www.ijmer.com Vol.1, Issue.2, pp-719-722 ISSN: 2249-6645

Analysis and Modification of Leaf Spring of Tractor Trailer Using Analytical and Finite Element Method

Prof. N.P.Dhoshi[1], Prof .N.K.INGOLE[2], Prof .U.D.GULHANE[3],
Associate Professor Assistant Professor Professor

*((Department of Mechanical Engineering, Bapurao Deshmukh College of Engg, Sewagram, India))

ABSTRACT

The leaf spring used in tractor trailer without much economical and technical consideration. In the present work improvement areas where one can improve the product quality while keeping the minimum cost. In the present work analytical and Finite element method has been implemented to modify the existing leaf spring with consider the dynamic load effect. Leaf spring manufactured by Awachat industries Pvt. Limited has been selected for stress analysis. One of the important areas where one can improve the product quality while keeping the cost low is the design aspect. One can design the product in such a way that its performance increases while the customer has to pay less as compared to the same product of other companies. 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. FEM and ANSYS software ensures a healthy approach of designing the leaf spring thus epitomizing the traits that are essential for the manufacturing.

Keywords – **Leaf spring, Stress analysis, Dynamic load**

1.INTRODUCTION

Leaf sprigs 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 leaf spring is analyzed for static strength and deflection using 3D finite element analysis. The general purpose finite element analysis software ANSYS is used for present study. The variation of bending stress and displacement values are predicted. With the Indian market becoming global and advent of multinationals in the market, a cut throat competition has a rise between the Indian companies and the Multinational company .thus to remain in the contest it has become necessary for the Indian industries to improve and innovate their product. There are 4-5 leaf spring manufacturers in vidharbha region having good potential but poor productivity having a scope for improvement M/s Awachat industries Limited, Wardha is one of the leading tractor trolley manufacturers in the region manufacturing 3000 trolley and above. Up to now they are manufacturing them without much economical and technical consideration. One of the important areas where one can improve the product quality while keeping the cost low is the design aspect. One can design the product in such a way that its performance increases while the customer has to pay less as compared to the same product of other companies.

2. ANALYTICAL DESIGN

The leaf spring behaves like a simply supported beam and the simply supported beam is subjected to both bending stress and transverse shear stress. Flexural rigidity is an important parameter in the leaf spring design and test out to increase from two ends to the center.

There are different capacities of trolley in each segment i.e. two wheeler and four wheeler. The capacities range from 3.5 tones to 10 tones also there are the dumper trailer which uses hydraulic means to dump the material contained in them. It is normally used only in construction work. A trolley of 5 tones capacity of m/s Awachat industries pvt. Limited is considered for analysis and designing of the leaf spring used in it.

2.1 Constant Thickness, Varying Width Design

In this design the thickness is kept constant over the entire length of the leaf spring while the width varies from a minimum at the two ends to a maximum at the center.

2.2 Constant Width, Varying Thickness Design

In this design the width is kept constant over the entire length of the leaf spring while the thickness varies from a minimum at the two ends to a maximum at the center.

Table 1: Specification of leaf spring

Description	Upper Spring(mm)	Lower Spring(mm)
Number of leaves {n}	6	11
Width of leaves {b}	70	70
Thickness of leaves {t}	10	10
Effective length	410	750
Young modulus {e}	2.04 * 105 N/mm^2	

Stiffness Existing Leaf Spring: Material SAE 9260 cr-v steel bending strength (fb) =1100 Mpa. The stiffness of the upper and lower springs is calculated by using the relation given below as:-

k= (f/v) = ((8enbt3)/ (3l3)) (1)

The stiffness k_1= 3315 N/mm, k_2=993 N/mm.

As the springs are connected in series and there are two leaf springs used as isolators in parallel.

