Scientific Journal Impact Factor (SJIF): 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

DYNAMIC ANALYSIS OF LEAF SPRING USING ANSYS

Amitkumar Magdum
Post Graduate Student, VIT University, Vellore, India.

Abstract- A leaf spring is the simplest type of suspension system, widely used in heavy commercial vehicles. The leaf spring is astructural member and acts as an energy absorbing system on the virtue of its deflection. In this research work leaf springs are analyzed using finite element methods considering the dynamic effect on stability of vehicle during cornering, off road drives etc. Parameters considered in the analysis are stiffness of the leaf spring, load acting on leaf spring. This paper includes the study of deflection and stress distribution of leaf spring for heavy duty vehicles, considering various recent materials. Also the paper aims at determining harmonic response of spring for different materials and loads. The results highlight the best suitable material for better dynamic behavior of leaf spring and its design optimization

Keywords- Leaf spring, Dynamic behavior, Stability, Static structural analysis, Harmonic response.

I. INTRODUCTION

A leaf spring is an elastic energy absorbing body, used as suspension system in heavy duty vehicles. The important function of the leaf spring is to deflect when loaded and come back to its original position when the load is removed. Leaf spring generally takes care of the load and vibration induced due to road surface irregularities. Leaf springs are generally monitored on the basis of its deflection attributes and ability to store and absorb the strain energy. Leaf spring used in automotive vehicles is generally of semi-elliptic form. In the construction of leaf spring, it is generally composed of number of curved plates, called leaf of the spring. The leaves of the spring are reducing in its length. The largest leaf is called master leaf; other leaves are called graduated leaves. All the leaves are assembled together with the help of the steel straps, nut and bolt. The leaf spring is on the axle of the vehicle with its ends attached to chassis frame. One of its ends is rigidly attached to the frame and other one is connected to chassis frame by shackle. The main purpose of shackle is to adjust the spring length when the road wheel comes across the road irregularities. That generally means, front end of the leaf spring is fixed and constrained in all directions while the rear end is constrained only in Y and Z directions and not in X-direction.

The energy absorbing capacity of spring is determined by the stiffness of springs. The main purpose of suspension system designed for automobile is to provide sufficient comfort for passengers as well as should improve the handling ability of car. Handling of car refers to the stability of vehicle during cornering, off road drives etc. To ensure design of spring to provide good comfort, the stiffness of springs should be less. On the contrary, to improve stability of vehicle the stiffness of springs should be more. But for automobile both comfort as well as stability is essential.

To obtain optimum comfort and handling of automobile, many of researches have done experiments and analysis of leaf springs. The stability achieved for an automobile varies with change in number of leaves, load acting, material, change in geometric parameters and type of leaf spring used for suspension. ShahrukhShamim [1] in a research paper presented the design and analysis of multi-leaf springs made of three different materials. The Static Structural analysis and Harmonic Response was done in ANSYS workbench 14.0. Harmonic analysis for vibrations due to road irregularity was carried out for all the materials. Von-Mises stress and deformation were the output parameters in static structural analysis. Yogesh Sharma [2] presented a paper determining the effect of change in cross section of leaf spring without changing the material. The modeling of leaf spring was carried in Catia

V5R20 modeling software and simulation was performed using ANSYS 14.5. Pengbo Wang [3] developed a nonlinear leaf spring FEA simulation technique. An explicit nonlinear FEA code which considers large deflection and inter-leaf contacts has been used in the simulation. Two different kinds of leaf springs which are variable stiffness leaf spring and tapered leaf spring have been studied using the FEA technology. The basic characteristics of leaf springs, stress, stiffness and inter-leaf slipage were accurately calculated. MurathanSoner [4] designed a leaf spring based on natural frequency in order to reduce noise and vibration. Prototypes of leaf springs were produced and their natural frequency measurements, stress levels under maximum load through strain gauges as well as life tests were completed. Correlation of virtual values and experimental outputs were compared and reported.

