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# Design & Analysis of (Mahindra-Bolreo) Leaf Spring by Using Composite Material

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A B S T R A C T

The Automobile Industry has shown keen interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance and tailor-able properties. The study aim's in the rear leaf spring analysis of "Mahindra Bolero".Highly important research issue in this modern world is the reduction of weight while increasing or maintaining strength of products. Composites are one among the material families which are attracting lot of researchers and are also a solution of such issues. This paper describe about design and analysis of composite leaf spring. For this purpose, a rear leaf spring for MAHINDRA "BOLERO" is considered. The objective also aims to compare the stresses, deformations and weight saving of composite leaf spring with that of conventional steel leaf spring, where stiffness is the design constraint. The Automobile Industry also shows great interest in replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. In this work an attempt is made to develop a natural and synthetic fiber reinforced hybrid composite material with optimum properties to replace the existing conventional steel leaf spring. The leaf spring was modeled in CATIA and the analysis was done using ANSYS 15.0 software.

**Keywords:** Hybrid composite, Suspension system, Static Analysis, Mahindra Bolero Leaf spring

## 1. INTRODUCTION

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. The advantage of leaf spring over helical spring is that the end of the springs may be guided along a definite path. Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason manufacturers have experimented with mono-leaf springs. Leaf springs were very common on automobiles, right up to the 1970s in Europe and Japan and late 70's in America when the move to front wheel drive, and more sophisticated suspension designs saw automobile manufacturers use coil springs instead. Today leaf springs are still used in heavy commercial vehicles such as vans and trucks, SUVs, and railway carriages. For heavy vehicles, they have the advantage of spreading the load more widely over the vehicle's chassis, whereas coil springs transfer it to a single point. Unlike coil springs, leaf springs also locate the rear axle, eliminating the need for trailing arms and a Pan hard rod, thereby saving cost and weight in a simple live axle rear suspension. A more modern implementation is the parabolic leaf spring. This design is characterised by fewer leaves whose thickness varies from centre to ends following a parabolic curve. In this design, inter-leaf friction is unwanted, and therefore there is only contact between the springs at the ends and at the centre where the axle is connected. Spacers prevent

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contact at other points. Aside from a weight saving, the main advantage of parabolic springs is their greater flexibility, which translates into vehicle ride quality that approaches that of coil springs. There is a trade-off in the form of reduced load carrying capability, however. The characteristic of parabolic springs is better riding comfort and not as "stiff" as conventional "multi-leaf springs". It is widely used on buses for better comfort. A further development by the British GKN company and by Chevrolet with the Corvette amongst others is the move to composite plastic leaf springs.

**Fig.1.1 New generation leaf spring**

## 2. Literature Review

Mr. Akshay Kumar [1] worked on Design, Analysis, Manufacturing and Testing of Mono Composite Leaf Spring Using UD E-Glass Fiber/Epoxy he concluded that comparison of steel leaf spring with E-glass/epoxy mono composite leaf spring under static load condition is observed. The same deflection with improve stiffness and weight reduction is 77.3%. From the result, it is observed that if we mixed carbon fiber with E-glass fiber to improve strength; possible to apply heavy weight vehicles.

Anjish M George [2] investigated on design and analysis of leaf spring by using hybrid composite material. the result of experiments and prediction model shows that, This research work provides comparative analysis between conventional steel, and E-Glass/Flax/Epoxy based hybrid composite leaf spring. The hybrid composite leaf spring is found to have lesser stresses and negligible higher deflection as compared to conventional steel leaf spring. Weight can be reduced by 88.49% if steel leaf spring is replaced by E- glass/Flax/Epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle.

Ajahar Sayyad [3] worked on Design and Analysis of Leaf Spring by Using Composite Material they have concluded that,

1. Static analysis of leaf spring for different material combination under similar loading condition has been done for all design cases.
2. Results for selected parameters are obtained for all design cases of leaf spring.
3. Total deformation, equivalent elastic strain, equivalent (Von-Mises) stress, strain energy and mass results have been analyzed for different material combination in different design cases of leaf spring.
4. Results are studied for above five parameters. It has been concluded that design case D2 is optimum for total deformation, equivalent elastic strain, equivalent (Von-Mises) stress, strain energy and mass optimization.
5. CAE tool Creo 2.0 is used for 3d modeling of leaf spring. This method is more cost effective less time consuming then other methods of modeling.
6. Leaf spring assembly file in IGES file format is exported to ANSYS 14.0 for analysis.
7. ANSYS 14.0 is used for meshing and analysis of leaf spring. This method of analysis is more cost effective, efficient and less time consuming than other methods of solution.

