

# Design and Analysis of Leaf Spring for the Enhancement of Load Carrying Capacity

Harikrishnan B, K. Jayakumar\*, L. Poovazhagan, Balaji S.R, Manikandan P, Naveen Bharath S

Department of Mechanical Engineering, SSN College of Engineering, Chennai-603110

\*Corresponding author: E-Mail: [kjayakumar@ssn.edu.in](mailto:kjayakumar@ssn.edu.in)

## ABSTRACT

In the present work, the design of the conventional leaf spring and the modified eight designs of leaf spring were carried. The material which we are using for the designing of leaf spring is 65Si7 steel. The length of the master leaf is taken as 753.55 mm is taken as constant for all models and the analysis of the leaf spring was done by using ANSYS 14.0. The static structural analysis in terms of equivalent stress, strain and total deformation were carried out by applying load at bottom loading condition with the eye end is said to be fixed and a force of about 10,000 N was applied in the end of the U-bolt. From the nine models, the minimum deformation is achieved as 0.0014 mm and minimum stress and strain obtained were  $3.66 \times 10^{-5}$  MPa and  $1.74 \times 10^{-10}$  MPa respectively. From the results, it is clear that the equivalent stress, strain and total deformation of the modified leaf spring have been comparatively low than the conventional leaf spring model. Also, the load carrying capacity of the modified model of the leaf spring obtained in this work is higher than the conventional leaf spring.

**KEY WORDS:** Design and analysis of Leaf spring, Deformation, Equivalent stress and strain.

## 1. INTRODUCTION

Leaf spring is one of the key components of vehicle suspension system. Leaf springs are used in suspension systems to absorb shock loads in automobiles and in rail systems (Pradeep Tapkir, 2015). Continuously, automobile manufacturers have been attempting to reduce the weight of the vehicle. Weight reduction of automobile can be achieved primarily by the introduction of better material, design optimization and manufacturing methods (Ashish, 2013).

More efforts are taken in order to increase the comfort of the user. Appropriate balance of comfort riding qualities and economy in the manufacturing of leaf springs has become an essential requirement. Multi-Leaf springs are vital suspension elements used on mini loader trucks necessary to minimize the vertical vibrations, impacts and jolts due to road inconsistency and to ensure safety of the passengers and cargo (Ashok Kumar, 2013). Also, deflection characteristics of leaf spring are highly nonlinear and the modeling and analysis using softwares aims to find the optimized shapes of the leaf spring (Dipendra Kumar Roy, 2013). Many past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47, 50CrMoCV, etc.

The introduction of the composite materials made it possible to reduce the weight of the leaf springs without any diminution of load carrying capacity and stiffness (Ghodake, 2013; Shahrukh Shamim, 2014), used non-ferrous metals for parts necessitating corrosion resistance. Finite element analysis using ANSYS software has been carried on multi-leaf springs to obtain approximate solutions to the boundary value problems in engineering.

The leaf spring suspension holds about 10-20% of vehicle unsprung mass. Thus it becomes an essential component for weight minimization by better design for getting minimum stress, strain and deflection.

## 2. MATERIALS FOR LEAF SPRING

**Materials:** According to Indian standards, the recommended materials are:

**For Automobiles:** 50 Cr 1, 50 Cr 1 V 23, and 65Si7 all used in hardened and tempered state.

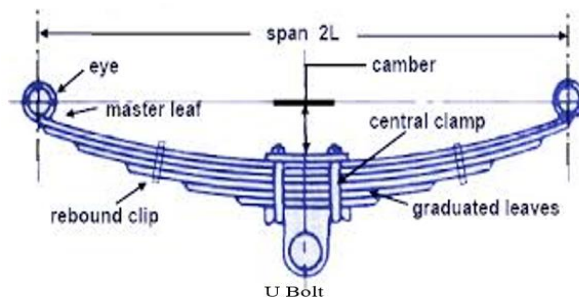
The material which we are using for the designing of leaf spring is 65Si7 steel. The composition and properties of 65Si7 steel are given in table 1 and 2.

