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Design, Optimization And FE Analysis of Composite Mono Leaf Spring

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Abstract: *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. The study of composite leaf springs has been popular in automotive light weighting. Particularly, the research on the fatigue reliability of composite leaf springs is crucial. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing mono steel leaf spring of a Maruti Alto 800 passenger vehicle is taken for modeling and analysis of modeling and analysis of a laminated composite mono leaf spring with glass fiber composite material.*
Keywords : *Composite Mono Leaf Spring, Design, Optimization, FEA.*

I. Introduction

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.To meet the need of natural resources conservation, automobile manufacturers are attempting to reduce the weight of vehicles in recent years. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles unsprung weight.This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness [3].

The composite materials made it possible to reduce the weight of machine element without any reduction of the load carrying capacity. Because of composite material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel. FRP spring also have excellent fatigue resistance and durability.Glass fibers are strong as any of the newer inorganic fibers but they lack rigidity of on account of their molecular structure. But the weight reduction of the leaf spring is achieved not only by material replacement but also by design optimization. Weight reduction has been the focus of automobile manufacturers in the present scenario. The replacement of steel with optimally designed composite leaf spring can provide 75%-78% weight reduction. Moreover, the composite leaf spring has lower stresses compared to steel spring. [3].

II. Problem Definition

The automotive leaf springs play a major role in the production cost and efficiency of vehicles. Manufacturers are continuously looking for improved design of automobile leaf springs to gain competitive advantage. Usage of composites materials in design and development of leaf springs can result in significant benefits to the manufacturers and end users. With the latest developments in the composites technologies and processes, it is possible to replace conventional materials used in leaf springs with composites at competitive price and for high volume production.

III. Objectives

1. To analyze structural stability of existing steel and optimized glass fiber mono leaf spring analytically and by finite element analysis.
2. Existing steel and optimized glass fiber mono leaf spring analyzed by finite element analysis.
3. Comparing FEA results with the analytical results obtained for steel and glass fiber mono leaf spring.

IV. Literature Review

Stephan Krall, Richard Zemann[1], the paper deals with the dynamic behavior of CFRP leaf springs. The experimental modal analysis is used for the investigation.Chen Qian, Wenku Shi, Zhiyong Chen, Shixiang Yang, Qianqian Song,[2] this paper proposed the fatigue law inference of the parabolic composite leaf spring, which was validated by fatigue bench tests.Mahmood M. Shokrieh Davood Rezaei[3] in this paper a four-leaf steel spring used in the rear suspension system of light vehicles is analyzed using ANSYS V5.4 software. Rajendran,S.Vijayarangan, [4] a formulation and solution technique using genetic algorithms (GA) for design optimization of composite leaf springs is presented here. Leaf spring contributes for about 10-20% of unsprung weight. This paper presents an artificial genetics approach for the design optimization of composite leaf spring. H.A. Al-Qureshi[5] this paper is to present a general study on the analysis, design and fabrication of composite springsJ.P. Hou, J.Y. Cherruault , I. Nairne, G. Jeronimidis R.M. Mayer [6] This paper presents the design evolution process of a composite leaf spring for freight rail applications. E. Mahdi. [7] This study introduces a new composite semi-elliptical spring by utilizing fiber reinforced composite strength in principal direction instead of shear direction.R D V Prasad [8], this paper deals with development of analytical formulation for Composite leaf spring in this project has been developed as a mono block construction with maximum thickness at the center which is preferably Carbon fiber reinforced polymer. M. Raghavedral, et.al [9], In the present work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle is taken for modeling and analysis of modeling and analysis of a laminated composite mono leaf spring with three different composite materials namely, E-Carbon/Epoxy, S-Carbon/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring.

