Study and Review on the Analyses of Leaf Spring

Pulkit Solanki[1] Dr. Ajay Kumar Kaviti[2]
[1]P.G. Scholar [2]HOD
[1,2]Department of Mechanical Engineering
[1,2]Sagar Institute of Science and Technology, Bhopal

Abstract—We know that the spring plays very essential part of every automobile for suspension point of view. Leaf spring is the main type of suspension system which is used in many light and heavy vehicles. Leaf spring used in many vehicles due to having some main characteristics which are shown below.

1) Uniformly load distribution
2) Lower cost
3) Rough used
4) Easier in Isolation and Tightly attached with working frame

Today every automobile company has been working on increasing the efficiency with reducing the weight without having any load carrying capacity. In this paper we would like to review some previous research work performed on the leaf spring by previous researchers for increasing the working condition and capacity with load reduction. The paper based on material composition, experimental testing and load (Steady, Dynamic) study etc.

Key words: Leaf Spring, Material Compositions, Mathematics, Experiments, ANSYS

I. INTRODUCTION

A leaf spring is the simple form of spring commonly used for the suspension in wheeled vehicles. Leaf spring is mainly made up of steel, but due to issue of weight today most of the automobile companies used composite materials for the manufacturing of leaf springs. The composite materials used like E-Glass/Epoxy, Graphite/Epoxy, and Carbon/Epoxy etc.

The classification of leaf spring included as Elliptical, Semi Elliptical, Three quarter Elliptical, Quarter Elliptical, and Teraservers. The leaf spring mainly consists of different parts like Master leaf, Center bolt, central clamp, Eye, and Rebound clip.

So, here in this paper we try to review all these previous journals for better understanding the work done. In previous researchers the analytics and software's determine the load carrying capacity. Material based study is used for light weight transformation of vehicles at various loading conditions used for working and checking of load durability. The paper also included the study and work which held in past and gives the brief study about the work performed by researchers in previous journals. The details of my study on previous papers are present in the next section (Literature survey).

II. LITERATURE REVIEW

The section here shows the review of previous journals based on study and analysis of leaf spring. The study in this section is subdivided into number of categories on the basic of work done in past.

A. Analysis of Leaf Spring on the Basis of Material and Its Compositions.

Shishay Amare Gebremeskel et.al [1] material plays very important role in every manufacturing process. The paper also describes and solves the major issues of vehicles weight through use of composite material E-Glass/Epoxy composite shown in Fig. 1. Their work focuses on constant cross section design, weight reduction, and design. The result shows that shear stress in much less than the shear strength (τ= 3mpa) and the design is safe even for flexural failure. They focus on their work for design of leaf spring used in three wheelers.

Fig. 1: E-glass/ Epoxy composite leaf spring curing on the mould set up [1]

Amol Bhanage and K. Padmanabhan et.al [2] the main aim in this paper is saving time, cost, and material by providing a simulation between steel materials (SAE 1045-450-QT steel and E-Glass/Epoxy).

Parameters	Material	
	SAE1045-450-QT	E-Glass epoxy composite
Maximum load in N	3250	3250
Absolute maximum stress , Mpa	724.52	715
Stiffness, N/mm	24.33	53.59

Table 1: Comparison result of Stress for SAE 1045-450 - QT and E-Glass epoxy composite. [2]

Modes	SAE1045-450- QT frequency (Hz)	E-Glass epoxy frequency (Hz)
1	13.13	17.15
2	54.55	56.16
3	78.59	72.19
4	116.89	119.36
5	178.49	202.78
6	243.27	288.43

Table 2: Natural frequency of SAE 1045-450-QT and E-Glass epoxy composite material. [2]

The results here in their paper comprises of fatigue sensitivity, biaxial indication, fatigue damage, and fatigue safety factor. The paper also concluded that fatigue life of E-Glass/Epoxy is higher than steel according to total life approach. The detail of results computed in their analysis is discussed in the Table. 1 and Table. 2 present above.