**Table.1. The composition of 65Si7 steel is tabulated below,**

GRADE	C%	Si%	Mn%	P%	S%	Cr%
65Si7	0.51-0.62	0.15-0.35	0.65-0.95	0.035 max	0.035 max	0.65-0.95

**Table.2. The properties of 65Si7 steel (Aggarwal, 2015)**

Parameter	Value
Material selected	Steel 65Si7
Young's modulus (MPa)	2.1E+05
Poisons ratio	0.266
Bulk modulus (Pa)	1.4957E+11
Shear modulus (Pa)	8.2938E+10
Tensile yield strength (MPa)	1158
Tensile ultimate strength (MPa)	1272



**Figure.1. Leaf Spring**

**Methodology:** The design of modified leaf spring was created by using solid works software. After modeling, the leaf spring, the analysis of leaf spring was done by ANSYS 14.0. The following types of static structural analysis are done for bottom load condition.

1. Equivalent stress 2. Equivalent strain 3. Total deformation

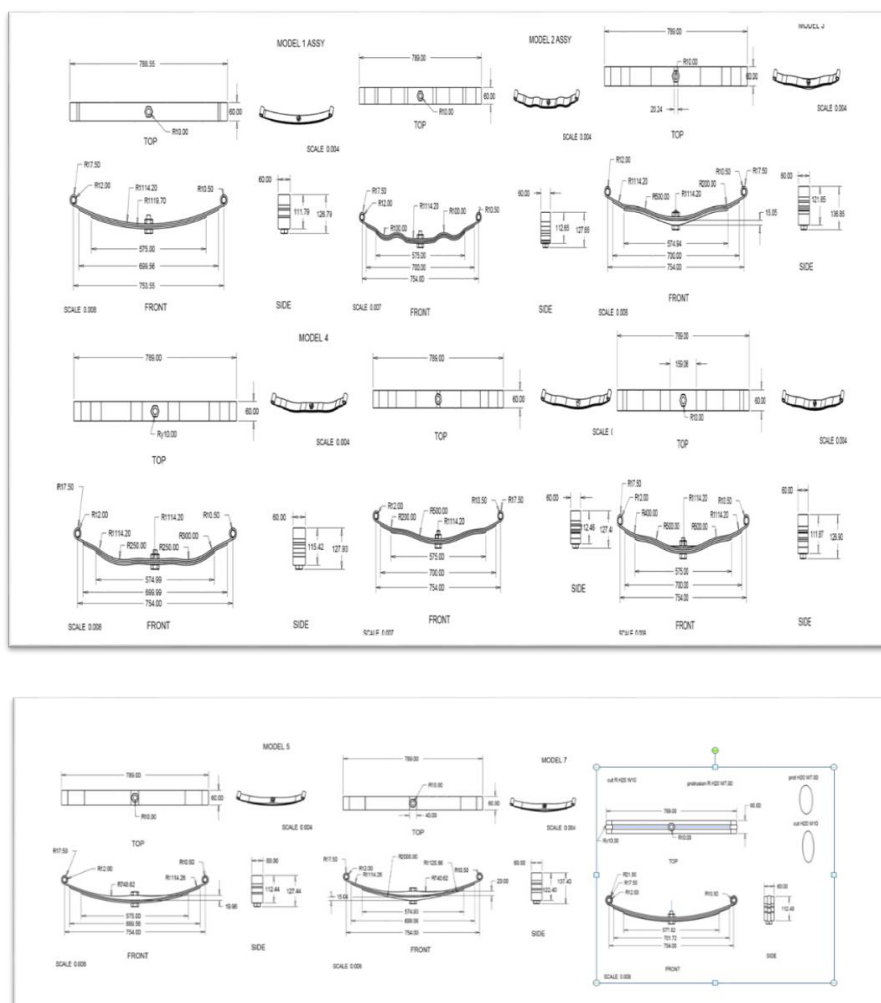
In bottom loading condition, the eye end is said to be fixed and a force of about 10,000 N is applied in the end of the U-bolt. The basic shape with major parts of leaf spring is shown in above figure 1.

#### Designing of leaf spring:

**Modeling of leaf spring using 65Si7 steel:** The design of the conventional leaf spring and the modified design of leaf spring is first done by using a designing software. The software which we are using for design is Solidworks.

