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Design Optimization and Analysis of a Parabolic Leaf Spring

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Abstract: A leaf spring is a simple form of spring, generally employed for the suspension in automotives. It is one of the important forms of springing techniques. Axle beam is located at the centre of the arc, at the end are the while tie holes which are employed for attaching to the vehicle body. The automobile industry has showed a great interest in the replacement of steel springs by parabolic leaf spring. Therefore, the aim of this research work is to present a general study on the analysis, design and fabrication of parabolic leaf springs. This research work is based on a complete study and design of leaf spring. Here Finite element models been deployed to optimize and improve the material with complete geometry of the parabolic spring based on the spring rate, long life and shear stress. The influence of elasticity ratio on performance of parabolic springs was investigated computationally.

Key words: Parabolic leaf spring · Composite materials · Finite element analysis and structural analysis.

INTRODUCTION

Leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Europe and Japan and late 1970's in America when the saw automobile manufacturers use coil springs instead. Today leaf springs and trucks, SUVs and railway carriages [1]. For heavy vehicles, they widely over the vehicle's chassis, whereas coil springs transfer it to also locate the rear axle, eliminating a Panhard rod, thereby saving cost and weight in a simple live axle rear suspension. An advantage of a leaf spring over a helical spring is that the end of Sometimes referred to as a semi-elliptical spring or cart spring, spring steel of rectangular cross-section. The center of the arc at either end for attaching to the vehicle body [2]. For several leaves stacked on top of each other in several be attached directly to the frame at both ends or other end attached through a shackle, a short swinging arm. to elongate when compressed and thus makes for softer springiness. end (seldom used now), to carry a swiveling member.

Elliptical or full elliptical springs refer to two circular arcs linked at their tips. These are joined to the frame at the top center of the upper arc.

Fig. 1: Leaf Spring

The bottom center is joined to solid front axle [3]. Additional suspension are needed for this design.

Semi-elliptical springs use a lower arc. Therefore, they don't need the additional suspension components [4].

Quarter-elliptical springs have the thickest part of the stack pieces of a ladder type frame. The free end is attached to the differential.

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Problem Definition and Objective

Problem Definition:

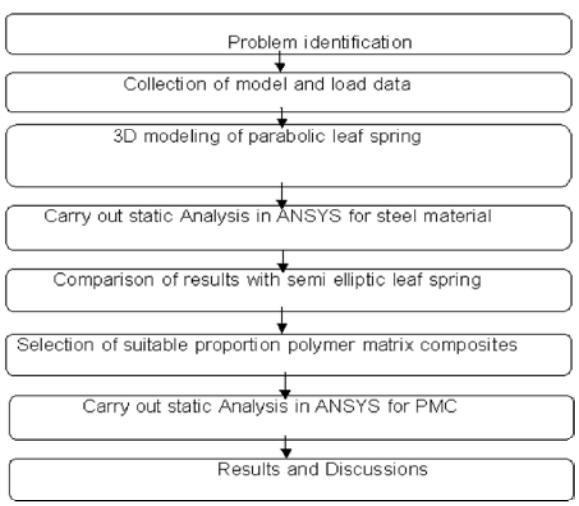
- When a leaf spring is compressed, the length of the leaves changes
- Be a source of noise and can also produce friction.
- Weight of steel leaf spring is around 9.2kg.

Objective: The main objectives of this study are

- Reduce the weight of the steel leaf spring by introducing composite material.
- To increase the load carrying capacity.
- To increase ride comfort for passengers.

MATERIALS AND METHODS

The Method Used in this Project Work



Finite Element Modeling: Parabolic spring was modeled using commercial software and all the geometry was and it consist of two leafs. As a preliminary study here, sever assumptions have been made i.e. the chosen material was homogenous, the frictional effect has not been taken into account, shackle and bush was not model together to reduce he complexity of simulation [5,6]. Shackle and bushing only presented by boundary condition and shot-peening stress effect and nip stress also omitted.

For the FEA simulation, 20-nodes hexahedral element was utilized. Model of a parabolic spring was partition into smaller region for easier meshing process. Boundary condition was set according to real static load at y axis and the rear eye was constrained in free x translation and y rotation [7]. Contact from main-to 2nd degree of freedom to represent spring together.