Sorathiya Mehul et.al [3] composite materials are those materials having higher stress to weight ratio and good corrosion resistance capacity. The paper here comprises of static analysis of leaf spring of composite material with the help of ANSYS software. The study consists of young's modulus, poison ratio, and modulus of rigidity for simulation of results shown in Table. 3. Leaf spring made up of steel is heavier than the composite material leaf spring and the load carrying capacity of both material springs are same. Now if we increase the number of leaf then the weight reduction achieved up to 90.09% without having any load carrying capacity.

Parameter	Analytical	FEA	Difference
Deflection	6.60	5.25	20.45 %
Bending Stress	197.683	224.26	11.86 %

Table 3: Comparison of Analytical and FEA result. [3]

D.N Dubey et.al [4] composite materials have more elastic capacity and higher strength to weight ratio as compare to conventional steel. The composite materials used for the manufacturing of leaf springs are made of HM and HS carbon polymers. A composed material of two or more constituents combined on a microscopic scale by mechanical and chemical bonds to form a composite material. Due to the better composition of material strength and modulus of composite materials are better than the traditional metallic material.

Grade	C%	Mn%	Si %	Cr%	Ni %	Mo %	S,P % (max)
En45	0.45 - 0.55	0.50-0.80	0.5 0 ma x	0.80 -1.20	-	-	.050*

Table 4: Reference Books by Mahindra Ugine Steel Company Limited (MUSCO) [4]

The paper briefly discussed the use of conventional steel leaf spring manufactured by EN45, 60SI7, EN47, 50CR4V2, 55SICR7, and 50CRMOCV4 etc. The experimental leaf spring made up of EN45 and its composition given in the Table. 4 represented above.

The stress analysis in the paper is performed with the help of FEM (Ansys). The analysis concluded the comparison between conventional and composite material leaf spring and Fig. 2 shows that the conventional leaf springs are more deform than the composite one at same load. The work in their paper shows the weight reduction of about 65.70% by using the composite material in place of original steel leaf spring.

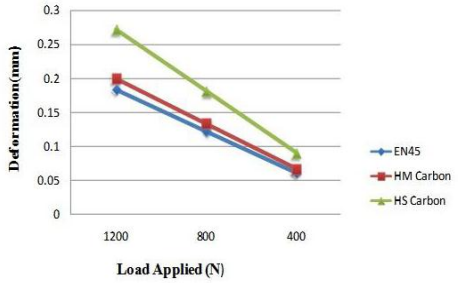

Fig. 2: Deformation at various Loads for Different material [4]

B. Experimental Analysis of Leaf Springs

Vinkel Arora et.al [5] Leaf spring used for real and front wheels for the purpose of providing suspension system. The paper here we focus comprises of work done on the front end leaf spring of commercial vehicle. The model consists of 37 parts and 65SI7 material is used for manufacturing of leaf spring. The design is made on CAD model prepared with the help of CATIA and analysis is performed on ANSYS software. The results of this computational analysis in later compared with the experimental values shown in the Table 5 and Table. 6. The calculation and results of the analysis shows that the design is more effective and safe as the maximum equivalent stress is 172.5 Mpa and 86.29 Mpa for full and half loaded leaf spring respectively.

Parameters	Exp. Results	CAE Results	Variation
Deflection	158 mm	156.15 mm	1.17%
Bending Stress	126 Kgf/mm2	141.56 Kgf/mm2	12.30%
Spring rate	221.5 N/mm	224.5N/mm	1.35%

Table 5: Experimental and CAE results for 35KN [5]

Parameters	Exp. Results	CAE Results	Variation
Deflection	79 mm	78.07 mm	1.1%
Bending Stress	221.5 N/mm	224.5 N/mm	1.35%
Spring rate	48 Kgf/ mm2	53.77 Kgf/ mm2	12.02%

Table 6: Experimental and CAE results for17.5KN [5]

AnandKumar et.al [6] the very first issue in every automobiles is weight reduction with maintenance of strength. The paper here comprises of use of 55SI2MN90 for steel leaf and Glass-fiber 7781 for composite leaf spring as a material. The work comprises of hand layup method and mathematical calculation the paper also discusses about the fabrication of leaf spring and for this a wooden made pattern is used. The pattern is created according to design dimensions. The mono composite made up of hand layup method shown with the help of Fig. 3 present below.

