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## A Review of Documentation in Design Modification and Analysis of Leaf Spring

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**ABSTRACT:** The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. In the present work improvement areas where more stress acting on the leaf spring one can improve the product quality while keeping the minimum cost. In the present work varying the thickness of leafs depending on the stress acting on the springs. The upper leafs of the spring get more stress then the bottom leafs. That way the project is modifying the leaf thickness. In this model the front leafs are containing more thickness than the lower leafs thickness. The modified leaf spring is modeling by Solid works and analysis using ANSYS11.Software.

After the analysis of the leaf spring we have some problem from stress concentration. Consider a single leaf the center portion of the leaf get more stress then the corner portion of the leaf. So we need again modify the leaf spring. The new modified leaf spring has center portion of the leaf more thickness then the corner portion of the leaf spring. The modified leaf spring is modeling by Solid works and analysis using ANSYS11.Software.

**KEYWORDS:** Leaf spring, Fatigue failure, Modifying the leaf thickness, Solid works, Ansys.

### I. INTRODUCTION

Leaf springs are crucial suspension elements used on light passenger vehicle necessary to minimize the vertical vibrations impacts and bumps due to road irregularities and to create a comfortable ride. Leaf springs are widely used for automobile and rail road suspensions. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly so increasing the energy storage capabilities of a leaf spring and ensures a more compliant suspension system. Three dimensional finite element analysis of the leaf spring consists of a computer model or design that is stressed and analyzed for specific results. A company that is able to verify a proposed design will be able to perform to the clients specifications prior to manufacturing or construction.

The external load applied upon the leaf spring induces bending stresses that are superimposed on the preliminary ones (i.e., created at assembly). In consequence, the maximum tensile stresses in the main leaf decrease, and those in the bottom leaf increase. Meanwhile, in the intermediate leaves, the stresses vary proportionally to the leaf location. Because the bottom leaves are subjected to a greater stresses, the spaces between stay small, thus lessening the influence of the preliminary stresses.

### PROPOSED DESIGN

Constant Width, Varying Thickness Design concept is using in the new design. The thickness is varying to length of the leaf basis the longer leaf having more deflection so it is should be having more strength otherwise the long more deflected leafs are damaged shortly. The above problems are rectifying the new design.

First leaf is longer so the thickness of the main leaf is more than the bottom leafs, it has 8 mm thickness and below two leafs has 7.5mm and the other below leafs are having thickness are 7mm,7mm,6.5mm,6.5mm and last two are 6mm thick . the other values of the leaf springs like width length and radius of curvature are maintain constant leaf spring of Mahindra - commander 650 di.

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The variation of the thickness in leaf spring induced more advantages in leaf spring

- Improve the fatigue life of the leaf spring
- Reduce fatigue failure due to the high deflection by the road condition.
- Better design to the automobile leaf spring industry

## II. PARAMETER OF LEAF SPRING

The design method is selected on the basis of mass production. From the comparative study, it is seen that the composite leaf spring are higher and more economical than convectional leaf spring. After prolonged use of conventional metal Coil Spring, its strength reduces and vehicle starts running back side down and also hits on the bump stoppers (i.e. Chassis). This problem is entirely removed by our special purpose Composite leaf Springs. from the result obtained it will be concluded that the development of a composite mono leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective. Future scope of this project [1] (a) Experimental work. (b) Harmonic analysis with finding and compression of first five natural frequencies. (c) Analysis leaf spring by varying thickness. The varying thickness is select for the project work. Harmonic analysis for vibration due to road irregularities and static analysis for gross vehicle mass load analysis are carried out for both materials, and comparative behaviors are observed such as stress and deflection of the multi leaf spring[2]

The objective of paper work is in order to meet the requirement of increased PL on the chassis. The axles, suspensions and wheel assemblies were examined for their maximum load carrying capacity. The chassis frame and axles are to be capable of carrying this higher PL, where as it was observed that, rear axle suspension requires modification / design improvements to carry the additional payload of 5000kgs. From this project taken, the special formula to finding stress for varying thickness leaf spring stress[3]

Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this paper we describe design and analysis of composite leaf spring[4],[5],[10],[11],[14]. But the cost of the composite materials are very high, Material and manufacturing process are selected upon on the cost and strength factor whereas the design method is selected on the basis of mass production Steel Leaf spring is reduce the material cost and moss production to commercial vechicle.[12][13] used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel products greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties[15] For automobiles: 50Cr 1, 50 Cr 1 V 23, and 55 Si 2 Mn 90 all used in hardened and tempered state. For rail road springs: C 55 (water - hardened), C 75 (oil-hardened), 40 Si 2 Mn 90 (water-hardened) and 55 Si 2 M N90 (oil-hardened). Select commonly used material 55SI 2Mn 90.[4][6] The procedure of eye design is to carry out leaf spring with actual design considerations and loading conditions.[6] The material used for Select commonly used material 55SI 2Mn 90.and selected vehicle is Mahindra - commander 650 di [4]

### PARAMETERS OF STEEL 55SI2MN90 LEAF SPRING.

= 1962 (N/mm<sup>2</sup>)

Yield strength ( $\sigma_y$ ) = 1470 (N/mm<sup>2</sup>)

Young's modulus (E) = 2.1x10<sup>5</sup> (N/mm<sup>2</sup>)

Design stress ( $\sigma_{des}$ ) = 508 (N/mm<sup>2</sup>)

Total length (2L) = 1120 (mm)

Spring rate (k) = 32.7 (N/mm)

Normal static loading (P) = 6685 (N)

Spring weight (W) = 20.37 (kg)

Poisson's ratio (1/m) = 0.3

Density = 0.000783 (kg/mm<sup>3</sup>)

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### SPECIFICATIONS FOR STEEL LEAF SPRING [4]

= Mahindra - commander 650 di

Leaf Span length	= 1120 mm
Width	= 50 mm
Thickness	= 6-8 mm
Outer eye dia	= 62 mm
Dia .of centre bolt	= 8 mm
Ineffective length	= 100 mm
Total no. Of leaves	= 10
No. of full length leaves	= 2
No. of graduated leaves	= 8
Vehicle weight	= 1910 kg

### GEOMETRIC PROPERTIES OF LEAF SPRING

Span	= 1120 mm
Thickness	= (6-8) mm
Width	= 50 mm
Number of full length leaves ( $n_f$ )	= 2
Number of graduated leaves ( $n_g$ )	= 8
Total Number of leaves ( $n$ )	= 10
Length of master leaf	= $2L_1 + 2(d + t)$

Where,

d- Diameter of the eye,

t- Thickness of master leaf,

$$\text{Length of smallest leaf} = \frac{\text{effectivelength}}{n-1} + \text{ineffective length of spring} \quad \text{Length of next leaf} = \frac{\text{effectivelength}}{n-1} \times$$

$2 + \text{ineffective length of spring}$

$$\text{Length of } (n-1)^{\text{th}} \text{ leaf} = \frac{\text{effectivelength}}{n-1} \times (n-1) + \text{ineffective length of spring}$$

Where,

Effective Length =  $2L - \text{width of central band}$ ,

Ineffective length = width of the central band.

### DIMENSION OF MODIFIED LEAF SPRING.

Table 5.1 Dimension of modified leaf spring.

### FORMULA FOR STRESS AND DEFLECTION OF EXISTING LEAF SPRING.

$$\sigma_{\max} = \frac{18PL}{(3n_f + 2n_g)bt^2}$$

$$\delta_{\max} = \frac{12PL^2}{(3n_f + 2n_g)Ebt^2}$$

Where,

$n_f$  = Number of full length leaves

$n_g$  = Number of graduated leaf

### THE STRESS AND DEFLECTION CALCULATION FOR EXISTING LEAF SPRING

Bending stress and deflection for existing leafs spring.