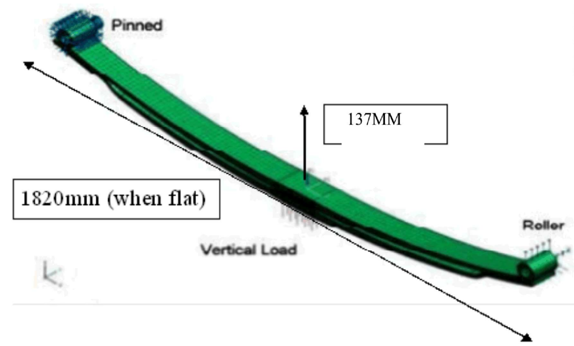


Fig. 2: Meshing element and boundary condition for the parabolic spring model

Finally, vertical load was applied at the center flat of the spring.

Cad Model

Parameters of Existing Steel Leaf Spring

Collected Data's

- Total length 1712 mm - main leaf
- Front half (the arc length from axle seat and to front eye) 559 mm
- Arc height at axle seat 120.4 mm
- Normal static loading 2500 N(Rated)
- Full bump loading 4660 N(Over)
- Spring Width 50-60 mm
- Spring Thickness 11-22 mm

Calculated Dimensions:

- Eye dia - 20 mm
- Center bolt dia - 10 mm
- Clip - 25 X 5 mm

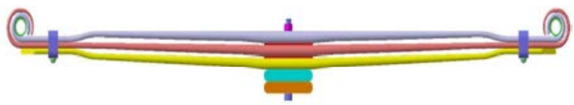
Material Specification:

- Material: Steel
- Young's Modulus : 2x10^5 Mpa
- Poisson's ratio : 0.3
- Density : 7.8 g/cc

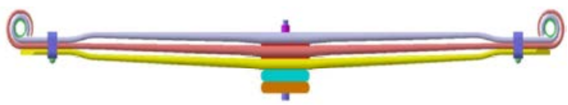
Modeled Using CATIA V5: CAD Modeling of any project is one of the most time consuming process. CAD Modeling is the base of any project [18]. in CAD model. Although most of the CAD Modeling of Fin ite Element software have capabilities of generating a but their off domain capabilities are not sufficient typical shapes of the

Table 5.1: Individual Leaf Dimension

	Leaf Length (MM)					
Leaf No	FRONT	REAR	TOTAL	Thick (MM)	End Thick (MM)	Width (MM)
1	856	856	1712	22	11	50
2	904	904	1808	22	11	50
3	734	734	1468	22	11	50



FRONT VIEW



ISO VIEW

Fig. 3:

product [19]. The model of the multi are difficult to make by any of other CAD modeling of the complete multi Leaf Spring structure [10]. CAD model of leaf spring consist of total design to make a complete multi leaf spring model, out of and size.

The CAD model of leaf spring is now imported into ANSYS-11. All the boundary conditions and material properties are specified as per used for the leaf spring for analysis approximately similar isotropic behavior and properties as compared to 65Si7 [15].

The procedure for performing analysis in ANSYS involves setting contact reign- Contact conditions are formed where bodies meet between various parts is automatically detected set up contact regions manually [20]. You across the contact boundaries and connect the the analysis can be linear or nonlinear. The differences bodies can move relative to one another. This is on what other settings are available. Most of these up of faces only. In this assembly the applies to regions of faces. Separation of faces in contact is not allowed, occur along contact faces. In general CONTA 72 and TARGET 71 are used

Specifying Joints: A joint is an idealized kinematics linkage that controls the relative movement between rotational and translational degrees of freedom as revolute joints are used between eye and pin. The joint rotation is 27° corresponding to no load camber angle of 153°.

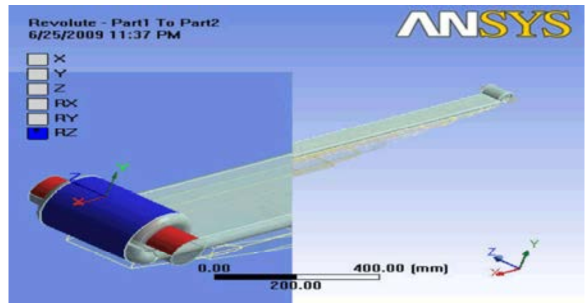


Fig. 4:

Meshing - Meshing is the process spatially discretized into elements and nodes.This mesh along with material stiffness and mass distribution of on a number of factors including the proximity of other topologies, body [13]. If necessary, the fineness of the mesh (eight times for an assembly) to achieve a successful mesh. In this assembly SOLID92 element is used for the results.