The paper presents design, analysis of spring and its behavior to improve the dynamic stability of automobile. In present work, multi-leaf spring with 5 leaves are designed and analyzed. The paper focuses on varying the material used for springs in order to change the stiffness. Also to understand the dynamic stability of spring the force acting on spring are varied as 12500 N and 18000 N. The modeling of spring is done in CREO 2.2 modeling software and the structural analysis is being done in ANSYS workbench 15.0. The spring deflection and equivalent stress obtained from the results are used to analyze the comfort and stability behavior of different springs. In the present scenario, composite materials are widely used in case of multi-leaf spring. Due to the use of composite materials weight reduction of leaf spring is possible without changing its load carrying capacity and stiffness. Some of the non-ferrous metals such as titanium alloys are also used to manufacture leaf spring, basically to improve its corrosion resistance. The various materials considered in this paper are titanium, s-glass epocxy and Kevlar composite. The paper also presents the harmonic response of spring for three different load and four different materials. The results are obtained in form of variation of amplitude of spring verses frequency ranging from 100 Hz to 1000 Hz.

II. METHODOLOGY

A. Problem Identification

1) Weight of the structural steel leaf spring is comparably high.
2) Varying stiffness required for achieve good comfort as well as stability.
3) Deflection attributes are poor in case of structural steel.
4) Poor ride properties due to the noise and friction

B. Objectives

1) To improve the stability(handling) of vehicle during cornering, off road drives etc.
2) To analyze the harmonic response and behavior of springs under varying loads.
3) To reduce weight of structural steel leaf spring by using other alloys and composite material.
4) To improve the deflection attributes of leaf spring.
5) To improve the ride properties and passenger comfort.

C. Correlation Parameters

1) Spring stiffness

Stiffness is generally expressed as ratio of force to deflection as,

K = force / deflection

Spring stiffness is important parameter to monitor spring deflection and its attributes.To improve the handling of vehicle the value of stiffness should be high.

2) Equivalent stress

Stress is the second important element for leaf springs. Equivalent Stress generally co-relate with durability of leaf springs.

3) Strain Energy

Strain energy is the energy stored in the elastic body under loading condition. Strain energy is the third co-relation parameter to compare the leaf springs with different materials.

D. Load Calculation

Vehicle name: Ford 5650

For Rated load condition;

1) Gross vehicle weight = 5000kg
2) Total Weight: 5000*10 = 50000 N
3) No. of leaf springs = 4
4) Load on each spring: 50000/4 = 12500 N

For Over load condition;

1) Gross vehicle weight = 4500kg
2) Load carried = 2700kg
3) Total weight: 7200*10 = 72000
4) No. of leaf springs = 4
5) Load on each spring: 72000/4 = 18000 N

E. Material Selection

Structural steel is the conventional material used for leaf spring. This research paper compares the result of structural steel with titanium alloy (Ti-6Al-4V) and composite materials having higher stiffness. The composite materials used are Kevlar and S-glass fiber composite. The properties of the materials used in the present work are as mentioned in Table I.

Table. I: Mechanical properties of materials.

Properties	**Structural Steel**	**Titanium Alloy**	**Kevlar Fabric**	**S-Glass Fiber Composi Te**
Density(g/cc)	7.85	4.43	1.42	2.48
Modulus of Elasticity(Mpa)	200000	113800	30000	86900
Poisson's Ratio	0.3	0.342	0.20	0.22
Tensile Yield Strength(Mpa)	250	880	-	

F. Modeling and Analysis

In the present work leaf spring of heavy duty commercial vehicles is taken for modeling and analysis, to compute and compare results. The spring modeled for the analysis is of Ford 5650 pick-up van. The dimensions for the same are obtained and modeled for 4 leaves including main leaf. The 3D modeling of leaf spring is carried out using CREO 2.2 and it is shown in Fig: 1.The dimensions of the leaf spring is shown in Table: II.

