INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

DESIGN AND ANALYSIS OF LEAF SPRING

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A B S T R A C T

Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring.The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance.This work deals with finding a suitable composite material that can be a replacement for conventional steel leaf spring.Thestressanddisplacements havebeencalculatedusing theoretically aswellasusing ANSYSforsteelleafspringand compositeleafspring. The model is designed in CREO software for the vehicle Mahindra "Model -commander 650 di". Analysis is done in ANSYS software for different materials (Steel, Kevlar and E-Glass Epoxy). The static analysis is done to determine the deformation, stress and strain for different materials.A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Transient analysis is done to determine the deformation, stress with respect to time for different materials. Fatigue analysis is done to determine the fatigue life for steel, E glass epoxy and Kevlar leaf spring.

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Key words: Leaf spring, CREO Software. Ansys software

I INTRODUCTION

INTRODUCTION AND HISTORY OF LEAF SPRING

A leaf spring is a simple form of spring commonly used for the suspension in wheeledvehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, appearing on carriages in England after 1750 and from there migrating to France and Germany.

CHARACTERISTICS OF LEAF SPRING

The leaf spring acts as a linkage for holding the axle in position and thus separate linkages are not necessary. It makes the construction of the suspension simple and strong. Because the positioning of the axle is carried out by the leaf springs, it is disadvantageous to use soft springs i.e. springs with low spring constant. Therefore, this type of suspension does not provide good riding comfort. The inter-leaf friction between the leaf springs affects the riding comfort. Acceleration and braking torque cause wind-up and vibration. Also wind-up causes rear-end squat and nose-diving. The inter-leaf friction damps the spring's motion and reduces rebound, which until shock absorbers were widely adopted was a great advantage over helical springs.

Glass fiber

The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low elastic modulus poor adhesion to polymers, low fatigue strength and high density, which increase leaf spring weight and size. Also crack detection becomes difficult.Materials constitute nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

LITERATURE SURVEY

Some journal papers were selectively studied which have direct relevance with my work. A brief discussion is presented below.

Pankaj Saini, Ashish Goel, Dushyant Kumar[1], are discussed about the design and analysis of composite leaf spring. The objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is used against conventional steel.

Naveen S, Natarajan R[2], are discussed about replacing the conventional materials by composites which has higher specific stiffness, good corrosion resistance and high strength. Finding a suitable composite material that can be a replacement for conventional steel leaf spring. The composites chosen are E-Glass/ Epoxy and Carbon/ Epoxy and are analyzed for minimizing weight of the composite leaf spring compared to that of conventional steel leaf spring.

DESIGN CALCULATIONS OF LEAF SPRING

The functions of springs are absorbing energy and release this energy according to the desired functions to be performed. So leaf springs design depends on load carrying capacity and deflection.

Weight and initial measurements of Mahindra "Model - commander 650 di" light vehicle are taken.

Gross vehicle weight = 2150 kg

Unsprung weight = 240 kg

Total sprung weight = 1910 kg

Taking factor of safety (FS) = 1.4

Acceleration due to gravity (g) = 10 m/s^2

There for; Total Weight (W) = 1910*10*1.4 = 26740 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight.

$2W = \frac{26740}{4} = 6685$ N

W =3342.5 N

Length of leaf $= \frac{\text{effective length}}{\text{np. of leafs} - 1} + \text{in effective length}$ ....(eq. 3.1)

Effective length =1120 mm, ineffective length =90 mm, no of full length leafs =2 , gradual length leafs =8, Total leafs =10.

Length of smallest leaf $= \frac{1120}{10-1} + 90 =$ 214 mm

ISSN: 2057-5688

Length of second leaf $= \frac{1120}{10-1} \times 2 + 90 = 338$ mm

Length of third leaf $= \frac{1120}{10-1} \times 3 + 90 = 463$ mm

Length of fourth leaf $= \frac{1120}{10-1} \times 4 + 90 = 588$ mm

Length of fifth leaf $= \frac{1120}{10-1} \times 5 + 90 = 712$ mm

Length of sixth leaf $= \frac{1120}{10-1} \times 6 + 90 = 837$ mm

Length of seventh leaf $= \frac{1120}{10-1} \times 7 + 90 = 961$ mm

Length of eighth leaf $= \frac{1120}{10-1} \times 8 + 90 = 1085$ mm

Length of ninth leaf = 1120 mm

Length of tenth leaf = 1120 mm

Table 3.1 shows the Design Parameters of Leaf Spring

Leaf no.	**Full leaf length (2L)**	**Half leaf length (L)**	**Radius of curvature R (mm)**
1	1120	560	961.11
2	1120	560	967.11
3	1085	542.5	973.11
4	961	480.5	979.11
5	837	418.5	985.11
6	712	356	991.11
7	588	294	997.11
8	463	231.5	1003.11
9	338	169	1009.11
10	214	107	1015.11

