Fluctuating analysis on leaf spring of a mini load carrier automobile

M Sai Krishna[*1], K Naresh Kumar [*2], Dr. B.Naga Raju [#3] , M. Raja Roy [#4]

[*1] PG Student, Anits Engineering College, Visakhapatnam, A.P, India

[*2,] Asst Prof of Mechanical Department, Anits Engineering College, Visakhapatnam, A.P, India

[#3] Professor of Mechanical Department, Anits Engineering College, Visakhapatnam, A.P, India

[#4] Asst Prof of Mechanical Department, Anits Engineering College, Visakhapatnam, A.P, India

Abstract

Leaf springs are widely used as suspension mechanical component for cars, trucks, and heavy motor vehicles to absorb the vibrations generated in the vehicle. The performance of the leaf spring mainly depends on the load with standing capabilities of the spring under fluctuating loading conditions and material selection. In this work an attempt is made to alter the material properties of leaf spring and study the performance of leaf spring by using Ansys workbench software against fluctuating loading conditions. The results are compared with the theoretical results under loading condition and the best material for the leaf spring is suggested against fluctuating load for a mini load carrier type of automobile.

Keywords - *Leaf spring materials, fluctuating load, Ansys work bench*

I. Introduction

A multi leaf spring consists of a series of flat plates, usually of semi elliptical shape in cross section. The leaf at the top has maximum length. The length gradually decreases from the top leaf to the bottom leaf. The longest leaf at the top is called master leaf. The extra full length leaves are stacked between the master leaf and graduated length leaves .Master leaf is bent at the ends to form spring eyes. Two bolts are s inserted through these eyes to fix the leaf spring to the automobile body. The leaves are held together by means of two U bolts and a centre clip. Rebound clips are provided to keep the leaves in alignment and prevent lateral shifting of the leaves during operation. At the centre, the leaf spring is supported to the axle of an automobile.

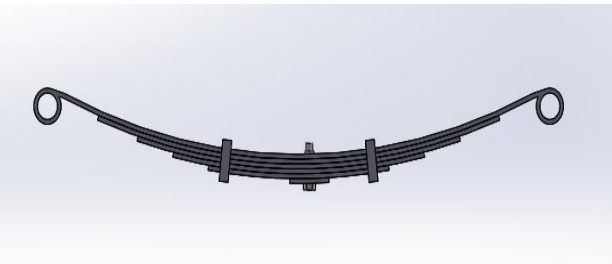

Fig1. Leaf spring of an automobile

II. Modelling and Analysis of Leaf Spring

A. Modelling

Modelling of the leaf spring was carried out by using solid works software and (.igs) format file of leaf spring was imported to ansys workbench. The dimensions of the leaf spring of a TATA SUPER ACE model type of mini load carrier used for this study are given in Table 1.

Table 1 Dimensions of leaf spring

S. No.	PARAMETER	VALUE
1	Total length of spring(eye to eye)	1050 mm
2	Number of graduated leaves	3
3	Total number of leaves	5
4	Thickness of each leaf	8.2 mm
5	Width of leaf spring	60.7 mm

Notations used in leaf spring analysis are

Total length of the leaf spring 2L= 1050 mm
L=525mm (From centroidal axis of U-bolt to centre axis of one end eye)
Total number of leaves N = 5 (n_f=2 & n_g = 3)
Width of each leaf b = 60.7mm
Thickness of each leaf t = 8.2 mm
Load applied on the leaf spring W = 75000 N