The total stiffness = 2*765=1530 N/mm

2.3 Dynamic Loading

There are different model available for calculating the load factor. The following spring mass having one degree of freedom is selected because since the leaf spring is attached to the trolley is single axle the centre of gravity of the trolley lies nears the wheels. The mass my represents the chassis of the trailer and the spring constant Ky represents the shock-isolator. The spring is considered as linear. Near the wheels.

$$Y''/g = [V_s\ f * 3.1415]/9.81 \quad (2)$$

$$= 0.64\ V_s\ F_n$$

Where V_s =shock velocity changes in m/sec

F_n = natural frequency of isolator experienced by chassis. Expressed as dimensionless multiple of the acceleration due to gravity. The value of Fn is calculated by:- $F_n=1/2*3.1415[K_y*1000/M]^{1/2}$ (3)

M=Maximum Load Acting on the System=6000kg

F_n=2.54 cps

TO find out V_s vertical downward velocity we know

$$s= ut+ [1/2]\ gt^2 \quad (4)$$

Where u= initial downward velocity

$$s= [1/2\ gt]^2 \quad \text{also } V_s = u + gt \quad (5)$$

We get $V_s= [2gs]^{1/2}$

Calculating value for Yo for different values of S

S=0.1m Vs = 1.4 Y"o = 2.24g

S=0.15m Vs = 1.7 Y"o = 2.79g

Considering a sudden drop of depth to 0.15 the various values for different values of the natural frequencies are calculated. Table 2 Shown that equivalent load capacity.

Table 2. Equivalent Load Capacity

Static Load(Kg)	Fn	Y"o	Equivalent static Capacity (kg)
1000	6.22	6.77g	6770
2000	4.40	4.78g	9574
3000	3.59	3.91 g	11731
4000	3.11	3.38 g	13546
5000	2.78	3.02g	15145
6000	2.54	2.76 g	16581

Equivalent static load for static load capacity at various values of multiple factor Y"**o** for different natural frequency. Thus considering the maximum load capacity of 6000 kg which is the capacity of the system and a sudden depth of 0.15m the dynamic load factor is 2.76.thus it means that the trolley leaf spring should have static strength sufficient to support 2.76 times their normal static.

2.4 Bending stresses and Deflections of leaf spring

Bending stress developed:
Considering the maximum load capacity of 6000 kg which is the capacity of the system and multiplying it with the dynamic load factor of 2.76 for the equivalent static capacity. We get the equivalent static capacity as:
Static load (kg) 6000 kg
Load factor 2.76

Equivalent static capacity = static load × load factor
There fore equivalent static capacity = 6000×2.76
= 16560 kg
Therefore F = 16560×9.8/2 = 81144 N

www.ijmer.com Vol.1, Issue.2, pp-719-722 ISSN: 2249-6645

Now bending moment $б_b$ = 3×F×L/ 2×N×B× (T^2) (6)

Where, F= Maximum static force = 81144 N
L= Length of the leaf spring = 435mm
N= number of leafs= 17
B= width of leaf = 70mm
T=thickness of the leafs= 10mm

= 3×81144×435/ (2×17×70×10^2)
= 444.92 N/mm^2

Developed stress i.e. bending stress is 444.92 N/mm^2

For Developed Deflections of Leaf Spring:
δ (developed) = 3×F×L^3/8×E×N×B× (T^3) (7)
Where, F= Maximum static force = 81144 N
L= Length of the leaf spring = 435mm
N= Number of Leafs= 17
B= Width of Leaf = 70mm
T=Thickness of the Leafs= 10mm
E=Modulus of Elasticity for Cr-Va Multiplate Leaf= 2.04×10^5
δ = 3×81144×435^3/ 8 × 2.04×10^5 × 17 × 70 × 1000
So, developed deflection = 10.3 mm

Also permitted stress бb (permitted) = 1100 N/ mm^2

and also σ_b (permitted) = 1100×Sz
S_z=0.8+2.5/t
= 1.05
σ_b= 1100×1.05
=1155 N/mm^2
For this permitted value of bending stress the permitted deflection can be calculated as:

1155= 3×F×435/2×17×70×100
F = 210643.678N
δ we get the permitted deflection as:

δ(permitted)=3×210643.678×435^3/ 8×2.04×10^5×17×70×1000

= 26.78 mm

Deflection Using The Number Of Graduated Leafs and Number Of Full Length Leafs**:**

δ= 3×F×L^3/8×E×Ng×B×T^3 [1/ (1+1.5(N_f/N_g))] (8)

Where, F= Maximum static force = 81144
L= Length of the leaf spring = 435mm
N= number of leafs= 17
B= width of leaf = 70mm
T=thickness of the leafs= 10mm
N_f=number of full length leaves=1

Ng=number of graduated leaves=16

δ = 10.02mm

Developed bending stress $б_b$ (developed)

=3×F×L/2×N×B× (T^2)[(1.5/(1+1.5 N_f/N_g))] (10)

= 404 N/mm^2.

