International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 04 Issue: 08 | Aug -2017 www.irjet.net p-ISSN: 2395-0072

Improve The Design Of Leaf Spring By Reducing The Frictional Stress

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Abstract - *The automotive suspension system is the one of the important unit in automotive design, especially leaf spring design. It absorbs payload and road load to give the comfort ride to a passengers in the vehicle. In the present trend peoples are interested to buy a vehicle with good mileage for this reason the automobile industry show an interest to reduce the weight of an vehicle components. The weight of vehicle and mileage are inversely proportional as the weight increases the mileage decreases .In the leaf spring the friction between the leaves of spring is one of the problem the friction between the leaves causes the wearing of the leaves and this leads to a breakdown of leaves. The objective of this project is to compare the deformation, strain energy, weight of the new model of leaf spring with conventional elliptical leaf spring and also the study of static and dynamic analysis of three models. Design modeling is done using CATIA V5R20 and analysis is carried out by using ANSYS 17.0 software.*

Key Words: Leaf spring, Frictional stress, Strain energy, mode shape & Natural frequency, CATIA V5R20, ANSYS 17.0

1. INTRODUCTION

Leaf spring was invented by Obadiah Elliot of London in 18thccentury. He simply pilled one steel plate on top of another pinned them together and shackled each end to a carriage it was the first ever leaf spring used on vehicle. Leaf spring as the name indicates it is made of leaf like structure with rectangular cross section placed one over the above. Leaf springs are used in vehicles such as heavy commercial vehicle like truck, dumpers, rails etc. When compare the leaf spring over the helical spring the advantage of leaf spring over the helical spring is that ends of spring may be guided along a definite path so as to act as a structural member in addition to shock absorbing device. The springs are used to absorb energy during the loading condition and then release it, then strain energy of material becomes a major parameter in designing the spring where as in the coil spring load transfer to single point. A leaf spring is directly attached to the frame or chassis of the vehicle. The leaf spring having the eyes at both the ends one end is directly attached to the frame of the vehicle while other end attached to shackle (Swinging arm). Due to bounces on the road surfaces the spring get compress at that time shackle makes the leaf spring to expand and thus makes for smoother springiness. The design of leaf spring involves it is flat thin and adaptable bit of spring steel or composite material that oppose bending. The basic principle of leaf spring design and assembly are moderately simple the number of leaves in an spring is relies on the weight conveying limit of a vehicle most heavy duty vehicle today use two pairs of leaf spring per axle. The leaf spring placed perpendicularly to support the weight of vehicle. The spring comprises of a number of plates with a rectangular cross section called as leaves. The leaves are in increasing length. The leaf having maximum length called as master leaf, the other leaves are known graduated leaves.. The leaf spring is fitted on the axle of the vehicle. The front end of the spring is connected to the chassis with a simple pin joint, while the rear end is connected with a shackle (flexible link).

2. SCOPE OF PROJECT

The scope of our project is to improve the design of leaf spring suspension by modifying the existing design. In automobile, suspension system is important consideration. Our scope is to improve riding comfort of a vehicle by modifying the existing design and also reducing the frictional stress, stress developed by friction between to mating surface which leads to a failure of the component. To create three models of leaf spring one is standard design and other two models are different. To determine the deformation, strain energy and stress developed and also compare the result of all three models of leaf spring. Analysis of mode shapes for different natural frequencies .our project scope is to reduce the weight of leaf spring suspension system.