Chaitali Chaudhari [4] published paper on Application of Design of Experiment (DOE) Method for Optimum Parameters of “Mahindra Bolero” Leaf Spring. They have concluded that

1. A new method of stress analysis is proposed and studied which is a combination of design of experiments method (Taguchi method) and computer aided spring simulation technique for analysis of stress induced in the leaf spring due to the effect of factors like material of leaf spring, width of leaves, thickness of leaves and number of leaves.

2. Using Ansys it is found that, Stress induced in composites leaf spring is much less than that of one made up of steel.
3. Material found to be most influential among the factors. Number of leaves had the least effect on the stiffness of leaf spring.
4. The optimized levels of selected design parameters obtained by Taguchi method are: (Material): Kevlar, (Width): 70mm, (Thickness): 8mm, (No. of leaves): 5
5. With Taguchi optimization method, the stress induced in the leaf spring can be reduced from 1.6619e3 MPa to 8.44922e2 MPa and stiffness is increased from 48.488 N/mm to 53.09 N/mm.
6. By theoretical calculation, the weight of Steel leaf spring is 211.28N and that of Kevlar leaf spring with optimum combination is 33.88N. Hence weight reduction of 83.96% is obtained.

## 3. Construction of leaf spring

Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps. The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes.

### *3.1. Leaf spring parameter*

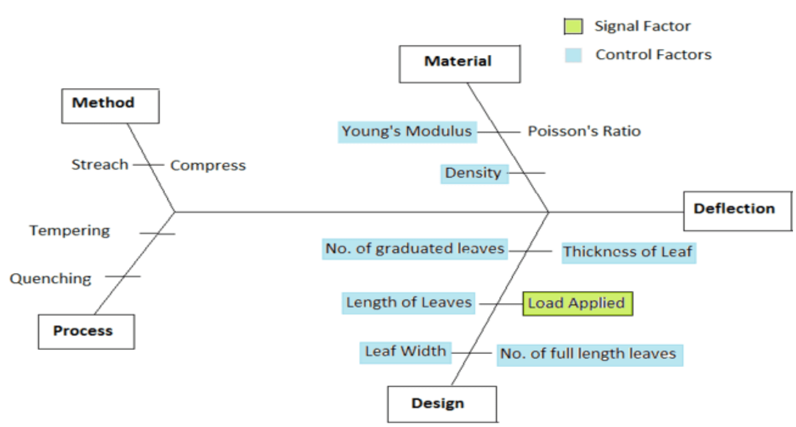



**Fig1. 1 Cause and effect diagram of leaf spring**

A Cause-and-Effect diagram is also known as Ishikawa diagram or fishbone diagram as shown in Fig. 1.2 is used in the brainstorming session to identify the cause-effect between factors related to cause. The main purpose of the Cause-and-Effect diagram is to generate a comprehensive list of possible causes at the first step in problem solving. From the brain-storming session, the main causes of the problem are identified. These causes can be categorized into control factors, noise factors, and signal factors. A parameter diagram studies all those factors which contribute to the output by a graphical way.

### *3.2. Objective of Suspension*

1) To prevent the road shocks from being transmitted to the vehicle components.
2) To safeguard the occupants from road shocks.
3) To preserve the stability of the vehicle in pitting or rolling, while in motion.

## 4. Types of suspension system

### *4.1. Plastic SuspensionSystem*

Viberitis. P.A of TURINE has developed a new type of suspension based upon the use of resilient plastic rings in compression. The suspension consists of a cylindrical container secured to the chassis, a shaft attached to the axle and free to slide within the plastic rings contained in the cylinder, there are two centering rings, the bottom one fixed to the lower end of the cylinder and the upper one is arranged as high as possible keeping in consideration that in the rebound position shaft must remain supported by it by the plastic rings and absorb the vertical dynamic load.

### *4.2. Independent Suspension System*

Independent suspension has become almost universal in the case of front axle, due to the simplicity of such a suspension system.When a vehicle with rigid axle suspension encounters road irregularities the axle tilts and the wheels no longer remain vertical. This causes the whole of the vehicle to tilt on one side. Such a state of affairs is not desirable. Apart from causing rough ride, it causes 'wheel wobble'. The road adhesion is also decreased. To avoid this, the wheels are sprung independent of each other, so that tilting of one does not affect the other. Besides the independent suspension also have the following advantages over rigid able type suspension.

