Design and Analysis of Automobile LEAF Spring

Ravindra Raju Mahajan, Prof. A. V. Patil

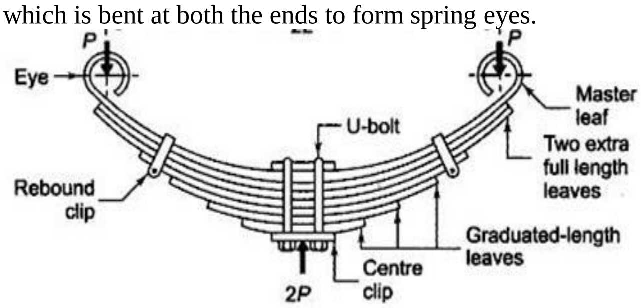
Abstract— **A multi-leaf spring is one of the most important components of automobile suspension system. Leaves are basically a series of flat plates, usually of semi-elliptical shape. Generally, a multi-leaf spring used in automobile suspension, consists of two types of leaves i.e., graduated-length leaves and full-length leaves. The present work is an attempt to estimate the magnitude of bending stresses in the above-mentioned leaves for a semi-elliptic multi-leaf spring made of steel. A lot of research work has been carried out in the context of leaf spring considering its material and a significant progress has been observed in the field of weight reduction, improvement of load carrying capacity when we replace the material of the spring by any advanced material like composites as E- glass/epoxy, carbon/epoxy etc. Finally referring to the results obtained in these research studies, the present work proposes a new idea regarding the construction of multi-leaf spring based on practical applications. Dimensions of the multi-leaf spring are taken from practical understanding and calculate dimension manually from standard chart of automobile spring. The multi-leaf spring was modeled in CATIA V5R18 and the same were analyzed under similar conditions using ANSYS (Workbench 12.0) software considering structural-steel as the spring material.**

Index Terms— **Ansys Workbench, CATIA V5R18, Design & Analysis Of Multi Steel Leaf Spring, LEAF Spring,**

I. Introduction

A spring is an elastic machine element which undergoes deflection for the application of any load and intends to regain its original shape depending upon the magnitude of the applied load. The major applications of spring may include its use as a shock and vibration absorber and storing potential energy by its deflection during the application of load. A multi-leaf spring or laminated spring is a very important component in automobile suspension system. It is one of the oldest suspension components too and still today it is extensively used in all the heavy and light duty commercial vehicles, railway wagons and usually in the rear suspension of passenger vehicles. It differs from the conventional helical spring in a way that it can be guided along a definite path and it deflects under the application of load while acting as a structural member. This concept is employed during the analysis of bending stresses in different leaves by consideration of cantilever beam. The present work makes an attempt to validate the above concept by performing static structural analysis using ANSYS software for the evaluation of maximum bending stress and subsequently bending stresses in different leaves, which in all, construct the entire spring. Finally, the reader may get an exposure regarding the bending stress variation for multi-leaf spring, which obviously differs from that of any cantilever beam section.

In its construction the leaf spring consists of a series of flat plates or leaves, usually of semi- elliptic shape, which are held together with the help of U-bolts and center clip. Generally, two types of leaves may be observed in a multi-leaf spring i.e., some graduated -length leaves and a few extra full-length leaves. The length of the leaves gradually decreases from top to bottom. The longest leaf in the top is known as master leaf which is bent at both the ends to form spring eyes.



II. LITERATURE REVIEW

Numbers of researchers & designers have done work on leaf springs and it is summarized as:

1) JOHN E. MUTZNER and DAVID S. RICHARD, General Motors Co, ltd Covington (2005) "Development and Testing Of Composite Truck Trailer Spring "Volume 2 Issue2 pp 103-107 Composite leaf spring constructed of glass fiber reinforced polymeric material has been recognized as a variable replacement for steel leaf springs since their introduction on the 1981 general motors corvette. This acceptance of composite leaf springs has given rise to applications in high volume production passenger cars and utility of composite leaf spring is clearly demonstrated in these applications.[6]