3. METHODOLOGY

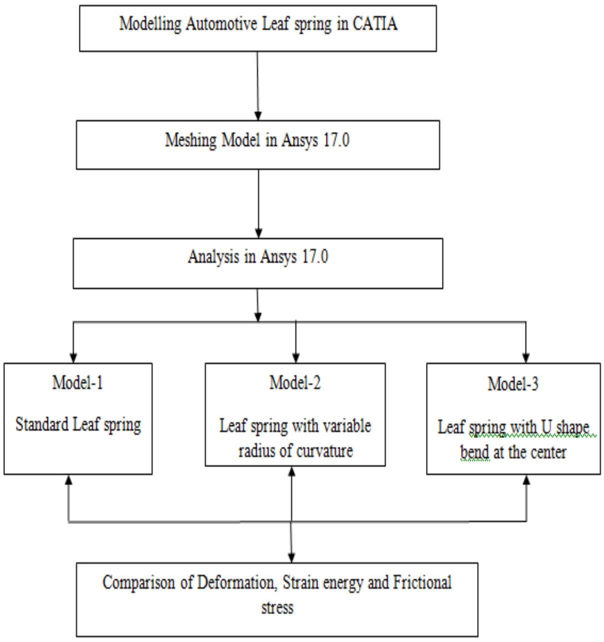

Fig3.1 Methodology of Project

3.1 DESIGN OF LEAF SPRING

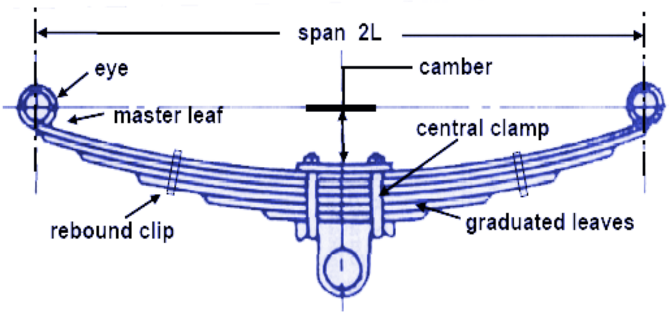

Fig 3.1.1 Design of leaf spring

W – Weight of leaf spring
2L – Span length of leaf spring
F – Maximum load on the spring
b – Width of all leaves
t – Thickness of the spring
n – Number of springs
E – Young's modulus of the material
C – Camber length

Maximum bending stress of leaf spring $\sigma_b = \frac{6FL}{nbt^2}$

Total deflection of leaf spring $\delta_{max} = \frac{6FL^3}{Enbt^3}$

3.2 GEOMETRY IN CATIA

The below all three models are designed in CATIA V5R20 ,it consist of number of leaves, U shape bolt for holding the axle, nut and coil spring for improving the riding comfort, rectangular plates for holding the leaves.

The models are created in CATIA software, starting with mechanical design and then goes to part design and the select the desire plane for 2D sketching, then created 2D sketch is converted to 3D model like this all the leaves are created

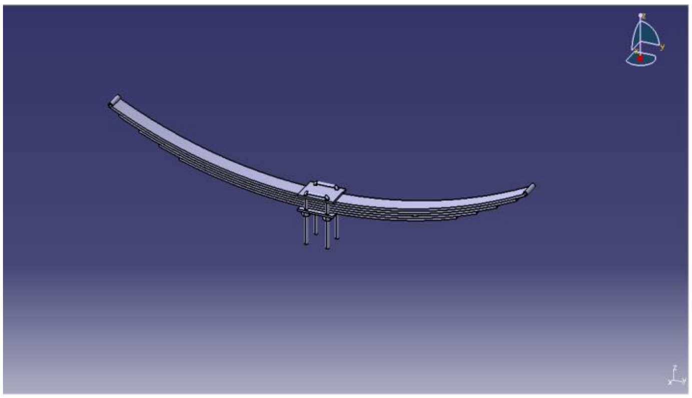

Fig 3.2.1 Model 1 Standard leaf spring

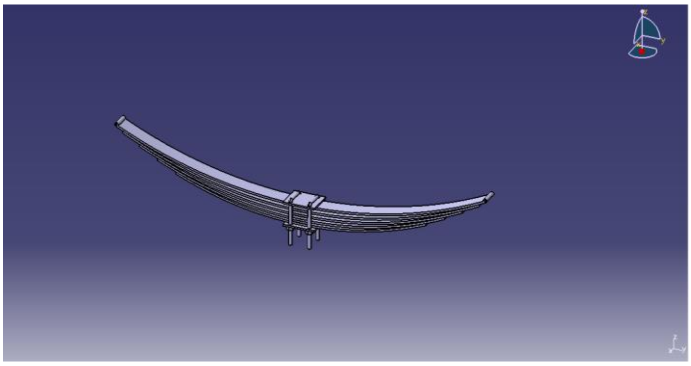

Fig 3.2.2 Model 2 leaf spring with variable radius curvature

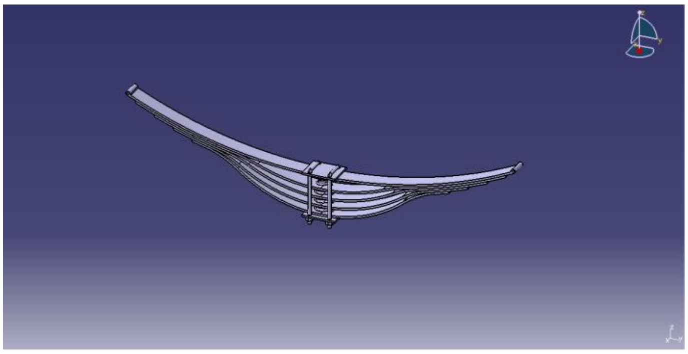

Fig 3.2.3 Model-3 Leaf spring with U shape bend at the center

3.3 MATERIAL PROPERTIES

Then assign the material of structural steel to all three models and compare the results. Structural steel differs from other material from its properties like compressive strength as well as tensile strength. For all three model namely Model-1 standard leaf spring, Model-2 leaf spring with variable radius of curvature, Model-3 Leaf spring with U shape bend at the center, The properties of structural steel are as follows.

