REVIEW PAPER ON DESIGN AND FATIGUE ANALYSIS OF LEAF SPRING FOR AUTOMOBILE SUSPENSION SYSTEM

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ABSTRACT

This paper reviews the general study on the configuration and investigation of leaf spring. A vehicle suspension system fundamentally influences the vehicle behaviour, i.e. vibration attributes stability and comfort. Leaf springs are generally utilized in the suspension system of a vehicle and are subjected to a fluctuating cycles resulting to failure by fatigue. A great amount of exploration has been conducted to enhance leaf spring performance. Presently in vehicle industry steel spring has replaced the composite leaf spring. Fiberglass material has better strength and is lighter in weight as contrast with steel for leaf spring. A wide amount of study has been conducted in this paper to investigate the design and analysis of leaf spring and leaf spring fatigue life. A leaf spring has also been designed on ANSYS Workbench

Introduction

A spring is an elastic body, whose expand in size when load applied and regain its original shape when removed. Leaf spring is the simplest form of spring used in the suspension system of vehicle.It absorbs automobile vibrations, shocks and loads by springing action and to some extend by damping functions.It absorbs energy in the form of potential energy. Springs capacity to absorb and store more strain energy makes the suspension system more comfortable. Most widely used leaf spring type is semi-elliptic inheavyand light automobile vehicles. The multi leaf spring comprises of various steps called blades while mono leaf spring is of only one step. Number of steps increases the spring absorbing capability.For heavy vehicles multi leaf spring are used while light vehicle mono leaf spring can be used.

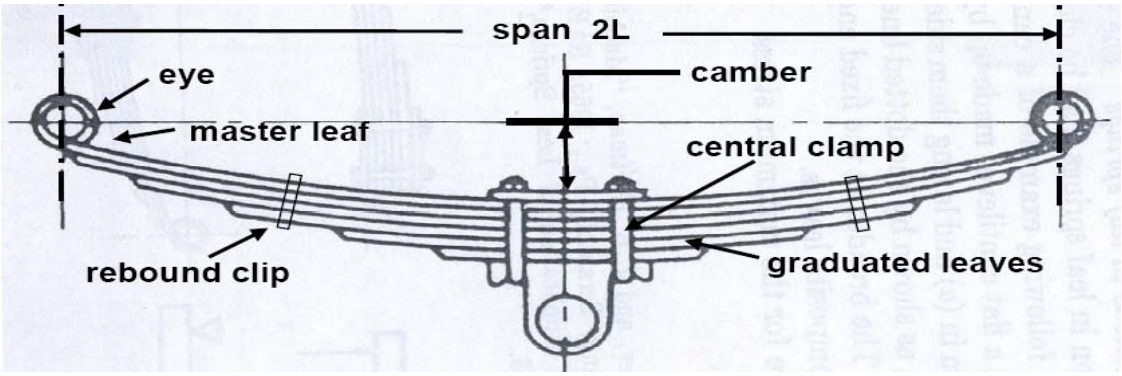
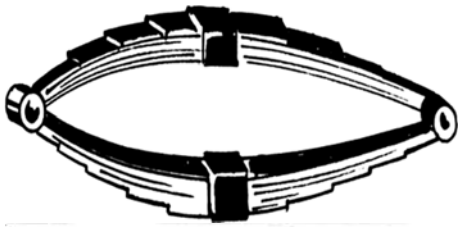


Fig. 1 Schematic of Laminated semi-elliptic leaf spring

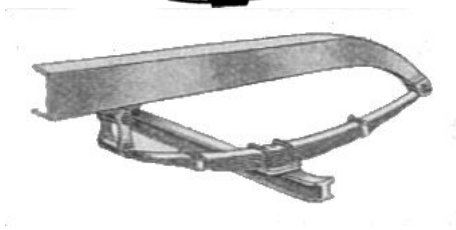
Springs initially given a camberso they will have a tendency to bend under loading condition. The leaf spring works under two hypothesis uniform strength and uniform width.

The master leaf spring is the longest and has eyes at its end while remaining steps of spring are called graduated leaves.Types of different leaf springs are shown in figure 2.