V. Design of mono leaf spring

5.1. In static condition:

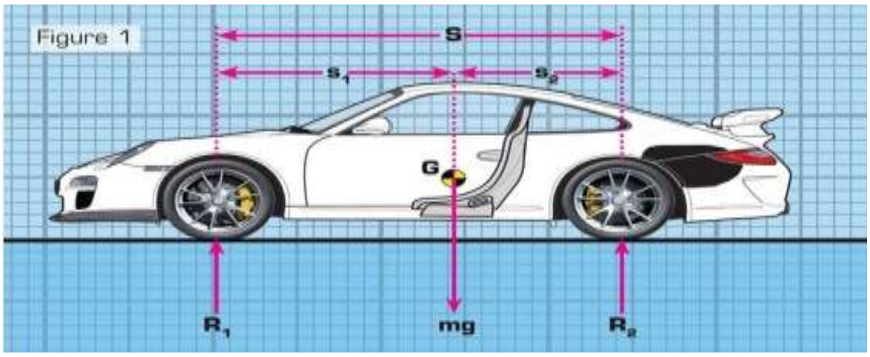

Fig. 5.1. Force diagram

Fig shows the forces on a stationary car. The earth's gravitational pull (mg) acts through the centre of gravity and the reaction (remember: to every action there is an equal and opposite reaction) acts through the contact patches between the tyres and the road. The vectors shown represent the combined reactions at both front wheels (R1) and both rear wheels (R2).

Total weight of the car = 25987.6 N

This weight must be divided into front axle weight and rear axle weight. 52% of total weight is taken by front axle and 48% of total weight is taken by rear axle.

Front axle weight = 13513.5 N

Reaction at one wheel = 6756.8 N

Rear axle weight = 12474.05 N

Axle weight on one wheel = 6237.02 N

Assuming 5 number of plates of leaf spring 1247.4 N

5.2. Calculation for deformation and stress in leaf spring:

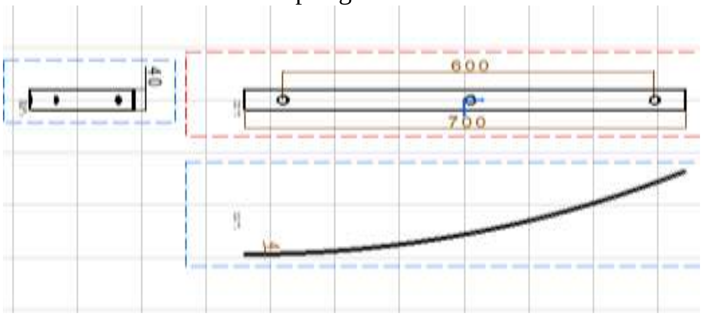

Fig. 5.2. Dimensions of leaf spring

W= 1247.4 N
b = 40,
d = 4
Length = 600
Hence,

Table 5.1. Calculated Properties of mono leaf spring

Area moment of inertia section properties (Units4)	=21324.8
Section modulus (Units3)	=1066.88
Radius of Gyration (Units)	=11.56
Extreme Point(Units)	=20
Area (Units)	=160

Considering simply supported beam load acting at center
Stress at center of constant cross section is given by 175.38 Mpa
(Same for both steel and Glass fiber)

Maximum deflection at load is given by,
Material Properties:

Table5.2: Mechanical properties for Steel

Property	Value
Young's modulus	2* 10 5 Mpa
Poisson's Ratio ,ν	0.3
Density, ρ	7.85 x 10-6 kg/mm3
Tensile Yield Strength	250 Mpa
Compressive Yield Strength	460 MPa
Compressive ultimate Strength	0 MPa

Table5.3. : Mechanical properties for Glass fiber

Property	Value
Young's modulus in z-direction, Ez	4* 10 5 Mpa
Poisson's Ratio ,ν	0.36
Density, ρ	6x 10-6 kg/mm3
Tensile Yield Strength	2500 Mpa
Compressive Yield Strength	3150 MPa

For Steel, S = 1.4 mm
For Glass fiber, S = 0.658 mm

VI. Numerical Methodology By Using Fea

6.1. CAD Model:

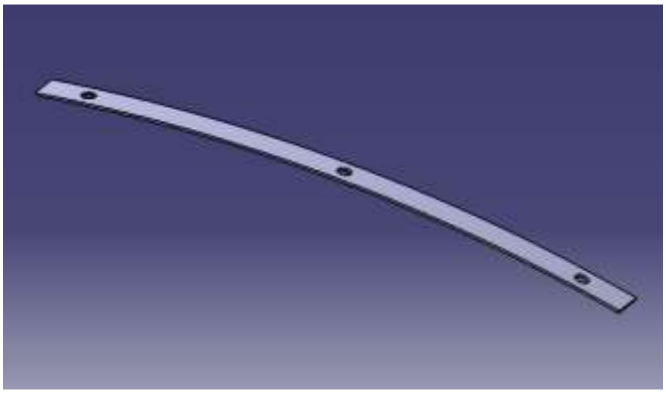

Fig. 6.1: Mono leaf spring

6.2. Finite Element Analysis:
6.2.1 Meshing: We are going to mesh the components using 3D elements. As all dimension of leaf spring are in proportion we use the tetra-hedralelements for meshing.