Density	$\rho = 7.85 g/cm^3$
Yield strength	$S_y = 250$Mpa
Young's modulus or modulus of elasticity	$E = 2\times10^5$Mpa
Poisson's ratio	$\upsilon = 0.3$

Table 3.3.1 Material property structural steel

3.4 MESHING

For meshing purpose CAD models are imported to ANSYS software. In the ANSYS design modeler cleaning of CAD models takes place because of some defects in CAD models like sharp edges, holes, small fillets etc these are cleaned by using clean up tools.. Meshing involves the discretization of given quantinum in to number of parts, each part is called as element.

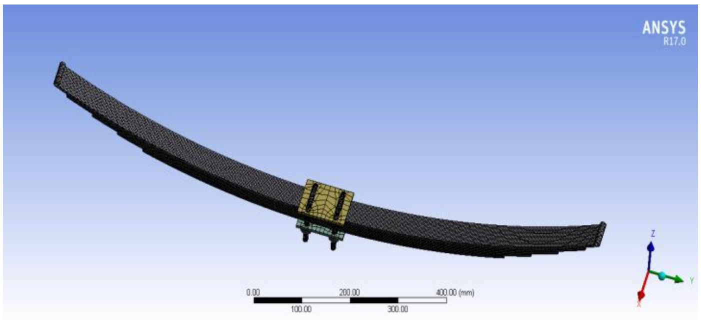

Fig 3.4.1 Meshing of Model 1 (Standard leaf spring)

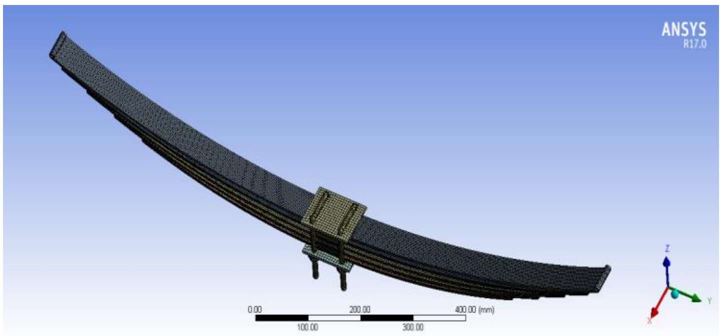

Fig 3.4.2 Meshing of Model 2 (leaf spring with variable radius of curvature)

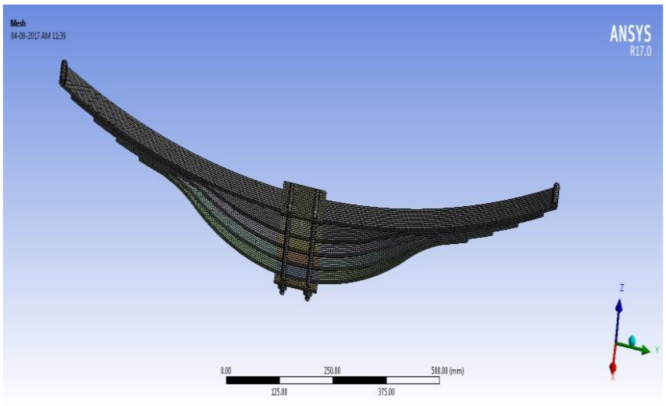

Fig 3.4.3 Meshing of Model-3 (Leaf spring with U shape bend at the center)

3.5 LOAD AND BOUNDARY CONDITION

In load and boundary condition, creating the symmetry plane at the middle of model for easy, accurate and time saving purpose. The front side eye of the leaf spring is connected to chassis by a pin. The pin provides a rotational motion but prevent a translation motion. The back side eye of the leaf spring is connected to the shackle (flexible link) other end of shackle is connected to chassis of automobile. The bottom plate of leaf spring is mounted on wheel axle which is fixed.

The force of 500N is applied on the two eyes of the leaf spring the leaf spring have the flexibility to slide along Y-direction, eye of the leaf spring to rotate about an pin in X-direction when the load applied on the spring so that displacement of eye is constrained in the X and Z direction.

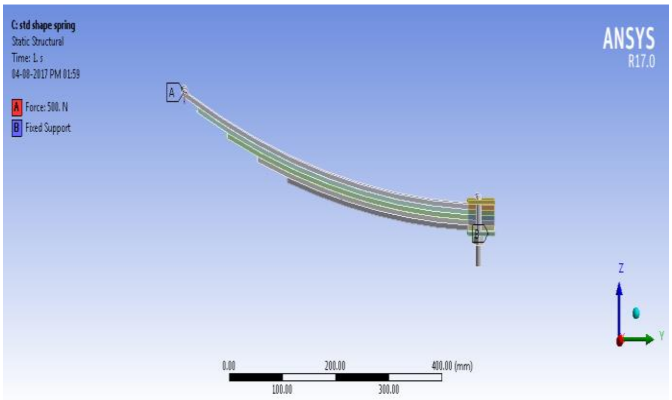

Fig 3.5.1 Load and boundary condition of Model 1 (Standard leaf spring)

