Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 1, Number 2; October-December, 2014 pp. 54-60

http://www.krishisanskriti.org/jmsme.html

Design and Static Structural Analysis of Simple Leaf SPRING of Maruti Omni

Shahrukh Salam[1], Gunendra Yadav[2] and Harsh R. Agrawal[3]

[1]CCET, Bhilai Plot-7, street-13, Pragati Nagar Risali, Bhilai, (Chhattisgarh)
[2]BIT, Durg Q. No-2E, Street-28A, Sector-10, Bhilai, (Chhattisgarh)
[3]BIT, Durg Behind Zila Collectorate, Tulsipur Rajnandgaon (Chhattisgarh)
E-mail: [1]shahrukhsalam786@gmail.com, [2]gunendrayadav0303@gmail.com, [3]harshagrawal1993@gmail.com

Abstract: *Leaf spring is one of the key components of vehicle suspension system. A big demerit of a leaf spring is that conventional leaf springs are usually manufactured and assembled by using number of leafs made of steel and hence the weight is more.*
So, by reducing the number of leaves and increasing the strength of leaves, we can reduce the weight of the leaf spring unit for absorbing the same amount of shock and thus providing better stability to the automobile. This will be a better suspension.
A composite leaf spring can be made by a composite material called as "E-Glass/Epoxy". EGlass fibre reinforced epoxy composites was fabricated by filling varying concentration of aluminium oxide(Al2O3), magnesium hydroxide(Mg(OH)2), silicon carbide (SiC), and hematite powder.
*Here, **PRO-E** and **ANSYS** are used for the modelling and analysis of leaf spring. Leaf springs made up of steel and E-Glass/Epoxy are analysed.*
*By the results obtained from the analysis, a comparison of two materials is also done to obtain the most suitable material. At present, the leaf spring unit used in the car has a total weight of about **16 kilograms.** So, we can replace the leaf spring used in the car with another leaf spring of a better material. It will also help to optimize the leaf spring suspension system by reducing the weight and increasing the stability.*

1. INTRODUCTION

According to A.M. Wahl (1991): "A mechanical leaf spring may be defined as an elastic body whose primary function is to deflect or distort under load (or to absorb energy) and which recovers its original shape when released after being distorted". A leaf spring is the main component of a suspension system.

2. SUSPENSION SYSTEM

"Suspension" is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. The suspension system of an automobile separates the wheel axle assembly from the body. The automobile chassis is mounted on the axle, not direct but through some form of springs.

All the parts which perform the function of isolating the automobile from the road shocks are collectively called suspension system. Broadly speaking, suspension system consists of a spring and a damper. The energy of road shocks causes the spring to isolate. These oscillations are restricted to a reasonable level by the damper, which is more commonly called a shock absorber.

3. LEAF SPRING

Semi elliptic leaf springs are universally used for suspension in light and heavy commercial vehicles. For cars, they are widely used for rear suspension. Leaf springs are also known as flat spring. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. Thus the leaf springs may carry lateral loads, brake torque, driving torque etc., in addition to shocks.

4. CONSTRUCTION

The leaf springs consist of a number of leaves called blades. The blades vary in length. The composite spring is based on the theory of a beam of uniform strength. The longest blade has eyes on its ends. This blade is called master leaf. All the blades are bound together by means of rebound clips or steel straps.

The spring is supported on the axle, front or rear by means of U- bolt. One end of the spring is mounted on the frame with a simple pin, while on the other end connection is made with a shackle. When the vehicles comes across a projection on the road surface, the wheel moves up, deflecting the spring. This changes the length between the spring eyes. If both ends are fixed, the spring will not be able to accommodate this change of length. This is avoided by means of a shackle at one end which provides a flexible connection.

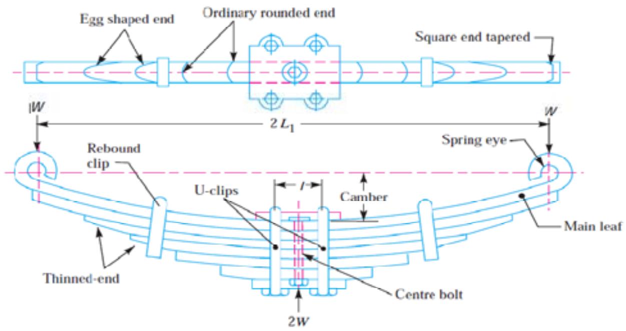


Fig. 1.1: Leaf Spring

5. COMPOSITE MATERIALS

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

Composites are made up of individual materials referred to as constituent materials. There are two main categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties.