### *4.3. Real Wheel Independent Suspension System*

Though the rear wheels are not to be steered, yet there is a considerable difficulty in the rear wheel springing if the power has to be transmitted to the rear wheel. But even the rear wheel independent springing is coming into prominence because of its distinct advantages over the rigid axle type. Universal couplings keep the wheel vertical, while the sliding coupling is required to maintain the wheel track constant, thereby avoiding scrubbing of the tyres: this method has been used in the DEDION type of axle.

### *4.4. Wishbone Type Suspension System*

The use of coil springs in the front axle suspension of car is now almost universal. It consists of upper and the lower wishbone arms pivoted to the frame member. The spring is placed in between the lower wishbone and the underside of the cross member. The vehicle weight is transmitted from the body and the cross member to the coil spring through which it goes to the lower wishbone member. A shock absorber is placed inside the coil spring and is attached to the cross member and the lower wishbone member. The wishbone type is the most popular independent suspension system.

### *4.5. Interconnected Suspension System*

In these systems, the front and rear suspension units or else the units on the two sides of the automobile are connected together. These are also called 'linked system'. Te major advantage of such a system is that tendency of the vehicle to bounce, pitch or roll is reduced and a constant desirable attitude of suspension. The other systems in current use are the Hydro elastic suspension, the Daimler – Benz suspension and the Hydra gas suspension system.

## 5. Selection of Material

### *5.1. Carbon/Graphite fibers:*

Their advantages include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength. Graphite, when used alone has low impact resistance. Its drawbacks include high cost, low impact resistance and high electrical conductivity**.**

### *5.2. Glass fibers:*

The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low elastic modulus poor adhesion to polymers, low fatigue strength and high density, which increase leaf spring weight and size. Also crack detection becomes difficult.

### *5.3. Composite materials:*

A composite material is made by combining two or more materials often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.

## 6. DESIGN, ANALYSIS & RESULTS OF LEAF SPRING

### *6.1. Design Parameter & Material Properties*

The design parameter for Mahindra Bolero using rear five leaf steel spring with material properties are given in Table No 5.1. The actual leaf spring is showing in Figure No 5.1

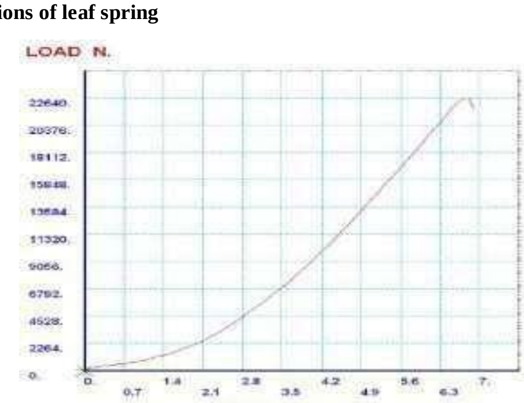
**Fig6. 1 Mahindra Bolero Rear Leaf Spring**

The design of the leaf spring is done in CATIA V5 R20. All the leaves, clamps and bolt are designed separately in the part drawing and are assembled in the assembly drawing section in CATIA. The leaves are assembled by giving surface contact between the bottom surfaces of one leaf to the top surface of the other leaf. In this way all the 10 leaves are assembled in the CATIA, after that the clamps and bolts are assembled in the leaf spring.

| Parameter | Value |
|---|---|
| Material selected-Steel | 55Si2Mn90 |
| Length of leaf spring Eye to Eye | 1168 mm |
| Arc height of axle seat (Camber) | 190mm |
| Width of the leaves | 63mm |
| Thickness of each leaves | 8mm |
| No. of full length leaves | 1 |
| No. of graduated leaves | 4 |
| Yield strength | 1470 N/mm2 |
| Tensile strength | 1962 N/mm2 |
| Young's modulus ($E$) | 2.1x105 N/mm2 |
| Design stress ($\sigma$b) | 653 N/mm2 |
| Spring rate | 65 N/mm |
| Maximum load carrying capacity | 11500 N |
| Leaf spring weight | 20.4 kg |

