Analysis of Leaf Spring for Alternative Material Subjected to Fluctuating Loads

Ms. N. V. Gore[1], Prof. S.R. Kulkarni[2], Prof. P.G. Karajagi[3]
[1]P.G. Student Dept. of Mechanical Engineering, Siddhaant College of Engineering, Sudumbare, Pune
[2] Asst. Professor and P.G. Coordinator Siddhaant College of Engineering, Sudumbare, Pune
[3] Head of Mechanical Department Siddhaant College of Engineering, Sudumbare, Pune

***Abstract*— Lighter cars are quicker and handling is much better. Weight of the vehicle can be reduced in many ways. Leaf spring is key suspension element on vehicle, it plays important role in minimizing vibrations due to road deformities and also it is one of the major weighing part. Weight reduction can be achieved by changing material. Now a days composite material is being suggested as a replacement to steel for manufacturing leaf spring. Leaf spring is subjected to repeated loading and hence it is very necessary to analyze it for fluctuating loads.This work is proposed for fluctuating load analysis of leaf spring made of composite material, E-glass epoxy.In this work both the steel and composite leaf springs are subjected to fluctuating load and corresponding variable stresses are determined using ANSYS.**

***Key words* — Composite materials, variable stress, Leaf spring, Fluctuating load.**

I. INTRODUCTION

IT has become necessary to conserve natural resources and energy economization, reduction of weight has become main aspect of automobile industries now a days. Lighter cars are quicker and handling is much better. Weight of the vehicle can be reduced in many ways but correct way must be selected which does not compromise with comfort and performance of the vehicle. One of the suitable way is by changing material for different parts of the vehicle. Leaf spring is one of the major weighted component. It accounts for 10% to 20% unsprung weight of the vehicle. For this reason it has been it has been a component of interest for reduction of weight from few years. To achieve desired weight reduction and conserve natural resources it has become necessary for automobile industries to study materials like composite as alternative materials for leaf spring. By reducing the weight of vehicle fuel efficiency can also be increased.To reduce weight of leaf spring replacing existing steel with a composite material is being suggested now a days. Earlier studies have shown that composite material can be used for manufacturing a leaf spring in static conditions. But as the leaf spring is subjected to variable loading, testing it for static conditions will not be sufficient. To confirm the replacement of steel by composite material analysis must be done for fluctuating load.
Composite materials are superior to all known structure materials in specific strength, stiffness, high temperature fatigue strength etc. Composite materials are made from two physically different type of materials. matrix and reinforcement.These elements are combined in proper to obtain a new material which has properties superior to both materials taken individually.These materials are being widely used in industries due to their high strength to weight ratio. Since strain energy of spring is inversely proportional to density and young's modulus it is better to use material having low density and modulus of elasticity. Composite materials are commonly made from carbon, glass, kevier, etc and these fibers are stack together with the help of resins such as epoxy, polyester, vinyl ester.
It is studied earlier that for same applied load deflection of composite leaf spring is more than that of steel leaf spring.[4]Also maximum stress induced in the composite leaf spring is less than stress induced in steel leaf spring.[3] Use of composite material increases load carrying capasity under static loading.[2] there are several techniques used for fabrication of composite leaf spring, hand lay up technique is best suited for unit production and it requires minimum cost.[5]Ashish P. Borhade and Prof. Dr. J. T. Pattiwar Determined natural frequency of steel leaf spring using FFT analyzer and validated results with FEA analysis.[6] Trivedi Achyut v And Prof. R. M. Bhorania performed dynamic analysis of carbon/epoxy and graphite/epoxy composite leaf spring using ANSYS and determined natural frequency.[7]
Fluctuating stress is also called as alternating stress. This stress given by the equation

II. LEAF SPRING SPECIFICATIONS

In this work Mahindra Bolero Di leaf spring is considered for analysis. Leaf spring is having uniform thickness and constant cross section. Leaf spring specifications are listed below in table1.