The physical properties of composite materials are generally not isotropic (independent of direction of applied force) in nature, but rather are typically anisotropic (different depending on the direction of the applied force or load). For instance, the stiffness of a composite panel will often depend upon the orientation of the applied forces and/or moments. Panel stiffness is also dependent on the design of the panel. For instance, the fibre reinforcement and matrix used the method of panel build, thermoset versus thermoplastic, type of weave, and orientation of fibre axis to the primary force.

Advantages of Composite Materials

a) Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic materials.
b) Because of their low specific gravities, the strength weight-ratio and modulus weight-ratios of these composite materials are markedly superior to those of metallic materials.
c) Another unique characteristic of many fibre reinforced composites is their high internal damping. This leads to better vibration energy absorption within the material and results in reduced transmission of noise and vibration to neighbouring structures.

COMPOSITE LEAF SPRING

The Composite leaf spring is lighter than steel, retains its original arch, (absolutely no "sagging") and gives more side bite on the track. The first major structural application of composite is the corvette rear leaf spring in 1981. A composite leaf spring can be made by a composite material called as “E-Glass/Epoxy”. E-Glass fibre reinforced epoxy composites was fabricated by filling varying concentration of aluminium oxide(Al_2O_3), magnesium hydroxide($Mg(OH)_2$), silicon carbide (SiC), and hematite powder.

6. DEMERITS OF CONVENTIONAL LEAF SPRING

a) They have less specific modulus and strength.
b) Increased weight.
c) Conventional leaf springs are usually manufactured and assembled by using number of leafs made of steel and hence the weight is more.
d) Its corrosion resistance is less compared to composite materials.
e) Steel leaf springs have less damping capacity.

7. MERITS OF COMPOSITE LEAF SPRING

a) Reduced Weight.
b) Due to laminate structure and reduced thickness of the mono composite leaf spring, the overall weight would be less.
c) Due to weight reduction, fuel consumption would be reduced.
d) They have high damping capacity; hence produce less vibration and noise.
e) They have good corrosion resistance.
f) They have high specific modulus and strength.
g) Longer fatigue life.

8. BRIEF DESCRIPTION OF MARUTI OMNI:-

Maruti Omni is a vehicle manufactured by Maruti Udyog in India. Maruti Omni is a micro van. In Maruti Omni, front suspension consists of McPherson strut type with gas filled shock absorbers and rear suspension consists of leaf spring with shock absorbers. Conventionally, leaf spring used in Maruti Omni is made up of steel. This leaf spring consists of a single leaf used in each side of rear axle and connected to the axle by a U bolt.

Fig. 1.2: Leaf Spring Used In Maruti Omni

9. LITERATURE REVIEW

Prediction and improvement of leaf spring strength – A few papers were discussed about developing and validating procedures for predicting the deflection and stress developed in the leaf spring.

The experimental results from testing the leaf springs under static loading containing the stresses and deflection were analysed (1). The Testing has been done for unidirectional E-Glass/Epoxy mono composite leaf spring only. Since the composite leaf spring is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. Since, the composite spring is designed for same stiffness as that of steel leaf spring, both the springs are considered to be almost equal in vehicle stability. The major disadvantages of composite leaf spring are chipping resistance. The matrix material is likely to chip off when it is subjected to a poor road environments (that is, if some stone hit the composite leaf spring then it may produce chipping) which may break some fibres in the lower portion of the spring. This may result in a loss of capability to share flexural stiffness. Composite leaf springs made of polymer matrix composites have high strength retention on ageing at severe environments.

Computer aided design and analysis of a conventional leaf spring was carried out (2), with experimental design considerations and loading conditions. The material of the leaf spring is 65Si7. The CAD model of leaf spring is prepared in CATIA and analysed using ANSYS 12. The CAE analysis of the leaf spring is performed for the deflection and stresses under defined loading conditions, using ANSYS 12. The experimental and CAE results are compared for validation.