Fig 3: Final layout of Leaf [6]

Table. 7 represent the results calculated by the analysis performed in their work and also concluded that the experimental and analytical values are nearly same.

Sr. No.	Parameter (For uniform width)	Load (N)	Stress induced, σmax (Mpa)	Deflection, δmax (mm)
1	Steel	500	615	42.3
2	Composite	35	43.05	48.5

Table 7: Experimental testing results [6]

C. Study of Leaf Spring On The Basis Of Mathematics and Computational Analysis.

Anil kumar et.al [7] the paper comprises of work done on the conventional steel leaf spring with variable composite materials like Graphite, Carbon, and E-Glass/Epoxy etc shown in Fig. 4 and Fig. 5. The different effects occurs on the working condition of leaf spring is analyze here with the

help of mathematics and Ansys software. The experiment is performed with the help of 10 leaf springs, 2 full length and 8 in graduated. Stress based analysis and modal analysis is performed with the help of ANSYS software shown in the figure given below. The results concluded that the static analysis of steel leaf spring displacement is 92.59mm which is below the chamber length of leaf spring and stiffness noted as 35.60mm.

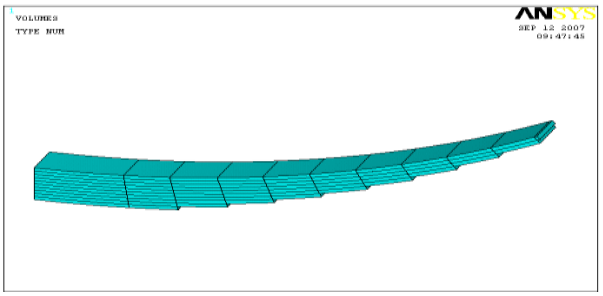

Fig. 4: Solid Model of Steel Leaf Spring [7]

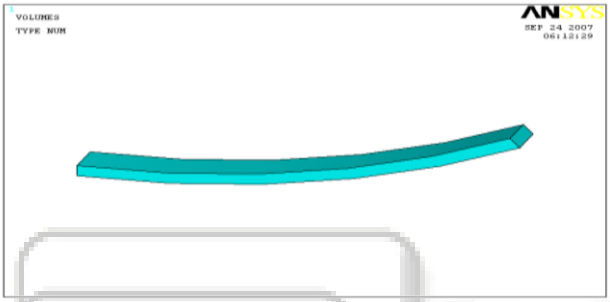

Fig. 5: Solid Model of E-Glass/Epoxy Mono Composite Leaf Spring [7]

Senthilkumar Mouleeswaran et.al [8] due to irregularities of load leaf spring shows vertical vibrations. A leaf spring stored a potential energy in the form of strain energy and dissipated slowly. So due to this a maintenance of leaf spring material is also an important factor like minimizing the modulus of elasticity in longitudinal direction and maximizing the strength.

Fig. 6: Electro-hydraulic leaf spring test rig. [8]

The work done here consists of study of fatigue failure behavior of composite material under the application of load. All the analysis here is performed with the help of experimental and computational simulation. The electro hydraulic leaf spring test Fig. 6 is performed with variation of steel and composite material under static load condition. The results also concluded that the natural frequency of composite material leaf spring is 41.5Hz which is 3.46 times maximum than the load frequency and these values shows that resonance will not occurs.