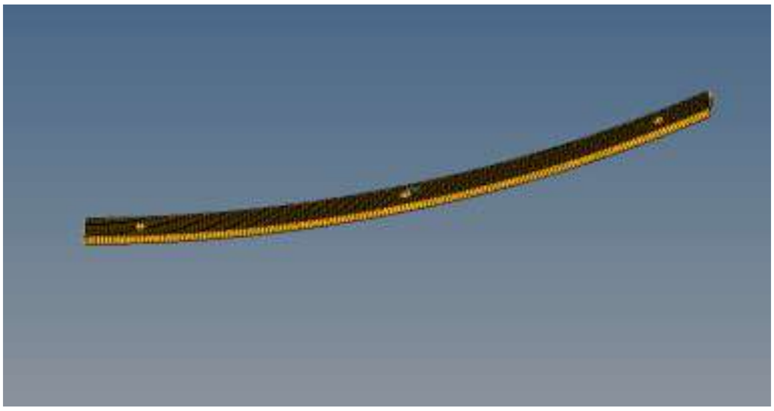

Fig.6.2: Quad meshing on leaf spring

Number of nodes: 1873
Number of elements: 1678

6.3 Boundary Condition: As shown in below figure vertical load is applied at joint2, and fixed on the other two sides.

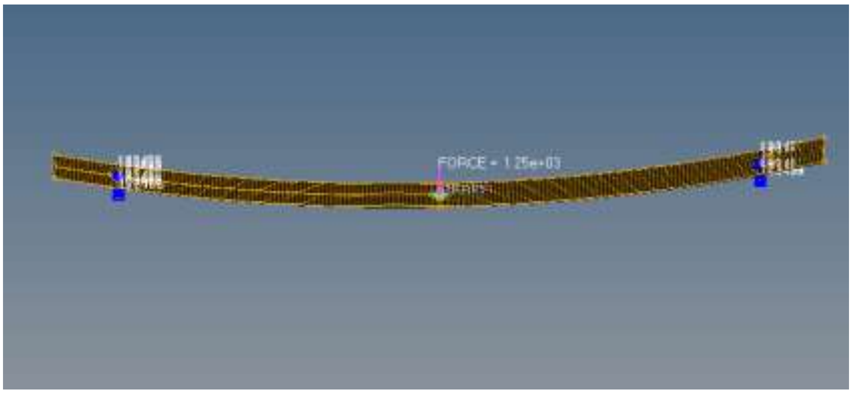

Fig.6.3: Boundary condition applied in Hypermesh

Meshed and boundary condition applied model is imported to the solver. Analysis process starts after applying run in the solver software ANSYS.