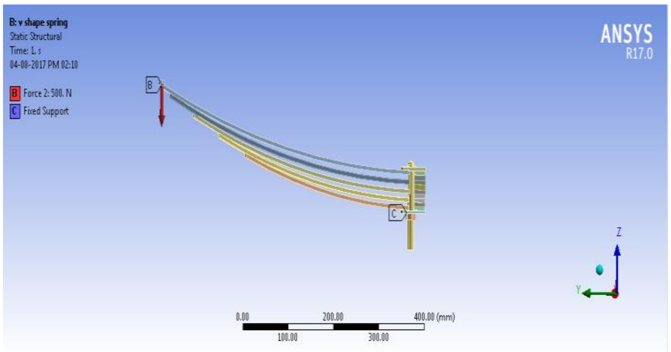

Fig 3.5.2 Load and boundary condition of Model 2 (leaf spring with variable radius of curvature)

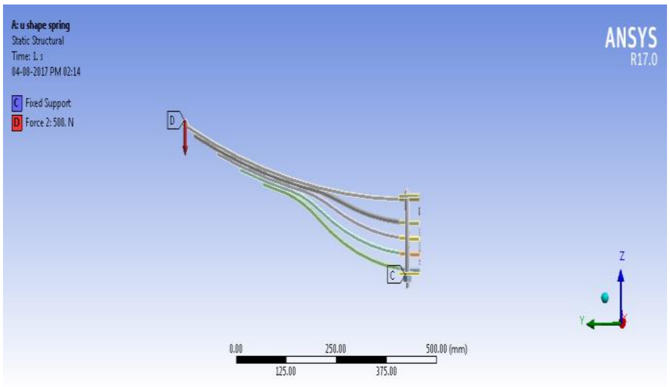

Fig 3.5.3 Load and boundary condition of Model-3 (Leaf spring with U shape bend at the center)

4. RESULT AND DISCUSSIONS

4.1 NATURAL FREQUENCIES AND MODE SHAPES MODEL 1

The modal analysis technique is used to determine the vibration characteristics (i.e. natural frequencies and mode shapes)of linear elastic structures.

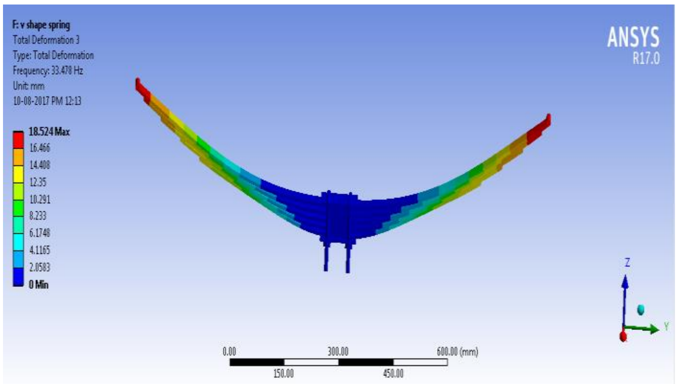

Fig 4.1.1 Mode 1

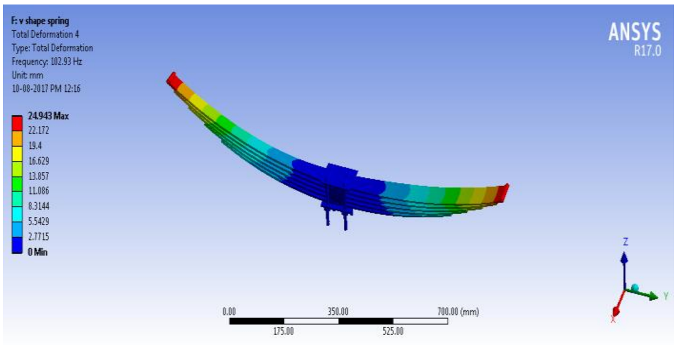

Fig 4.1.2 Mode 2

The Fig 4.1.1 shows that the natural frequency of 99.806 Hz, and the mode shape for this frequency is in longitudinal direction. The Fig 4.1.2 shows that the natural frequency of 159.2 Hz, and the mode shape for this frequency is in lateral direction.