The values are approximately similar to that of calculated before without considering the number of graduated leaves and full length leaves independently.
As from above δ (developed) ‹ δ (permitted), hence the design is safe.
Also бb (developed) ‹ бb (permitted), hence the design is safe. Also the factor of safety can be calculated as:
F.O.S = бb (permitted)/ бb (developed)
= 1155 N/mm^2 /444.92 N/mm^2
= 2.6

2.5 Modification in Leaf Spring

As this value of factor of safety is very high considering the range of it from 1-2 hence considering the following cases:

Case 1: Decreasing the Number of Leafs By 2
Decreasing one inner leaf and one outer leaf we get the corresponding values of bending stresses and deflections as.
$б_b$ (developed) =3×F×L/ 2×N×B× (T^2)
= 3×81144×435/ (2×15×70×1)
=504.252 N/mm²
Also developed deflection, δ = 3×81144×435^3/ 8 ×2.04× 10^5× 15 ×70×1000
= 11.69mm
Factor of safety (F.O.S) = бb (permitted)/ бb (developed)
=1155 N/mm^2 /504.252 N/mm²
=2.3 (very high)

Case 2. Decreasing the number of leafs by 4
Decreasing two inner leaves and two outer leaves we get the corresponding values of bending stresses and deflections as.
$б_b$ (developed) =3×F×L/ 2×N×B× (T^2)
= 3×81144×435/ (2×13×70×10^2)
= 581.829 N/mm^2
Also developed deflection, δ = 3×81144×435^3/ 8 ×2.04×10^5 ×13 ×70×1000
= 13.49mm

Factor of safety (F.O.S) = бb (permitted)/ бb (developed)
=1155 N/mm^2 /581.829 N/mm^2
=1.985(Which is under the permitted value)
Hence on decreasing the number of leaves by 4 the factor of safety can be kept under 2.which is the best suitable case.
Also calculating the deflection using the number of graduated leafs and number of full length leafs:
δ= 3×F×L^3/8×E×Ng×B×T^3[1/ (1+1.5(Nf/Ng))]
Where, F= Maximum static force = 81144
L= Length of the leaf spring = 435mm
N= number of leafs= 17
B= width of leaf = 70mm
T=thickness of the leafs= 10mm
N_f=number of full length leaves=1
Ng=number of graduated leaves=16
δ = 10.02mm
Also developed bending stress бb (developed)
=3×F×L/ 2×N×B× (T^2) [(1.5/ (1+1.5 N_f/N_g))]
= 404 N/mm^2.

www.ijmer.com Vol.1, Issue.2, pp-719-722 ISSN: 2249-6645

The values are approximately similar to that of calculated before without considering the number of graduated leaves and full length leaves independently.

3. FINITE ELEMENT ANALYSIS OF LEAF SPRING

FEA with differential equation of system and end with solving them approximately. It goes through a number of steps in between. It converts differential equation in to integral equation by using variation approach or weighted residual method. Next it divides the problem domain into elements and develops the elements equations. It assembles the element equation to obtain the global system matrix equations. The boundary condition and external loads are applied to this system before solving. The result of the solution are available at the nodes of the elements .finite element analysis can display them in graphical form to analyse them, to make design decisions and recommendations.Conventional analytical method for solving stress and strain becomes very complex. In such cases finite element modeling becomes very convenient means to carry out the analysis. Finite element process allow for discretizing the intricate geometries into small fundamental volumes called finite element. It is possible to write the governing equations and material properties for these elements. These elements are then assembled by taking proper care of constraints and loading, which result in set of equations .these equations when solved give the result that described the behavior of original complex body being analyzed.

3.1 Model of Leaf Spring

In Figure 1 shown that solid model of leaf spring.