6.4 Results displayed for stress and deformation for Steel:

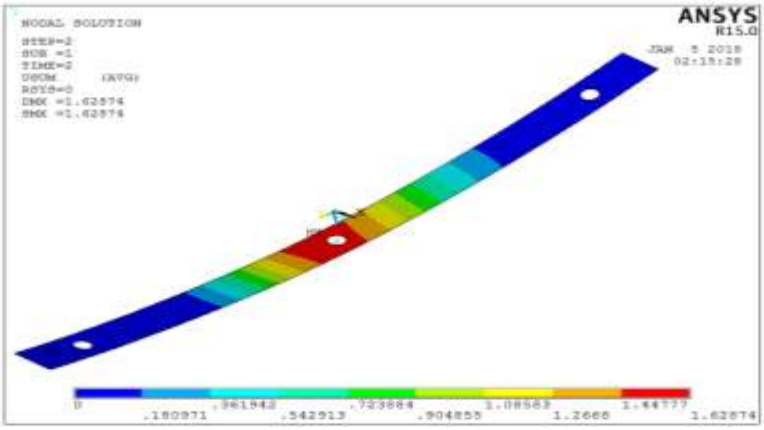

Fig 6.4: Displacement result for leaf spring

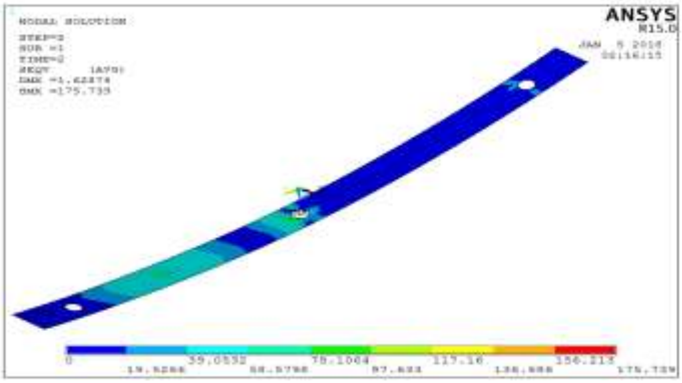

Fig. 6.5: von-misses stress for leaf spring

6.5 Results displayed for stress and deformation for composite leaf spring:

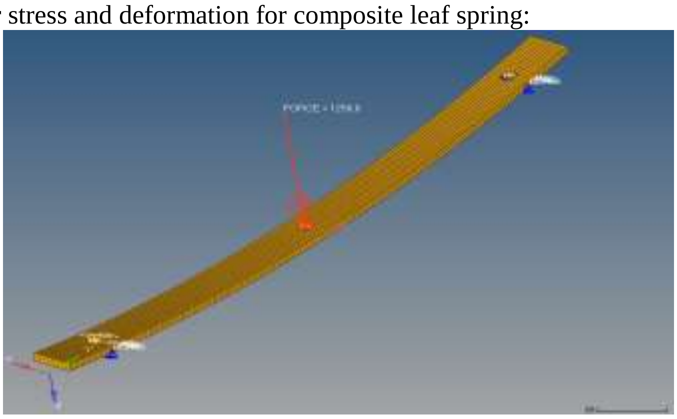

Fig.6.6: meshed model for Glass fiber leaf spring and applied boundary conditions

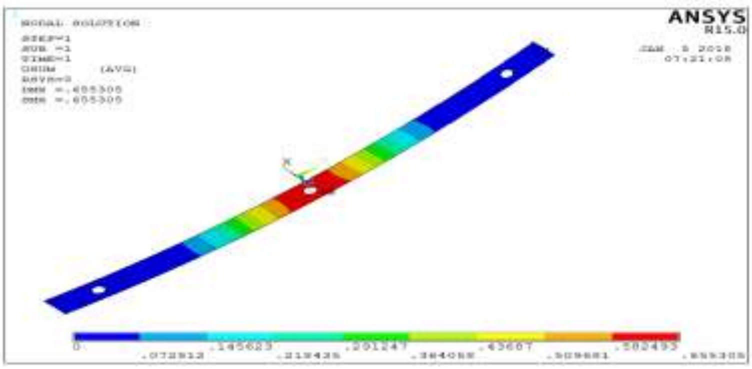

Fig.6.7: Displacement result for composite leaf spring

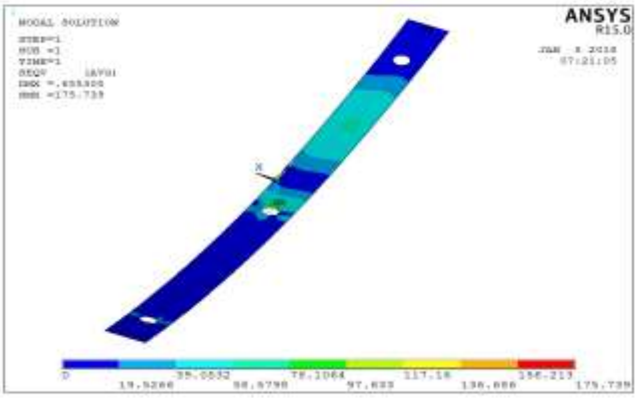

Fig. 6.8: von-misses stress for composite leaf spring

VII Results

Table No.7.1. Result table

Type of Analysis	Steel		Glass Fiber	
	Deformation (mm)	Stress (Mpa)	Deformation (mm)	Stress (Mpa)
Analytical	1.4	175.38	0.655	175.38
Finite Element Analysis	1.6	175.73	0.655	175.73

VIII. Conclusion

Maximum deformation in the existing steel mono leaf spring is 1.4 for maximum permissible load of 1250 N and in optimized glass fiber is 0.655 which is nearly half of the value for existing steel spring for the same design whereas the equivalent stress generated in both the cases is 175.38 Mpa. FEA results are in good arrangement with the analytical results obtained for steel and glass fiber mono leaf spring. Hence, the newly material optimized glass fiber is recommended as high structurally stable than the steel mono leaf spring.

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