The finite element modelling and analysis of a multi leaf spring has been carried out (3). It includes two full length leaves in which one is with eyed ends and seven graduated length leaves. The material of the leaf spring is SUP9.The FE model of the leaf spring has been generated in CATIA V5 R17 and imported in ANSYS-11 for finite element analysis, which are most popular CAE tools. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining them under defined boundary condition. Bending stress and deflection are the target results. A comparison of both i.e. experimental and FEA results have been done to conclude.

The linear analysis method that is used in virtual analysis of the structure gave more precise results on leaf spring instead of non-linear analysis (4). No significant differences between two tested boundary conditions were found (i.e. bigger bushing that turns freely or while the smaller bushing that is free in the x axis). It has been observed that computer-aided analysis can be used as an alternative for laboratory tests because the results that were obtained from both methods were quite similar. Based on these results , using computer aided calculation methodologies is both cost effective and can help develop better, market specific products. The results of this study could also be used when developing new automobile models, before construction of real prototypes and pre-serial production cars.

FEM gives the prediction of critical areas from the viewpoint of static loading(5) . The results of non-linear static analysis of 2D model of the leaf spring using the commercial solver and analytical results show better correlation. The stiffness of the leaf spring is studied by plotting load versus deflection curve for whole working load range which shows the linear relationship. Using the constant amplitude loading, the fatigue damage and life of the spring has been predicted. From the damage contour, the highest damage value is in acceptable range. This study will help to understand more, the behaviour of the spring and its give information for the manufacturers to improve the fatigue life of the spring using CAE tools. It can help to reduce cost and times in research and development of new products

10. PROBLEM IDENTIFICATION

The Maruti Omni van is basically a Japanese commercial van that has been converted with some modification into a passenger vehicle. This is basically an underpowered vehicle mainly due to its excessive weight.

It is heavier than a car because its body is not aero dynamical, also due to its stance, it appears to be slightly unstable. In high speed crosswinds, the Omni becomes unstable and shaky because their wheels are small and the Centre of gravity is high.

Fig. 3.1: Non aero dynamical shape of Maruti Omni.

The Omni also has tendency to pitch and bounce on an uneven terrain. The ride quality is also not up to regular standards due to the suspension, which appears to be leaf spring linkage.

Current issue in Automobile, Aerospace, and Marine etc. is to reduce the weight of product by maintaining its strength. In Automobile sector, Leaf spring of steel material which is used in suspension system can be replaced by composite material due to its high strength to weight ratio and the composite materials have more elastic strain energy storage capacity.

11. OBJECTIVES OF STUDY:-

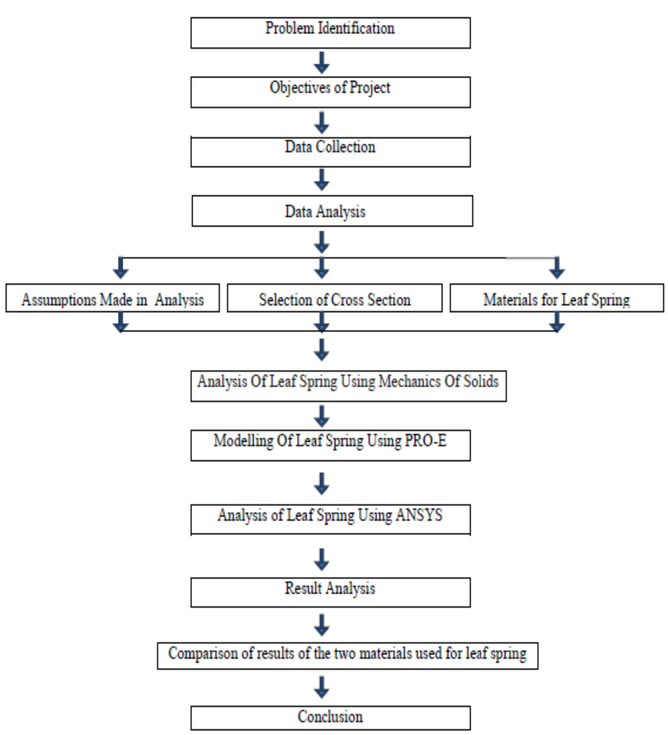
This study tackles and overcomes with these problems sequentially, which are stated below:-

- Static analysis of simple mono steel leaf spring using mechanics of solids.
- Modelling of simple steel leaf spring and analysis using PRO-E & ANSYS.
- Analysis of composite leaf spring.
- Comparison of result of both the analysis.
- Composite leaf spring can be a better alternate of steel leaf spring for the same amount of load and shocks.