International Journal of Modern Trends in Engineering and Research (IJMTER)
Volume 03, Issue 10, [October– 2016] **ISSN (Online):2349–9745; ISSN (Print):2393-8161**

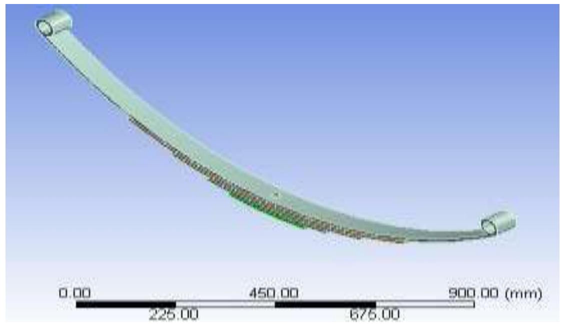

Fig. 1: Model of leaf spring

Table. II: Leaf spring geometry details

Parameters	**Dimensions for model**
Total span of leaf spring(mm)	1400
Width of each leaf(mm)	60
Thickness of master leaf(mm)	10
No. of leaves	5
Rated load (N)	12500
Over load(N)	18000

G. Meshing of the model

Mesh generation process is one of the important processes in finite element analysis. Meshing discretize entire model into very small elements. In this work "fine mesh" is selected for meshing the 3D model of the leaf spring. The meshed model of the leaf spring is shown in Fig: 2 below.

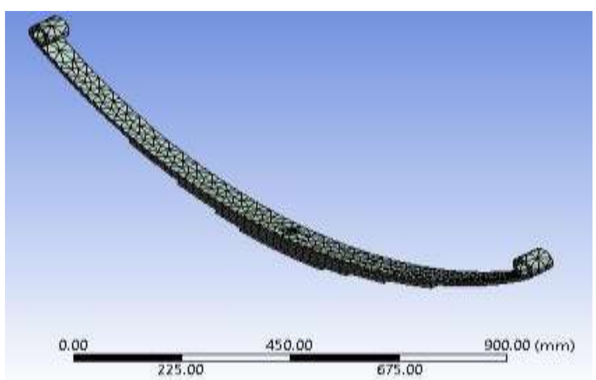

Fig. 2: Meshed model

H. Boundary conditions

Fig: 3 and Fig: 4 show the boundary conditions employed in front and rear ends of leaf spring. The front end is fixed to the frame and allowed to displace only in Z-direction (rotation). The rear end is connected to the frame with shackle and allowed to displace in X-direction (translation) and in Z-direction (rotation).

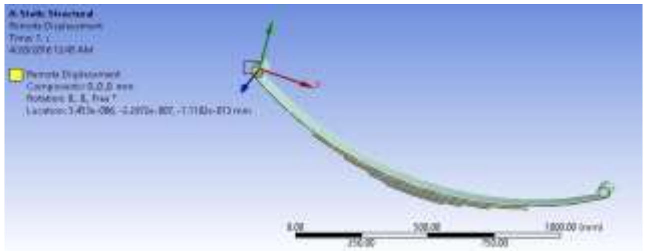

Fig. 3: Front end

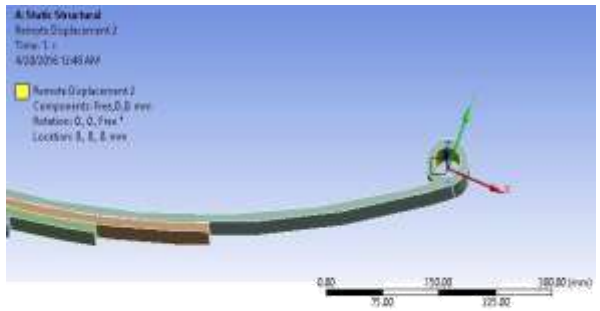

Fig. 4: Rear end

III. RESULTS AND DISCUSSIONS

A. Static Structural Analysis

3.1.1 Applied load = 12500 N

Static structural analysis was carried out on leaf springs with four different materials and their corresponding deflections and von misses stresses were determined. Total deflection and Von misses stress results are shown in Fig: 5 and Fig: 6 respectively.

