for improved security. It was used by support crew for the All Blacks during their 1999 Rugby World Cup campaign.

Fire Resistance

The ability for composites to withstand fire has been steadily improving over the years. There are two types of systems to be considered

Fire Resistant - More difficult and made with the likes of Phenolic Resins. These are difficult to use, are cured with formaldehyde, and require a hi degree of post curing to achieve true fire resistance.

Other materials are also becoming more readily available to be used as in tumescent layers, which expand and blanket the surface, preventing spread of flame. There is a paint on coating usually applied to the back of the product laminate, plus a thin fiber film to go under the Gelcoat giving the outer surface a blanketing coat as well.

Fiberglass Developments Ltd produces a Fire Door as part of our SteridorTM range. Use of special Phenolic resin has allowed us to create the only fully tested Composite door in Australasia. Fire rated by BRANZ to 4 hours, this door is also approved by MAF as meeting all their Hygiene requirements.

Electrical Properties

Fiberglass Developments Ltd produced the Insulator Support straps for the Trans Rail main trunk electrification. The straps, although only 4mm thick, meet the required loads of 22kN, as well as easily meeting insulation requirements.

Chemical & Weathering Resistance

Composite products have good weathering properties and resist the attack of a wide range of chemicals. This depends almost entirely on the resin used in manufacture, but by careful selection resistance to all but the most extreme conditions can be achieved. Because of this, composites are used in the manufacture of chemical storage tanks, pipes, chimneys and ducts, boat hulls and vehicle bodies.

FDL manufactured architectural panels for the construction of the Auckland Marine Rescue Centre. Composite panels were chosen because of their ability to withstand salty sea side conditions without corrosion.

Color

Almost any shade of any color can be incorporated into the product during manufacture by pigmenting the gelcoat used. Costs are therefore reduced by no further finishing or painting. Soluble dyes can be used if a translucent product is desired.

We do not however, recommend dark colors. These produce excessive heat on the surface which can lead to the surface deteriorating and showing print through, where the Resin matrix cures more and shrinks, bringing the fibers to the surface. In extreme cases delamination can occur.

<u>Translucency</u>

Polyester resins are widely used to manufacture translucent moldings and sheets. Light transmission of up to 85% can be achieved.

<u>Design Flexibility</u>

Because of the versatility of composites, product design is only limited by your imagination.

<u>Low Thermal Conductivity</u>

Fiberglass Developments has been involved in the development and production of specialized meat containers, which maintain prime cuts of chilled meat at the correct temperature for Export markets. They are manufactured using the RTM process, with special reinforcing and foam inserts.

Manufacturing Economy

Fiberglass Developments produces several models of fuel pump covers for Fuel quip. Fiberglass is an ideal material for producing items of this type for many reasons, including being very economical.

The work materials chosen was kelvar/epoxy e-glass/epoxy and silicon manganese steel.

Table 3. 1 Properties of Materials

Sr no.	**Properties**	**E-glass/Epoxy**	**Kevlar/Epoxy**	**Silicon Manganese Steel**
1.	Mass density of the material (ρ). Kg/m3	2600	1400	7800
2.	Young's Modulus (Mpa)	40,000	76000	190,000
3.	Poisson's Ratio	0.22	0.37	0.29
4.	Tensile Strength: Ultimate	40.53	85	620
5.	Tensile Strength: Yield	64	90	360

3.2. Case Study Model Specification

Table 3. 2 Tata Sumo Gold Specification

Sr no.	**Particulars**	**Value**
1.	Make & Model	Tata Sumo Gold
2.	Engine	2956 cc
3.	Max Power	62.52 kW, 85PS@3000 rpm
4.	Max Torque	250 Nm @1000 – 2000 rpm
5.	Rear Suspension	Leaf springs and antiroll bar
6.	L x W x H (mm)	4258 x 1700 x 1925
7.	Kerb Weight (wk)	1940 Kg
8.	Gross Weight(wg)	2625 Kg

3.3. Model Components

Table 3. 3 Model Components and parameters

Sr no.	**Model Components**
1.	Master Leaf
2.	Leaves
3.	Clip
4.	Plate
5.	Nut
6.	U-bolt
7.	Pin

3.4. Calculations of Model Components Design

1. Master Leaf

Total length of leaf: 975mm
Thickness of leaf: 10mm
Width of leaf: 70mm
Inside diameter of eye: 18mm
Radius of curvature: 1368mm
Composite leaf for which the maximum stress and maximum deflection are known. From the stress and deflection equations the thickness of the spring plate, h, can be obtained as,

$$\mathbf{h} = \frac{\sigma_{max} L^2}{E \delta_{max}} = \frac{\sigma_{des} L^2}{E \delta_{des}}$$

