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DESIGN AND ANALYSIS OF THREE LEAF COMPOSITE SPRING FOR LIGHT WEIGHT VEHICLE BY FINITE ELEMENT ANALYSIS METHOD

S. Vinoth Kumar[1], T.S.Kiruba Shankar [2]C. Arun[3], M.Yuvaperiyasamy[4],

Assistant Professor, Department of mechanical Engineering, V.S.B Engineering College, karur – 639111[1,2,3,4].
Email: vkthermal@rediffmail.com[1], arunmech003@gmail.com[3], yuvaperiyasamyvsb@gmail.com[4],

Abstract - Composition materials are nowadays widely used in the engineering field. The equitable of this project is to be design and analysis of composition semi-elliptical spring for light weight vehicle. semi-elliptical spring are commonly used in the suspension system of automobile. If the weight of semi-elliptical spring is reduced then the fatigue stress induced in the semi-elliptical spring is also reduced. The weight is reduced by replacing nine- semi-elliptical spring with three leaf composition materials spring under the identical condition of design parameters. Since the strength to weight ratio of composition materials is superior that of metals the weight of the leaf spring is reduced drastically. The composition spring is designed to possess constant width and varying thickness method. The composition materials are used is E-glass/epoxy. Both steel and composition materials semi-elliptical springs are modeled and analyzed using ANSYS software. Modeled developed has been validated using theoretical calculations. Stresses and deflection loading on spring are derived. The results verify that the performance is same as that of semi-elliptical leaf spring and the stress of the composition materials leaf spring is found to be lower than that of the semi-elliptical leaf spring. A reduction of 64.89% weight is achieved when a nine semi elliptical spring is replaced with a three-leaf composition materials spring under identical condition of design parameters is analyzed.

Keywords: Leaf Spring, Composite, Static analysis,

INTRODUCTION

In order to conserve natural resources and economize energy weight reduction has been the main focus of automobile manufacture in the scenario. Weight reduction can be achieved primarily by the introduction of better materials design and better manufacturing process. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for twenty percent of the weight. This helps in achieving the vehicle with improved riding qualities. It is well known that springs are designed to absorb and store energy and release it [1]. It can easily observe that material becomes a major factor in designing the springs. It can easily observe that material having lower modulus and density will have a greater specific strain energy capacity and stiffness [6]. Composite materials having more elastic strain energy storage capacity and high elastic strain storage capacity strength to weight ratio compared with those of steel multi leaf steel spring are being replaced three leaf spring. In every automobile four wheelers and railway the leaf spring is one of the main components and provides a good suspension and it plays a vital role of automobile application [4] . The advantage of leaf spring is over the helical spring is that the ends of the spring may be guide along a definite path as it deflects act a structural member in addition to energy absorbing device[1].

DESIGN PARAMETER OF STEEL LEAF SPRING:

Static analysis:

The dimensions of the **Ambassador deluxe nova car** leaf spring is taken for analysis is shown below

- Length of Master leaf =1219 mm
  Seventh leaf = 1160
  Sixth leaf = 1046 mm
  Fifth leaf =1000 mm
  Fourth leaf = 843 mm
  Third leaf = 668 mm
  Second leaf = 473 mm
  First leaf = 280 mm
- Width = 38 mm
- Thickness = 6 mm
- Camber = 180 mm

Table 1 Ambassador deluxe nova car leaf spring dimensions

LOAD (N)	DEFLECTION (mm)	STRESS (N/mm^2)
500	2.586	153.108
1000	5.177	306.159
1500	7.758	459.326
2000	10.354	612.776
2500	12.981	766.424

Leaf spring consists of two master leafs and five graduated leafs as shown in the Figure 1

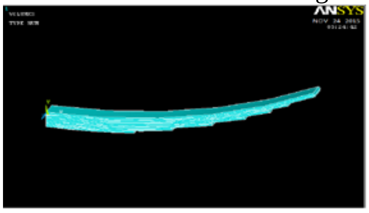


Figure 1.Assembled view of steel leaf spring.