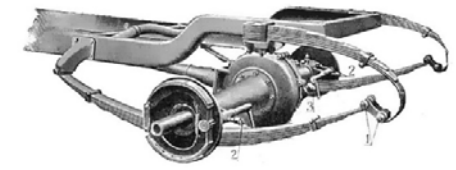
Elliptic



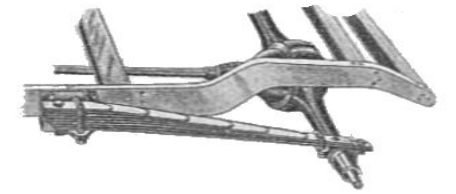
Semi elliptic



Three quarter elliptic



Quarter elliptic



Transverse leaf spring

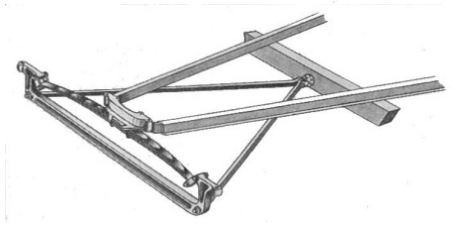


Figure 2 Types of leaf spring

Literature review

Mahmood M. shokrieh and DavoodRezaei[1] studied design, analysis and optimization of leaf spring. In their study they have replaced a steel leaf spring by a composite one. Primary target of their study was to design a spring that possess least weight and is capable of bearing a given static externalforce without any failure. They conducted work on a four-leaf steel spring which used in back suspension system of light and heavy vehicles. They used ANSYS V5.4 to study the four-leaf steel spring. Theyobtained the deflection and stress results and compared their results with analytical and experimental results available. Utilizing the results obtained for steel leaf spring they designed a composite leaf spring considering spring geometry optimization made of fiberglass with epoxy resin with stress and displacement as design constraints. They analysed this spring utilizing ANSYS and verified their results with experimental results and of finite element solution of same dimensions. They found that composite leaf spring weigh 80% less and stress developed is also less compared to steel leaf spring. The composite leaf spring natural frequency is found to be higher that of steel leaf spring and can avoid the resonance at the road.

AjitabhPateriya, Mudassir Khan[2] studied dynamic characteristics of spring loadedusing ANSYS. Fluid-solid interaction mesh deformation between the valvedisc and surrounding fluid has been used to study the

motion of the valve disc for differentmaterials. Differentmaterials have been used consideringsimilar boundary condition for finding the best suitable material. FEM analysis result shows that La2Zr2O7 is best suitable material. Maximum shear stress considered is 0.20395 MPa which is greaterfor Aluminium alloy. For weight and cost comparison the Aluminiumalloy material should be preferred.

Pozhilarasu V. and T ParameshwaranPillai [3] studied analysis of steel and composite leaf spring. They compared the conventional leaf spring and composite (Glass fibre reinforced plastic – GFRP) leaf spring. They used ANSYS software for studying conventional steel leaf spring and composite leaf spring for similar conditions. They fabricated a glass/epoxy composite leaf spring using hand layup method. The universal testing machine has been used to test the results of conventional steel and composite leaf spring. Under the same static loading condition deflection and stress of conventional steel and composite leaf spring has been obtained and results shows a wide difference between the results.

Aishwarya A.L., A. Eswarakumar, V.Balakrishna Murthy [4] conducted free vibration analysis of composite leaf springs. They generated a three dimensional leaf spring on ANSYS. They studied the effect of variation of width, relative movements of the leaves, friction between the spring leaves. They noticed that friction coefficient does not affect the results. They noticed that leaf width improves the natural frequency.

T.N.V.Ashok Kumar, E. VenkateswaraRao, S. V. Gopal Krishna [5] conducted design and material optimization of heavy vehicle leaf spring. They conducted their study to find out the effect on displacement, deflection, weight and frequencies. They used ANSYS to conduct their study and compared their results between steel leaf spring and composite leaf spring made of glass/epoxy and Kevlar/epoxy. They used layer stacking method by changing the reinforcement angled for 3 layers, 5 layers and 11 layers. They compared the weight of conventional steel leaf spring with that of composite leaf spring and found a weight reduction of 27.5%.