Table 1 Leaf spring specifications

Total Length (L)	950 mm
Length of spring from eye to eye	800 mm
Thickness (T)	9.53 mm
Width (W)	63.5 mm
Load given on the leaf spring	8000 N

Material properties of 55Si2Mn90 steel are specified in the table 2.

Table 2 Material Properties of 55Si2Mn90 Steel

1	Ultimate tensile strength Su (Mpa)	1962
2	Yield tensile strength Su (Mpa)	1470
3	Modulus of elasticity E (Gpa)	210
4	Poisson ratio 0.3	0.3

A. Selection of composite material

In spring potential energy is stored as strain energy and then released slowly. So, it is desirable ho have a spring having increased energy storage capacity. It is studied earlier that stresses developed in composite leaf spring are much more less than steel leaf spring. But selection of correct composite is also important to get desired results, superior to steel leaf spring. Earlier study has shown that E-glass epoxy is the best suited composite amongst the several available composite materials.[9] Also cost of E-glass fibers is less as compared to Carbon or Graphite fibers. It has high chemical resistance.

resins For fabricating fiber reinforcement plastics (FRP) resins such as epoxy, polyester, vinyl ester, are being used. Among these resins epoxy show better inter laminar shear strength and good mechanical properties. Hence, epoxide is found to be best resins that would suit this application. Among different grades of epoxy resins Dobeckot 520F and 785 grade of hardener is used.[4]

Material properties of E-glass/Epoxy composite are specified in table 3.

Table 3 Material Properties of E-Glass/Epoxy

1	Tensile Strength (Mpa)	900
2	Compressive Strength (Mpa)	450
3	Poisson's Ratio	0.217
4	Density (Kg/m^3)	2.16×10^5
5	Flexural Modulus (Mpa)	40000

III. FINITE ELEMENT ANALYSIS OF LEAF SPRING

Finite analysis is carried out using ANSYS 14.5 version. First static analysis is done to find out maximum deflection and vonmises stress. After finding stress under static loading fluctuating load analysis is done for both steel and composite leaf spring. For analysis SOLID 46 eight noded element is used.

One end of the leaf spring is completelyconstrained and other end is constrained as $U_y = 0$, $U_z = 0$. Load of 8000N is applied and deformation and stress for both materials are computed.

A. Static Analysis

3-D model of leaf spring is drawn in CATIA V5R18 and analysis is done in ANSYS 14.5.