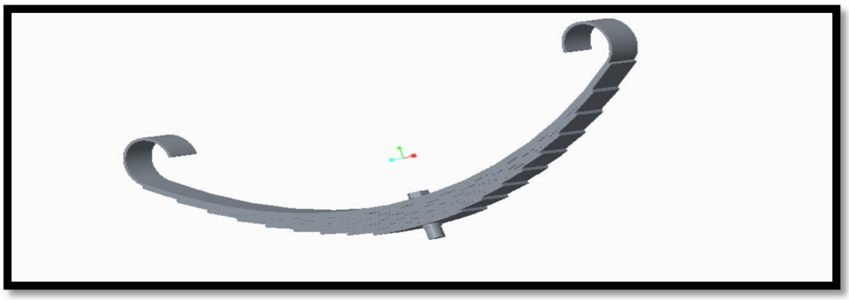
Table 3.2 shows the Specifications of Leaf Spring

S.NO.		
1	Total Length of the spring (Eye to Eye)	1120mm
2	Free Camber (At no load condition)	180mm
3	No. of full length leaves	2
4	No. of graduated leaves	8

5	Thickness of leaf	6 mm
6	Width of leaf spring	50mm
7	Maximum Load given on spring	6685 N

CREO parametric modules:

- Sketcher
- Part modeling
- Assembly
- Drafting



MATERIAL PROPERTIES OF STEEL 55 Si 2 Mn 90

Table 4.1 Material properties of steel

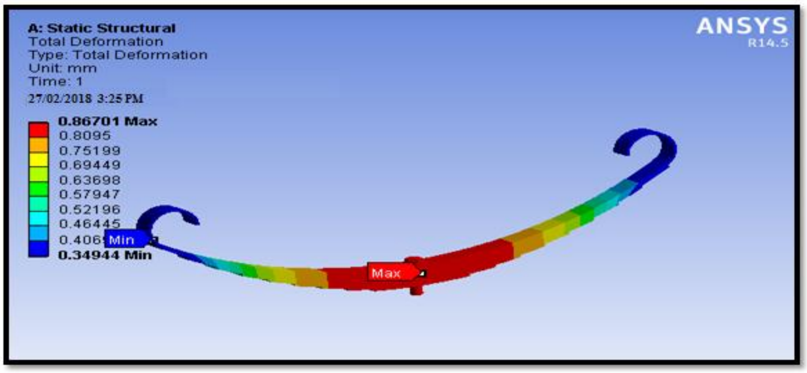
Parameter	Values
Material selected	55 Si 2 Mn 90
Young's modulus	2*105MPa
Passion's ratio	0.3
BHN	534-601
Tensile strength ultimate	1962 MPa
Tensile strength yield	1470 MPa
Density	7850 Kg/m3

ISSN: 2057-5688

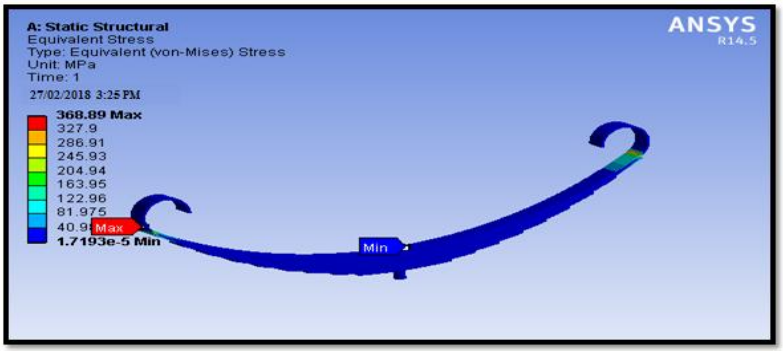
STATIC ANALYSISOFSTEELLEAFSPRING

Static structural analysis for bending stress and deflection for steel leaf spring are shown in Figure 4.2 and 4.3 respectively. Figure 4.2 shows that maximum deformation contours at the centre portion of leaf spring and minimum is at the eye ends. Figure 4.3 shows that maximum stress contours at the eye ends of the leaf spring and minimum at centre portion of leaf spring.

TOTAL DEFORMATION



STRESS



RESULTANALTSISOFSTEELLEAFSPRING

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

Table 4.2 Comparison of theoretical and analysis results for steel leaf spring.