4.2 NATURAL FREQUENCIES AND MODE SHAPES MODEL 2

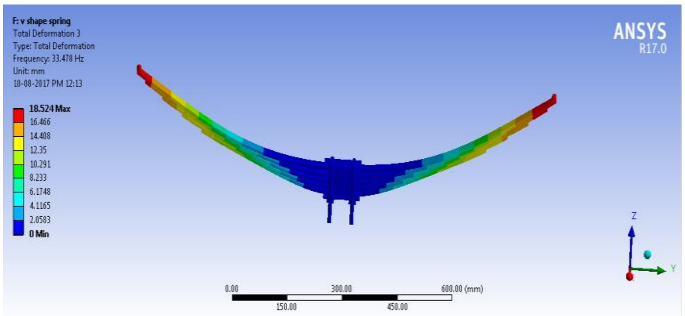

Fig 4.2.1 Mode 1

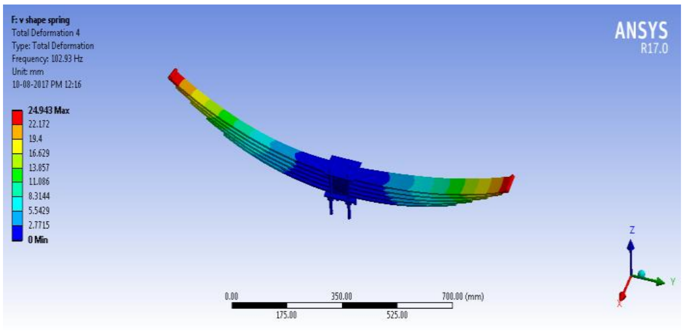

Fig 4.2.2 Mode 2

The Fig 4.2.1 shows that the natural frequency of 33.478 Hz, and the mode shape for this frequency is in longitudinal direction. The Fig 4.2.2 shows that the natural frequency of 102.93 Hz, and the mode shape for this frequency is in lateral direction.

4.3 NATURAL FREQUENCIES AND MODE SHAPES MODEL 3

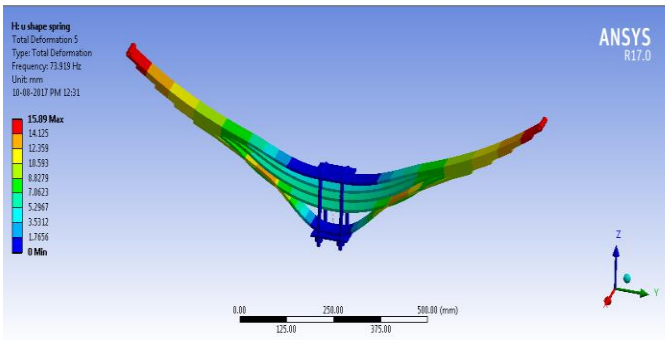

Fig 4.3.1 Mode 1

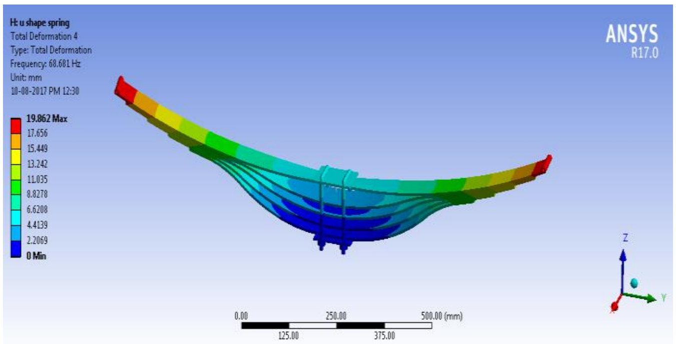

Fig 4.3.2 Mode 2

The Fig 4.3.1shows that the natural frequency of 73.919 Hz, and the mode shape for this frequency is in longitudinal direction. The Fig 4.3.2 shows that the natural frequency of 68.681 Hz, and the mode shape for this frequency is in lateral direction.

4.4 DEFORMATION

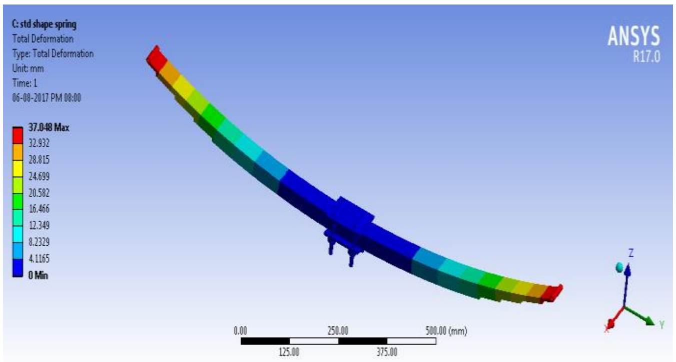

Fig 4.4.1 Deformation result of model 1(Standard leaf spring)

