STRESS ANALYSIS & OPTIMIZATION OF LEAF SPRING BY USING TAGUCHI METHOD

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Abstract:

A leaf spring is a simple form of spring, generally used for the suspension in Automotive. It is also used as a shock absorber in Automotive. It looks like a slender arc-shaped having length of a spring steel of rectangular cross-section. The automobile industry has shown increased interest in the replacement of steel springs with fiberglass reinforced composite leaf springs. Therefore, the aim of this project is to analyse leaf spring and to replace the material by composite. A single leaf, variable thickness spring of glass fibber reinforced plastic (GFRP) with similar mechanical and geometrical properties of the multi-leaf steel spring.

This project is based on a complete design and analysis of leaf spring. Here Finite element models were developed to optimize the material and geometry of the composite elliptical spring based on the spring rate, long life and shear stress. The influence of the elasticity ratio of performance of composite elliptical springs was investigated computationally.

I. INTRODUCTION

A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of shock absorption system. Leaf spring consists of flat bars of varying lengths clamped together and supported at both ends, thus acting as a simply supported beam. This can also be referred to as a semi-elliptical spring or cart spring; it has the form of a slender arc-shaped length of spring steel of rectangular cross-section. The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. According to Indian standards, the recommended materials are C 55 (water-hardened), C 75 (oil-hardened), 40 Si 2 Mn 90 (water-hardened), 55 Si 2 Mn 90 (oil-hardened). Steel is an alloy of iron that contains the element iron as the major component and small amounts of carbon as the major alloying element. The carbon contents in steel ranges from 0.02% to 2.05 by weight. Small amounts, generally on the order of a few per cent, of other alloying elements such as manganese, silicon, chromium, nickel, and molybdenum may also be present, but it is the carbon content that turns iron into steel.

II. MANUFACTURING PROCESS OF LEAF SPRING

The manufacturing process carried out at our works is detailed below. Spring leaves are sized to the required length; they are subjected to various processes like punching, eye rolling, cover/wrapper rolling, end cropping, and taper rolling, and so on. The spring leaves are then fed into a walking beam furnace with automatic temperature controls where they are heated to the critical temperature depending upon the grade of the material used. Past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, 60Si2Mn, EN47, 50 Cr 4 V2, 55 Si Cr 7 ,55 Cr Mo CV4, and 55 Si 2 Mn90 etc.

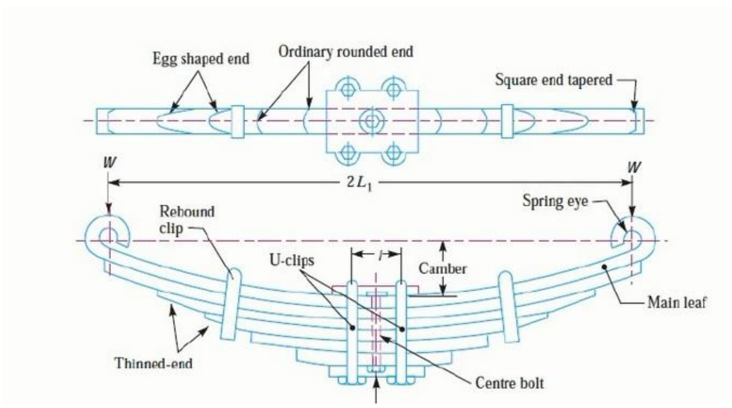

Fig.1 Leaf Spring

Table.1 Element Composition

ELEMENTS IN LEAF SPRING	% OF ELEMENTS
CARBON	0.5-0.65
SILICON	0.15-0.35
MANGANESE	0.65-0.95
PHOSPHORUS	0.035
SILICON	0.035
CHROMIUM	0.65-0.95

A. MATERIAL SELECTION

Composite materials

The term composite can be defined as a material composed of two or more different materials with the properties of the resultant material being superior to the properties of the individual materials that make up the composite. A number of composites are found in nature. The common example of a composite is wood. Wood is composite of cellulose and lignin. Artificial composite materials are cementing concrete, fiberglass, bimetallic strip used in thermostats. Composite materials exhibit superior mechanical properties such as high strength, toughness, young's modulus, fairly good fatigue and impact properties. As fiber composite is lightweight materials, the specific strength and specific modulus are much higher than the conventional materials. The Composite materials used in this design are Carbon epoxy.