E = The Modulus of Elasticity material property and depends on the type of spring material chosen.
L= The characteristic length of the spring. Therefore, once the design parameters, given on the left side of the above equation, are fixed the value of plate thickness, h can be calculated. Substitution of h in the stress equation above will yield the value of plate width b.
F = Force applied to leaf spring.
b = Width of leaf spring
h = Height or thickness of leaf spring

$$\mathbf{b} = \frac{3FL}{\sigma_{des} h^2}$$

2. Leaves
Thickness of Leave: 10mm
Width of Leave: 70mm
Leave 1:
Total length of Leave: 760mm
Leave 2:
Total length of Leave: 590mm

3. Clip

Length: 122mm
Thickness: 13mm

4. Plate
Length x width x Thickness: 150x100x13mm

5. Nut
Outer Diameter: 40mm
Inside Diameter: 22mm
Thickness: 20mm
Nut width across the flat surface (also known as size across flat) = (1.5 D) + 3 mm.
D in mm is the nut's diameter.
The nut thickness is equal to (0.8 D) to D.
The radius of the front chamfer is 1.5 D.

6. U-bolt
Diameter: 22mm
Length: 153mm
U-bolt Size (C) = Diameter (A) x Distance Between Legs (B) x Leg Length

7. Pin
Diameter: 13mm
Length: 140mm

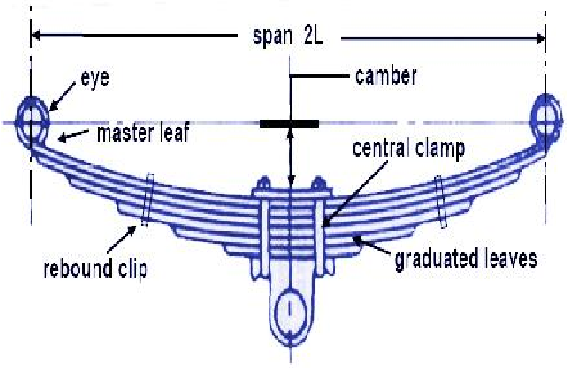


Fig 3. 2 Components of Composite Leaf Spring

CAD Modelling

In present work, the solid modelling of leaf spring was carried out in CATIA software with available design data.

3.5. Design Calculation for Composite Leaf Spring

1. Load acting on leaf spring (W):
Minimum load acting on leaf spring (Wmin):

$$W_{min} = \frac{\left(\frac{w_k}{4}\right) \times 9.81}{2} \text{ N}$$

Wmin = 17000 N
Maximum load acting on leaf spring (Wmax):

$$W_{max} = \frac{\left(\frac{w_g}{4}\right) \times 9.81}{2} \text{ N}$$

Wmax = 2378.93 N

2. Length of leaf spring (L):

$$L = \left(\frac{Z}{2}\right) \text{ mm}$$

L: 975mm

3. Deflection of a leaf spring

$$\delta = \sigma \times L^2/4E.$$

4. Bending stress

$$\sigma = \frac{M}{Z} = \frac{W L}{b t^2/6}$$

$$= \frac{6 W L}{b t^2}$$

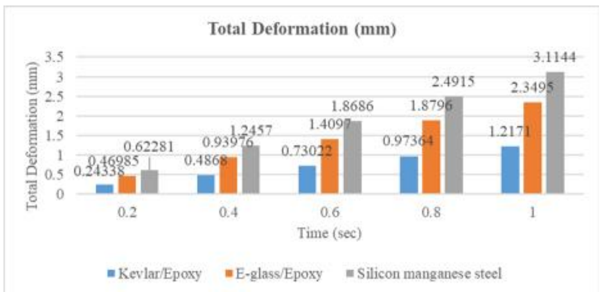
Where, σ = bending stress, W = load on spring, b = width of spring, t = thickness of spring

IV. RESULTS

4.1 Structural Analysis:

Table 4. 1 Total Deformation

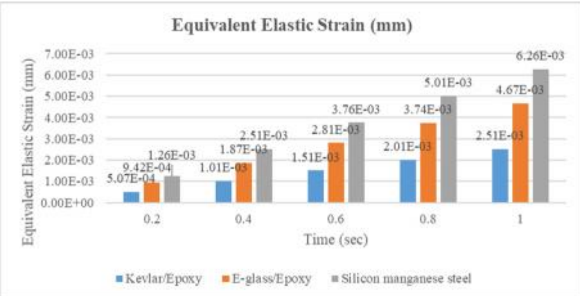
Time (sec)	Total Deformation (mm)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	0.24338	0.46985	0.62281
0.4	0.4868	0.93976	1.2457
0.6	0.73022	1.4097	1.8686
0.8	0.97364	1.8796	2.4915
1	1.2171	2.3495	3.1144