**CAD models:** CAD Models were created for nine models (one model is existing standard one and eight different modified models from the present work) and the dimensions of leaf spring are,

The length of the master leaf is 754mm. The width of the leaf is 60mm. The inner radius of the eye is 12.00mm and outer radius of the eye is 17.50mm. The cut is made in the leaf for a height of 20mm and width of 10mm. The radius of U-Bolt is 10mm. The height of the leaf spring is 126.90mm. The CAD models are shown in Fig. 2.



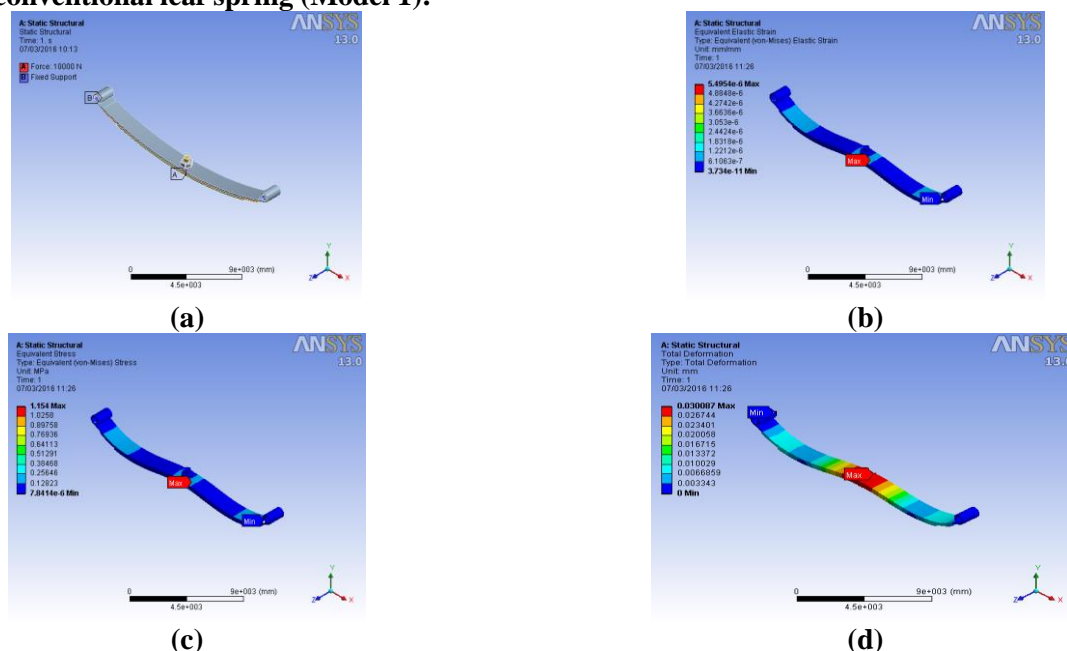
**Figure.2. Nine different CAD models of leaf spring**

#### Analysis:

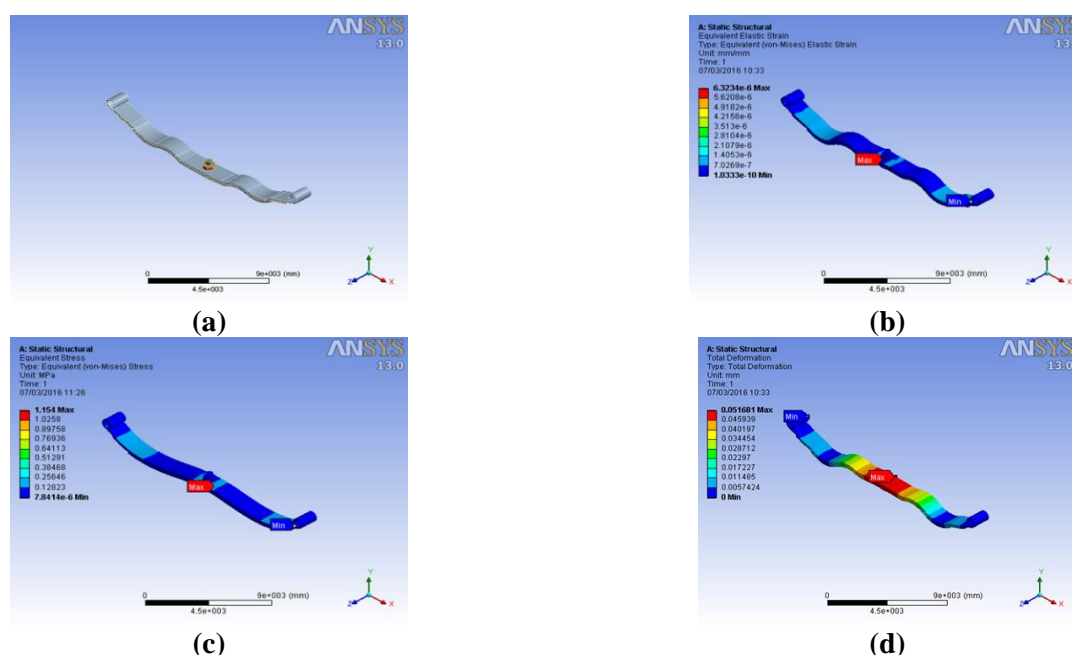
Analysis of leaf spring at bottom load condition:

**Analysis of conventional leaf spring (Model 1):** Using ANSYS, static analysis is carried out after applying the boundary conditions for bottom loading condition for all nine models. The maximum equivalent stress, maximum equivalent strain and maximum deformation in 65Si7 steel are found for all nine models. Vertical load ranging 10,000 N is applied on the model and the corresponding maximum stress, strain and deformation are noted down. The obtained values of stress, strain and deformation obtained from ANSYS software are plotted in graphs and are shown in below figures 3 to 11.

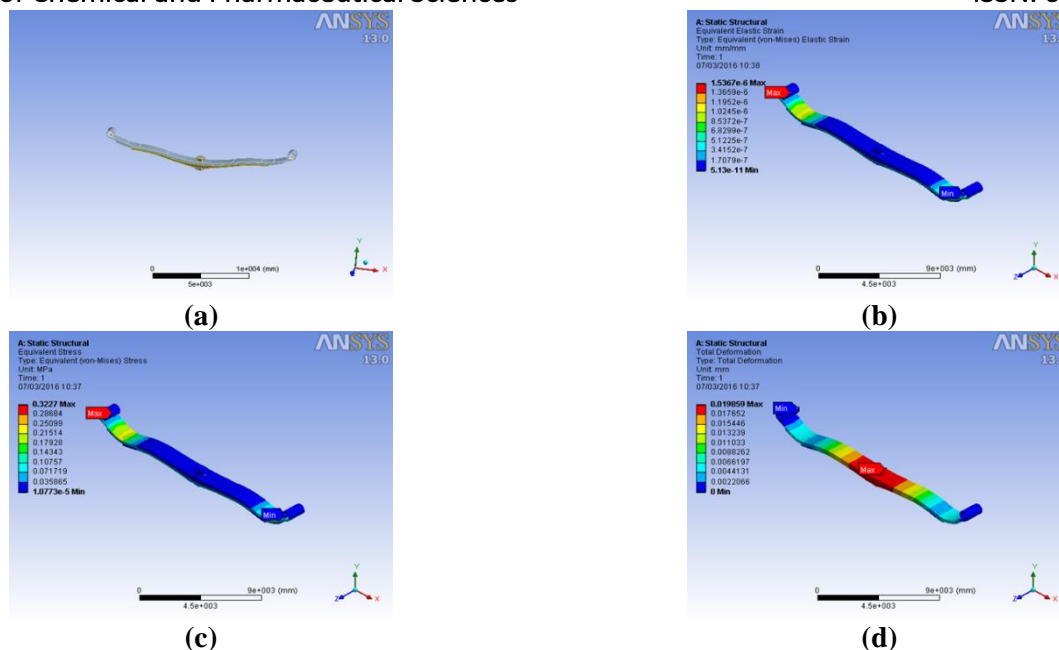
**Analysis of conventional leaf spring (Model 1):**