Table 1 The material property

Serial No.	Material Property	Values
1	Young's Modulus,(E), N/mm^2	210000
2	Poisson Ratio,(m)	0.217
3	Coefficient of Friction,(μ)	0.3
4	Density,(ρ), kg/mm^3	7500

FINITE ELEMENT ANALYSIS OF STEEL LEAF SPRING:

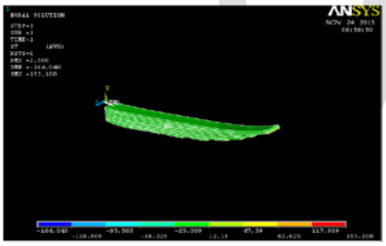


Figure 2 Stress developed in steel leaf spring.

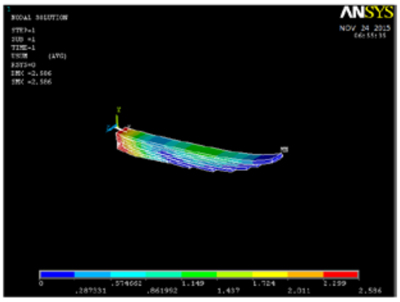


Figure 3.Deflection developed in steel leaf spring.

Table 2 Theoretical calculations of steel leaf spring

LOAD (N)	DEFLECTION (mm)	STRESS (N/mm^2)
500	2.985	143.96
1000	5.970	287.714
1500	8.955	431.87
2000	11.940	575.82
2500	14.537	719.78

ANALYSIS OF COMPOSITE LEAF SPRING:

Design Selection:

The leaf spring is designed based on the following three concepts.

1. Constant Thickness, Varying Width Design.
2. Constant Width, Varying Thickness Design.
3. Constant Cross-section Design [13].

Out of the above- mentioned three design concepts, the constant width and varying thickness method is selected due to the following reasons[23].

- Due to its capability for mass production and accommodation of continuous reinforcement of fibers.
- Since the cross-section area is constant through-out the leaf spring, same quantity of reinforcement fiber and resin can be fed continuously during manufacture
- Also this is quite suitable for filament winding process [5]

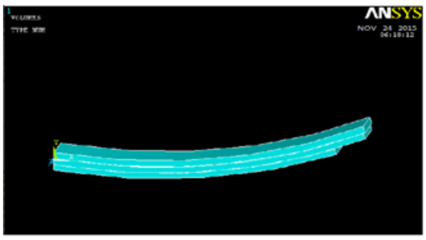
Table 3 Dimensions of the composite Leaf spring [1,9]

PROPERTIES	VALUE
Tensile Modulus along X direction, (E_x), MPa	34000
Tensile Modulus along Y direction, (E_y), MPa	6530
Tensile Modulus along Z direction, (E_z), MPa	6530
Shear Modulus along XY direction, (G_{xy}), MPa	2433
Shear Modulus along YZ direction, (G_{xy}), MPa	1698
Shear Modulus along ZX direction, (G_{xy}), MPa	2433
Poisson ratio along XY direction, (NU_{xy})	0.366
Poisson ratio along YZ direction, (NU_{yz})	0.217
Poisson ratio along ZX direction, (NU_{zx})	0.366
Mass Density of the Material,(ρ),Kg/mm^3	2.5e-6

LOAD (N)	DEFLECTION (mm)	STRESS (N/mm^2)
500	0.11723	26.42
1000	0.12982	52.78
1500	0.134492	79.261
2000	0.13853	101.641
2500	0.142317	126.834

Serial No.	Geometry	Values (mm)
1	Length of the spring, L,	1219
2	Breadth of the spring at the centre, B	38
3	Thickness of the spring T	15
4	Camber of the spring	180

Table 4 Geometry of leaf spring



4. Model of the composite Leaf spring

3.2 MATERIAL SELECTION & PROPERTIES:

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 material has been selected[3].