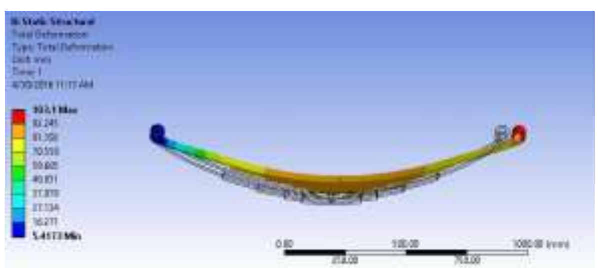

Fig. 5(a): Structural Steel

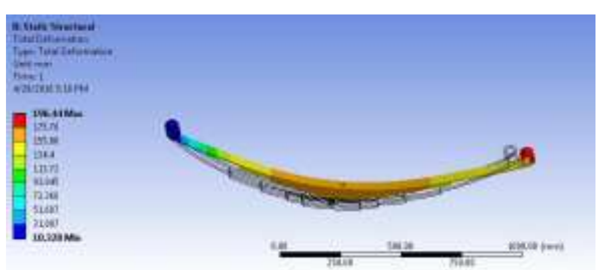

Fig. 5(b): Titanium Alloy

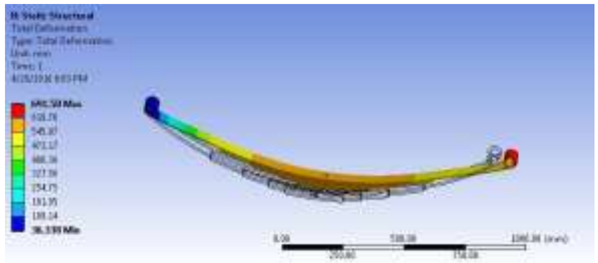

Fig. 5 (c): Kevlar

Results show that Structural steel is having least deflection due to high elastic modulus. Titanium alloy is having second least deflection, while Kevlar is having the highest total deflection among the leaf spring materials chosen for analysis.

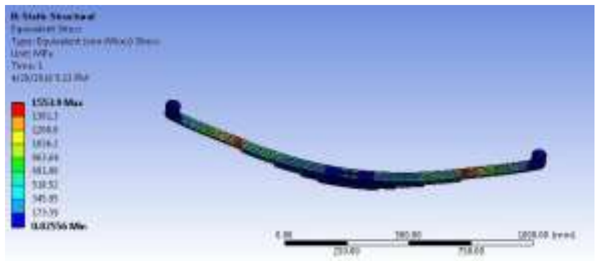

Fig. 6 (a): Structural Steel

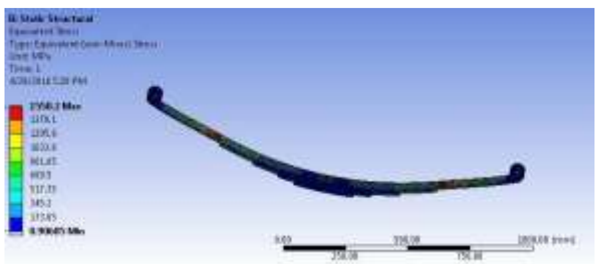

Fig. 6 (b): Titanium Alloy

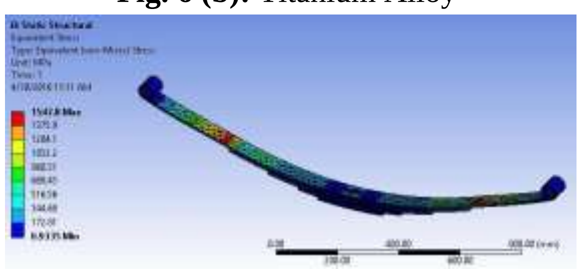

Fig. 6 (c): Kevlar

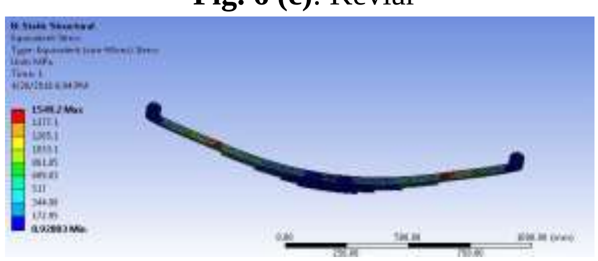

Fig. 6 (d): S-Glass Fiber Composite

From plot of equivalent stresses it is clear that the stresses developed for steel is maximum, while for composite materials it is less. Stresses for steel is 1553.9 MPa, for titanium alloy is 1550.2 Mpa, for S-Glass Fibre composite is 1549.2 MPa and for Kevlar fibric it is 1547.8 MPa. This is because the modulus of elasticity is high for steel compared to that for composite and deflection for composite are more than that compared to steel. Hence, capacity to absorb energy is more in composite as compared for conventional steel. Hence to improve stability of vehicle and enhance good comfort conditions as well, composite prove to be more liable materials.