Graph 4.1: Total Deformation(mm)

Table 4. 2 Equivalent Elastic Strain

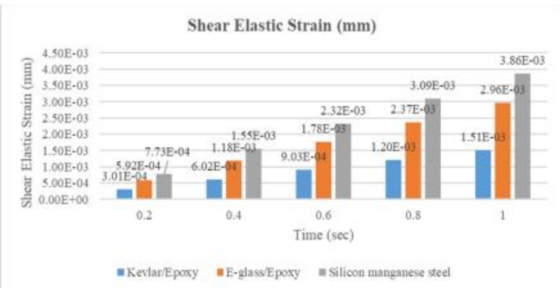
Time (sec)	Equivalent Elastic Strain (mm)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	5.07E-04	9.42E-04	1.26E-03
0.4	1.01E-03	1.87E-03	2.51E-03
0.6	1.51E-03	2.81E-03	3.76E-03
0.8	2.01E-03	3.74E-03	5.01E-03
1	2.51E-03	4.67E-03	6.26E-03



Graph 4.2: Equivalent Elastic Strain (mm)

Table 4.3 Shear Elastic Strain

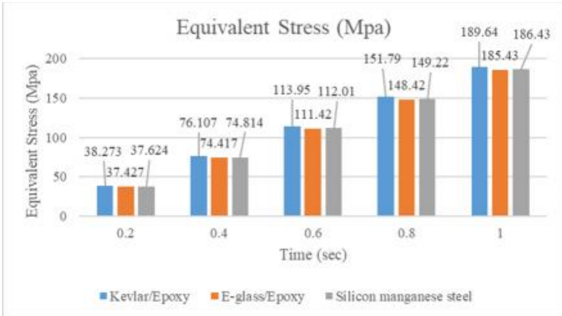
Time (sec)	Shear Elastic Strain (mm)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	2.62E-04	4.47E-04	6.31E-04
0.4	5.21E-04	8.88E-04	1.25E-03
0.6	7.80E-04	1.33E-03	1.88E-03
0.8	1.04E-03	1.77E-03	2.50E-03
1	1.30E-03	2.21E-03	3.12E-03



Graph 4.3: Shear Elastic Strain (mm)

Table 4.4 Equivalent Stress

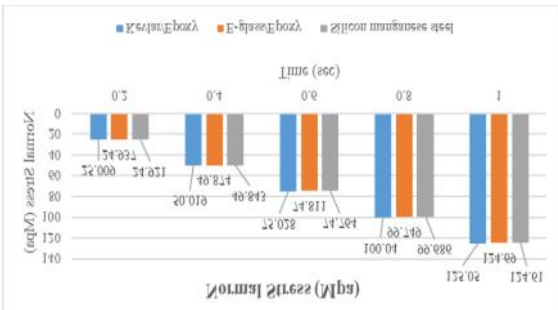
Time (sec)	Equivalent Stress (Mpa)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	38.273	37.427	37.624
0.4	76.107	74.417	74.814
0.6	113.95	111.42	112.01
0.8	151.79	148.42	149.22
1	189.64	185.43	186.43



Graph 4.4: Equivalent Stress (Mpa)

Table 4.5 Normal Stress

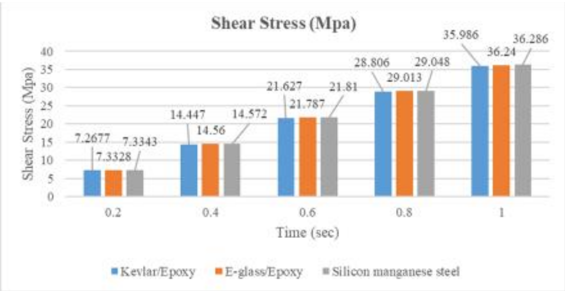
Time (sec)	Normal Stress (Mpa)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	25.009	24.937	24.921
0.4	50.019	49.874	49.843
0.6	75.028	74.811	74.764
0.8	100.04	99.749	99.686
1	125.05	124.69	124.61



Graph 4.5 Normal Stress (Mpa)