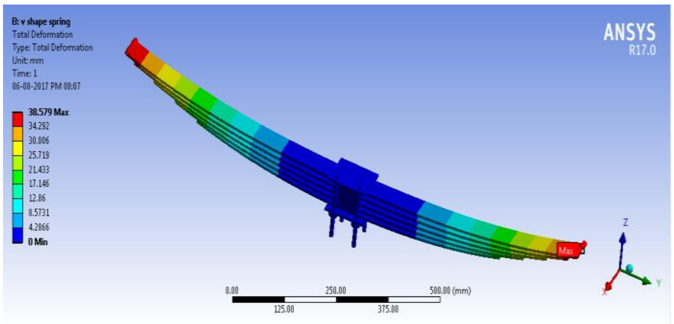

Fig 4.4.2 Deformation result of model 2 (leaf spring with variable radius of curvature)

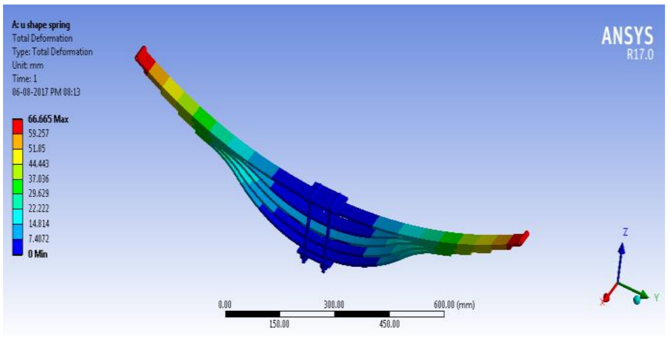

Fig 4.4.3 Deformation result of model 3 (Leaf spring with U shape bend at the center)

In the model 1 (Fig 4.4.1) the maximum deformation is 37.048 mm at eyes and minimum deformation of 4.1165 mm at the center of leaf spring. In the model 2 (Fig 4.4.2) the maximum deformation is 38.579 mm at eyes and minimum deformation of 4.2866 mm at the center of leaf spring. In the model 3 (Fig 4.4.3) the maximum deformation is 66.665 mm at eyes and minimum deformation of 7.4072 mm at the center of leaf spring.

4.5 STRAIN ENERGY

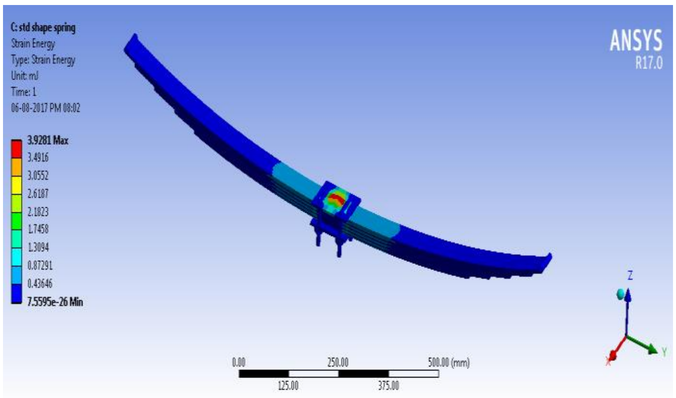

Fig 4.5.1 Strain energy result of model 1(Standard leaf spring)

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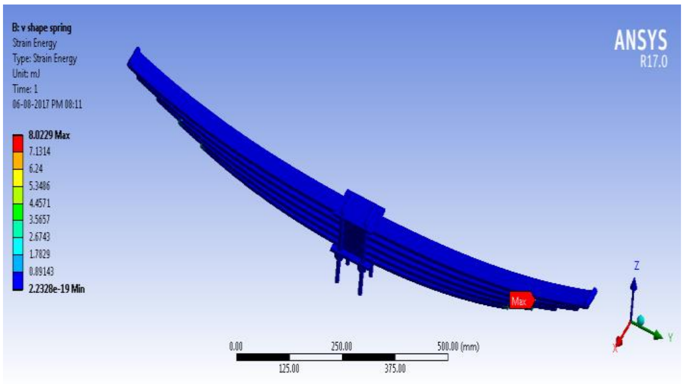

Fig 4.5.2 Strain energy result of model 2(leaf spring with variable radius of curvature)

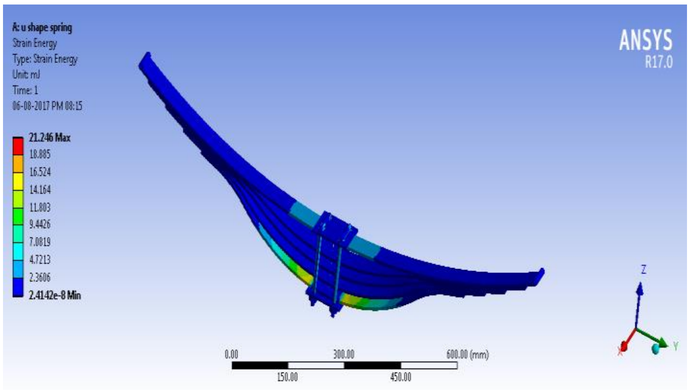

Fig 4.5.3 Strain energy result of model 3 (Leaf spring with U shape bend at the center)

In the model 1 (Fig 4.5.1) the maximum strain energy is 3.9281 mJ at the center and minimum strain energy of 7.5595e-26 mJ at the eyes of leaf spring. In the model 2 (Fig 4.5.2) the maximum strain energy is 8.0229 mJ at the center and minimum strain energy of 2.2328e-19 mJ at the eyes of leaf spring. In the model 3 (Fig 4.5.3) the maximum strain energy is 21.246 mJ at the center and minimum strain energy of 2.4142e-8 mJ at the eyes of leaf spring.