3.1.2 Applied load = 18000 N

Structural analysis is conducted for over load conditions and the total deflection and von misses stress obtained for Kevlar leaf spring material is shown in Fig: 7 and Fig: 8 respectively below.

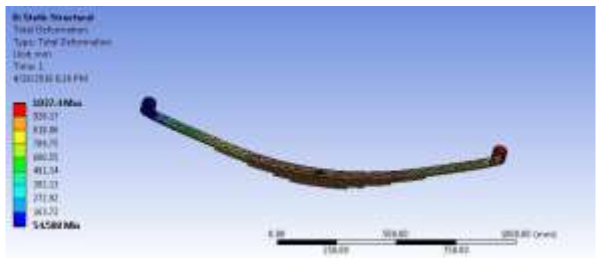

Fig. 7: Kevlar

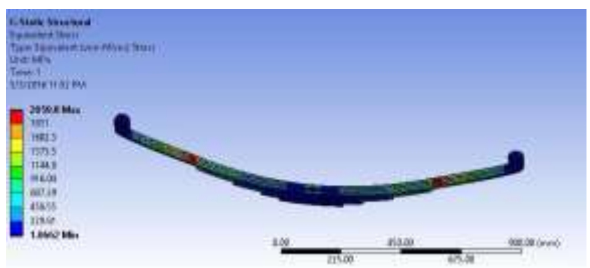

Fig. 8: Kevlar

Results obtained show the same deflection order as that of the previous case with only increase in the magnitude of deflection

From plot of equivalent stresses it is clear that the stresses developed for steel is maximum, while for composite materials it is less. Stresses for steel is 2321.7 MPa, for titanium alloy is 2257.4 Mpa, for S-Glass Fibre composite is 2189.7 MPa and for Kevlar fibric it is 2059.8 MPa. The reason for this is same as that mentioned for equivalent stresses for 12500N load.

Table. III: Deflection of leaf spring in mm

Material	12500N load	18000N load
Structural steel	103.1	154.65
Titanium alloy	196.44	294.66
s-glass fibre	238.55	357.5
Kevlar fabric	691.58	721.4

B. Harmonic Analysis

3.2.1 Applied load = 12500 N

Modal analysis is done for the Kevlar type of leaf springs and its frequency responses is plotted as shown in Fig: 9.

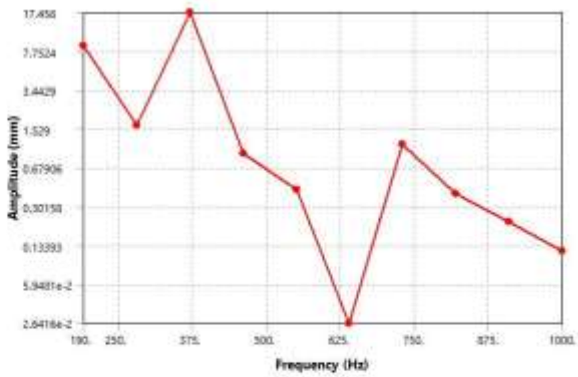

Fig. 9: Kevlar

The harmonic analysis has been done for a frequency range of 100Hz to 1000Hz. The analysis consists of plot of amplitude of spring which is nothing but the deflection of spring plotted against the defined frequency range. From the above graphs it can be realized that for certain frequency values we get maximum deflection. This frequency is not the natural frequency of that materials but the frequency near to the natural frequency for which we get maximum deflection.

