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Design and Static Analysis of a Light Weight Vehicle Leaf Spring

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Abstract— *Now a days automobile industry has more awareness to increase the fatigue life of the product, for that they are going to several research. In automobiles, the suspension system gives a smooth riding comfort for rider and passengers. The main function of leaf spring assembly is a suspension system in automobile, it supports vertical load and also it isolate the road-induced vibrations. . The main objective of this paper is to reduce the bending stress and increases the fatigue life, it is achieved by changing the design of the leaf spring without changing the material. Modeling design was done by using CATIA V5 and analysis of both the conventional and tapered leaf springs was done by using ANSYS 14.5 software. Compared to the steel leaf spring the tapered leaf spring has less bending stress.*
Keywords*: *Bending stress, Conventional leaf spring, Tapered leaf spring.

I. INTRODUCTION

Generally leaf springs are built up of a number of plates or leaves. Generally the leaves are initial curvature or cambered so that they will have a tendency to straighten under the load. The leaves are kept together by means of a band shrunk around them and a bolt is passing through the center. The top of the plate is called as a master leaf, it has front eye end at front side and rear eye end at rear side. It is placed on the axe of the vehicle so total load is acting on the leaf spring.

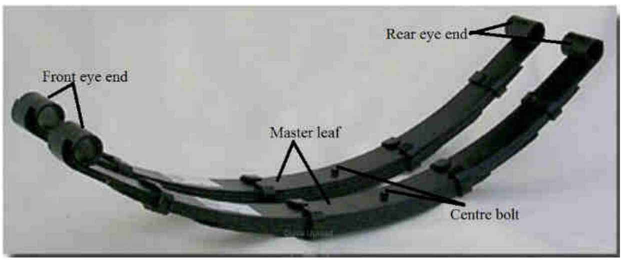

Fig.1.Schematic diagram of Leaf spring

The leaf spring is one of the potential items in automobile suspension system. Leaf spring is a longitudinal type, it absorb the vertical vibration due to the irregularities in the road and it store the energy in the form of strain energy and finally release the stored energy. Hence, the strain energy of the material becomes a major factor in designing the springs. Fatigue failure is the main mode of in-service failure of several automobile components, particularly the leaf spring used in the suspension system of automobile. The fatigue life of the any product is mainly depend on the induced stress which is developed at given loading condition. If reduction of the induced stress at same loading condition is possible the life span of the product should increase.

In the present work, a ten-leaf steel springs are used in a light passenger vehicle is replaced with a tapered leaf spring made of a same material. The length and width of the leaves are same only thickness is changed. The main intension of this work was to reduce the bending stress and increase the fatigue life by shape optimization of the leaf spring.

II. STEEL LEAF SPRING

2.1. Model design

Solid model preparation is the first and forward step for doing any analysis and testing. For modeling the steel spring, the dimensions of a conventional leaf spring of a light weight passenger vehicle are chosen.

In this work by using CATIA V5 modeling software the model was prepared with the specification of the leaf spring is shown in Table 1. The leaf spring is symmetric about its total length.

Table 1. Specifications of leaf spring

Parameters	Values
Length of the leaf, mm	1120
Arc height at axle seat, mm	180
No of full length leaves	2
No of graduated leaves	8
Spring width, mm	50
Spring thickness, mm	6

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Static load given on spring	4800
Maximum load, N	6700
Spring weight, kg	17
Density, kg/m^3	7860
Modulus of elasticity, MPa	210000
Poisson's Ratio of the material	0.3

2.2. Length calculation of leaves

In this design model the total number of leaves are 10. The effective length of the leaf is 1020mm and in-effective length or band length is 100mm.

Length of the smallest leaf (for No of master leafs =2)

$$= \frac{Effective\ length}{n-1} + Ineffective\ length$$

where n = Total number of leaves

Length of 10th leaf

$$= \frac{1020}{10-1} \times 1 + 100$$

=213.333mm

Length of 9th leaf

$$= \frac{1020}{10-1} \times 2 + 100$$

=326.667mm

Length of 8th leaf

$$= \frac{1020}{10-1} \times 3 + 100$$

=400mm

Length of 7th leaf

$$= \frac{1020}{10-1} \times 4 + 100$$

=5553.333mm

Length of 6th leaf

$$= \frac{1020}{10-1} \times 5 + 100$$

=666.667mm

Length of 5th leaf

$$= \frac{1020}{10-1} \times 6 + 100$$

=780mm

Length of 4th leaf

$$= \frac{1020}{10-1} \times 7 + 100$$

=893.333mm

Length of 3th leaf

$$= \frac{1020}{10-1} \times 8 + 100$$

=1006.667mm

Length of 2nd leaf

$$= \frac{1020}{10-1} \times 9 + 100$$

=1020mm

Here the number of full length are 2, so the length of the 1st leaf is equal to the length of second leaf that is 1020mm.