12. METHODOLOGY

The analysis of simple leaf spring is done by conventional technique and by using ANSYS 14.0. The flowchart below

shows the steps used in the analysis:-



13. DATA COLLECTION:-

Table 4.1: Design Specifications Of Steel Leaf Spring Used In Maruti Omni

Total length of 1 leaf	**1050 millimetres**
Normal static load of car (Curb Weight)	785 kgf
Thickness of 1 leaf	5 millimetres
Width of 1 leaf	50 millimetres
Per spring weight	8 kilograms
Total weight of spring on the axle	16 kilograms (2 leaves)
Leaf camber	140 millimetres

So, it can be seen that the conventional steel leaf spring used in Maruti Omni is very heavy and it can thus result in instability of the vehicle. Its strength to weight ratio is also less.

In this analysis, the conventional steel multi leaf spring of Maruti Omni (8 seater) is tested for static load condition analytically and results are compared with an experimental test. With the results, we shall check the replacement of steel leaf spring by composite leaf spring theoretically by the use of PRO-E and ANSYS. Here we are going to compare weight to strength ratio of both. **"Here, we have tested the leaf spring for a load of 50 kgf."**

DATA ANALYSIS

ASSUMPTIONS MADE IN ANALYSIS

- ➢ All non-linear effects are excluded.
- ➢ The stress-strain relationship for composite material is linear and elastic; hence Hooke's law is applicable for composite materials.
- ➢ The leaf spring is assumed to be in vacuum.
- ➢ The load is distributed uniformly at the middle of the leaf spring.
- ➢ The leaf spring has a uniform, rectangular cross section.

SELECTION OF CROSS SECTION

The following cross-sections of mono-leaf spring for manufacturing easiness are considered.

- ➢ Constant thickness, varying width design.
- ➢ Varying width, varying thickness design.
- ➢ Constant thickness, constant width design.

In the present work, only constant cross-section design method is selected due to the following reasons: due to its capability for mass production and accommodation of continuous reinforcement of fibres. Since the cross-section area is constant throughout the leaf spring, same quantity of reinforcement fibre and resin can be fed continuously during manufacturing.

MATERIALS FOR LEAF SPRING

The material used for leaf springs is usually a plain carbon steel (C-45) having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel produces greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

A composite material E-GLASS/EPOXY is also being tested under same loading conditions to find out whether it can replace steel or not.

14. ANALYSIS OF LEAF SPRING BY CONVENTIONAL METHOD (USING MECHANICS OF SOLIDS)

As per MOS, consider a single plate fixed at one end and loaded at the other end as shown in Fig. . This plate may be used as a flat spring.

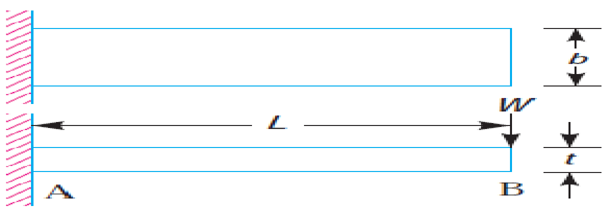


Fig. 4.1: Flat spring (cantilever type)

Let, t=Thickness of Plate,
b=Width of Plate, and
L=Length of Plate or Distance of the Load W from the Cantilever end.

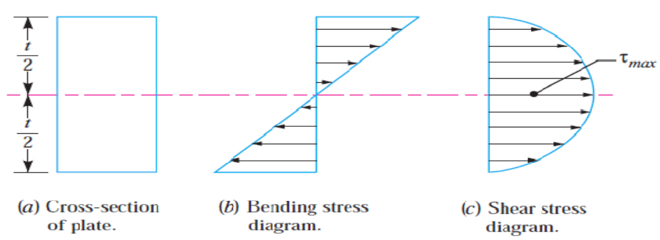


Fig. 4.2: Stress diagrams

An automobile spring (semi-elliptical spring) with length 2*L* and loaded in the centre by a load 2*W*, may be treated as a double cantilever.