$$\sigma_{\max} = \frac{18 \times 6685 / 2 \times 560}{22 \times 50 \times 7^2} = 625.1 \text{ N/mm}^2$$

$$\delta_{\max} = \frac{12 \times 6685 / 2 \times 560^2}{(3 \times 2 + 2 \times 8) 2.1 \times 10^5 \times 50 \times 8^2} = 90.1 \text{ mm}$$

Table.1 Specification of leaf spring

Leaf no.	Full leaf length 2L (mm)	Thickness t (mm)	Half leaf length L (mm)	Radius of curvature R (mm)	Width b (mm)
1	1120	8	560	961.11	50
2	1120	8	560	969.11	50
3	1007	7.5	503.5	976.61	50
4	894	7.5	447	984.11	50
5	780	7	390	991.11	50
6	667	7	333.5	998.11	50
7	554	6.5	277	1004.61	50
8	440	6.5	220	1011.11	50
9	327	6	163.5	1017.11	50
10	214	6	107	1023.11	50

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## SAE DESIGN FORMULAE FOR VARYING LEAF THICKNESS

The formulae that form standards for practical application are based on widely Accumulated professional experience. The published source for designing leaf Springs is the SAE Spring Design Manual, issued by the Spring Committee of the Society of Automotive Engineers Introducing the varying leaf thickness, the simplified Formulae as follows. The expression for bending stresses,

$$\sigma_{\max} = \frac{Lt}{2\Sigma I}P$$

$$\delta_{\max} = \frac{Pl^3}{2E\Sigma I}(1/F.S)$$

Where,

- $t_i$  = thickness of leaf (mm)
- $I$  = moment of inertia of leaf ( $\text{mm}^4$ )
- $P$  = load applied on the spring (N)

## BENDING STRESS AND DEFLECTION FOR NEW LEAFSPRING

Table 6.2 Bending stresses of individual leaf

Leaf no	Max Bending stresses $\sigma_{\max}$ N/mm <sup>2</sup> (Theoretical method)
1	508.32
2	508.32
3	428.474
4	380.39
5	309.76
6	264.88
7	167.41
8	162.25
9	111.30
10	72.84

$$\sigma_{\max} = \frac{560 \times 8}{2 \times 14279.5}P = 508.31N / \text{mm}^2$$

$$\delta_{\max} = \frac{(6685/2)560^3}{2 \times 2.1 \times 10^5 \times 14279.5}(1/1.4) = 68.31N / \text{mm}^2$$

## BENDING STRESS FOR INDIVIDUAL LEAF.

The bending stresses are calculated by above formula. The calculated bending stress is tabled below.

### III. MODELING OF LEAF SPRING

Solid works software was used for this particular model and the steps are as follows:

- Start a new part model with Metric units set.
- Draw the sketches of the trajectories of each leaf of spring with the radius obtained from calculations with span 1120mm.

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- Using sweep command draw a section 50 mm X 8 mm thick Extrude along the above drawn curves of leaf.
- The spring design manual the eye diameter is formed on the first leaf.
- Thickness of leaves = 6-8mm.
- After all the features of all leaves as are modeled, generate family table for each leaf.
- Generate models for U-clams, Axle rod, etc.
- Assemble each of the leaf in an assembly model and assemble all other models.
- Export the model to IGES – solid – assembly – flat level.



Figure.1 3D view of Existing Leaf spring

## IV. STATIC ANALYSIS

For the above given specification of the leaf spring, the static analysis is performed using ANSYS to find the maximum safe stress and the corresponding pay load. After geometric modeling of the leaf spring with given specifications it is subjected to analysis. The Analysis involves the following discretization called meshing, boundary conditions and loading. However modal analysis does not need loading.

### Meshing

Meshing involves division of the entire of model into small pieces called elements. This is done by meshing. It is convenient to select the free mesh because the leaf spring has sharp curves, so that shape of the object will not alter. To mesh the leaf spring the element type must be decided first. Here, the element type is solid 72. The element edge length is taken as 15 and is refined the area of centre bolt to 2. Fig 7.2 shows the meshed model of the leaf spring.