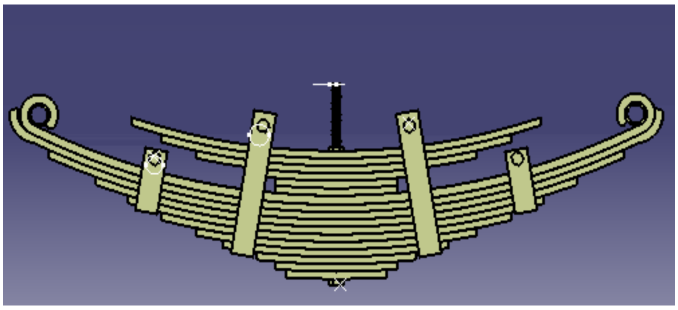

Fig 1.Solid Model of multi-plate leaf spring

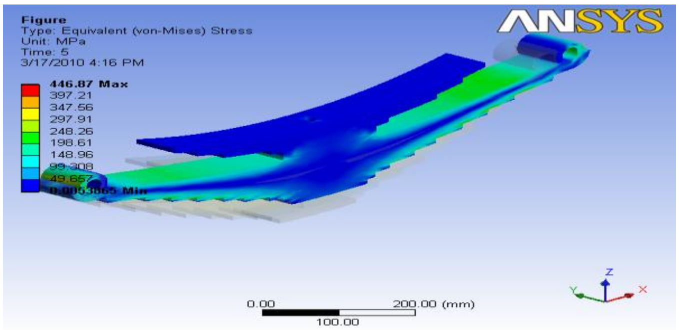

Fig 2.Von Mises Stresses on Leaf Spring

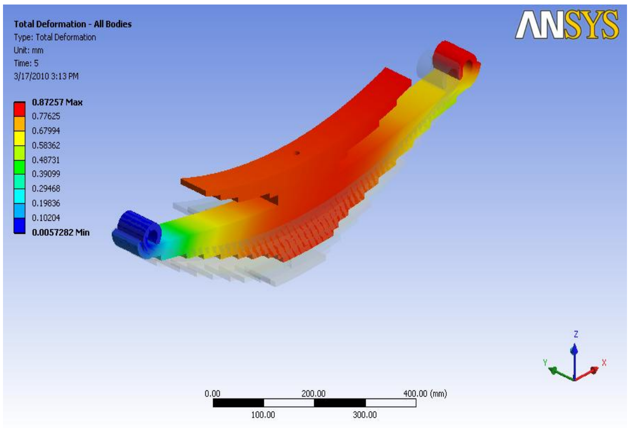

Fig 3. Deflection of Leaf spring

In fig 3 and 4 shown that, Von Mises stress and deflection on leaf Spring is 446 Mpa. it is nearly same as per analytical result.

4. RESULT, DISCUSSION AND CONCLUSION

The project illustrates the importance of analytical and micro-analysis. FEM analysis is done in ANSYS 11.0 and the project shows the importance of Stress analysis. On reducing the number of leaf spring from 17 to 13will further reduce the weight by approximately 6kg and the production cost by nearly 20%. The project highlights the need of FEM analysis in industries ranging from small scale to large one, as this will reduce cost also it will improve accuracy**.**

REFERENCES

[1] Rajendran, I., Vijayarangan, S. Optimal Design of a Composite Leaf Spring using Genetic Algorithms Int. *Jr. of Computer and Structures 79 2001: pp. 1121 – 1129.*

[2] Rajendran, I., Vijayarangan, S. Design and Analysis of a Composite Leaf Spring *Journal of Institute of Engineers India 82 2002: pp. 180 – 187.*

[3] Daugherty, R. L. Composite Leaf Springs in Heavy Truck Applications. K. Kawata, T.Akasaka (Eds). Composite

[4] Materials Proceedings of Japan-*US Conference Tokyo, 1981: pp. 529 – 538*

[5] Dharam, C. K. Composite Materials Design and Processes for Automotive Applications. *The ASME Winter Annual Meeting, San Francisco, December 10-15, 1978: pp. 19 – 30.*

[6] Tanabe, K., Seino, T., Kajio, Y. Characteristics of Carbon/Glass Fiber Reinforced Plastic *Leaf Spring, SAE 820403 1982: pp. 1628 – 1634.*

[7] Yu, W. J., Kim, H. C. Double Tapered FRP Beam for Automobile Suspension Leaf Spring Comp. Structure *1998: pp. 279 – 300*.

[8] Jones, R. M. Mechanics of Composite Materials. 2e, Mc Graw-Hill Book Company, 1990.