Table 4.6 Shear Stress

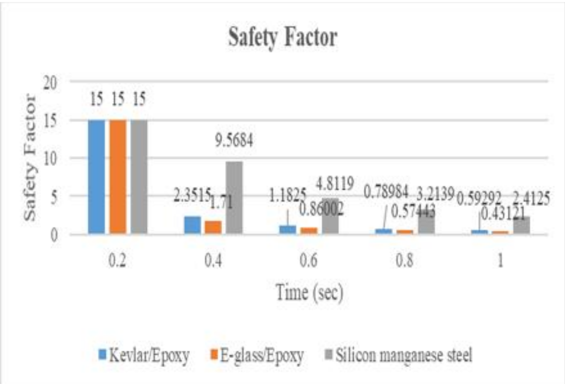
Time (sec)	Shear Stress (Mpa)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	7.2677	7.3328	7.3343
0.4	14.447	14.56	14.572
0.6	21.627	21.787	21.81
0.8	28.806	29.013	29.048
1	35.986	36.24	36.286



Graph 4.6: Shear Stress (Mpa)

Table 4.7 Safety Factor

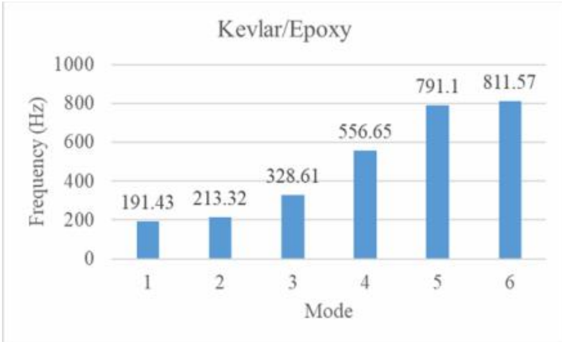
Time (sec)	Safety Factor		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
0.2	15	15	15
0.4	2.3515	1.71	9.5684
0.6	1.1825	0.86002	4.8119
0.8	0.78984	0.57443	3.2139
1	0.59292	0.43121	2.4125



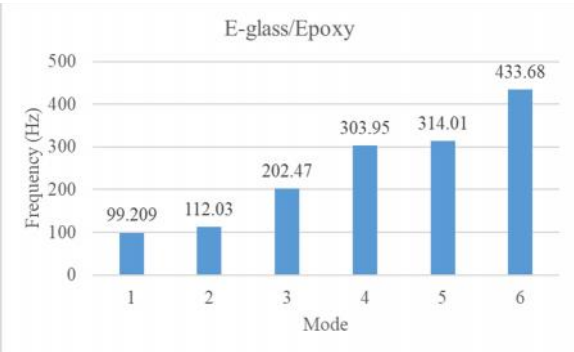
Graph4.7: Safety Factor

Table 4.8 Dynamic Analysis

Mode	Frequency (Hz)		
	Kevlar/Epoxy	E-glass/Epoxy	Silicon manganese steel
1	191.43	99.209	49.817
2	213.32	112.03	55.703
3	328.61	202.47	101.59
4	556.65	303.95	150.69
5	791.1	314.01	157.69
6	811.57	433.68	215.48

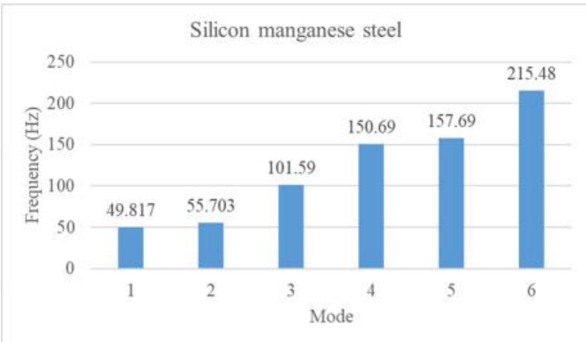


Graph 4.8 : Kevlar /Epoxy



Graph:4.9 E-glass/Epoxy

Graph: 4.10 Silicon manganese steel



Graph: 4.11 Comparison of Dynamic Analysis for Kevlar/Epoxy E-glass/Epoxy Silicon manganese steel

V. CONCLUSION

TATA Sumo leaf spring is considered in this study of analysis on Composite leaf spring for application in passenger's cars. The results observed during this analysis are within range with similar available existing results and governing standards. The following points can be concluded from the results observed during this study.

1. Analytical analysis performed on Composite leaf spring are as observed in analysis chapter, which lists the elements present in material with observed and specified values.
2. Composite leaf spring porotype is manufactured using conventional hand layup method by following proper thumb rules.
3. Finite element analysis is performed on Composite leaf spring. In static structural analysis system deflection of leaf spring under loading condition is observed.
4. Comparative Analysis done for selected three composite materials, in that the composite Kevlar/epoxy and E-glass/epoxy was used for leaf spring static and dynamic stress analysis. The results indicated that the fiber orientation and stacking sequence plays a vital role to enhance the strength of material.
5. The stresses in composite leaf springs were found to be much lower than steel leaf spring with substantial weight savings. It was observed that shear stresses produced are also within the specified limits of the material.

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