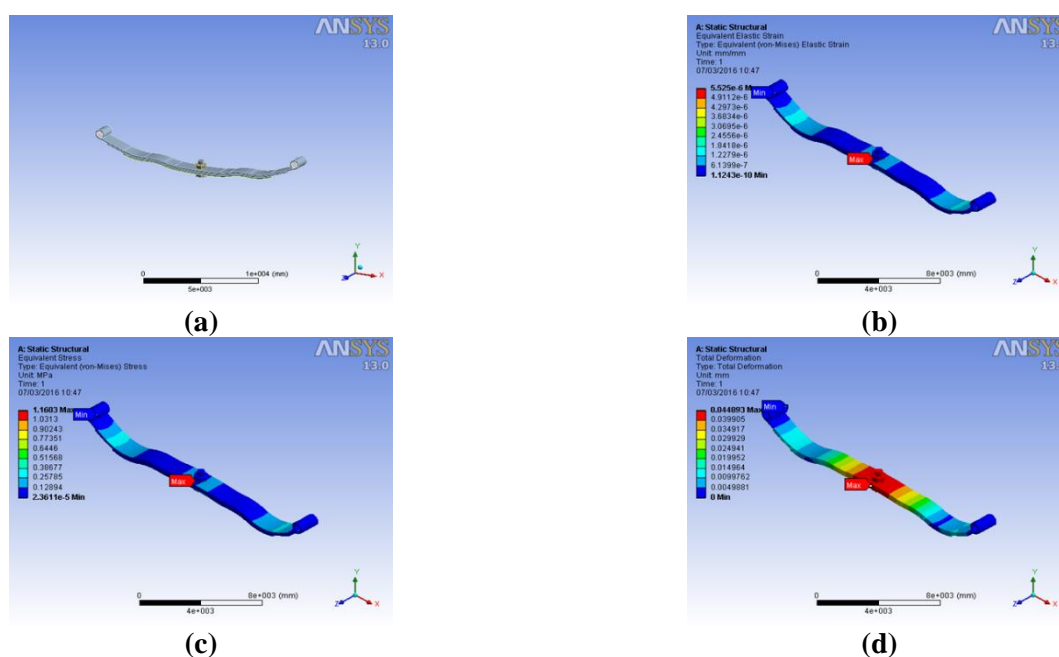
**Figure.3. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Analysis of Modified Leaf Spring (Model 2)**



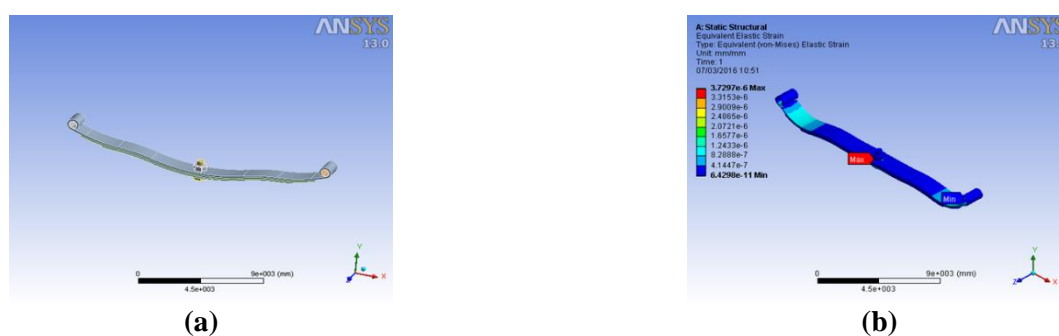
**Figure.4. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Analysis of Modified Leaf Spring (Model 3)**

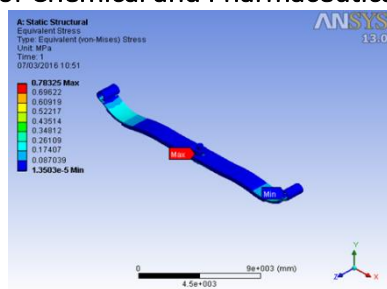


**Figure.5. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Analysis of Modified Leaf Spring (Model 4)**

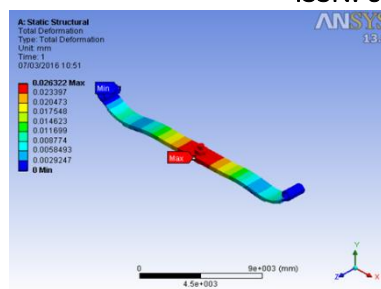


**Figure.6. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Analysis of Modified Leaf Spring (Model 5)**





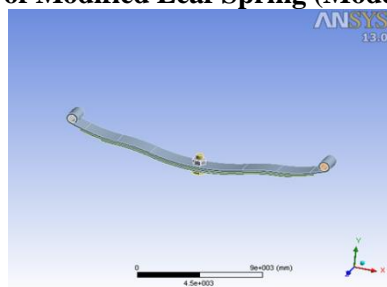
(c)