The plate of cantilever is cut into a series of *n* strips of width *b* and these are placed as shown in Fig.

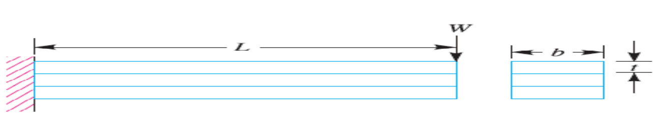


Fig. 4.3: Cantilever Cross-Section

The final formulae used for calculating the stress and deflection of the leaf spring is given by:-

$$\sigma_G = \frac{12\, W.L}{b.t^2\ (2\, n_G + 3\, n_F)}$$

$$\delta = \frac{12\, W.L^3}{E.b.t^3\ (2\, n_G + 3\, n_F)}$$

Where,
σ_G=stress induced in the graduated leaf.
δ=deflection of graduated leaf.
W=static load coming on the leaf.
L=length of leaf between the two eye ends.
b=width of leaf.
t=thickness or depth of leaf.
E=Young's modulus of material.
n_G=number of graduated leaves (including master leaf).
n_F=number of extra full length leaves.

FOR STEEL LEAF SPRING

Given, W=25kgf =25*9.81 =245.25N
L=525mm=0.525 m
b =50 mm=0.05 m
t=5 mm=0.005 m
E=200 GPa
n_G=1
n_F=0

By putting values in the formula,

$$\sigma_G = \frac{12\, W.L}{b.t^2\ (2\, n_G + 3\, n_F)}$$

σ_G=620.35 MPa

$$\delta = \frac{12\, W.L^3}{E.b.t^3\ (2\, n_G + 3\, n_F)}$$

δ=120.42 mm

15. MODELLING AND ANALYSIS OF LEAF SPRING USING PRO-E AND ANSYS (BASICS)

Design of components:

- The designing of all the mechanical members is first done by following the basic concepts of engineering mechanics, mechanics of solids, theory of machines and elements of machine design.
- Machine elements are designed in such a way so that parts are easily available in the local market and hence, the cost of the prototype doesn't exceed a limit.
- Care is taken while designing to keep fabrication process as simple as possible.

Computer Aided Design:

- Using modelling software Pro-E 5.0, all the components to be used are modelled and assembled to form an assembly for both original and modified frames.

Computer Aided Analysis:

- Using analysis software Ansys 14.0, both the assemblies are subjected to respective static loads and analyzed and certain results are obtained.

Software to be used:

- PRO-E wildfire 5.0.
- ANSYS workbench 14.0.

16. MODELLING OF LEAF SPRING ASSEMBLY USING PRO-E

The model of the leaf spring and its various components is made in PRO-E and then they are connected together to get the complete leaf spring assembly.

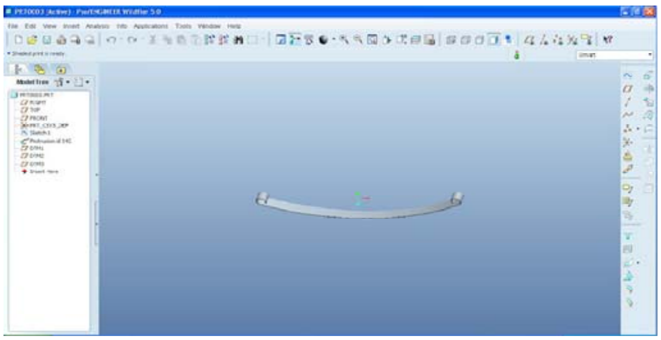


Fig. 4.4: Simple Leaf Spring in PRO-E

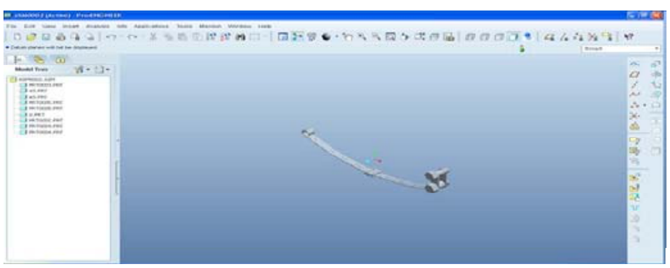


Fig. 4.5: Assembly of simple leaf spring system

17. ANALYSIS OF LEAF SPRING USING ANSYS

Parameters That Remain Constant during the Whole Analysis

In the experiment, we are analysing 2 leaf springs made up of 2 different materials which are subjected to forces of same magnitude.