Table 2. Length of the leaf springs

Leaf number	Full length of the leaves, mm	Half length of the leaves, mm
1	1120	560
2	1120	560
3	1007	503.5
4	894	447
5	780	390
6	667	333.5
7	554	277
8	440	220
9	327	163.5
10	214	107

By using table 2, the model was designed by using CATIA V5 modelling software and it is shown in Fig.2

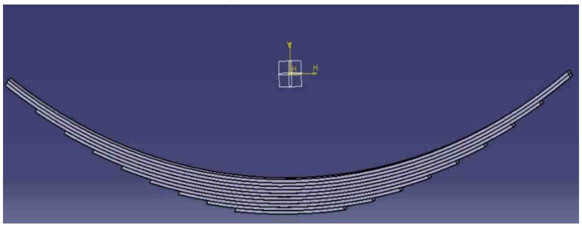

Fig.2 Leaf spring model

2.3. Analysis of Steel Leaf Spring

Now the designed model of leaf spring was analyzed by using the ANSYS 14.5 software. The model was symmetric about its length, so for simplification of analysis only half of the part was taken. The following table was showing the material properties of the steel.

Table 3. Length of the leaf springs

Parameter	Value
Material	65Si7
Young's modulus, MPa	210000
Poisson's ratio	0.266
Shear modulus, MPa	82900
Tensile Strength, MPa	1158
Ultimate tensile strength, MPa	1272
Density, kg/m^3	7860

These material properties are given to the designed model. The model is a half, so its looks like a cantilever beam i.e., one of the beam is fixed and another end is free. The designed load is applied on the free end of the model and another end is fixed. The analysis steps in ANSYS was shown in below flow chart.