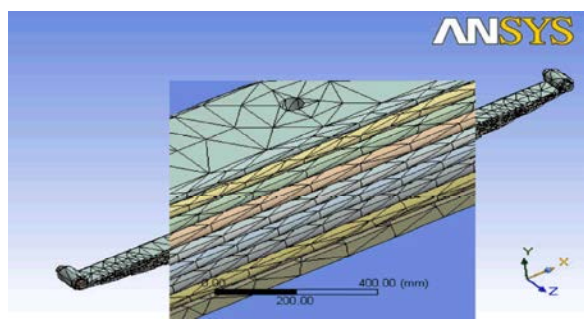


Fig. 5:

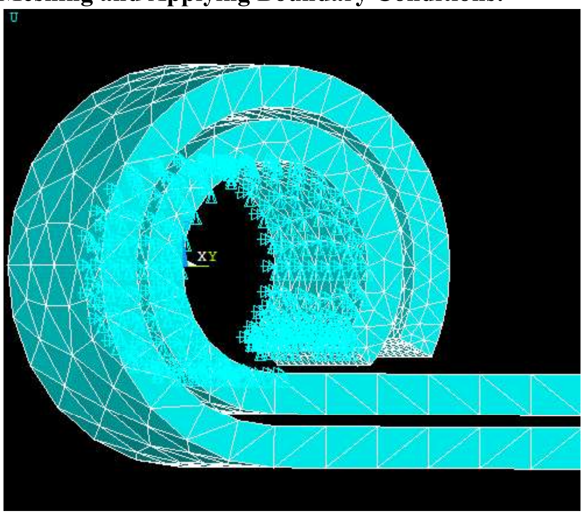
Setting Analysis Environment: A static structural analysis in structures or components caused by loads that do response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time takes into consideration conditions, support conditions, joints and contacts which are to be specified as the input to the pre processing of the analysis [14].

Setting Boundary Conditions: The boundary conditions are applied by taking into consideration the experimental loading conditions [17].

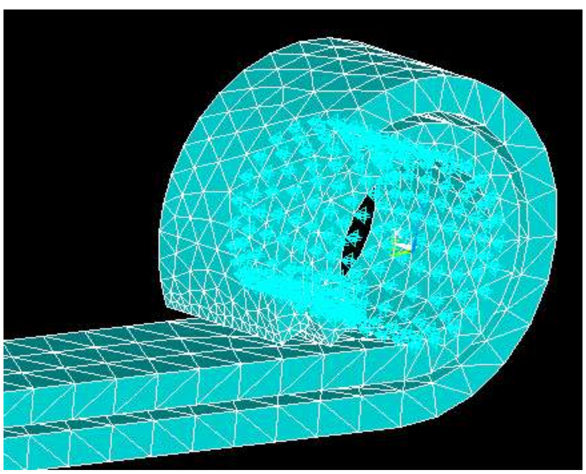
Chapter 6: Static Structural Analysis of Steel Leaf Spring

Ansys Assumptions:
Element Type: Solid - 8 node 183 structural solid element
Contact - 3D Target 170 represents contact and sliding between adjacent surfaces of leaves

Meshing and Applying Boundary Conditions:



ALL DOF'S CONSTRAINT



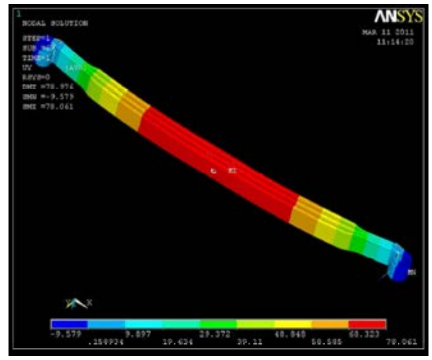
ROTATION ABOUT Z AXIS CONSTRAIN ALL DOF'S EXCEPT

Fig. 6:

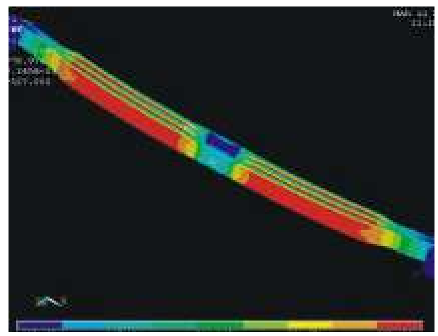
Applying Loads and Results: Static analysis is carried out for following conditions