Parameters	Analytical Results	Static analysis results	Percentage variation
Von-mises stress (M Pa)	590.42	630.02	6.28%

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IJTE
ISSN: 2057-5688

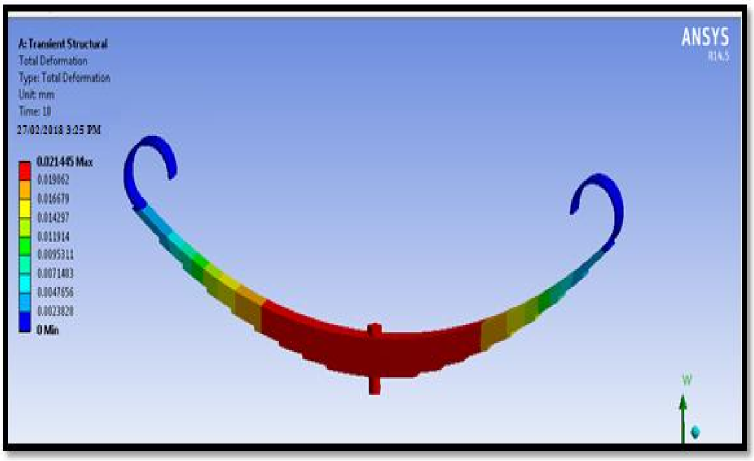
Deflection (mm)	138.2	143.75	3.86%

TRNSIENT ANALYSIS OF LEAF SPRING

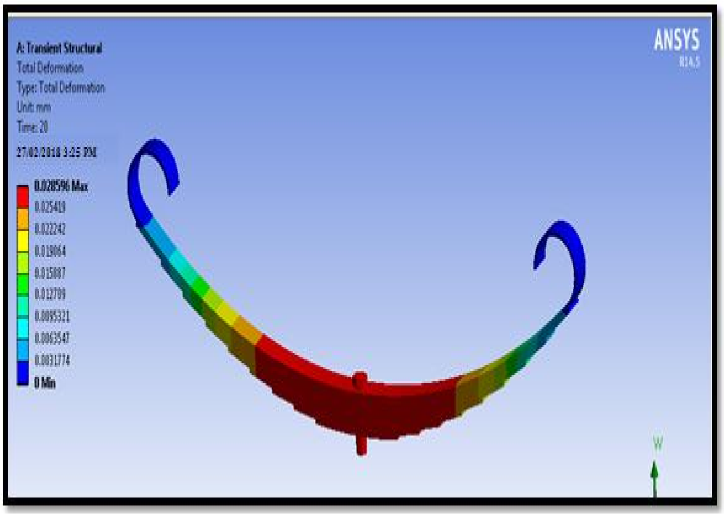
A transient dynamic analysis is used to determine the response of a structure subjected to a time-dependent loading considering inertia and damping effects. It is often referred to as a time-history analysis. The full method in ANSYS uses the full system matrices to calculate the transient response at each solution point. The model-superposition method scales the mode shapes and sums them to capture the dynamic response.

Below Figures 5.1 to 5.3 shows the deformation of the leaf spring at 10, 20 and 30 sec respectively for the given load.

DEFORMATION



STRESS



CONCLUSIONS

The design and static structural analysis of steel leaf spring and composite leaf spring has been carried out. Comparison has been made between composite leaf spring with steel leaf spring having same design and same load carrying capacity. The stress and displacements have been calculated using theoretically as well as using ANSYS for steel leaf spring and composite leaf spring. From the static analysis results it is found that there is a maximum displacement of 143.75 mm in the steel leaf spring and the corresponding displacements in E-glass/epoxy and Kevlar are 102.5 mm and 100.08 mm. From the static analysis results, it also seen that the von-mises stress in the steel leaf spring is 630.02 MPa corresponding in E-glass/epoxy and Kevlar are 527.46 MPa and 490.27 MPa respectively. The two composite leaf springs have lower displacements and stresses than that of existing steel leaf spring.A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 74.54% for E-glass/epoxy and 79.77% for Kevlar over the steel leaf spring.

From the transient analysis results, it is seen that the two composite leaf springs have the lower stress value than that of steel leaf spring. The stress value occurred is minimum for Kevlar leaf spring compared to E glass epoxy and steel leaf spring.

From the fatigue analysis results, it is seen that the fatigue life estimated is more for Kevlar leaf spring compared to E glass epoxy and steel leaf spring.

It can be concluded that Kevlar composite material can be a replacement for the conventional steel leaf spring.

7.2 FUTURE SCOPE OF WORK

- Analysis can be done on leaf spring by changing the fiber orientation of composite material.

It can be obtained by doing the analysis with metal matrix composite leaf spring.

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IJTE

ISSN: 2057-5688