Table 4.2: Unit System

Unit System	Metric (m, kg, N, s, V, A) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Analyzing the leaf spring made of steel and Epoxy:-

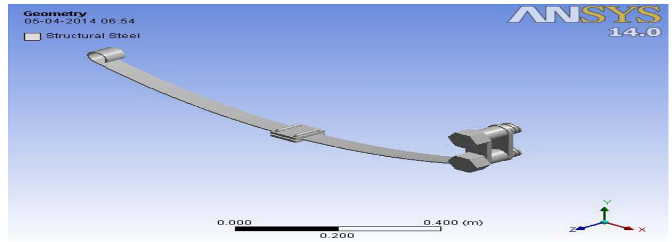


Fig. 4.9: Geometry of steel and Epoxy leaf spring

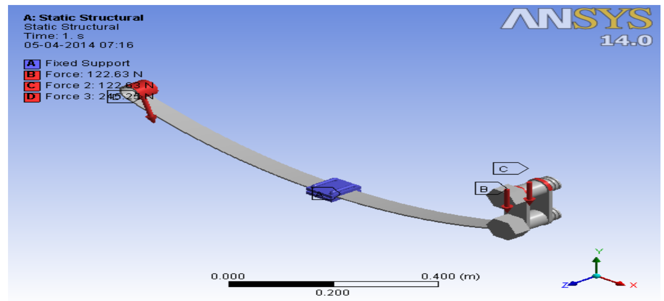


Fig. 4.10: Load Application on Leaf

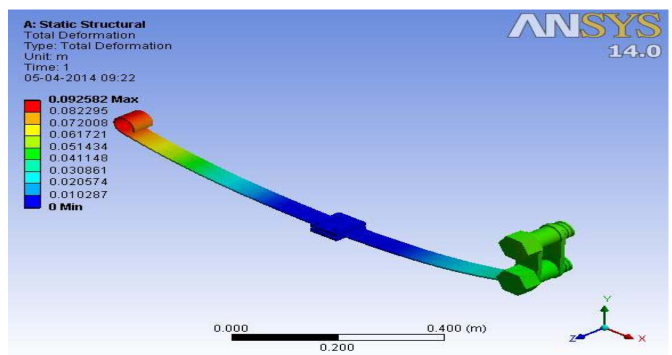


Fig. 4.11: Total Deformation in Steel Leaf Spring

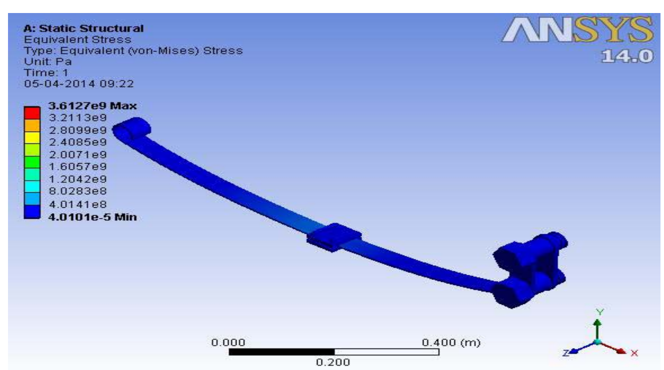


Fig. 4.12: Equivalent Stress in Steel Leaf Spring

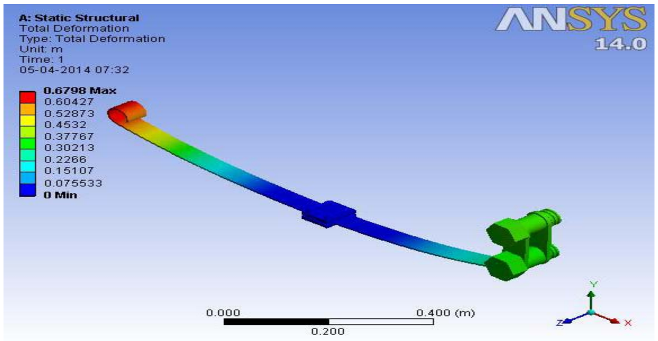


Fig. 4.13: Total Deformation in Epoxy Leaf Spring

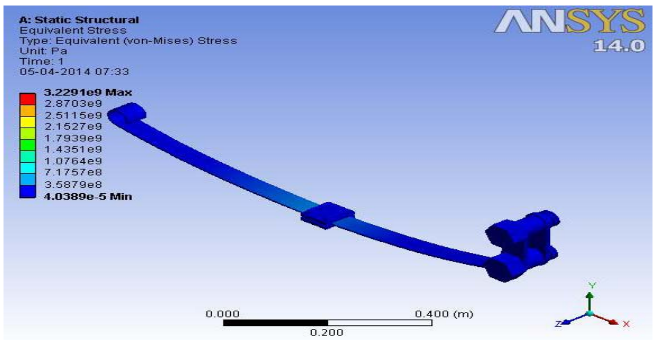


Fig. 4.14: Equivalent Stress in Epoxy Leaf Spring

18. RESULT

From the analysis, we get the following result:-

Table 5.1:- Comparison of Specifications And Analysis Results of Steel Leaf Spring used in Maruti Omni with that of Composite Leaf Spring

Points	Steel Leaf Spring	Composite Leaf Spring (Epoxy Leaf Spring)
Total length of 1 leaf	1050 millimetres	1050 millimetres
Normal static load on spring	50 kgf	50 kgf
Thickness of 1 leaf	5 millimetres	5 millimetres
Width of 1 leaf	50 millimetres	50 millimetres
Mass of a single leaf	10.071 kilograms	8.2051 kilograms
Stress Induced	0.62 GPa	0.43 GPa

Here, stress induced is taken as the mean of the last three colour band values of the equivalent stress Fig.

Therefore, we can replace the Conventional Leaf Spring used in Maruti Omni with a Composite Leaf Spring which will have lower stress for the same amount of load and thus will be a better suspension.

Composite material generally includes:

- Reinforced plastic such as fibre reinforced polymer.
- Metal composite.
- Ceramic composite.

E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view, as the E-glass/epoxy composite material has:

- Longer life than other type of composite material.