Carbon epoxy

Epoxy or poly epoxide is a thermosetting epoxide polymer that cures (polymerizes and cross links) when mixed with a catalysing agent. Stress transfer in the fibber/matrix inter phase requires a strong interfacial bond between the two components. Carbon fibber's, when used without any surface treatment, produce composites with low inter laminar shear strength which, in turn, affects most of the other mechanical properties. Consequently, in order to optimize their mechanical properties and use their full potential, a variety of surface modification techniques has been developed to promote interfacial bonding. However, for the most part, an improvement of the coupling often causes a decrease in impact strength since too strong adhesion can limit the energy-absorption mechanisms, making the composite more brittle.

Table.2 .Properties of Carbon epoxy

1	Fibber volume fraction v_f (%)	50
2	Tensile strength (MPa)	600
3	Tensile modulus(GPa)	36.9
4	Tensile strain to failure (%)	2.2
5	Flexure strength (GPa)	1023
6	Flexure modulus(GPa)	43.3
7	Shear modulus(GPa)	5
8	Poisson ratio	0.3

III. MODEL OF DESIGN PARAMETER OF LEAF SPRING

Computer **A**ided **T**hree-dimensional **I**nteractive **A**pplication is a powerful program used to create complex design with a great precision. The design intent of any 3-D model or an assembly is defined by its specification and its use. The powerful tools of CATIA are used to capture the design intent of any complex model by incorporating intelligence into the design. To make the designing process simple and quick, this software package has divided the steps of designing into different modules. This means each step of designing is completed in a different module. For, example generally a design process consists of the following steps.

1. Sketching using the basic sketch entities.
2. Converting the sketch features and paths.
3. Assembling different parts and analysing them.
4. Documentation of parts and the assembly in terms of drawing views.
5. Manufacturing the final part and assembling.

All the above steps divided into different modes of CATIA namely, sketch mode, part mode, assembly mode, drawing mode and manufacturing mode. CATIA is a feature- based solid modelling tool. A feature is defined as the smallest building block and any solid model created in CATIA is an integration of a number of these building blocks. Each feature can be edited individually to bring in any change in the solid model. This feature provides greater flexibility. CATIA allows make modification some values in the same part.

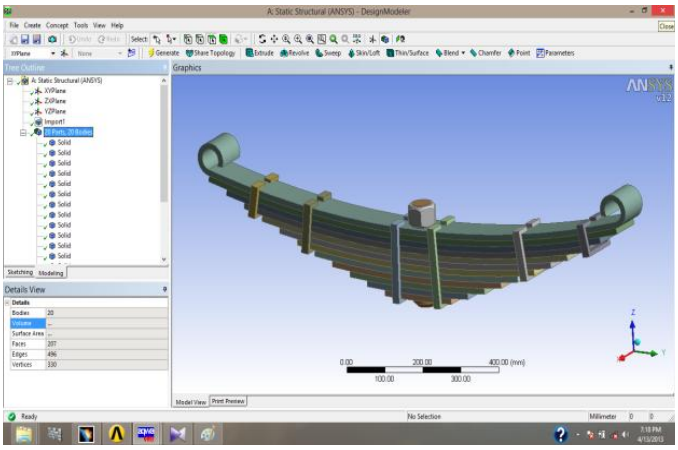

Fig.2 Modelled Leaf Spring

IV. ANALYSIS OF LEAF PRING

Assembly model of leaf springs are imported to Ansys workbench design modeller. The art of subdividing a structure a structure into a convenient number of smaller elements is known as discretization. The analysis is used to determine the stress and deformation of the leaf spring..