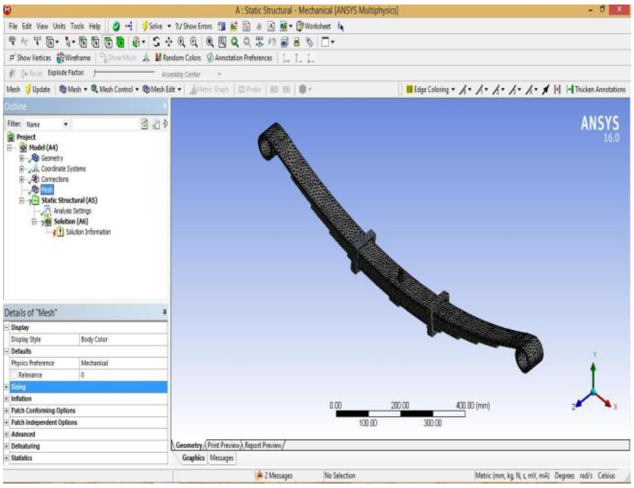

Fig 2. Leaf spring imported to ansys workbench

B. Loading and boundary conditions

The total load acting on the leaf spring is distributed to act equally at each end of the eye cross section of the leaf spring. In this analysis, the load acting on the leaf spring is considered as a fluctuating load varying from positive to negative with mean component of stress equal to zero. The total load acting on the spring is given by 2P = 75000 N. Therefore P value acting at each eye of the leaf spring is 37500N.The top and bottom portion of the bolt is fixed for this analysis which is used to join all the leaves together and clamped by using U –bolt to the rear wheel of an automobile. Many authors have worked on analysing the ability of leaf spring to sustain the loads by altering the material properties and performed static and modal and experimental works [1-9]. The present analysis is related to analysing the behaviour of the leaf spring against fluctuating loads acting on the ends of the eye of leaf spring. The estimated life and vonmises stresses were plotted for different materials and optimum material is selected for the design and manufacturing of the leaf spring.

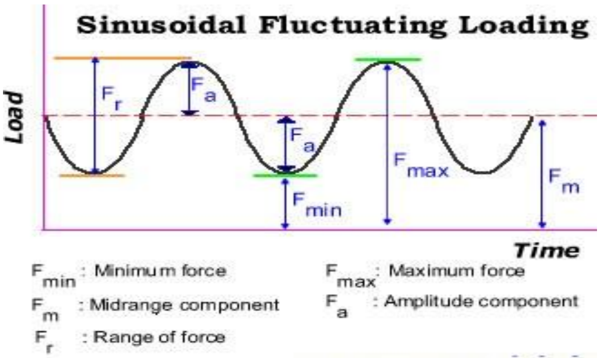

Fig 3. Sinusoidal fluctuating loading acting on Leaf spring

Table 2 Values of alternating stress varying with respect to number of cycles

Cycles	Alternating stress in (Pa)	Mean stress
10	3.99E+09	0
20	2.83E+09	0
50	1.90E+09	0
100	1.41E+09	0
200	1.07E+09	0
2000	4.41E+08	0
10000	2.62E+08	0
20000	2.14E+08	0
1.00E+05	1.38E+08	0
2.00E+05	1.14E+08	0
1.00E+06	8.62E+07	0

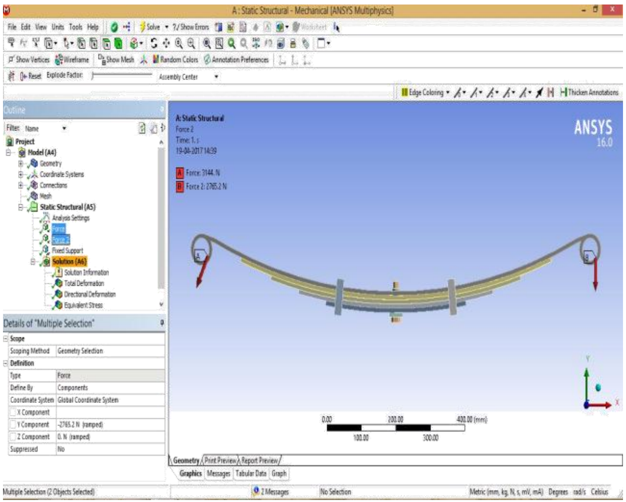

Fig 4. Position of load acting at the end of each eye of a leaf spring

C. Materials

The material selection for the leaf spring plays a vital role to with stand the fluctuating loads acting on the spring. At present plain carbon steel material is widely used in leaf spring suspension components for medium duty applications of automobile. For heavy duty applications of load carrying automobiles like trucks, alloy steels are widely used. The material selection for the leaf spring has to withstand the loads acting on the components and absorb the vibrations induced in the vehicle. The following table gives the materials used to analyse the behaviour of the leaf spring under fluctuating loading conditions.