M.M Patunkar et.al [9] leaf spring is mainly used for suspension purpose in commercial vehicles. The paper here shows the study with the help of test performed on static load condition and the results then simulated with virtual model leaf spring made up of composite material. The design here is prepared by virtual model prepared on Pro-E 5.0 CAD software and analysis is performed on ANSYS 10.0. Material used for conventional leaf spring is 60SI7 (BIS) and Glass/Epoxy for composite leaf spring. A finite element analysis is taken place here for the study of cyclic creep and cyclic deformation of both kinematic and dynamic type shown in the figure given below. The results concluded that at the same conditions deflection of composite leaf spring is less than the conventional one shown in Fig. 7 and Fig. 8. The table presented below shows the results and also given that the weight reduction of 84.40% is achieved.

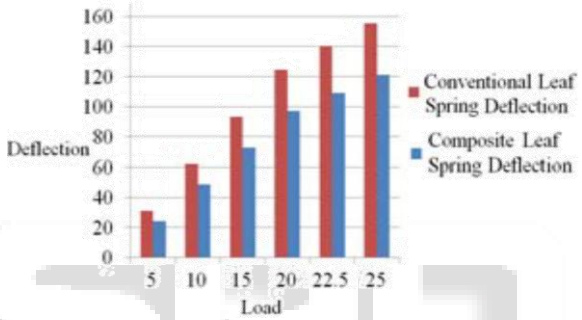

Fig. 7: behavior of the leaf springs when subjected to load and its effect on Deflection [9]

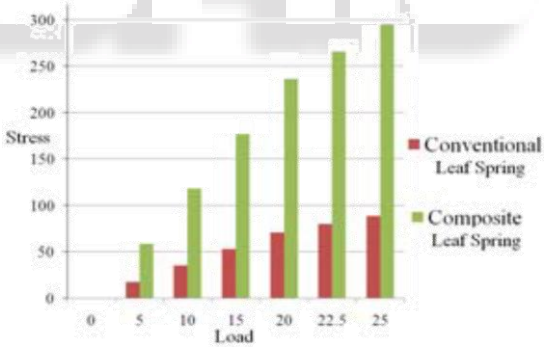

Fig. 8: behavior of the leaf springs when subjected to load and its effect on Stress. [9]

R.B Charde et.al [10] the deflection in spring shows that potential energy is stored in the form of strain energy due to impact load and elastic nature of material used in manufacturing of leaf spring. The paper here shows the study of failure, stress, deflection, and bending behavior of leaf spring. This approach is actually based on the cantilever beam theory and actual prototype is considered under static loading condition. Stress analysis is considered from fixed end to 15, 125, 235, and 345 mm for leaf spring. The results in the paper easily explained with the help of figures and graphs shown below. Their results also concluded that the analytical equation fails to measure the maximum stress value in the master leaf and it only useful to know the maximum value of stress at the support. So the experimental and finite element method is suitable for the evaluation of

resulting stress away from the support. In their present study master leaf cannot obey the rule of cantilever beam theory but when we add another full length leaf spring the theory is validated.

III. CONCLUSION

The study done by us here gives a review on previous paper and journals based on different ideas and modifications with the help of mathematics, experiments, and computational methods. Now in this portion we concluded here the main parameters analyze by us from the study of these previous papers.

1) The main area focuses about the material used for manufacturing of leaf spring. Now a day's composite material is used in heavy manner as a leaf spring material in place of steel.
2) The main components used for manufacturing of composite leaf springs are E-Glass/Epoxy, C-Glass/Epoxy, and S-Glass/Epoxy for reduction of weight as compare to conventional steel leaf spring.
3) The main advantage of using a composite material is to increase strength to weight ratio and they also have a higher corrosive resistance.
4) The composite materials are more elastic then the conventional material (Steel).
5) The papers also shows the heavy amount of work with the help of computational software's because of saving time and cost with great accuracy. The papers used here focus on different computational software's like ANSYS, N-code design, and COMSOL for analysis and software's like CATIA, CAD, and PRO-E for design purpose.
6) The study here presents a method named hand layup for quick and desired results with minimum time.

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