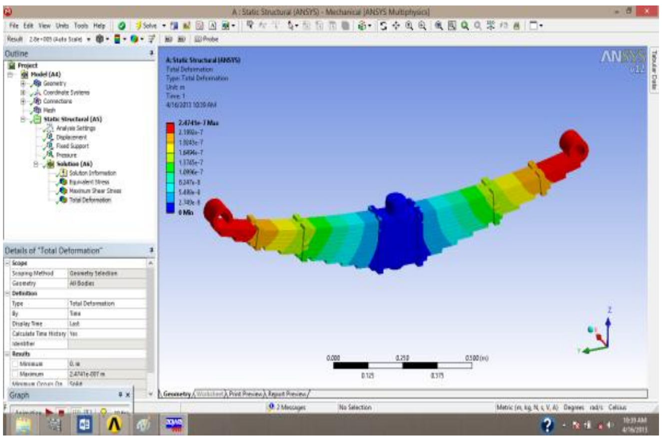

Fig.3. Analysis of leaf spring

V. RESULTS AND DISCUSSION

A. Stress and deformation of Steel leaf spring

The stress and deformation of Steel leaf spring is determined by ANSYS. The deformation is found be maximum for the leaf spring having the 610 mm effective length and 90 mm width. The stress is found be maximum for the leaf spring having the 580 mm effective length and 88 mm width.

Table.3 .Stress and deformation of Steel leaf spring

S.NO	No of leaf	Effective length (mm)	Width (mm)	(Stress) (N/m²)	Deformation (m)
1	12	580	86	2.09e5	2.44e-7
2	12	590	88	2.07e5	2.47e-7
3	12	600	90	2.02e5	2.49e-7
4	12	610	92	2.28e5	2.53e-7
5	13	580	88	2.49e5	2.44e-7
6	13	590	86	2.39e5	2.41e-7
7	13	600	92	2.48e5	2.49e-7
8	13	610	90	2.2e5	2.52e-7
9	14	580	90	2.3e5	2.43e-7
10	14	590	92	2.26e5	2.45e-7
11	14	600	86	2.18e5	2.46e-7
12	14	610	88	2.05e5	2.51e-7
13	15	580	92	2.48e5	2.41e-7
14	15	590	90	2.53e5	2.44e-7
15	15	600	88	2.1e5	2.47e-7
16	15	610	86	2.2e5	2.49e-7

B. ANOVA of Steel leaf spring

In factor **'A' F_{cal} > F_{table}** i.e. It is clear that the factor A have **significant** effect on the Stress. Since F_{cal} for the factor A is greater than F_{table}. Hence factor A is the best factor among the three factors available to us. So by increasing the value of factor A i.e. No. of leaf increases the Stress decreases.

Table.4 .ANOVA for Stress and deformation of Steel leaf spring

Sum of variance	Sum of Square	Degree of freedom	Mean Sum of square	F_{cal}	F_{table} at α = 0.05	Remark
A	2.0×e9	3	0.6×e9	4.9	4.76	**Sign**
B	577.2×e6	3	0.1×e9	1.3		Insig
C	733.2×e6	3	0.2×e9	1.7		Insign

C. Stress and deformation of E-glass/Epoxy & Carbon epoxy leaf spring

The table shows the comparison result of E-glass/epoxy and Carbon epoxy composite materials. Among these, materials the carbon epoxy has minimum deformation and stress.

Table.5 .Stress and deformation of E-glass/Epoxy & Carbon epoxy leaf spring

Material	Stress (N/m^2)	Deformation (m)
E-glass Epoxy	1.83e5	1.83e-7
Carbon Epoxy	1.52e5	1.52e-7

D. Comparison result of steel and composite material

Table.6 .Stress and deformation of Steel and E-glass/Epoxy & Carbon epoxy leaf spring

Material	No. of leaf	Effective length(m)	Width (m)	Stress (N/m^2)	Deformation (m)
Steel (Existing)	12	600	90	2.02e5	2.04e-7
E-glass/ epoxy	12	600	90	1.83e5	1.83e-7
Carbon epoxy	12	600	90	1.52e5	1.52e-7

From this table we know that the carbon epoxy material is the best material to manufacture the leaf spring, which has given weight reduction and long life time for heavy load vehicles.

VI. CONCLUSION

The life time of the leaf spring can be increased by reducing the deformation that takes place in the spring. From the above results it is clear that the **carbon epoxy** has minimum deformation and stress. Moreover the life span of the carbon epoxy is also high compared to other materials. So, among two composite materials, carbon epoxy is preferred for the leaf spring. Thus we concluded that the carbon epoxy material is the best material to manufacture the leaf spring, which has given a long lifetime for heavy load vehicles.

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