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Finite Element Modeling and Analysis of Parabolic Leaf Spring

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Abstract:

Static and fatigue analysis of parabolic leaf spring made of plain carbon steel (SUP11A) and E Glass/epoxy resin has been carried out. Primary objective is to compare the load carrying capacity, stiffness and weight savings of parabolic composite leaf spring with that of steel leaf spring at rated-load and over-load condition and to justify the usage of composite material for replacing the leaf spring, which is made up of steel. Implicit analysis and fatigue analysis has been carried out for the parabolic leaf springs made up of steel and E Glass/epoxy composite material. Stress and defections were estimated at rated and overload conditions. For the rated load conditions fatigue analysis has been carried out. The results were compared. Implicit analysis of the leaf spring has been carried out using Ansys12.1.

1. LEAF SPRING:

A leaf spring is a long, flat, thin, and flexible piece of spring steel or composite material that resists bending. The basic principles of leaf spring design and assembly are relatively simple.It can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm.There are three basic designs of leaf springs that are used, namely.They are parabolic spring, Multi-leaf springs and Mono-leaf springs. Leaf springs (which is not stretched or compressed beyond the elastic limit) obey Hooke's law.

F=Kx

Where,

x - Displacement vector (the distance and direction in which the spring is deformed).

F - Resulting force vector (the magnitude and direction of the restoring force of spring)

K - Spring constant or force constant of the spring.

The amount of elastic energy that can be stored by a leaf spring volume unit is given by

$$S = \frac{\sigma^2}{2E}$$

Where,

σ - is the maximum allowable stress induced into the spring.

E - is the modulus of elasticity, both in the longitudinal direction.

2. LITERATURE SURVEY:

In the present scenario, weight reduction has been the main focus of automobile manufactures. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for ten to twenty percent of the unsprung weight, which is considered to be the mass not supported by the leaf spring. The introduction of composite materials made it possible to reduce the weight of the leaf spring without any reduction on the load carrying capacity and stiffness.From literature review, most of the literature has been focused on the optimization of semi-elliptical leaf spring. In most of the literature mono leaf composite model has been developed and 2d leaf spring alone taken for the FE method without considering shackle end. So from those literatures there is wide area where design optimization of 3d parabolic leaf spring has not been done and parabolic composite leaf spring has not been developed. So this project will be focusing on this area.

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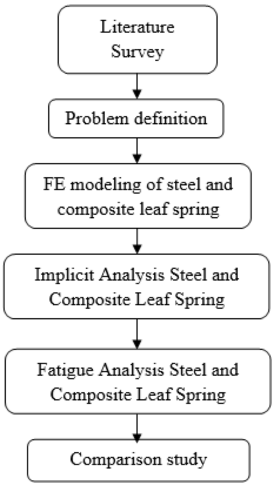
3. OBJECTIVES AND METHODOLGY:

Primary objective of the project is to develop the FE model of the steel and E Glass / Epoxy composite parabolic leaf spring.To perform implicit analysis to study the deflection and stress distribution at rated and over load condition. Below is the methodolgy of the project.



4. PREPROCESSING:

Model is designed by using CATIA V5.The main objective is to focus on three leaf of the spring on which various analysis performed. Checking for free edges and cracks is the basic step in order to get the perfect model. Before starting, the FE modelling, free edges of the surfaces should be corrected.FE modeling is carried out.One end of the modal is constraint in all degree's freedom except rotation about Z-axis other ends of the spring is attached to shackle.In the formulation of finite elements, a local parametric coordinate system is assumed for each element type, how well the physical coordinate systems, both element, and global, match the parametric dictates element quality.For 3d FE model steel material of SUP11A has been assigned.For 2d FE model composite material of E glass/epoxy resin has been assigned. Composite materials like E-glass/epoxy in the direction of fibers have good characteristics for storing strain energy. So, lay up is selected to be unidirectional along the longitudinal direction of spring.

5.IMPLICIT ANALYSIS:

In implicit method the dynamic equilibrium equation is solved at time t and t+Δt after each increment the analysis does Newton-Raphson iterations to enforce equilibrium of the internal structure forces with the externally applied loads.

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5.1 Modal Analysis

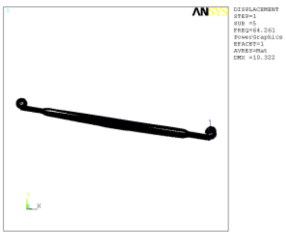
Constraint Modal Analysis For Parabolic Steel Leaf Spring:

Mode1

Mode2

Mode3

Mode4



Mode 5

MODE	Frequency(Hertz)
1	11.976
2	21.4
3	30.382
4	44.031
5	64.261

First five natural frequency of parabolic steel leaf spring

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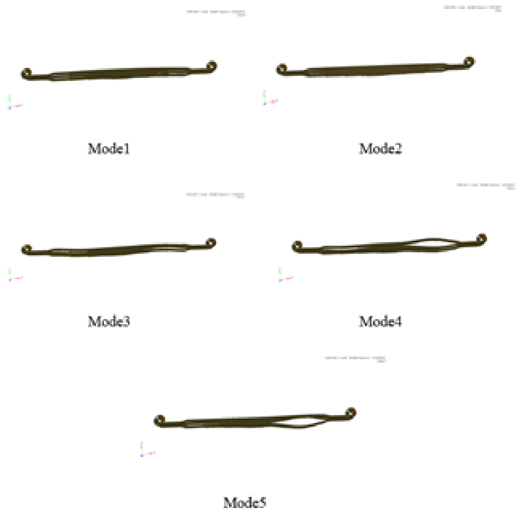
Constraint Modal Analysis For Parabolic Composite Leaf Spring:



MODE	Frequency(Hertz)
1	25.7
2	93.07
3	111
4	131.4
5	135.7

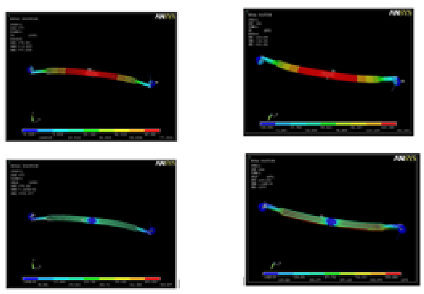
First five natural frequency of parabolic composite leaf spring

5.2.Static Analysis

5.2.A.Static Analysis Of Parabolic Steel Leaf Spring:

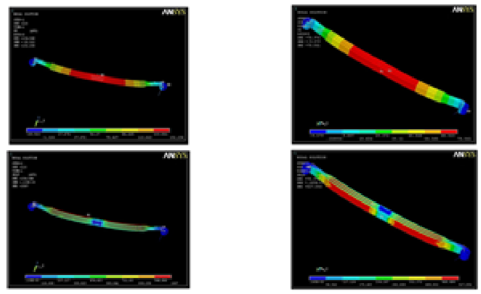
A finite element stress analysis is performed under rated and over loading condition at 1g Static condition at clamped and unclamped condition.

Clamped Condition:



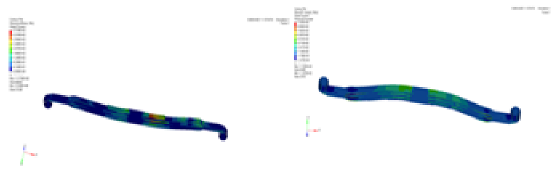
Displacement and stress plot for clamped rated load condition. Displacement and stress plot for clamped over load condition.

Unclamped Condition:



Displacement and stress plot of unclamped over loading leaf spring Displacement and stress plot of unclamped rated loading leaf spring

5.2.B.Static Analysis Of Parabolic Composite Leaf Spring:



Stress plot of parabolic composite leaf spring at rated load Stress plot of parabolic composite leaf spring at over load

At rated load condition interlaminar shear stress was found to be 373.4N/mm².

At over load condition interlaminar shear stress was found to be 1020N/mm².

6. DURABILITY ANALYSIS:

Fatigue occurs when a material is subjected to repeat loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the surface. Eventually a crack will reach a critical size, and the structure will suddenly fracture. Stress-Life module calculates the fatigue life of a part under constant amplitude oscillatory loading assuming the stress range controls fatigue life.

6.1. Endurance Limit:

Certain materials have a fatigue limit or endurance limit which represents a stress level below which the material does not fail and can be cycled infinitely. If the applied stress level is below the endurance limit of the material, the structure is said to have an infinite life.

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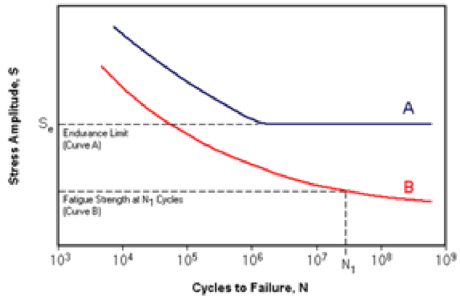
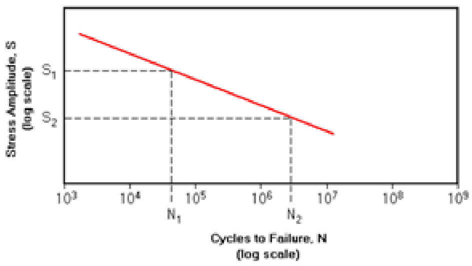


Endurance limit two different material.