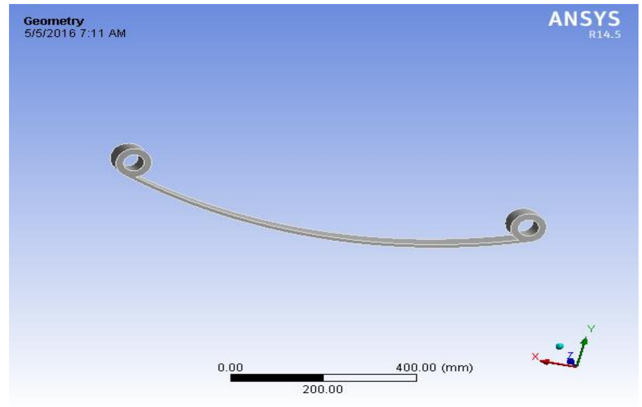

Fig. 1: 3-D Model of steel leaf Spring

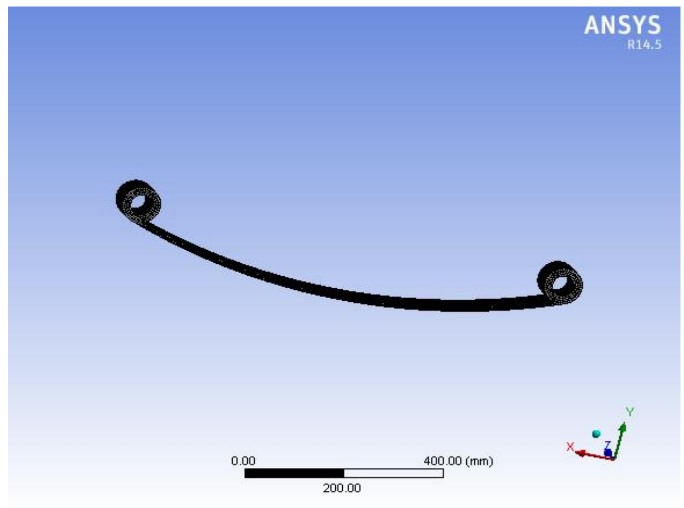

Fig. 2: Meshed model of steel leaf spring

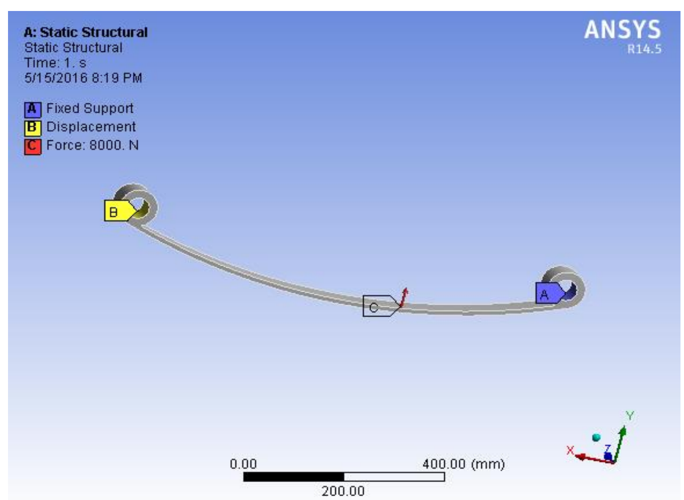

Fig.3: Boundary Conditions of steel leaf spring

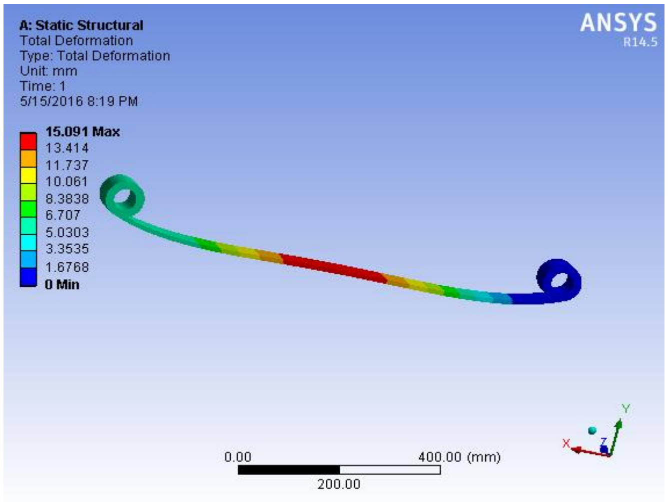

Fig. 4:Deformation of steel leaf spring.

Maximum deflection in steel leaf spring is 15.091 mm

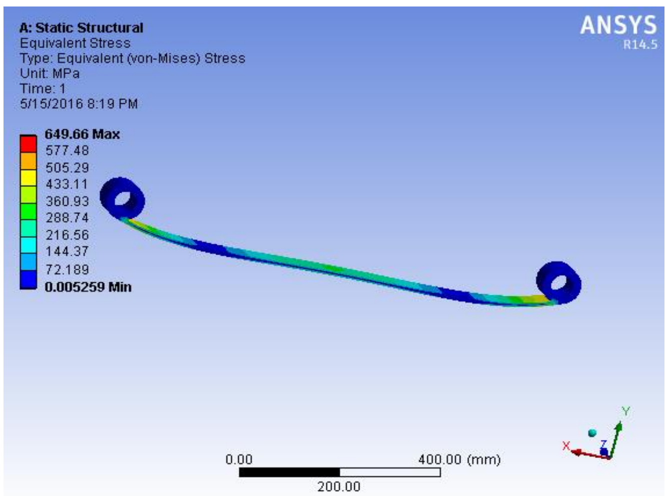

Fig.5: Stress induced in steel leaf spring.