2). KIKUA TANABE, TAKASHI SEINO of Central Engineering Laboratories, Nissan Motors co., ltd. Yokosuka, Japan (1999) "Characteristics Of Carbon/Glass Fiber Reinforced Plastic Leaf Spring "volume 7, Pp.241–249. Designed and fabricated and evaluated a tapered leaf spring made of carbon fiber reinforced plastics. To construct the leaf spring, a carbon/glass fiber hybrid lamination is selected. This selection was made in concentration of chipping resistance, impact resistance and fatigue resistance. They constructed a prototype of leaf spring which weighed approximately 2kg included the front and rear steel eyes. In comparison with the steel spring, this represents a weight reduction of 76%. Prototype is put through a series of evaluations both on the bench and on the vehicle

3) Eerol Sancaktar. Shenyang Jinzhou University, China (1999) "Design and manufacture of a functional composite leaf spring for solar powered light vehicle" Research Vol. 66, February 2007 pp 128-134

The main objective of this work was to provide and understanding of the manufacture, use and capabilities of composite leaf spring. The material selected for the

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fabrication of the initial design leaves consisted of a full thickness of unidirectional E-glass fibers with two layers of bi-directional fabric on the outer layers embedded in a vinyl ester resin matrix. The bi-directional fabric used to prevent leaf deformation and subsequent failure in bending about its longitudinal axis it was selected due to overall weight reduction of the vehicle primarily considered.

III. MATHEMATICAL FORMULATION

For the purpose of analysis, the leaves are divided in two groups as master leaf along with graduated length leaves forming one group and the extra full-length leaves forming the other group.

Let, nf = number of extra full-length leaves,

ng= number of graduated-length leaves including the master leaf,

n = nf + ng =Total number of leaves present in the multi-leaf spring, b = width of each leaf (mm),

t = thickness of each leaf (mm),

L = half the length of the semi-elliptic spring or the length of the cantilever (mm), P = force applied at the end of the spring (N),

Pf = portion of P taken by the extra full-length leaves (N), Pg. = portion of P taken by the graduated-length leaves (N),

So, P = Pf + Pg

.

Now, from practical considerations for an automobile leaf spring, that is of semi-elliptical shape usually, for a length of 2L and a load of 2P acting at the center, the entire beam can be considered as a double cantilever. If the leaves are cut into two equal halves in longitudinal plane and then combined accordingly, to form almost a triangular plate then,

The maximum bending stress is given by (Sb) max = 6P.L/n.b.t2

The bending stress in the graduated-length leaves is given by

(Sb) g= 12P.L/ (3. nf +2.ng).b.t2

The bending stress in the extra full-length leaves is given by

(sb)f = 18P.L/(3. nf +2.ng).b.t2

It is to be noted that, the maximum bending stress occurs at the supports for such a plate. The above relations hold good for the leaves (or plates), having uniform cross-section. Also, it is seen that the bending stresses in extra full-length leaves are 50% more than that of the graduated length leaves

i.e. (sb)f = 1.5(sb)g

Calculation of length of different leaves:

For the calculation of length of different leaves, following relations were used and subsequently, the results were implemented while modeling the multi-leaf spring in CATIA V5R18 software.[15]

Length of the smallest leaf = 1*Effective length/ (n-1) + Ineffective length

Length of the next leaf = 2*Effective length/ (n-1) + Ineffective length

Similarly, Length of the (n-1)th leaf = (n-1)*Effective length/ (n-1) + Ineffective length

Length of master leaf = 2.L+ 2.P.(d+t)

Ineffective length = Distance between the centres of U-bolts = l

Effective length = 2.L – 2.l/3 and

d = inside diameter of eye

IV. DESIGN SPECIFICATION

The objective of the project study includes, determination of maximum bending stress for three different loading conditions and to establish the relationship for the magnitude of bending stresses existing in the graduated-length leaves and extra full-length leaves (i.e. (sb)f = 1.5(sb)g)

Here Weight and initial measurements of four-wheeler "TATA ACE" Light commercial vehicle is taken.

Weight of vehicle= 1200kg

Maximum load carrying capacity= 1000 kg Total weight= 1200+ 1000 = 2200 kg Taking factor of safety (FS) = 2 Acceleration due to gravity (g) = 9.81m/s2 Therefore;

Total Weight = 2200×9.81 = 21582N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one 4th of the total weight. 21582/4 = 5395.5 N

But 2F = 5395.5 N, F = 2697.75 N

Span length, 2L = 1072 mm, L= 536mm.