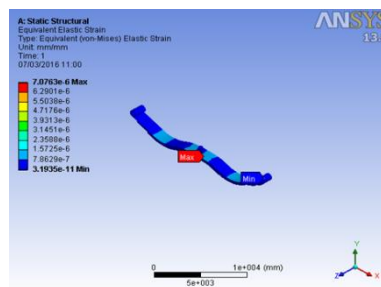
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**Figure.7. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation**  
Analysis of Modified Leaf Spring

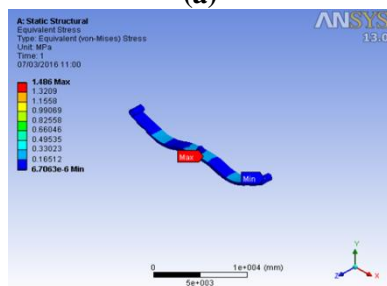
### Analysis of Modified Leaf Spring (Model 6)



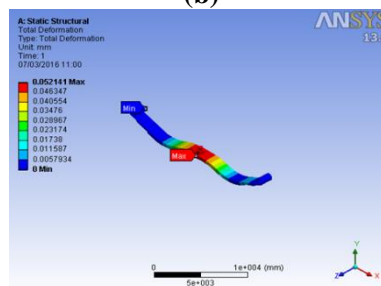
(a)



(b)



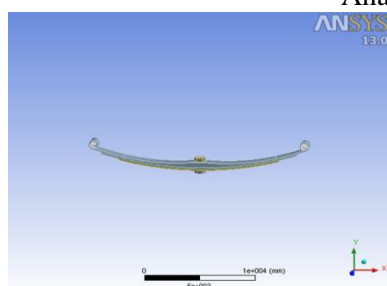
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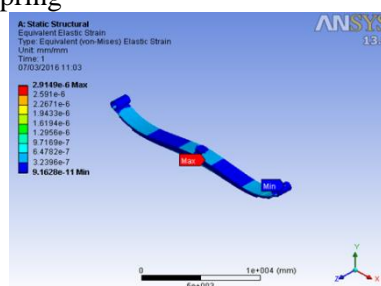
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**Figure.8. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation**  
Analysis of Modified Leaf Spring (Model 7)

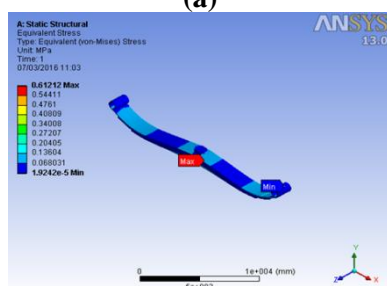
### Analysis of Modified Leaf Spring



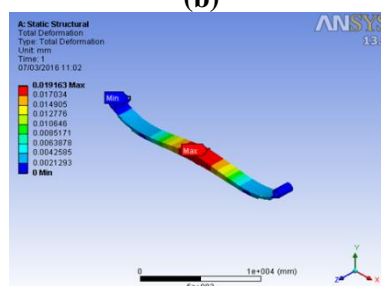
(a)