Table 3 Material properties of various materials used in leaf spring analysis

Material	Young's modulus (E) Mpa	Density (g/cm^3)	Poisson's ratio	Ultimate tensile strength (Mpa)	Yield strength (MPa)
Structural steel	2x10^5	7.85	0.3	500	250
Aluminium alloy	68.9x10^3	2.7	0.32	290	276
Carbon fiber reinforced composite	228x10^3	1.59	0.28	3500	1750
Co-Cr-Ni Allloy	245x10^3	8.4	0.32	655	350

III. THEORETICAL CALCULATIONS

For the purpose of analysis, the leaves are divided in to two groups namely, master leaf along with graduated length leaves forming one group and extra full length leaves forming the other group. The group of master leaf along with graduated length leaves can be treated as a triangular plate.

The permissible bending stresses induced in the full length leaves is given by

$$\sigma_b = 6PL / nbt^2$$

$$= (6x37500x525) / (5x60.7x8.2x8.2)$$

$$\sigma_b = 5788.35 \text{ N / mm}^2$$

The permissible deflection at the end of the spring is given by

$$\delta = 12P L^3 / Eb t^3. (3 nf + 2 ng)$$

$$= \frac{(12x37500x525^3)}{(210 x10^3 x60.7x8.2^3x(6+6)}$$

$$\delta = 772.07 \text{ mm}$$

Where nf = Number of full length leaves = 2
ng = Number of graduated length leaves =3
E is young's modulus of steel material = 210GPa