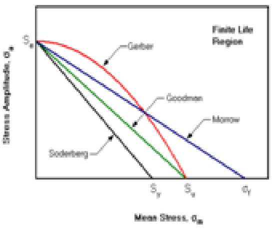


Idealized S-N Curve

6.2. Haigh Diagram:

Goodman:	$\frac{S_a}{S_e} + \frac{S_m}{S_u} = 1$
Gerber :	$\frac{S_a}{S_e} + \left(\frac{S_m}{S_u}\right)^2 = 1$
Soderberg:	$\frac{S_a}{S_e} + \frac{S_m}{S_y} = 1$
Morrow:	$\frac{S_a}{S_e} + \frac{S_m}{\sigma_f} = 1$

Mean stress correction methods



Graphical representation of those equations

6.3S-N Curve For Composite Material:

$$N = \{B(1-r)\}^{\frac{1}{c}}$$

N= Number of cycles to failure,

B = 10.33 & C = 0.14012

r = σ_{max}/ σ_{UTS}

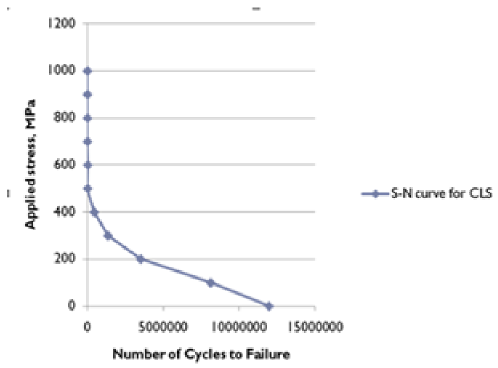
σ_{max}= Maximum stress.

Ultimate Tensile Strength σ_{UTS} = 1000MPa.

Load cycle for the fatigue analysis is defined. Max load = 26.75 KN and the duration of one cycle is 3 secs i,e. 20 strokes/min .Load Definition parameters are defined for the event. Life of steel leaf spring can withstand upto 145900cycles.

Maximum stress (MPa)	Applied stress level	Number of cycles to failure
100	0.1	8143500
200	0.3	3515500
300	0.4	1354800
400	0.5	450900
500	0.6	12700
600	0.7	25000
700	0.8	3200
800	0.9	200
900	1	-
1000		-

Fatigue life at different stress levels of composite leaf spring



Based on the S - N graph, it is observed that Parabolic composite leaf spring, which is made up of E-glass/epoxy, is withstanding 676875 cycles.

7.CONCLUSION:

First natural frequency of parabolic composite leaf spring is found to be 53.69% more than the existing Parabolic steel leaf spring. From this result natural frequency of parabolic composite leaf spring has higher first natural frequency the excitation frequency of the road condition**.**

MODE	Frequency(Hertz)(steel)	Frequency(Hertz)(composite)
	Steel	E Glass/Epoxy
1	11.976	25.7
2	21.4	93.07
3	30.382	111
4	44.031	131.4
5	64.261	135.7

Natural frequency comparison between steel and composite leaf spring

Parabolic composite leaf spring is found to have lesser stress of 29.15% than parabolic steel leaf spring at rated load condition.

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Parabolic composite leaf spring is found to have lesser stress of 4.4% than parabolic steel leaf spring at over load condition.

Unclamped	Steel(SUP11)		Composite(E glass/epoxy)	
	Rated (2765kg)	Over (4815kg)	Rated (2765kg)	Over (4815kg)
Stress induced (N/mm^2)	527.056	1067	373.4	1020

Stress comparison between steel and composite parabolic leaf spring.

Life of parabolic steel leaf spring is obtained and it can withstand up to 145900 cycles. So from this life of the parabolic leaf spring made of E glass/epoxy resin composite has been predicted that it would withstand up to 676875 cycles.

8. ACKNOWLEDGMENT:

I would like to express my profound gratitude and deep regards to Mr. K.Bichafor his exemplary guidance, monitoring and constant encouragement throughout the course of this thesis. The blessing, help and guidance given by beloved principal shall carry them a long way in the journey of life on which they are about to embark.

8.REFERENCES:

[1]Daugherty R. L.Composite Leaf Springs in Heavy Truck Applications, International Conference on Composite Materials, Tokyo 1981: pp. 529 – 538.

[2]Morris CJ, Composite integrated rear suspension. Comp Struct 1986; 5:233–42.

[3]Breadmore P., Johnson C. F, the Potential for Composites in Structural Automotive Applications, Composite Science and Technology, 26, 1986, pp. 251 – 281.

[4]ANSYS 12.0, Ansys, Inc.,

[5]Bourmistrova,Storey and Subic, Multi-objective Optimization of Active and Semi-Active Suspension Systems with Application of Evolutionary Algorithm,2007.

[6]Hawang, W., Han, K. S., Fatigue of Composites – Fatigue Modulus Concept and Life Prediction Journal of Composite Materials 20 1986: pp. 154 – 165.

[7]Yasushi M, Prediction of Flexural Fatigue Strength of CFRP Composites under Arbitrary Frequency, Stress Ratio and Temperature, J. Com. Materials, 1997: pp. 619 – 638.

[8]Yu, W. J., Kim, H. C. Double Tapered FRP Beam from Automotive-Suspensions Leaf Spring Composite Structures, 1988: pp. 279 – 300.

[9]Corvi A, A preliminary approach to composite beam design using fem analysis, Comp Structures 1990; 16:259–75.

[10]Rajendran I., Vijayarangan S, Optimal Design of a Composite Leaf Spring Using Genetic Algorithms Intl,Journal of Computers and Structures ,79/11,2001: pp. 1121 – 1129.