The following are the material properties of the given leaf spring.

Material = Manganese Silicon Steel,  
Young's Modulus  $E = 2.1E5$  N/mm<sup>2</sup>,  
Density  $\rho = 7.86E-6$  kg/mm<sup>3</sup>,  
Poisson's ratio = 0.3 and  
Yield stress = 1680 N/mm<sup>2</sup>.

### Boundary Conditions

The leaf spring is mounted on the axle of the automobile; the frame of the vehicle is connected to the ends of the leaf spring. The ends of the leaf spring are formed in the shape of an eye. The front eye of the leaf spring is coupled directly with a pin to the frame so that the eye can rotate freely about the pin but no translation is occurred. The rear eye of the spring is connected to the shackle which is a flexible link; the other end of the shackle is connected to the frame of the vehicle. The rear eyes of the leaf spring have the flexibility to slide along the X-direction when load applied on the spring and also it can rotate about the pin. The link oscillates during load applied and removed. Therefore the nodes of rear eye of the leaf spring are constrained in all translational degrees of freedom, and constrained the two rotational degrees of freedom. So the front eye is constrained as UX, UY, UZ, ROTX, ROTY and the nodes of the rear eye are constrained as UY, UZ, ROTX, ROTY. Figure 4 shows the boundary conditions of the leaf spring.

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## Loads Applied

The load is distributed equally by all the nodes associated with the center bolt. The load is applied along Fy direction as shown in Figure. To apply load 6685N, it is necessary to select the circumference of the bolt hole and consequently the nodes associated with it. It is necessary to observe the number of nodes associated with the circumference of the bolt hole, because the applied load need to divide with the number of nodes associated with the circumference of the center bolt.

The total deformation of the modified leaf spring indicate stress distribution and deformation due to the stress

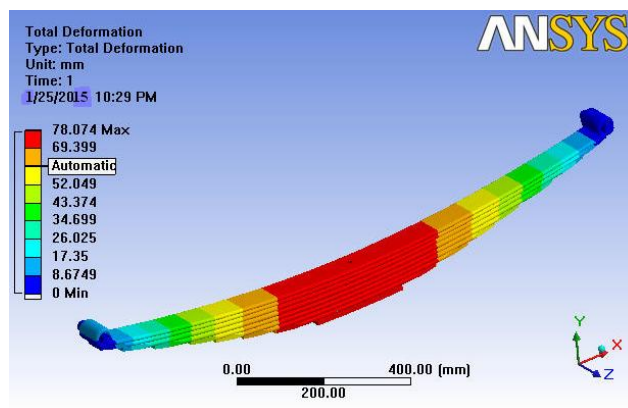


Figure.3 Analysis of Existing leaf spring

Consider a single leaf spring the deformation due to the stress is show from analys diagram in single leaf.

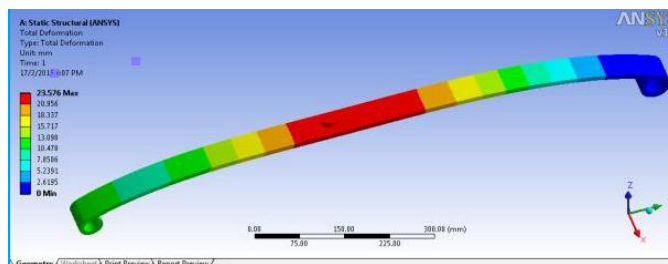


Figure.4 Analys diagram in single leaf

The centre portion of the leaf spring is get more deformation so the centre portion of leaf strength should be improve, so we need modified design to rectify this problem

## MODELING OF MODIFIED LEAF SPRING

Solid works software was used for this particular model and the steps are as follows: Start a new part model with Metric units set. Draw the sketches of the trajectories of each leaf of spring with the radius obtained from calculations with span 1120mm. Using sketch command draw a section 50 mm X 9-7 mm thick (thickness varying from centre of the leaf to end of the leaf.) Extrude along the above drawn curves of leaf. According the spring design manual the eye diameter is formed on the first leaf. Thickness of leaves (Maximum and Minimum) = 9-5mm. After all the features of all leaves as are modeled, generate family table for each leaf. Generate models for u-clams, axle rod, etc. Assemble each of the leaf in an assembly model and assemble all other models. Export the model to igs – solid – assembly – flat level.