**Table6. 1 Design specifications of leaf spring**


**Graph No. 6.1 Tensile modulus test graph.**




**Graph No.6. 2 Tensile strength test graph**

### *6.2. CAD Drawing of Leaf Spring*

CAD model designs with conventional and composite materials of mono leaf spring are created in CATIA V5 R20 which contains special tools in generating typical surfaces, which are later converted into solid models

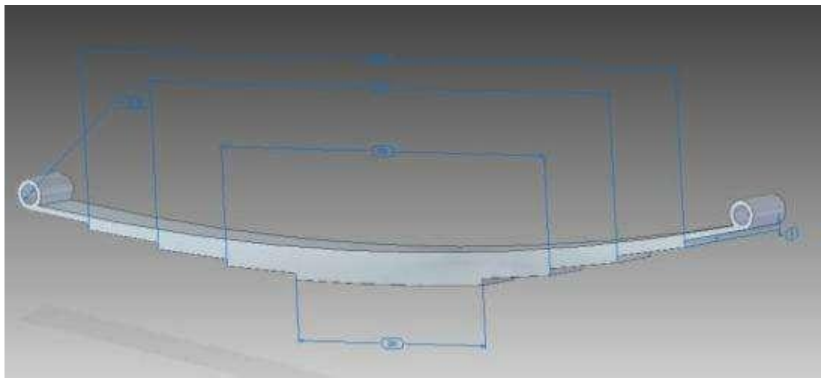


**Fig6. 2 CAD model of Conventional steel leaf spring**

### *6.3. Analysis Procedure of Leaf Spring*

***1. Geometry:*** First generate the geometric model of the leaf spring from CATIA into Ansys software.

***2. Define Materials:*** Define a library of materials for Analysis. In this Analysis of leaf spring, selected materials are steel, Epoxy glass, Epoxy carbon, Aluminum Alloy, Titanium Alloy. These materials can be selected from the engineering data available in Ansys software.

***3. Generate Mesh:*** Now generate the mesh. This divides the drawing into finite number of pieces. It will show the number of nodes and elements present in the drawing after meshing is completed.

4. ***Apply Boundary conditions:*** Simply supported boundary conditions are considered for the leaf spring. In this case both the ends of the leaf spring are given fixed support and the load on the leaf spring is applied at the bottom leaf in upwards direction.

5. ***Obtain solution and generate results:*** Now obtain the solution for the stress, deformation and elastic strain and generate the results.

### *6.4. Analysis of Leaf Spring*

Now, let us check the results obtained in Ansys for stress, deformation, elastic strain and weight for the specified materials.

