Static Analysis of Leaf Spring for Light Vehicle using Composite Material

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Abstract— In this study analysis of leaf spring using composite is done by comparing the conventional steel leaf spring which is used by Force Motors Trax Cruiser vehicles. The main aim of this paper is to substitute the steel leaf spring with composite material. This analysis results improve strength with reduced weight of existing leaf spring. The composites used for this analysis is Carbon epoxy, Resin epoxy and E glass/epoxy. Combination of alternate leaf of steel with composite is also used for analysis. Ansys workbench is used for analysis purpose. This analysis result Carbon Epoxy best replacing material for existing leaf spring in terms of strength and weight.
Key words: Composite, Deflection, Strength, FEM, ANSYS

I. INTRODUCTION

Suspension system is important essential part of the vehicles. It absorbs unwanted vibration when the wheel meets projections or obstacles on the road. Laminated leaf spring is a suspension system which is used in four wheeled vehicles. It supports whole vehicles weight. It is mounted on axle. It has two ends. Front end is mounted to frame by pin joint and other rear end is connected to shackle of the vehicles. Pin joint act as a fixed joint while shackle joint provides motion parallel to vehicles. Longest leaf of spring is called master leaf which contains eyes. Other leaves are called graduated leaves with varying length. Over a last few decades composite materials are dominant energy materials. Due to high strength to weight ratio of the composite material it becomes a perfect substitute for steel leaf spring. So we select such composite which result maximum weight reduction without affecting load carrying capacity of spring. For this purpose the chosen materials are Carbon epoxy, E glass/ epoxy, Resin epoxy. So aim of the project is to make comparative study with steel leaf spring to composite leaf spring. And to choose the best composite which give best result in terms of strength, weight and deflection. Ansys software is used to analyze the spring and result is compared to theoretical calculation in terms of bending strength, weight and deflection. In theoretical calculation it is assumed that spring is fixed at middle and load is applied to its free end. Force Motors Trax Cruiser is considering for design of leaf spring problem in relatively easy way.

Degree of freedom	Eye 1	Eye 2
Translational in x-axis	0	Free
y-axis	0	0
z-axis	0	0
Rotation about x-axis	0	0
Rot y-axis	0	0
Rot z-axis	Free	Free

Table 1: Boundary Conditions for Analysis

II. LITERATURE REVIEW

Various related literature such as transactions, proceeding of various national and international conferences and other journals which available on Google scholar were reviewed.

- [K. K. Jadhao et.al,2017] analyze the dynamic behaviour of steel and composite leaf spring and compared to theoretical output .The spring of Tata Ace four wheeled vehicles was taken for study. From result it is found that composite leaf spring had more strain energy than steel leaf spring.
- [Amitkumar Magdum,2016] analyzed the laminated leaf spring using finite element method considering the dynamic effect on stability of vehicle during cornering off road drives etc. Load acting on leaf spring and its stiffness were parameters considered in the analysis. It also considered deflection and stress distribution of leaf spring for heavy duty vehicles considering various recent materials as substitute. It also investigated harmonic response of spring. Weight reduction and deflection is maximum for Kevlar Fabric. Natural frequency is more for composite. The capacity to absorb energy was more in Kevlar fabric than in s-glass composite and less in steel.
- [Prof.N.P.Dhoshi et.al, 2016] In the present work analytical and FEM has been implemented to modify the existing leaf spring with considering the dynamic load effect. ed had been selected for stress analysis. Material and manufacturing process were selected upon on the cost and strength factor whereas the design method is selected on the basis of mass production. On reducing the number of leaves spring from 17 to 13 would further reduced the weight by 6 kg and the production cost by nearly 20 percent.
- [Dasari Ashok Kumar, 2016] Compared the load carrying capacity, stresses, stiffness, contact stiffness, and weight savings of the E-Glass Epoxy composite leaf spring with that of steel leaf spring. And it was found that the composite leaf spring had 29.981% lesser stresses, 12.951% of higher stiffness than steel leaf spring.
- [Putti Srinivasa Rao, 2015]In that paper worked was carried out on a laminated leaf spring having five leaves used by commercial vehicle. By using composite material the weight of multileaf spring is reduced drastically. In that work four composite materials were considered. They were E glass/ epoxy, Graphite epoxy, Carbon epoxy and Kevlar epoxy. The modal analysis was carried out theoretically for finding the natural frequencies for all the materials of the leaf spring for the first five modes. To validate the theoretical modal analysis was conducted in ANSYS.