K. A. Sai Anuraagand Bitragunta Venkata Sivaram [6] studied the comparison of static, dynamic & shock analysis for two & five layered composite leaf spring. They modelled their leaf spring using Unigraphics software NX7.5. They sued ANSYS to analyse their study. They have done static, dynamic and shock analysis. For analysing the results they have used five layered and two layered composite leaf spring. They noticed maximum displacement in the two layered leaf spring compared to five layered 101.5mm to 83.23mm. They noticed that Von-mises stress for five layered leaf spring is more compared to two-layered. For shock analysis as time increases, the displacement initially increases, reaches a maximum and then decreases for a two layer mode, for five layered the deflection v/s time for five layer mode where the displacement initially decreases, reaches a minimum and then increases as the time progresses.

E. Mahdi a, O.M.S. Alkoles[7] conducted study on light composite elliptic springs for vehicle suspension. They numerically and experimentally studied the impact of ellipticityratio on woven roving wrapped composite elliptical springperformance.They conducted different experiments by changing the ellipticity ratio (a/b) from one to two for composite leaf springs. They found that spring rate and failure loads get influenced by ellipticity ratio and get highest spring rate for ellipticity ratio (a/b) 2.0. They represented a failure mechanics and found that with wall thickness, spring rate and failure increases. They concluded that composites leaf spring can be utilized for light and heavy trucks.

Y. N. V. Santhosh Kumar, M. VimalTeja[8] studieddesign and analysis of composite leafspring. In addition to they talked about the advantages of composite material like higher specific stiffness and strength, higher strength to weight proportion. In their study they have used composite leaf spring utilizing E-Glass/Epoxy instead of steel leaf spring.They targeted their study towards the reducing the weight of it. They used Pro-E to design the spring and ANSYS Metaphysics to analyses it. They found that composite leaf spring with epoxy weighs 60.48 less compared to conventional steel leaf spring and stresses developed were within limits with factor of safety.They also concluded that good strength has been found if fibres in the laminate oriented longitudinally.

PankajSaini, AshishGoel, Dushyant Kumar[9] conducted study on light vehicles design and analysis. They aimed their study at reducing weight and compare the stress developed in the composite leaf spring compared to steel leaf spring. They selected three materials glass fibrereinforced polymer(E-glass/epoxy),carbon epoxy and graphite epoxy is utilized against ordinary steel. They found that composite leaf spring weigh 92% less and developed less stresses compared to steel leaf spring. From the static examination results it is found that there is a most extreme relocation of in the steel leaf spring. After conducting experiments they found that only graphite/epoxy composite leaf spring has higherstresses compared to steel leaf spring. E-Glass/Epoxy reduces the weight by 81.22%, Graphite/Epoxy by 91.95% and 90.51 % for Carbon/Epoxy over steel leaf spring. Thus they concluded that E-glass/epoxy composite leaf spring can be utilized in place of steel leaf spring.
ManasPatnaik, NarendraYadav,[10] conducted finite element and experimental study on parabolic leaf spring. Eye Distance & Depth of camber have been selected as input parameter for DOE. They focused this study on mini loader truck parabolic leaf spring, with loading capacity of 1 Tonne. CATIA V5 R20 has been used to model the leaf spring.Eye Distance and Depth of camber have beenvaried to see their effect on von-misses and displacement andresults have been plotted.They concluded with camber,average amount of displacement decreases and average amount of von misses stress increases,with eye distance,average amount ofdisplacementand von misses stress increases.They concluded that the optimum dimensions pertaining to parabolic leaf spring can be achievedby various plots obtained from design ofexperiments.
Ashish V.Amrute, Edward Nikhil karlus[11] studied design and evaluation of leaf spring. They targeted their study towards the comparison of composite leaf spring and steel leaf spring. Different comparison parameters were stress developed, weighing capacity and load carrying capacity.Tata ace ex vehicle leaf spring has been considered in the present study. In their study they have tried to replace the steel leaf spring by composite leaf spring. Bending stress has been found to be decreased by 25.05% i.e. for the same load carrying capacity less stresses developed in the composite leaf spring. The steel leaf spring weighs around 10.27kg while composite leaf spring with E-glass/Epoxy weighs just 3.26 kg. They concluded that the weight get reduced by 67.88%.
H.A.AI-Qureshi [12] conducted study on composite material leaf spring.They considered a composite car and focused their study on design, analysis and fabrication of its leaf spring. Design, fabrication and testing on amono composite leaf spring with variable thickness with same mechanical and geometrical properties to multileaf steel spring wereconducted. They did field test preceded by laboratory experiments to check ride qualities on various GFRP spring which were mounted insteadof steel spring on jeep. They found GFRP springsto be more adaptable and produces less noise and harshness compared to steel leaf spring. They also noticed 80% less weight and higher natural frequency.