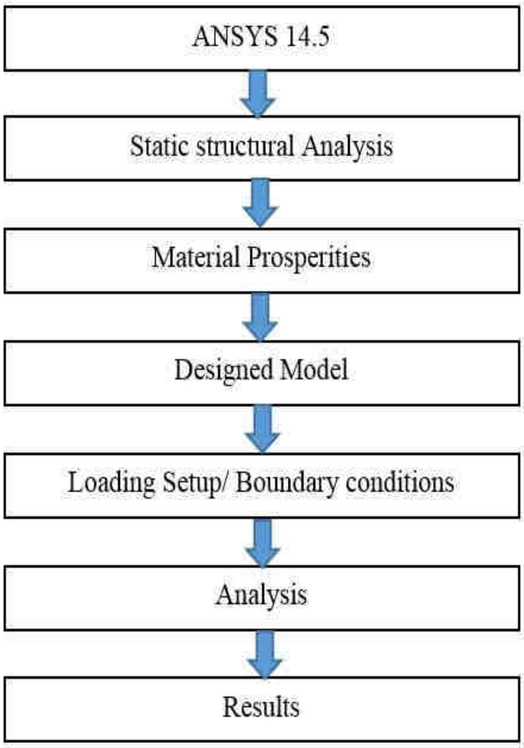

Fig.3 Steps in ANSYS

2.4. Finite element analysis results

At static load=2400N

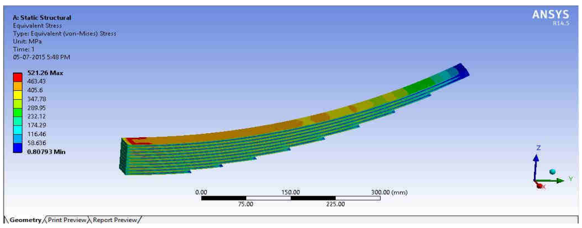

Fig.4 Equivalent stress = 521.26MPa

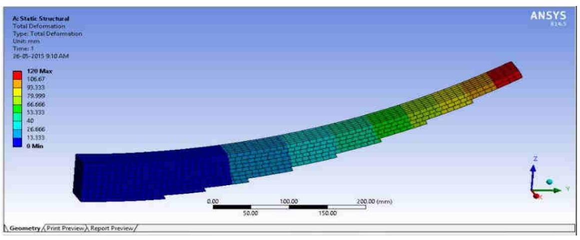

Fig.5 Deflection = 120mm

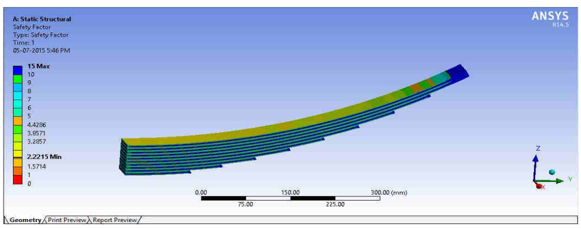

Fig.6 Factor of safety = 2.2215

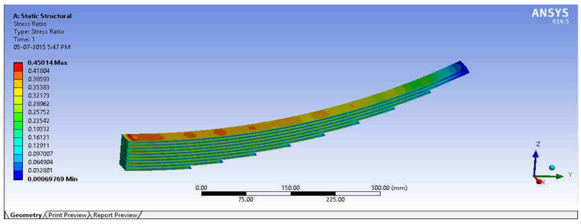

Fig.7 Stress ratio = 0.45014

At maximum load=3350N

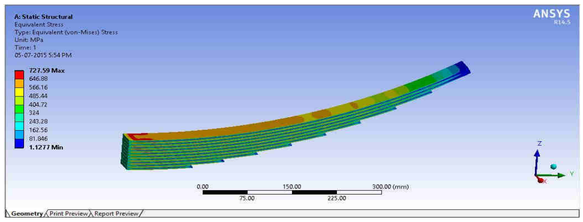

Fig.8 Equivalent stress = 721.59MPa

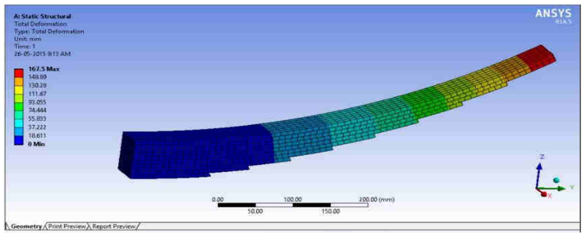

Fig.9 Deflection = 167.5mm

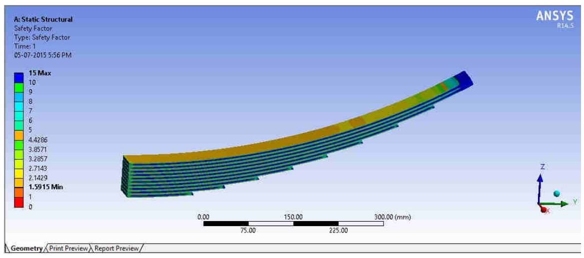

Fig.10 Factor of safety = 1.5915

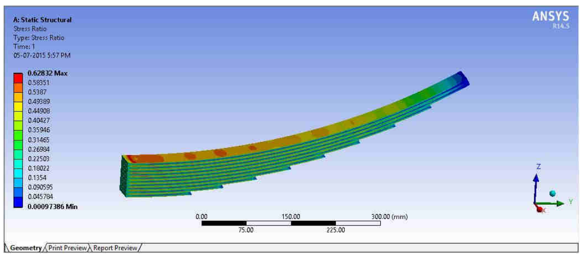

Fig.11 Stress ratio = 0.62832

III. TAPERED LEAF SPRING

The shape of the conventional leaf springs are replaced by leaf springs with taper from center to eye. The total number of the leaves in conventional leaf spring was 10 whereas here only 6 number of plates are used. The

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thickness of the conventional leaf spring is same along its entire length but in the tapered plates the thickness varies along its length. The thickness at the tip is 6mm and 9 mm at root. In the tapered leaf spring 2 full length leaves and 4 graduated leaves are used. The total length is 1120 mm for both the cases. Tapered leaf spring is also symmetric about its length and the analysis conducted only for the half of the section.