Maximum stress induced in steel spring is 649.66 Mpa

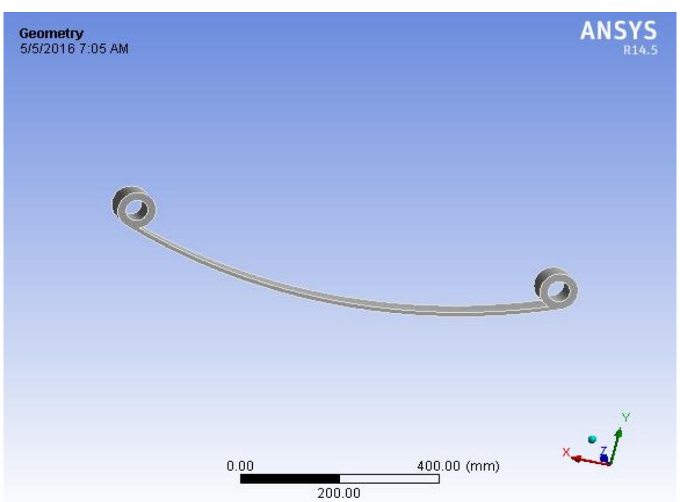

Fig.6: 3-D Model of composite leaf spring

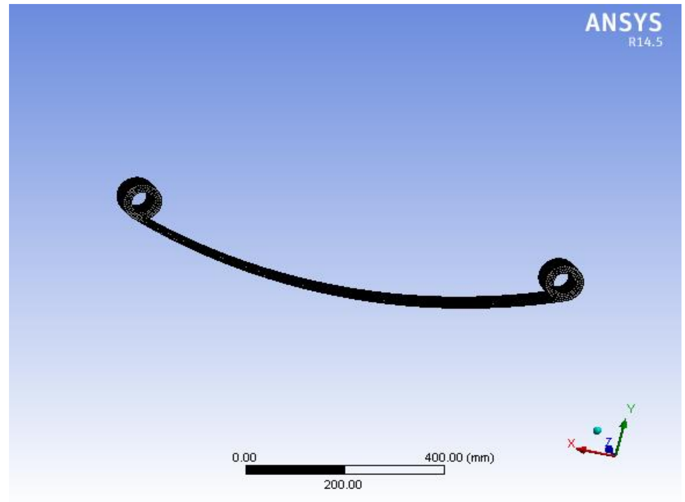

Fig.: 7 Meshing of composite leaf spring

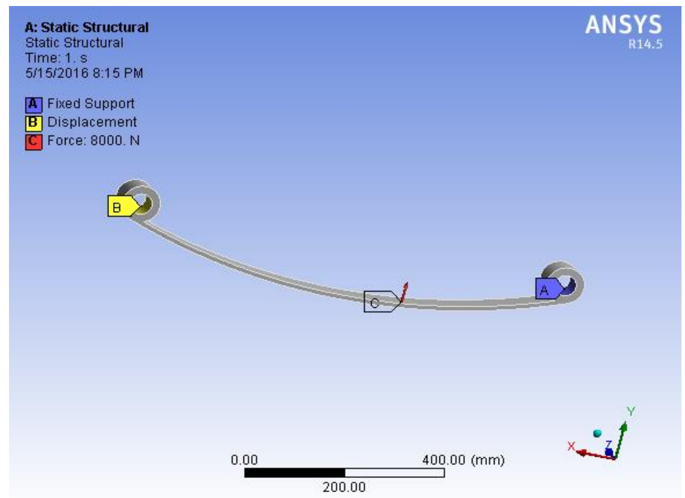

Fig.8: Boundary conditions for composite leaf spring

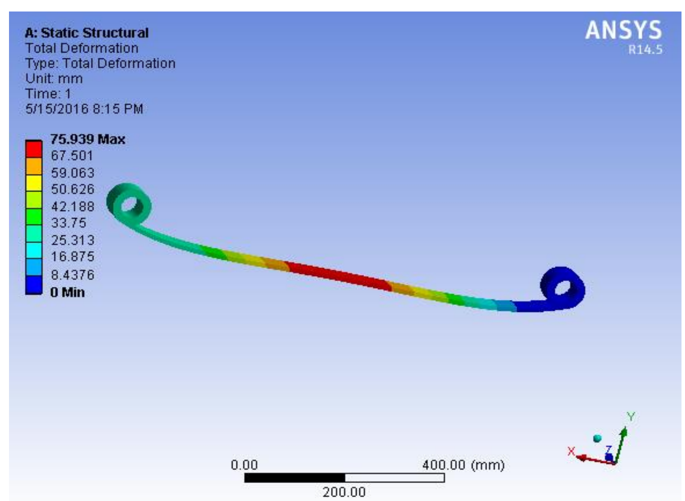

Fig.9: Displacement of composite leaf spring

Maximum displacement of composite leaf spring is 75.939 mm

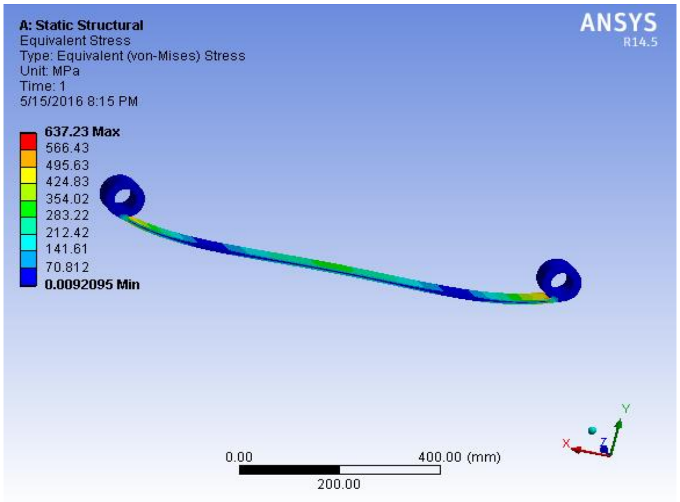

Fig.10: Max stress induced in composite leaf spring

Maximum stress induced in composite spring is 637.23 Mpa

B. Fluctuating load Analysis

When the material is subjected to repeated loading and unloading, fatigue is said to occur.At the loads above a certain threshold, developing of microscopic cracks starts in the areas such as surface, persistent slip bands (PSBs), and grain interfaces where stress concentration is high. After reaching a critical size, propagation of crack is sudden and this results in fracture of the structure. Analysis of vibration is one of the important component of a design, and hence it should not be overlooked. Life of structure or equipment gets shortened due to inherent vibrations. This may also result in complete or premature failure, which often causes hazardous situations. Hence it is required to do Detailed fatigue analysis to study possibility of failure or damage resulting from the rapid stress cycles of vibration.

For proper fatigue characterization of a material for a given application it is necessary to test the material for fluctuating loading. By applying cyclic load alternative stresses developed in steel and composite leaf spring are determined as follows. Stress ratios are also determined for both materials.