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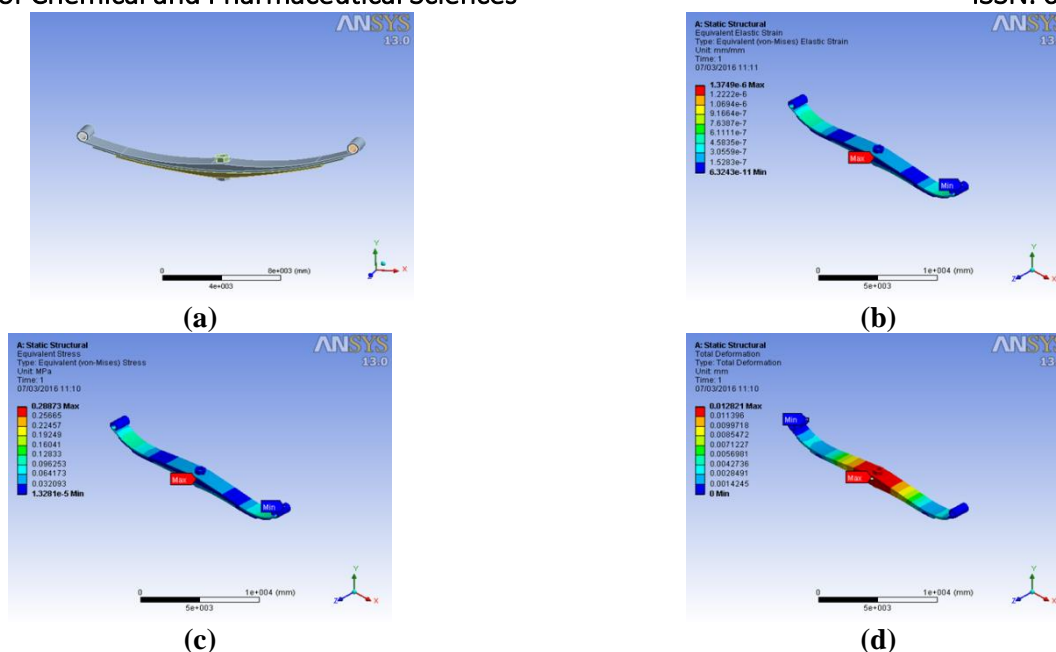


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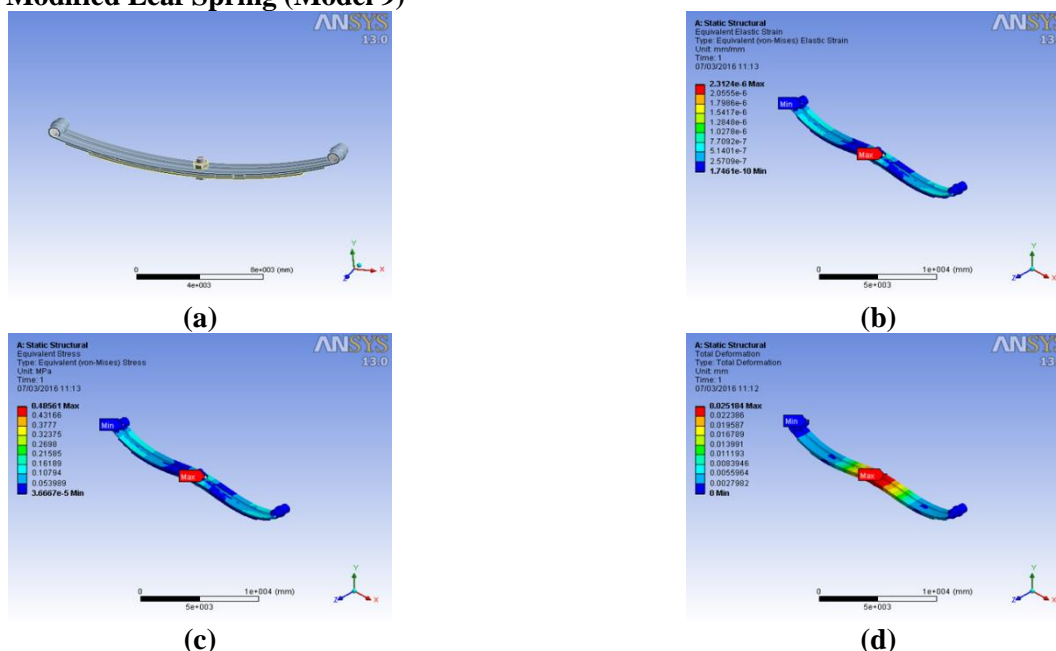


(d)