3.1. Static analysis of Tapered leaf spring

At static load=2400N

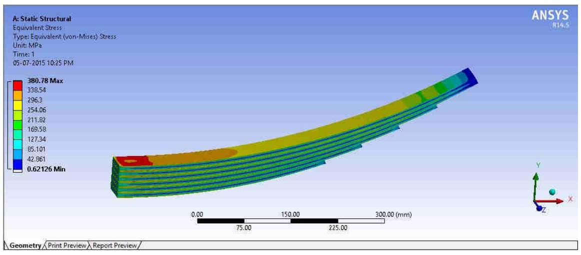

Fig.12 Equivalent stress = 380.78MPa

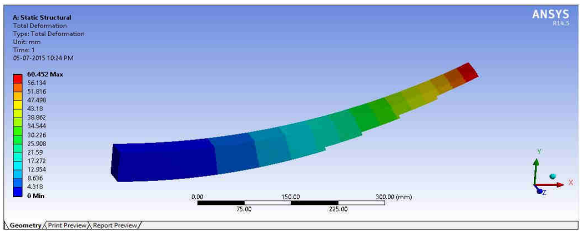

Fig.13 Deflection = 60.45mm

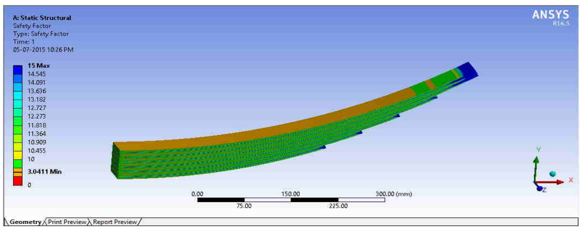

Fig.14 Factor of safety = 3.0411

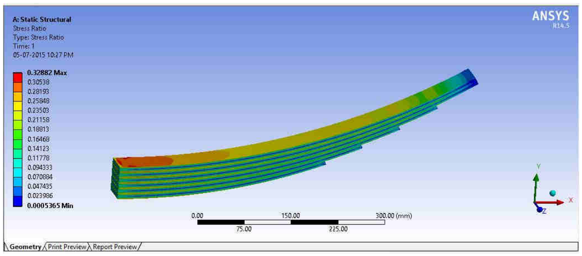

Fig.15 Stress ratio = 0.32882

At maximum load=3350N

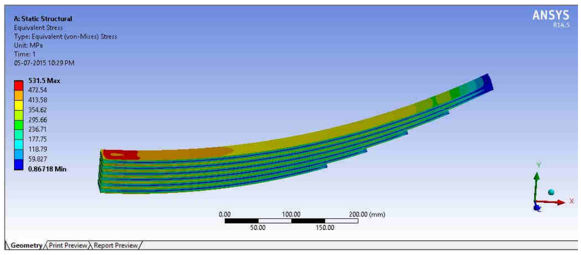

Fig.16 Equivalent stress = 531.5MPa

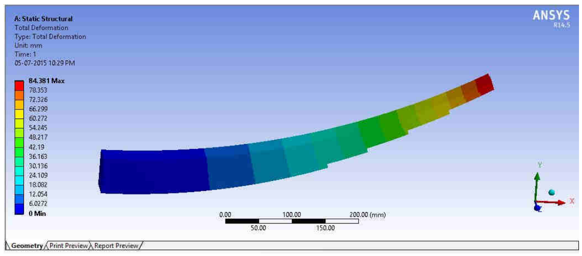

Fig.17 Deflection = 84.381mm

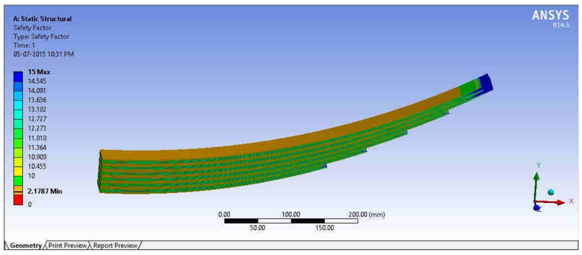

Fig.18 Factor of safety = 2.1787

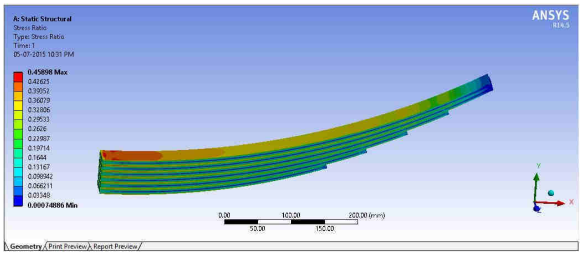

Fig.19 Stress ratio = 0.45898

IV. RESULTS AND DISCUSSIONS

From the results of static structural analysis of steel leaf spring, the deflection of the spring is 167.5mm is lower than axle seat height of the leaf spring. The maximum equivalent stress is 721.59 MPa is lower than the yield tensile strength of the material.

After that the tapered leaf spring made with the same material is analyzed by using ANSYS 14.5 analysis software. The bending stress is lower than that of the conventional leaf spring.

Table 5. Stress comparison

Loading condition	Equivalent Stress in MPa	
	Conventional	Tapered
Static load	521.26	380.78
Maximum load	721.59	531.5

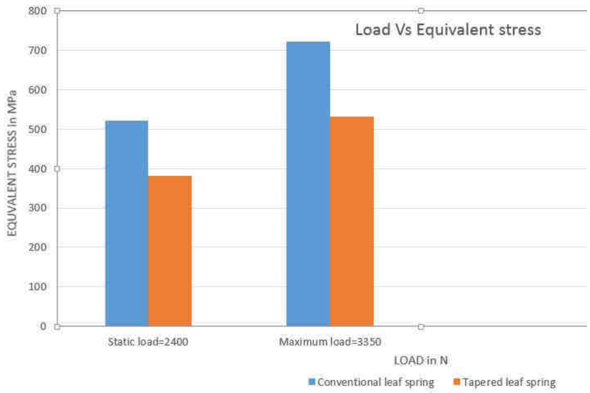

Fig 25. Load vs. Equivalent stress

V. CONCLUSIONS

Compared to the conventional leaf spring, the tapered leaf spring is found to have around 24% lesser stress for the same material. The fatigue life of the tapered leaf spring is more compared to the conventional leaf spring due to lower stress values. Therefore, it is concluded that the tapered leaf spring is an effective replacement for the existing conventional leaf spring in the light passenger vehicle.

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