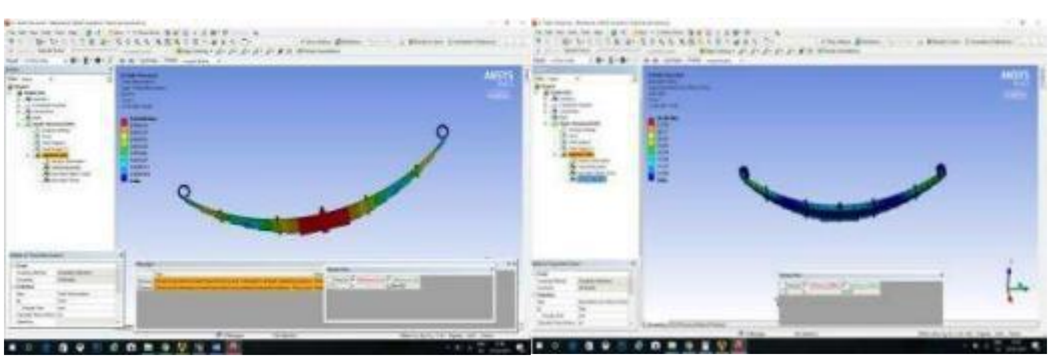


**Fig6. 3 Steel material**

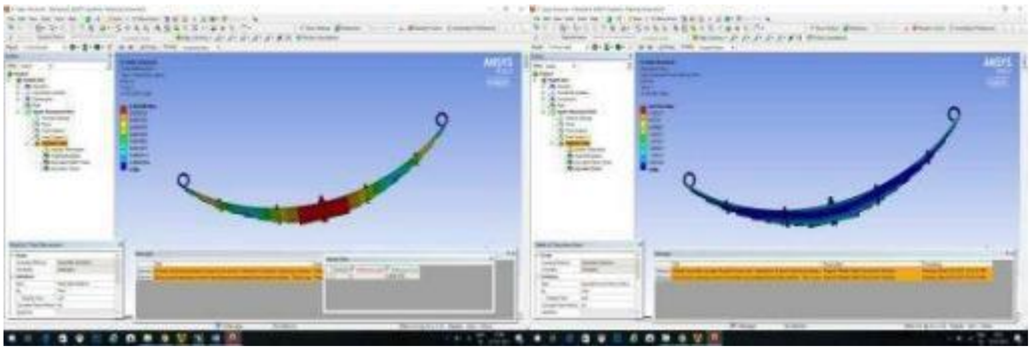


**Fig 6.4 E-Glass/Epoxy**

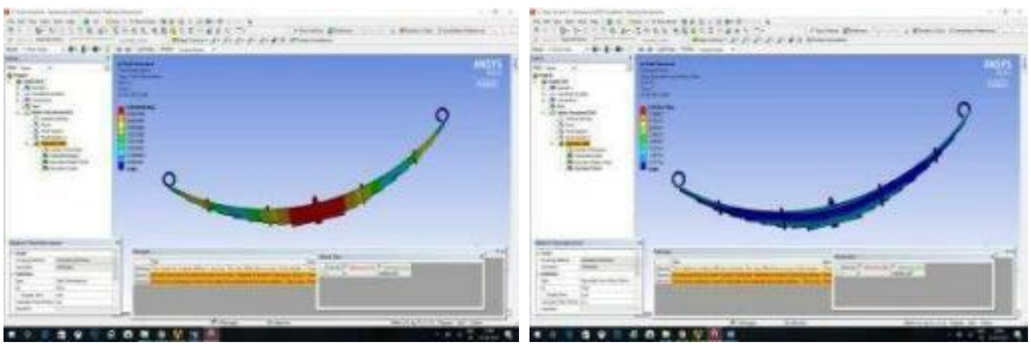


**Fig6.5 Epoxy Carbon**

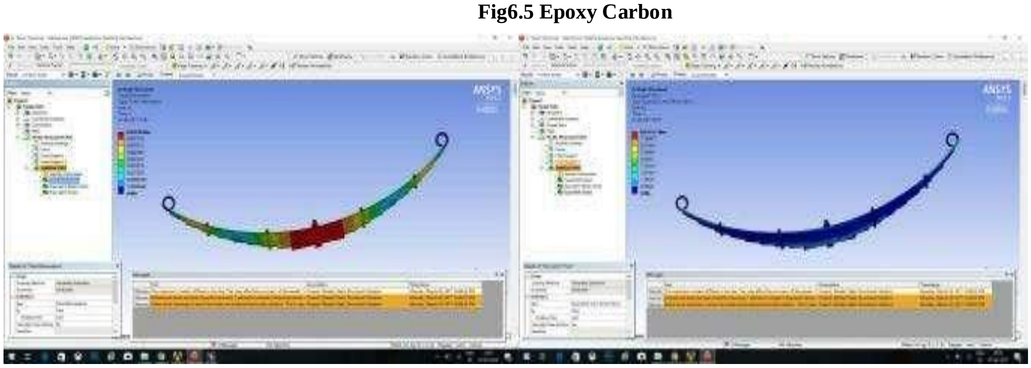


**Fig6.6 Aluminum Alloy**

**Fig6.7 Titanium Alloy**

## 7. COMPARISON OF THEORETICAL AND ANALYSIS RESULT:

Comparison of theoretical stress, deformation and weight with that of the results obtained from the Ansys software:

| SR.NO. | MATERIAL | THEORETICAL ($(N/mm^2)$) | ANSYS ($N/mm^2$) |
|---|---|---|---|
| 1 | STEEL | 60 | 58.38 |
| 2 | E-GLASS/EPOXY | 60 | 62.20 |
| 3 | EPOXY CARBON | 60 | 64.15 |
| 4 | ALLUMINIUM ALLOY | 60 | 60.15 |
| 5 | TITANIUM ALLOY | 60 | 58.92 |

**Table7. 1 Comparison of Stress**

| SR.NO. | MATERIAL | THEORETICAL ((MM) | ANYSYS (MM) |
|---|---|---|---|
| 1 | STEEL | 0.135 | 0.139 |
| 2 | E-GLASS/EPOXY | 2.97 | 3.50 |
| 3 | EPOXY CARBON | 2.90 | 3.22 |
| 4 | ALLUMINIUM ALLOY | 0.38 | 0.386 |
| 5 | TITANIUM ALLOY | 0.288 | 0.277 |