**Figure.9. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation**  
Analysis of Modified Leaf Spring (Model 8)



**Figure.10. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Analysis of Modified Leaf Spring (Model 9)**



**Figure.11. (A)-3D Model, (B)- Equivalent Strain, (C)- Equivalent Stress, (D)- Total Deformation Comparison Value of Leaf Spring Models:**

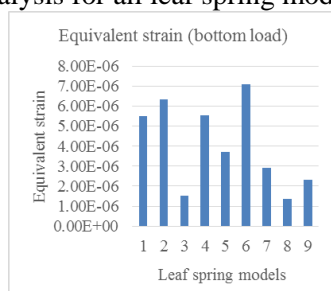


**Table.3. Comparison Value of Leaf Spring Model (Bottom load condition)**

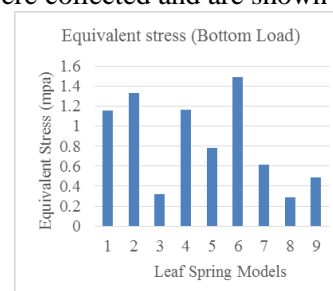
Model(Bottom load)	Total Deformation		Equivalent Stress		Equivalent Strain	
	mm		mpa			
	min	max	min	max	min	max
<b>Standard Design</b>	<b>0.0033</b>	<b>0.0301</b>	<b>7.84E-06</b>	<b>1.154</b>	<b>3.73E-11</b>	<b>5.49E-06</b>
Model 1	0.0057	0.0516	2.1E-05	1.327	1.03E-10	6.32E-06
Model 2	0.0022	0.0198	1.07E-05	0.322	5.13E-11	1.53E-06
Model 3	0.0049	0.0448	2.36E-05	1.161	1.12E-10	5.52E-06
Model 4	0.0029	0.0263	1.35E-05	0.783	6.42E-11	3.72E-06
Model 5	0.0057	0.0521	6.71E-06	1.486	3.19E-11	7.07E-06
Model 6	<b>0.0021</b>	<b>0.0191</b>	<b>1.92E-05</b>	<b>0.612</b>	<b>9.16E-11</b>	<b>2.91E-06</b>
Model 7	<b>0.0014</b>	<b>0.0128</b>	<b>1.33E-05</b>	<b>0.288</b>	<b>6.32E-11</b>	<b>1.37E-06</b>
Model 8	<b>0.0027</b>	<b>0.0251</b>	<b>3.66E-05</b>	<b>0.485</b>	<b>1.74E-11</b>	<b>2.31E-06</b>

### 3. RESULTS AND DISCUSSIONS

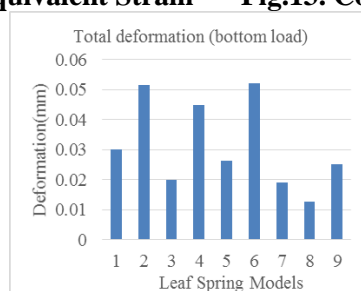
**Comparison graphs for Equivalent stress, strain and deformation:** The results of equivalent stress, strain and deformation analysis for all leaf spring models obtained from ANSYS were collected and are shown in Table 3.



**Figure.12. Comparison Graph for Equivalent Strain**



**Fig.13. Comparison Graph for Equivalent Stress**



**Figure.14. Comparison Graph for Total Deformation**

The tabulated results are plotted in the bar chart for better understanding and are shown in Figs.12, 13 and 14. From the chart, the value of equivalent stress, strain and deformation for the models 7, 8, 9 obtained are lesser than other models. Since the models 7, 8 and 9 (Fig. 9.a, Fig. 10.a, Fig. 11.a) have minimum number of bends they tend to have low stress, strain and total deformation. Also, modified model 3 of the leaf spring has been successful in case of lower equivalent strain. Thus the conventional leaf spring can be replaced by these modified successful models.

### 4. CONCLUSIONS

The 3-D modeling of nine different models of leaf spring were created and analyzed. From the above results it is clear that the equivalent stress, strain and total deformation of the modified leaf springs (model 7, 8 and 9) have been comparatively low than the conventional leaf spring model.

From the results, it is clear that the load carrying capacity of the modified model of the leaf spring is higher than the conventional leaf spring. The future scope of the project is to compare with composite leaf spring material.

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