IV. Results

A. *Carbon fiber reinforced composite leaf spring*

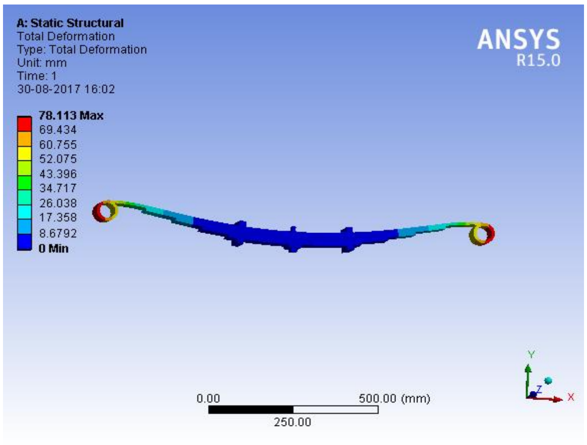

Fig 5. Deformation of CF reinforced leaf spring

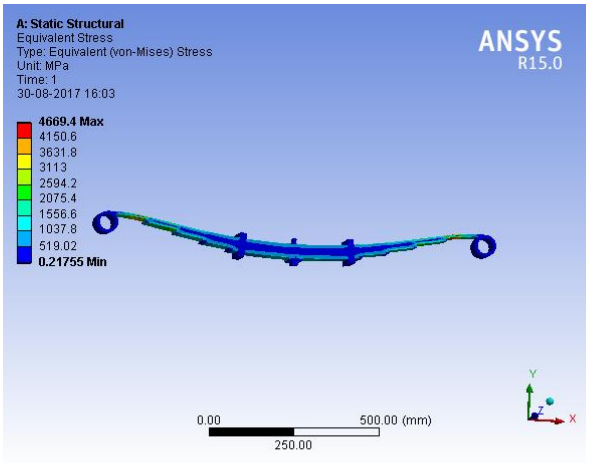

Fig 6. Vonmises stress values of CF reinforced leaf spring

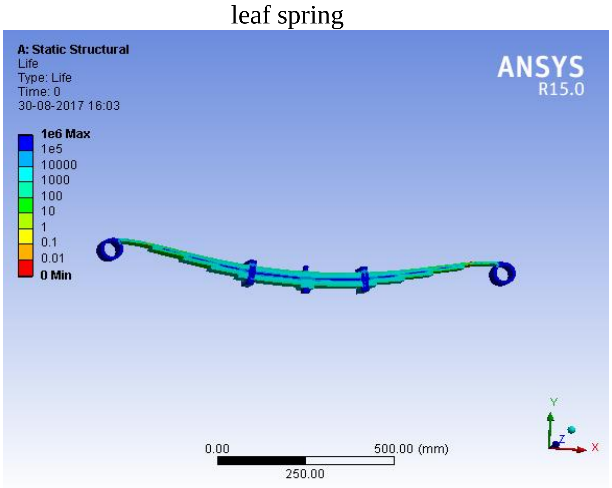

Fig 7. Life of CF reinforced leaf spring

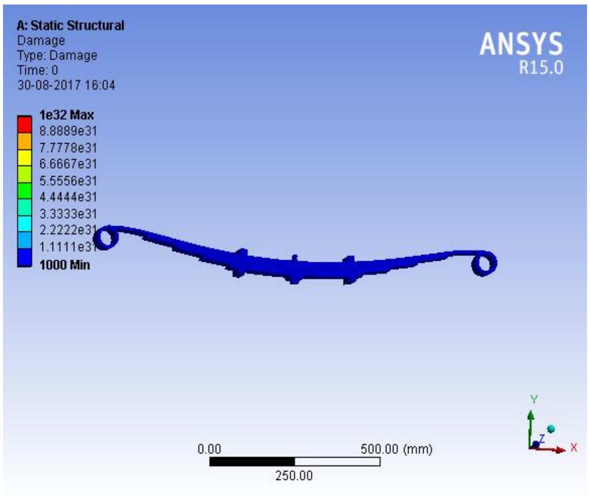

Fig 8. Damage of CF reinforced leaf spring

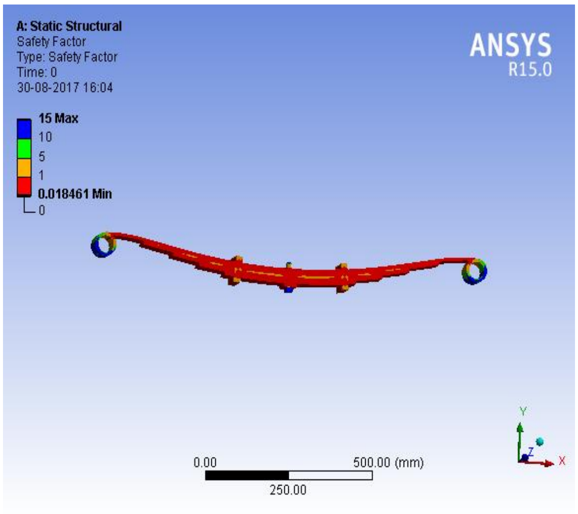

Fig 9. Safety factor of CF reinforced leaf spring

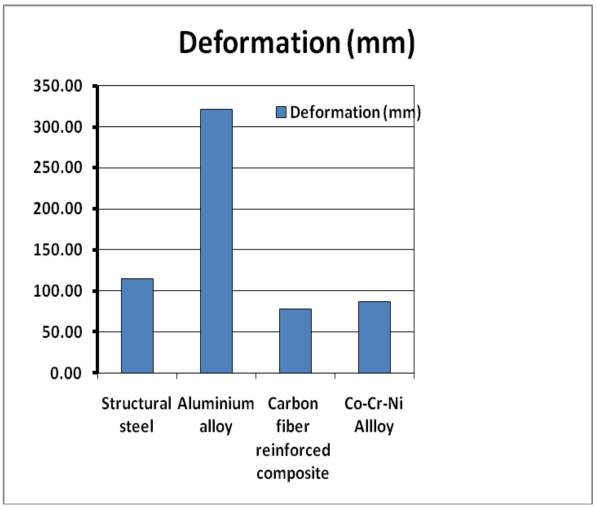

Fig10. Values of deformation for different materials

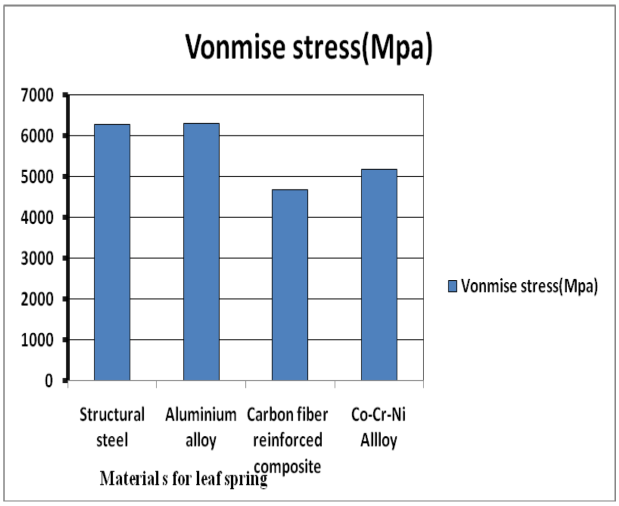

Fig11. Values of vonmises stress distribution for different materials

Table4. Values of different materials for leaf spring under fluctuating loads

Material	**Defor mation (mm)**	**Vonmises stress (Mpa)**	**Life**	**Damage**
Structural steel	114.59	6287.1	1x 10^6	1x 10^32
Aluminiu m alloy	321.35	6295.3	1x 10^8	1x 10^32
Carbon fiber reinforced composite	78.113	4669.4	1x 10^6	1x 10^32
Co-Cr-Ni Allloy	86.674	5181.11	1x 10^6	2.7x 10^7

V. CONCLUSION

In this work an attempt is made to alter the materials for the leaf spring of a mini load carrier type of automobile of TATA ACE make. The material properties of the leaf spring were altered and the behavior of the leaf spring was analyzed for fluctuating loading conditions. The analysis was performed by using ansys work bench to check the values of deformation, vonmises stress, life and damage with respect to the given fluctuating loads at the end of the eye. Based on the results, it was observed that the values of deformation and vonmises stresses values are less for carbon fiber reinforced composite laminated plate compared to other materials. It was also observed that, carbon fiber reinforced composite plate can easily sustain fluctuating loads and the value of Vonmises stress are below the permissible value of bending stress for the leaf spring material. The values of CO-Cr Ni alloy are also closer to the carbon fiber reinforced composite leaf spring plate. The values of Vonmises stress and deformation for CO-Cr Ni alloy is below the permissible values of the material. Therefore, carbon fiber reinforced composite plate and CO-Cr Ni alloy can be successfully used to replace the current existing materials for a mini load carrier type of automobile applications.