Materials under selection are S2- Glass fibers, E-glass fibers, Carbon fibers which have good mechanical propertiesthansteel;E-glass/epoxy is selected for the current work due to good mechanical properties and low cost. The material is assumed to be linearly elastic and orthotropic. Composite materials like the E-glass/epoxy in the direction of fibers have good characteristics for storing strain energy. So, the layup is selected to be unidirectional along the longitudinal direction of the spring [1]. Epoxies are found to be the best resin that would suit this application [22]. The material property of composite leaf spring is shown in table. Table 2.5 [11]
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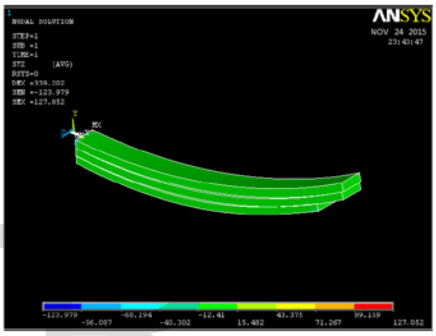
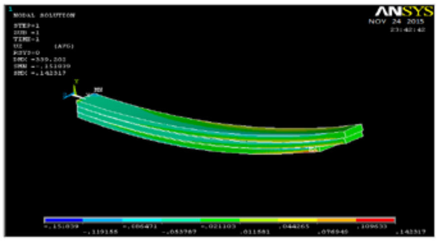
3.3 FINITE ELEMENT ANALYSIS OF COMPOSITE LEAF SPRING:

Static analysis is performed on the composite leaf spring by using ANSYS 11.0. SOLID 187 elements are used for the static analysis. The steps required for static analysis are Preprocessor, Solution and Postprocessor, are done sequentially. The deflection and stress of Steel leaf spring for the load of 2500 N is obtained from ANSYS is shown the fig.



5. Stress developed in composite leaf



6. Deflection developed in composite leaf spring

4.1 PROBLEM FORMULATION

The objective of the problem is to minimize the weight of the leaf spring with the prescribed strength and stiffness. The objective function identified for the leaf spring problem is given in equation (2). The composite leaf spring is designed based on the constant width and varying thickness methods.

$$f(w) = \rho LBT$$

A design problem usually involves many design parameters, of which, some are highly sensitive. These parameters are called design variables in the optimization procedure. In the present problem, the following variables are considered, centre width, B and

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LOAD N	DEFLECTION (mm)	STRESS (N/mm2)	DEFLECTION (mm)	STRESS (N/mm2)
500	2.586	153.108	1.172	26.42
1000	5.177	306.159	1.298	52.78
1500	7.758	459.326	1.344	79.26
2000	10.354	612.776	1.385	101.64
2500	12.981	766.424	1.423	126.834

centre thickness, T. The upper and lower bound values of design variables are given as follows

B_{max} = 50 mm and B_{min} = 25 mm

T_{max} = 50 mm and T_{min} = 8 mm

Design parameters usually remain fixed in relation to design variables. Here, the design parameters are length of leaf spring, L, design load, W, material properties density, ρ, modulus of elasticity, E and maximum allowable stress, σ_{max} [2].

A behavior constraint is defined as an inequality that must be satisfied in order to have a feasible design. In this problem, the constraints are the bending stress and vertical deflections given in equation (3) and equation (4). [7]

$$\delta = \frac{6WL^3}{ENBT^3}$$

$$\sigma = \frac{6WL}{NBT^2}$$

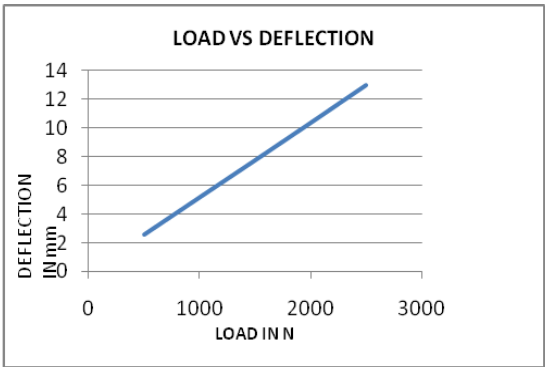
Weight = 2.929Kg
Breadth = 38 mm
Thickness = 15 mm
Deflection = 0.1423 mm
Stress = 126.83 N/mm2