- Rated load - 2500 N
- Over load - 4660 N

Under Rated Load Condition:

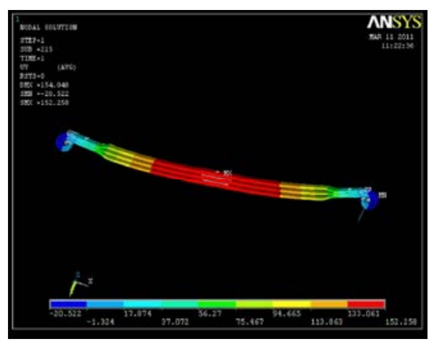


Max Deflection of 78.061mm in y-axis

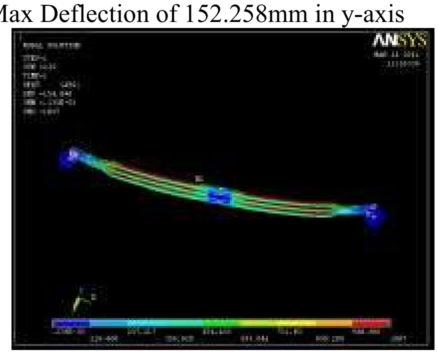


Max Von misses stress is 27.056 Mpa
Fig. 7:

Under over Load Condition:



Max Deflection of 152.258mm in y-axis



Max Von misses stress is 1067Mp
Fig. 8:

Comparison of Results

Table 6.1: Comparison of Results

Loading condition	Deflection (mm)		Stress (Mpa)	
	Semi elliptic	Parabolic	Semi elliptic	Parabolic
Rated load	120.4	78.06	483.3	527.056
Over load	209.3	152.25	844.4	1067

CHAPTR 7:
Design of Composite Leaf Spring

Material Selection:

- Material selected should be capable of storing more energy in leaf spring.
- Elastic energy that can be stored by a leaf spring volume unit is given

by

S= σ²/2 X E

- σ - is the maximum allowable stress induced into the spring
- E - is the modulus of elasticity

Considering material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring,composites have these properties.

Polymer Matrix Composite: Polymer Matrix Composite (PMC) is the material consisting of a polymer Polymer Matrix Composites are very popular due to their low cost and simple fabrication methods[16].

Matrix and Reinforcement Material
Epoxy Resin Matrix:

- Cost is low, exhibits moderate shrinkage, Interlaminar fracture toughness is low and mechanical properties are good.

E-glass Fibers:

- Lighter, stiffer and stronger
- Crashworthiness and water resistan

Mechanical Properties Epoxy Resin Matrix:

- Axial and Transverse modulus - 3.4 Gpa
- Poisson's Ratio - 0.3
- Density - 1.15 - 1.2 g/cc
- Shear strength - 34 Mpa

E-glass Fibers:

- Axial and Transverse modulus - 85 Gpa
- Poisson's Ratio - 0.2
- Density - 2.54 g/cc
- Shear strength - 35 Mpa

Volume Fraction: Volume fraction is taken as shown below in Table 7.1.

$V_f + V_m = 1$

Where,

Fiber volume fraction V_f
Matrix volume fraction V_m

Table 7.1: Volume fraction of materials

Trials	Volume Fraction	
	Epoxy Resin	Glass Fibre
1	0.6	0.4
2	0.7	0.3

Properties of Overall Composite
Density:

$\rho_c = \rho_f V_f + \rho_m V_c$

Where,

Pc = Density of composite, g/cc.
Pf = Density of fibre, g/cc.
Pm = Density of matrix, g/cc.

Young's Modulus

$$\frac{1}{E_2} = \frac{V_f}{E_f} + \frac{V_m}{E_m}$$

Where,

E_2 = Youngs modulus of composite, g/cc.
E_f = Youngs modulus of fibre, g/cc.
E_m = Youngs modulus of matrix, g/cc.

Poisson's Ratio

$$\nu_{12} = \nu_f V_f + \nu_m V_m$$

Where,

ν_{12} = Poisson ratio of composite, g/cc.
V_f = Poisson ratio of fibre, g/cc.
V_m = Poisson ratio of matrix, g/cc.