Rupesh N. Kalwaghe, K. R. Sontakke[13] conducted study on Design and Analysis of Composite Leaf Spring by Using FEA and ANSYS. They substituted a steel leaf spring by a composite leaf spring.Because for same load carrying capacity composite leaf spring possess high strength to weight proportion for same dimensions. A semi-elliptical composite multi leaf spring made of E-glass/epoxy is designed. Less stresses and deflection has been found for same load carrying capacity. Results compared well with the theoretical results.They had done a comparative study and found that composite leaf spring with E-Glass/Epoxy weighs 67.88% less compared to steel leaf spring. In their study they suggest to use E-glass/epoxy composite leaf spring from stiffness and stress perspective.

C.Madan Mohan Reddy, D.RavindraNaik, Dr M.Lakshmi Kantha[14] Reddy conducted study on analysisand testing of two wheeler suspension helical compression spring.They focused their study on suspension system springs modelling, analysis and testing. They try to replace the steel helical spring in automobiles. They carried a comparative study. They calculate the stress and deflection of helical spring. They compared their FEA results with experimental values.The found chrome vanadium steel spring has 13-17% less maximum stress and 10% less specific weight compared to steel spring. They validate their FEA results with the experimental values and found excellent similarity of 95% in deflection and of 97% in shear stress pattern.

Figure 3 shows the sketch of the leaf spring designed in ANSYS. Effect of load applied by the vehicle will be studied on this spring. Stress and strain analysis will also be done on the designed leaf spring. Table 1 shows the dimensions of the leaf spring designed in ANSYS.

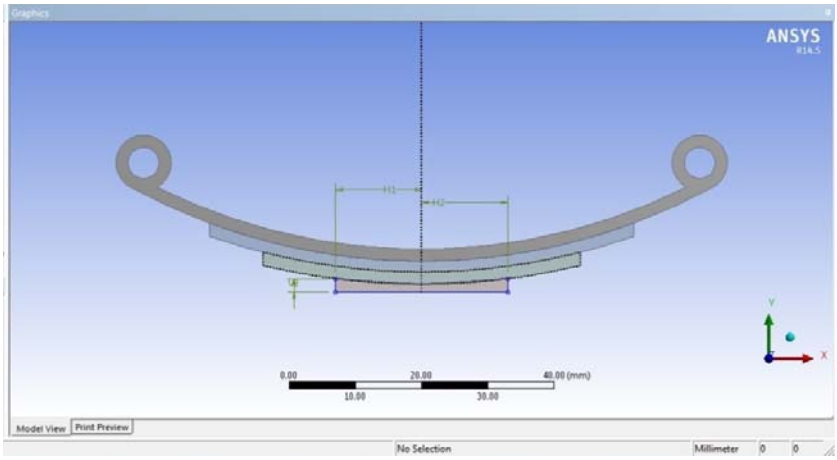


Figure 3 Model of leaf spring designed in ANSYS

Table 1 Details about the leaf spring

Leaf Spring Part	Top part	Bottom part	Radius	Vertical Distance
Eye outer part			4.2mm	
Eye inner part			2.3mm	
Master leaf	40mm	45mm		
Graduated leaf 1	32mm	32mm		2mm
Graduated leaf 2	24mm	24mm		2mm
Bottom leaf	17mm	17mm		2mm
Load applied	40N			
Span (Eye centre to centre)	85mm			
No of graduated leafs	3			
Width of leafs	6mm			

Conclusion

From the writing survey it is seen that the goal was to get a spring with least weight that is prepared to do conveying given static outside powers by limitations restricting burdens and removals. For that the steel leaf spring is supplanted by composite leaf spring. Composite leaf spring is superior to steel leaf spring. Composite materials have more flexible strain and high quality to weight ratio to steel.It is reasoned that composite leaf spring is a successful trade for the current steel leaf spring in car. The burdens in the composite leaf spring are much lower than that of the steel spring.

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