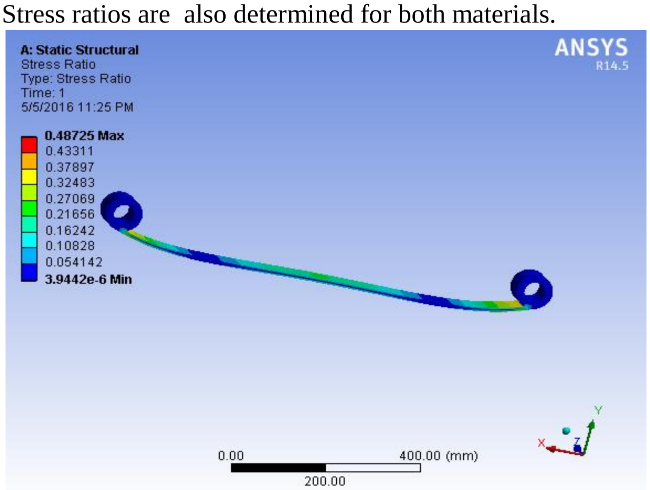

Fig.11: Stress ratio for steel leaf spring

Maximum stress ratio obtained for steel leaf spring is 0.48725 Mpa.

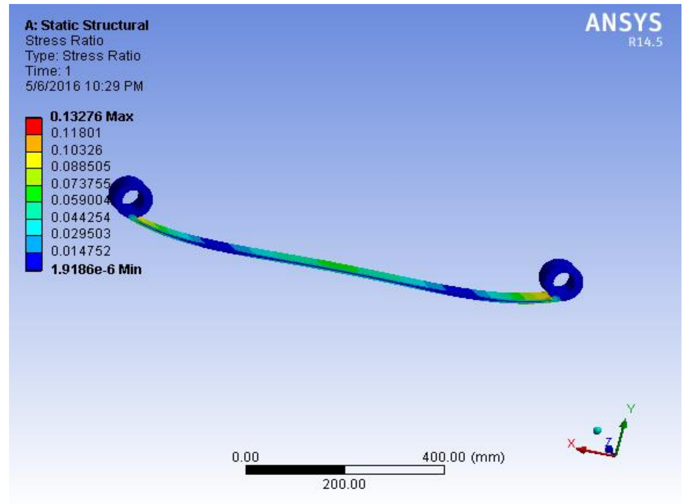

Fig.12: Stress ratio for compositeleaf spring

Maximum stress ratio obtained for composite leaf spring is 0.13276 Mpa.

IV. Results and Discussion

Stress, displacement and alternative stress for steel and composite leaf spring are determined by FEA analysis. Results are shown in the table below.

Table 4: stress and displacement in static condition

Measured Entity	Steel leaf spring	Composite leaf spring
Maximum stress (Mpa)	649.66	637.33
Maximum deformation (mm)	15.091	75.939

Table 5: Alternating stress for steel leaf spring

Fluctuating Stress MPa	Cycles
1069	200
441	2000
262	10000
214	20000
138	1.e+005
114	2.e+005
86.2	1.e+006

Table 6: Alternating stress for composite leaf spring

Fluctuating Stress MPa	Cycles
700	900

6	0	0	1 0 0 0
5	0	0	3 0 0 0 0
3	0	0	1.e+006
2	0	0	4.e+006
1	0	0	8.e+006
	0		1.75e+007

Stress ratio i.e. ratio of minimum stress to the maximum stress is obtained from fluctuating load analysis is are as shown in the table below.

Table 7:Stress ratio

	Steel leaf Spring	Composite leaf spring
Stress Ratio	0.48725	0.13276

V.CONCLUSION

1) FEA analysis of steel and composite leaf spring is carried out to determine static stress, deflection and fluctuating stress.
2) Maximum stress induced in steel leaf spring is 649.66 Mpa while that for composite leaf spring is 637.33 Mpa.
3) Maximum deformation of steel leaf spring is 15.091 mm while that for composite leaf spring is 75.939 mm.
4) Maximum stress ratio for steel leaf spring is 0.48725 and that for composite leaf spring is 0.13276.
5) Maximum number of cycles the steel leaf spring can sustain is 1.e+006 for the stress 86.2 Mpa and for composite leaf spring it is 1.75e+007 for 0 stress.

So it can be concluded from above results that using a composite material for leaf spring can give better performance than a steel leaf spring, For the same applied load both static and fluctuating stress induced in the composite leaf spring are much lesser than that for steel leaf spring.
Also it is found that fatigue life of composite leaf spring is more than that of steel leaf spring.

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