Calculated Properties of Overall Composite

Table 7.2: Overall properties of materials

Trials	Density (G/cc)	Young's Modulus (Gpa)	Poisson's RATIO
1	1.736	5.52	0.26
2	1.602	4.77	0.27

Chapter 8: Static Structural Analysis of Composite Leaf Spring

Ansys Assumptions:
Element Type: Solid - 185 tetrahedra structural solid element

Consider as homogeneous material and its properties are calculated.

Meshing and Applying Boundary Conditions:

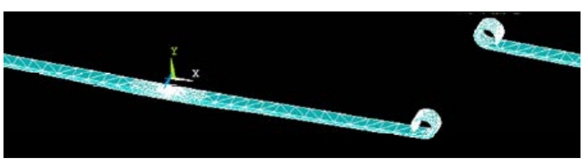
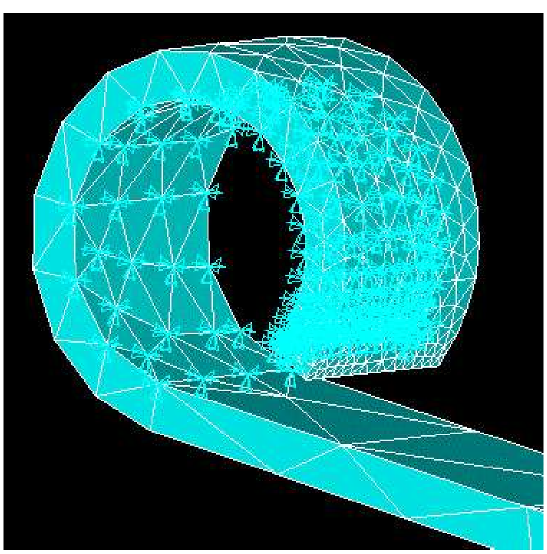
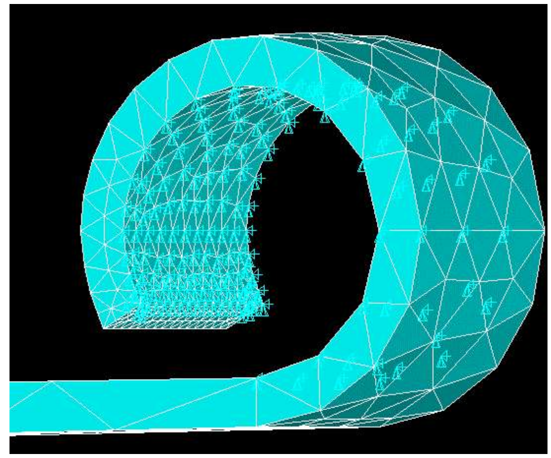


Fig. 9: MESH GENERATED



ALL DOF'S CONSTRAINT

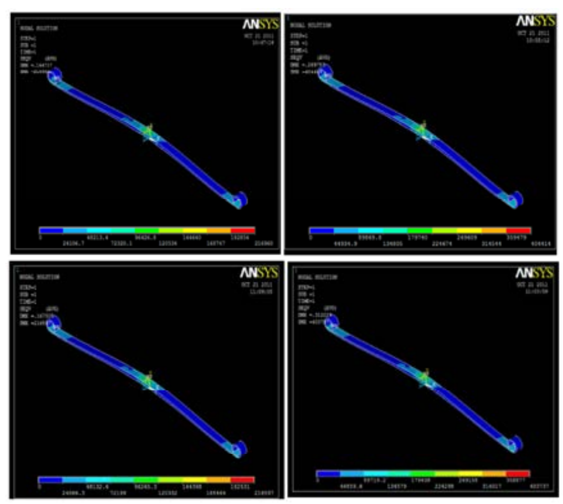


ALL DOF'S EXCEPT X-AXIS CONSTRAINT
Fig. 10:

Applying Loads and Results: Static analysis is carried out for following conditions

- Rated load - 2500 N
- Over load - 4660 N

Trial 1 at Rated Load Trial 1 at over Load



Comparison of Results:

Table 8.1: Comparison of Results

Loading condition	Deflection (mm)		Stress (Mpa)	
	Trial 1	Trial 2	Trial 1	Trial 2
Rated load	14.5	16.7	216.96	404.414
Over load	26.9	31.2	216.59	403.737

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