- Excellent adhesion, chemical and heat resistance.
- Excellent mechanical properties.
- High strength to weight ratio than other type of composite materials

19. CONCLUSION

By reducing the weight of automobile spare parts and increasing their strength (i.e. increasing their strength to weight ratio), we can increase the stability of a vehicle by reducing the unsprung weight and thus, preventing the vehicle from toppling under driving conditions. Suspension systems can be modified. The steel leaf spring used in Maruti Omni can be replaced with a composite leaf spring as composite materials are better in strength point of view as compared to steel. The stress coming in leaf spring made of composite material is less as compared to steel leaf spring for the same amount of load.

Bibliography

[1] Gulur Siddaramanna Shiva Shankar, SambagamVijayarangan, "Mono Composite Leaf Spring for Light Weight Vehicle: Design, End Joint Analysis and Testing", Vol. 12, 2005.

[2] VinkelArora, Dr.M.L.Aggarwal, Dr.GianBhushan, "A Comparative Study of CAE and Experiment Results of Leaf Springs in Automotive Vehicles", IJEST, 2011.

[3] Krishan Kumar, M.L.Aggarwal, "Finite Element Approach for Analysis of Multi Leaf Spring using CAE Tools", Research Journal of Recent Sciences, Vol. 1, 2012.

[4] ArifSenolSener, "Determination of Vehicle Components Fatigue Life Based On FEA Method and Experimental Analysis", International Journal Of Electronics, Mechanical And Mechatronics Engineering, Vol. 2, 2012.

[5] V.K. Aher, R.A. Gujar, J.P. Wagh, "Fatigue Life Prediction of Leaf Spring Based on Finite Element Analysis and Fatigue Life Simulation Method", 2012.

[6] Society of Automotive Engineers, "Spring Design Manual", 2011 Publication.

[7] R.S. Khurmi & J. K. Gupta, "A Textbook of Machine Design", 14th Edition, Eurasia Publishing House.