Now the Maximum Bending stress of a leaf spring is given by the formula

$$\sigma = \frac{6 \times f \times l}{n \times b \times t^2}$$

$$\sigma = \frac{6 \times 2697.75 \times 536}{3 \times 60 \times 8^2}$$

σ = 753.12N/mm2 The Total Deflection of the leaf spring is given by

$$\delta = \frac{6 \times f \times l^3}{E \times n \times b \times t^3}$$

$$\delta = \frac{6 \times 2697.75 \times 536^3}{2.1 \times 10^5 \times 3 \times 60 \times 8^3}$$

$\delta = 128.79mm$

Measured data of the above stated light weight four wheeler vehicle. Straight length of the parabolic leaf spring (L) =1072mm

The ratio of camber length of parabolic leaf spring

$C/L = 0.089$

$C = 0.089 \times 1072$

$C = 95.4mm$

Since the leaf spring is fixed with the axle at its centre, only half of it is considered for analysis purpose. Since analyzing half of the leaf spring is enough, half of the applied force would have been taken, but here we took as it is to account over loadings of the vehicle and flexures of the leaf spring.

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Hence,
$L/2 = 536mm$ F=2697.75N t=? b=?
Calculation for "t" and "b" dimensions which are capable of withstanding the loading behavior of the conventional and composite parabolic leaf spring is the result of this design. From equation of strength of material we have, now the Maximum Bending stress of a leaf spring is given by the formula,Bending Stress

$$\sigma = \frac{6 \times f \times l}{n \times b \times t^2}$$

The Total Deflection of the leaf spring is given by

$$\delta = \frac{6 \times f \times l^3}{E \times n \times b \times t^3}$$

Solving these two equations the thickness and width of the parabolic leaf spring can be, formulated, respectively, as follows;

$$\sigma = \frac{6 \times 2697.75 \times 536}{3 \times b \times 8^2}$$

$$753.12 = \frac{6 \times 2697.75 \times 536}{3 \times b \times 8^2}$$

b=60mm

The Total Deflection of the leaf spring is given by

$$128.79 = \frac{6 \times 2697.75 \times 536^3}{2.1 \times 10^5 \times 3 \times 60 \times t^3}$$

t=8mm

The objective of the present course of study includes, determination of maximum bending stress for three different loading conditions and to establish the relationship for the magnitude of bending stresses existing in the graduated-length leaves and extra full-length leaves (i.e. (σb)f = 1.5(σb)g), with the following dimensional specifications, Table 1 Specification of multi-leaf spring Parameters Value Notation Total length of the semi-elliptic spring (distance between two eyes) 1243 mm 2L width of each leaf 100 mm b thickness of each leaf 14 mm t number of extra full-length leaves 2 nf number of graduated-length leaves including the master leaf 8 no Total number of leaves present in the multi-leaf spring 10 n Load acting at the center of the spring 15000 N,10000 N,5000 N 2P The dimensions are taken from practical understanding and the standards available in the market. Structural steel was considered as the leaf material with an elastic modulus E = 2.1*105 MPa, tensile yield strength Syt = 250 MPa and Poisson's ratio=0.3 while performing the analysis in ANSYS (Workbench 16.0) software.

V. Conclusion

The analysis of a leaf spring has been done in this research work to optimize the model in respect of design material properties. The analysis was compared with the experimental observations for significant parameters. The experimental work was also used as reference to validate the analysis of leaf spring models. From the results obtained as of both approaches number of result comparative discussions have been made Following conclusions have made from the comparative result discussions which can be considered to check in respect of research objectives: From the practical and ANSYS result we concluded that we conducted test analyst the leaf spring on various load on specific time period.

	Von-misses stress N/mm^2	
Load N	**Practical**	**ANSYS**
7000	1953.7	1922.133
8000	2332.5	2284.372
9000	2511.9	2497.681

The variation in ANSYS results and experimental results are less than up to 10 % in dynamic analysis of equivalent stress in leaf springs, which indicates the results are acceptable for prediction of fatigue life of leaf springs.

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