– [Syambabu Nutalapati, 2015]In that paper leaf spring was considered COMMANDER vehicles. The aim was to compare the stresses, deformations and weight saving of composite spring to steel leaf spring. The selected composite was E-glass/epoxy. The fatigue life of both composite and conventional steel leaf spring was compared using ANSYS software which also gave satisfactory result.

III. METHODOLOGY

In this section framework is to optimize the strength to weight ratio and to analyse different composite cylinder subjected to dynamic conditions. Various parameters which are used for the process are explained in detail.
List of activities that has been performed in order to achieve our goal is enlisted below:

1) Problem identification
2) Literature survey
3) Study of parameters
4) Study of suspension system
5) Selection of material
6) Selection of simulation process
7) Application of FEA on modal analysis
8) Comparison of FEA result to theoretical result
9) Finally conclusion will be discussed.

IV. SELECTION OF MATERIAL

Materials of leaf spring subjected to different static and dynamic conditions have significant contribution to the quality and its performance. Even a small amount in weight reduction and increased strength may have a wider economic impact on its performance. So composite materials are proved as suitable substitutes for steel. Hence, the composite materials have been selected for analysis of leaf spring.

– Resin epoxy
– Carbon epoxy
– E-glass epoxy

V. RESULT

Below table shows that static analysis fairly matches with the analytical results but it also shows that static analytical results underestimate the results.

Parameter	Analytical result	FEM
Von-misses stress(Mpa)	712	740

Table 2: Comparison Table 1

Model no.	Model 1(steel leaf spring)	Model 2(resin leaf spring)	Model 3(carbon epoxy spring)	Model 4(e glass spring)
Von –misses stress(Mpa)	740	282	272	279
% reduction in stress compare to steel leaf spring		61	63	62

Table 3: Comparison between Different Models of Leaf Spring

Model no.	Model 5(resin-steel)	Model 6(carbon epoxy-steel)	Model 7(E glass epxy-steel)
Von misses stress	1260	430	552

Table 4: Comparison Table if Alternate Leaves of Steel and Composite used Simultaneously

Parameter	Analytical deflection	FEM deflection
Deflection	176	175

Table 5: Comparison in Deflection

parameter	Model 1	Model 2	Model 3	Model 4	Model 5	Model6	Model 7
Deflection (mm)	175	518	32	75	72	21	36

Table 6: Comparison in Deflection of Different Model

Parameter	Model 1	Model 2	Model 3	Model 4
Weight	18.35	2.71	3.7	4.67
% reduction		85	80	74

Table 7: Comparison in Weight

VI. CONCLUSION

Overall the research study reveals that the carbon epoxy can be best replacement for existing leaf spring among three sets given composite material. There are some important facts observed during this research work which is given below.

1) From the static analysis results, it has been seen that the von-mises stress in the steel leaf spring is 740 MPa and in resin epoxy, Carbon epoxy and E-glass/epoxy are 282 MPa, 272 MPa and 279 MPa respectively. Thus carbon epoxy has lowest induced stress. It also gives satisfactory result in combination with steel.
2) Only two among the three composite leaf springs have lower displacements than conventional steel leaf spring. From the static analysis results it is found that there is a maximum displacement of 175 mm in the steel leaf spring and the corresponding displacements in resin epoxy, Carbon epoxy and E glass/epoxy are 518 mm, 32 mm and 75 mm. Carbon epoxy with steel give least deflection among three combination model i.e 21 mm.
3) Composite leaf spring reduces the weight by 85% for resin epoxy, 80% for Carbon epoxy and 74% for E-glass/epoxy over steel leaf spring.

VII. FUTURE SCOPE

1) Transient analysis of leaf spring can be done.
2) Calculation of stress concentration due to curvature effect
3) Fatigue analysis
4) More Variation in leaf material.

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