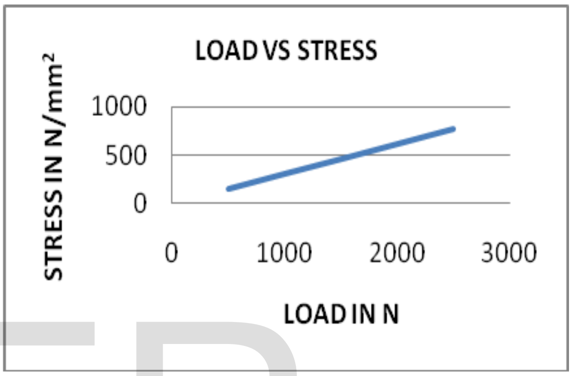
RESULT AND DISCUSSION

Weight reduction formula for composite leaf spring:
Weight = volume * density
Weight = 590.8*15*38*2.5*10^-6
= 0.9765 for first leaf spring
Weight = 530*38*15*2.5*10^-6
= 0.75525 for third leaf spring
Total weight of composite leaf spring
= 0.9765+0.9765+0.75525
= 2.70825 Kg

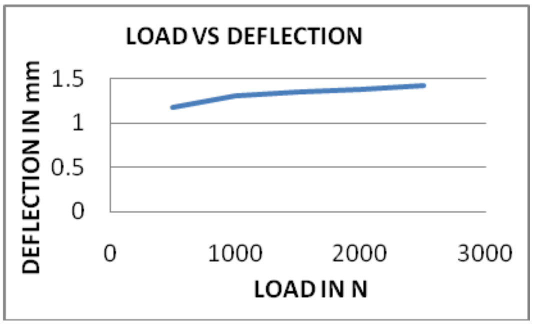
5. COMPRASIONRESULTS OF LOAD STRESSES AND DEFLECTION

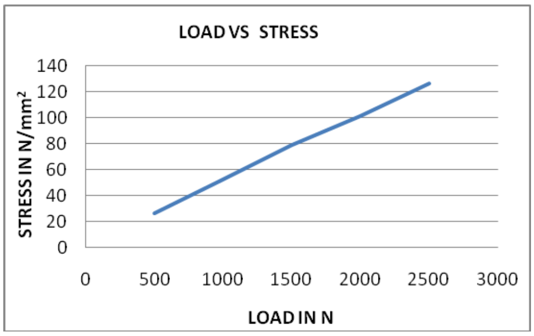
5.1 GRAPH FOR STEEL LEAF SPRING LOAD VS STRESS & DEFLECTION





5.2 COMPOSITE LEAF SPRING LOAD VS STRESS & DEFLECTION





5.4 WEIGHT REDUCTION

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The weight of composite leaf spring is to be 27.08 the steel leaf spring weight is 83.77 N. Percentage reductions in weight by material replacement

= 83.33- 27.08 / 83.33

= 67.50%

5.5 CONCLUSION

The Steel Leaf Spring and the Composite Leaf Spring was analyzed by finite element method in ANSYS 11.0. From the result, it is clear that the composite leaf spring deflects less to that of the steel leaf spring and the stress induced in the composite leaf spring is found to be lower than that of the steel leaf spring. A reduction of **67.50%** weight is achieved by replacing the nine leaf steel spring with the three leaf composite spring under identical conditions of design parameters

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