**Table7.2 Comparison of Deformation at 3200N**

| SR.NO. | MATERIAL | THEORETICAL | ANYSYS |
|---|---|---|---|
| 1 | STEEL | 16.85 | 18.50 |
| 2 | E-GLASS/EPOXY | 4.25 | 3.66 |
| 3 | EPOXY CARBON | 3.14 | 3.56 |
| 4 | ALLUMINIUM ALLOY | 5.90 | 6.61 |
| 5 | TITANIUM ALLOY | 9.87 | 11.85 |

**Table7.3 Comparison of Weight**

Table 7.1 shows the comparison of stress in theoretical and computational for the steel and other composite materials, the theoretical stress is 60 N/mm2, where as the stress values obtained using Ansys for different materials are nearly to 60 N/mm2. Now the theoretical values are very close to the computational using ANSYS

Table7.2 shows the comparison of the theoretical and Ansys results of deformation for various materials. The Ansys values are close to the theoretical values

Table7.3 shows the comparison of the theoretical and Ansys results of weight of the leaf spring for different materials. The ANSYS values are close to that of the theoretical leaf spring weight.

## 8. CONCLUSION:

This research work provides comparative analysis between conventional steel, and E-Glass/Flax/Epoxy based hybrid composite leaf spring. The hybrid composite leaf spring is found to have lesser stresses and negligible higher deflection as compared to conventional steel leaf spring. Weight can be reduced by 88.49% if steel leaf spring is replaced by E- glass/Flax/Epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle. Also following result have been concluded with this research work.

1. Static analysis of leaf spring for different material combination under similar loading condition has been done for all design cases.
2. Results for selected parameters are obtained for all design cases of leaf spring.
3. Total deformation, equivalent elastic strain, equivalent (Von-Mises) stress, strain energy and mass results have been analyzed for different material combination in different design cases of leaf spring.
4. This method of analysis is more cost effective, efficient and less time consuming than other methods of solution.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**REFERENCES**


1. Mr. Akshay Kumar *et.al*, Design, Analysis, Manufacturing and Testing of Mono Composite Leaf Spring Using UD E-Glass Fiber/Epoxy. International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 12, December 2014 ISSN (online): 2348 – 7550
2. Anjish M George *et.al*, DESIGN AND ANALYSIS OF LEAF SPRING BY USING HYBRID COMPOSITE MATERIAL International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 04 Issue: 04 | Apr -2017 www.irjet.net p-ISSN: 2395-0072
3. Ajahar Sayyad *et.al*, Design And Analysis Of Leaf Spring By Using Composite Material International Research Journal of Engineering and Technology **(**IRJET) Volume: 07 Issue: 08 | Aug 2020 e-ISSN: 2395 p-ISSN: 2395-0072
4. Chaitali Chaudhari Application of Design of Experiment (DOE) Method for Optimum Parameters of "Mahindra Bolero" Leaf Spring International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE) Volume 2, Issue 4, April 2017 **13** ISSN (Online): 2456-1290
5. G. Goudah, E. Mahdi, A.R. Abu Talib, A.S. Mokhtar, et al.Automobile Compression Composite Elliptic Spring. IJET. 2006; 3(2): pp-139-147.
6. M. M. Patunkar, D. R. Dolas. Modelling and Analysis of Composite Leaf Spring under theStatic Load Condition by using FEA.IJMIE. 2011; 1(1): pp-1-4.
7. VinkelArora, GianBhushan, M.L. Aggarwal. Eye Design Analysis of Single Leaf Spring in Automotive Vehicles Using CAE Tools.IJAET. 2011; 1(1): pp-88-97.
8. Kumar Krishan, Aggarwal M.L. A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools. RJRS. 2012; 1(2): pp-92-96.
9. Dara Ashok, M. V. Mallikarjun, Venkata Ramesh Mamilla. Design and Structural Analysis of Composite Multi Leaf Spring.IJETED. 2012; 5(2): pp-30-37.
10. M. Raghavedra, Syed Altaf Hussain, V. Pandurangadu, et al. Modeling and Analysis of Laminated Composite Leaf Spring under the Static Load Condition by using FEA. IJMER. 2012; 2(4): pp-1875-1879.