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Figure.2. 3D view of modified Leaf spring

## ANALYSIS MODIFIED LEAF SPRING USING ANSYS

The CAD model of leaf spring now imported into ANSYS 12.1 the boundary conditions and material properties are specified as for the standards used in the practical application. The material used for the leaf spring for analysis is structure steel, which have approximately similar isotropic behavior and properties as compared to Existing leaf spring.

## BOUNDARY CONDITION

Model of parabolic spring was partition into small region for easier meshing process method is used patch conforming method the boundary condition was set according to rear static load which is the front eye was allowing on a rotational at y axis and rear eye was constrained in y and z translation and x and z rotations allowing free x translation and y rotation. Finally vertical load was applied at the center of the leaf spring

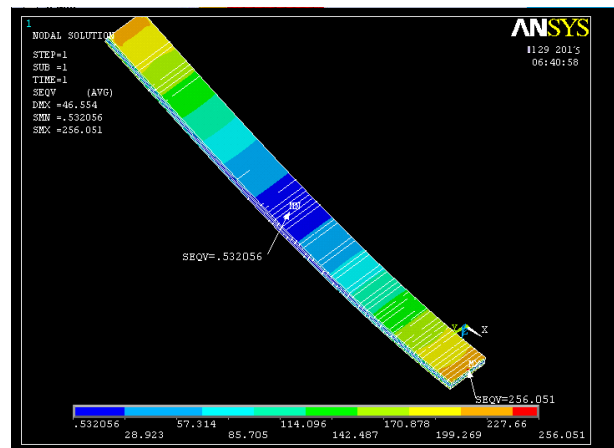


Figure.5 Analysis of modified leaf spring.

The stress distribution of the modified leaf is shown from this analysis diagram and the deformation is shown below



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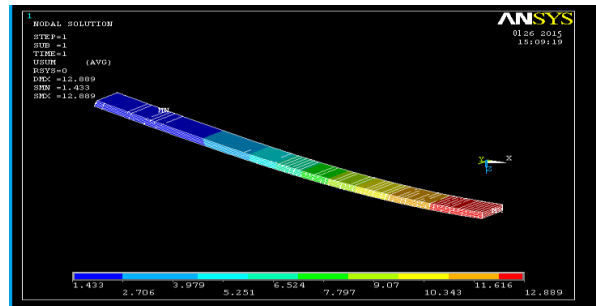


Figure.6 Analysis of modified leaf spring.

## COMPARATIVE THEORETICAL STRESS AND DEFLECTION AND ANALYSIS OF STEEL LEAF SPRING

The theoretical stress and ansys stress are given below and comparing of the Maximum deflection are given in table.

Table.3 Leafspring Stress comparison

SPRING	THORITICAL	ANALYSIS	DIFFERENCE
EXSISTING STRESS	625.1 N/mm <sup>2</sup>	702.24 N/mm <sup>2</sup>	11%
EXSISTING DEFLECTION	90.1 mm	94.6 mm	05%
MODIFIED LEAF SPRING STRESS	508.31 N/mm <sup>2</sup>	564.25 N/mm <sup>2</sup>	10%
MODIFIED LEAF SPRING DEFLECTION	68.75 mm	78.07 mm	13%

## V. CONCLUSIONS

A comparative study has been made between Existing leaf spring and steel leaf spring with respect to weight, stiffness and strength. From the analysis result the stress distribution and modified leaf spring is again improve strength of the centre portion of the leaf by varying thickness in the single leaf. The centre portion of the leaf stress is also compared, from the result the more stresss acting area was putected.

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