5. RESULT SUMMARY

Sl NO	Parameters	Model 1	Model 2	Model 3
1	Deformation (in mm)	37.048	38.579	66.66
2	Strain energy (in mJ)	3.928	8.0229	21.246

Table 5.1 Result table

The above table shows the Deformation and strain energy result of three models of leaf spring suspension. By applying the load at the eyes and fix the plate which is mounted on the axle. By comparing the deformation result of all three models, the model 1 having the lowest deformation of 37.048mm compare to other two models because there is no gap between the leaves and leaves are bounded by the bounded contact. The model 2 having the deformation of 38.579 mm which is slightly larger than model 2 and smaller than model 3 this due to leaves in the model 2 having the different radius of curvature there is no complete contact between leaves, there will be small gap between the leaves. The model 3 having the deformation 66.66mm which is larger than all three models this due to an installed spring between leaves of model 3. The strain energy of model 1 is 3.928mJ which is smaller comparing to all three models because there is no gap between in the leaves and leaves are properly bounded. The strain energy of model 2 is 8.0229 mJ which slightly larger than the model 1 and smaller than model 3 this is due to a variable radius of curvature of model 2 and there is gap between the leaves of model 2. The strain energy of model 3 is 21.246mJ which is larger than other two models this is due to installing the spring between the leaves. From all three models, model 3 having larger strain energy which improves the riding comfort of vehicle.

6. VALIDATION

Dimensions of "TATA ACE" commercial goods vehicle is taken for validation and dimensions are as follows.

Leaf span	860mm
Free Camber	90mm
Width of all leaves	60mm
Thickness of the spring	8mm
Weight of leaf spring	10.26Kg
Total Number of full leaves(including master leave)	3
Maximum Load given on spring	4169 N

6.1 ANALYTICAL CALCULATION

Total Weight of the vehicle= 700 kg
Maximum load carrying capacity= 1000 kg
Total weight= 700 + 1000 = 1700 kg
Taking factor of safety (FS) = 2
Acceleration due to gravity (g) = 9.81 m/s^2
Total Weight =1700 ×09.81 = 16677 N
TATA ACE vehicle has four wheels, each leaf spring per wheel ($\frac{1}{4}$ th of total vehicle weight)

$\frac{16677}{4}$ = 4169 But 2F = 4169 N. F = $\frac{4169}{2}$ = 2084 N.

Span length, 2L =860 mm, L = $\frac{860}{2}$ = 430 mm.

Maximum Bending stress of a leaf spring is given by

Bending Stress, $\sigma_b = \frac{6FL}{nbt^2}$

$= \frac{(6\times2084\times430)}{(3\times60\times8^2)}$ = 466.84 Mpa

Total Deflection of the leaf spring is given by

Total Deflection $\delta_{max} = \frac{6FL^3}{Enbt^3}$

$= \frac{(6\times2084\times430^3)}{(2.1\times10^5\times3\times60\times8^3)}$ = 51.38 mm