ACKNOWLEDGMENT

The authors would like to thank Anits engineering college, A.P, India for providing the original licensed Solid works and Ansys software for doing this project.

REFERENCES

[1] Roselita Fragoudakis eta l .Optimizing the development and manufacturing of 56SiCr7 leaf springs , Science direct , Elsevier, International journal of fatigue 103(2017), 168-175.

[2] Michail Malikoutsakis et al .Design , analysis and multi disciplinary optimization of high performance front leaf springs, Science direct , Elsevier, Theoretical and applied fracture mechanics 83(2016), 42-50.

[3] Chen Qian et al. Fatigue reliability design of composite leaf springs based on ply scheme optimization. , Science direct, Elsevier, Composite structures 168(2017), 40-46.

[4] Y.S.Kong et al . Fatigue life prediction of parabolic leaf spring under various road conditions. Science direct, Elsevier, Engineering failure analysis 46(2014), 92-103.

[5] Y.S.Kong et al. Failure assessment of a leaf spring eye design under various load cases , Science direct, Elsevier, Engineering failure analysis , 63(2016), 146-159.

[6] Stephan Krall et al .Investigation of dynamic behaviour of CFRP Leaf springs, Science direct, Elsevier, , 25th DAAAM international symposium Procedia Engineering 100(2015), 646-655.

[7] Goran Vukelic et al .Failure analysis of a motor vehicle coil spring , Science direct, Elsevier, , 21st European conference on fracture, Procedia Structural integrity 2 (2016), 2944-2950.

[8] C.K.Clarke et al. Evaluation of a leaf spring failure, ASM International, (2005)6: 54-63.

[9] S.Rajesh et al. Performance of leaf springs made of composite materials subjected to low frequency impact loading, springer, journal of mechanical science and technology 30(9), (2016) 4291-4298.