3.2.2 Applied load = 18000 N

The harmonic response of spring for 18000N load is shown in fig.10. The conclusion obtained from the graphs can be understood on same basis as that done for 12500 N load. The difference here we get is that for frequency range of 100Hz to 1000Hz the average maximum deflection for all the materials gets increased

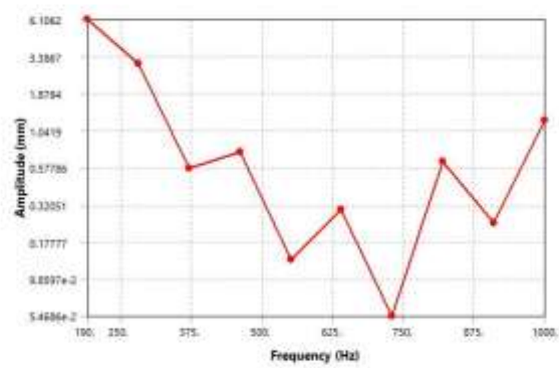

Fig. 10: Kevlar

IV. CONCLUSIONS

Hence the static structural analysis and harmonic analysis was done for leaf spring with four different materials.The analysis was done by considering different parameters

1. Effect of variation of load
2. Effect of variation of material
3. Effect of operating frequency

Thus from above analysis, it can be concluded that

1) Deflection for composite leaf spring is more as compared to conventional steels for both 12500 N load and overload (18000 N). Deflection for Kevlar fabric is maximum and is equal to 691.58 mm and that for conventional steel is 103.1 mm. For titanium alloy and s-glass fiber composite the deflection is 196.44 mm and 238.55 mm respectively
2) But the equivalent stresses developed in the composite materials are less than that developed in conventional steel. For overload of 18000 N the stress in Kevlar is 2059.8 MPa and that in steel is 2321.7 MPa.
3) Hence, the capacity to absorb energy is more in Kevlar fabric than in s-glass composite and less in steels.
4) Also from harmonic response, for frequency range of 100Hz to 1000Hz the average maximum deflection is more in steels and minimum in titanium alloys and other two composite materials.
5) The mass of leaf spring of Kevlar composite, s-glass fiber composite and titanium alloy is 3.300 kg, 5.841 Kg and 10.421 kg, while mass for conventional leaf spring of steel is 18.509 Kg.
6) Therefore leaf spring made of composite have higher natural frequencies.

Therefore to improve the stability (handling) of automobile during cornering, off road drives it is suggested to have the leaf spring of composite materials. Moreover leaf spring of Kevlar fabric as well as s-glass fiber composite is light in weight, have higher natural frequency and thus can achieve optimum automobile stability and comfort.

V. REFERENCES

[1] Shahrukh Shamim, JamilAnwer, "Design and optimization of Automotive multi leaf spring by finite element method", international journal of research in aeronautical and mechanical engineering,year 2014.
[2] Yogesh Sharma, Dr. V.N. Bartaria, "Comparison of Performance of Multi Leaf Springs of Automobile after Changing Its Cross Section", year 2015.
[3] Pengbo Wang, Chongliang Zhang and Yongquan Liu, "Simulation and Design of Leaf Spring Characteristics", SAE Technical paper, year 2009.
[4] MurathanSoner, MetinTanoglu, NilayGuven, Mustafa Karaagac, Rasimakyali, OzayAksoy, TolgaErdogus and AhmetKanbolat, "Design and Fatigue Life Comparison of Steel and Composite Leaf Spring", SAE Technical paper, year 2012.
[5] A SrinivasKurna, ArpitMathur, and Sandeep Sharma, "Investigation of Stresses and Deflection in Multi Stage Leaf Spring of Heavy Duty Vehicle by FEM and Its Experimental Verification", SAE Technical paper, year 2015.
[6] SubhashChandrabose, C. Thamotharan, P. Naveenchandran and R. Anbazhagan, "Design Optimization and Analysis of a Parabolic Leaf Spring", Middle-East Journal of Scientific Research, year 2014.
[7] Rupesh N. Kalwaghe, Prof. K. R. Sontakke, "Design and Analysis of Composite Leaf Spring by Using FEA and ANSYS", International Journal of Scientific Engineering and Research, year 2015.
[8] R.S. Khurmi J.K. Gupta, "A textbook of Machine Design". Eurasia Publishing, Year 2005.