6.1 ANSYS RESULT

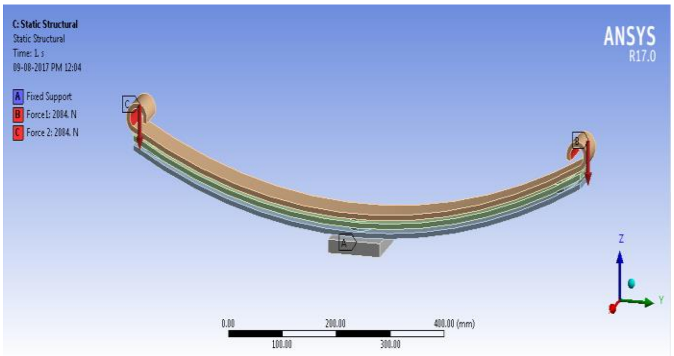

Fig 6.1.1 Load and boundary condition of steel leaf spring

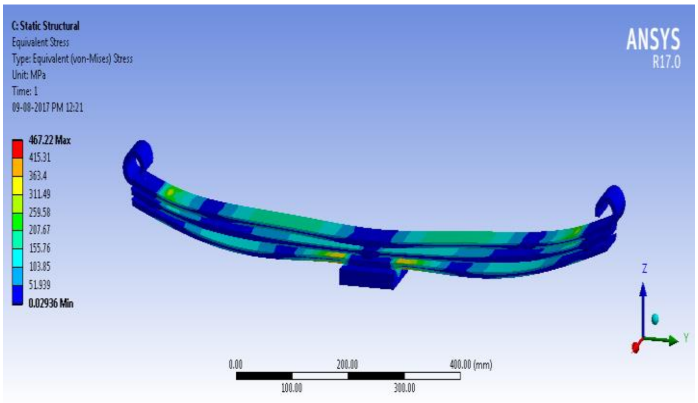

Fig 6.1.2 Bending stress of steel leaf spring

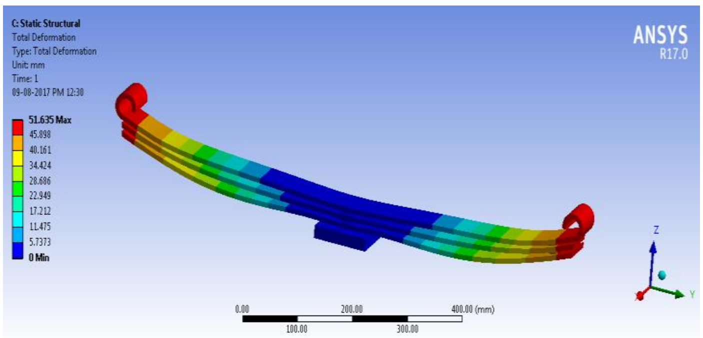

Fig 6.1.3 Total deformation of steel leaf spring

6.2 VALIDATION TABLE

SI.NO	Parameters	Analytical result	Ansys result	% Error
1	Bending stress	466.84	467.22	0.0814
2	Total deformation	51.38	51.63	0.4866

Table 6.2.1 Validation Table

7. CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION

The project was mainly aimed to minimize the frictional stress developed between the leaves. therefore changing the design of leaf spring by modifying the traditional leaf spring. three modified design of leaf spring was created including traditional leaf spring, Model 1 Standard leaf spring, Model 2 leaf spring with variable radius of curvature, Model 3 Leaf spring with U shape bend at the center. In model 2 and Model 3 the area of contact between the leaves are reduced.

- Due to reduction in the area of contact between leaves in Model 2 and Model 3 compare to Model 1, the frictional stress developed will be minimum in Model 2 and Model 3.
- The riding comfort of vehicle was improved due to increase in a strain energy in model 2 and model 3 compare to model 1.
- The natural frequency and mode shapes show the modal behavior of the leaf spring suspension system under excitation.
- There is substantial reduction in weight, the modified leaf spring having the less number of leaves.

7.2 FUTURE SCOPE

- From the obtained results, carry out the fatigue analysis for the vibration of a leaf spring suspension system to predict the life.
- Carry out the random analysis with PSD data
- Carry out the fatigue analysis to determine the life
- To minimize the deformation of leaf spring.
- Use alternate materials for the leaf spring and study the result.

8. REFERENCES

1. Zheng Yinhuan, Xue Ka, Huang Zhigao. Finite Element Analysis of Composite Leaf Spring, The 6th International

Conference on Computer Science & Education (ICCSE 2011) August 3-5, 2011. Superstar Virgo, Singapore.

2. Mahmood M. Shokrieh, Davood Rezaei. Analysis and optimization of a composite leaf spring, Composite Structures 60 (2003) 317–325, in 2003.
3. H.A. Al-Qureshi. Automobile leaf spring from composite material, Journal of Material Processing Technologies 118 (2001) 58-61.
4. D.Younesian, M.S. Fallahzadeh. Numerical and Experimental Analysis of Nonlinear Parabolic Springs Employed in Suspension System of freight cars, International Journal of Automotive Engineering Vol. 4, Number 3, Sept 2014.
5. Prof. R.M.Bhoraniya, Trivedi Achyut V. Static and Dynamic Analysis of Automobile Leaf Spring (TATA ACE), IJSTE - International Journal of Science Technology & Engineering , Volume 1 , Issue 11 ,May 2015.
6. K.K.Jadhao, Dr. R.S.Dalu, Experimental Investigation and Numerical Analysis of Composite Leaf Spring, International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462 Vol. 3 No. 6 June 2011.
7. Ashish V. Amrute, Edward Nikhil karlus, R.K.Rathore. International journal of research in aeronautical and mechanical engineering, ISSN : 2321-3051,vol 1,issue 7, November 2013.
8. B.Vijaya Lakshmi, I. Satyanarayana. Static and dynamic analysis on composite leaf spring in heavy vehicle, International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974, IJAERS/Vol. II/ Issue I/Oct.-Dec.,2012/80-84.