# FINITE ELEMENT ANALYSIS OF LEAF SPRING AND REAR AXLE FOR REAR SUSPENSION

Anita Hase
P. G. Student Department of mechanical Engineering,
Savitribai Phule University/Sahyadri Valley College of Engineering & Technology Rajuri, Junnar Pune, Maharashtra-412409,India.

Dr. Sanjay Zope
Guide &Principal Sahyadri Valley College of Engineering & Technology Rajuri, Junnar Pune, Maharashtra-412409,India.

Prof. Amol Patil
Asst Prof. Sahyadri Valley College of Engineering & Technology Rajuri, Junnar Pune, Maharashtra-412409, India.

**ABSTRACT**
Leaf spring and rear axle are major parts of vehicle suspension system which is subjected to millions of varying stress cycles leading to fatigue failure. In a commercial light vehicles engine is placed at front or middle providing large space to the rear axle. Advantages of the new rear suspension design of the light commercial vehicle have been captured. In most of the vehicle Engine is placed at rear to have low engine noise and vibration inside cabin of vehicle. In This paper we are suggesting best material for leaf spring & rear axle .Oil tempered carbon steel and manganese silicon steel analyzed and found that oil tempered carbon steel is best for leaf spring of light duty vehicles. Similarly For rear axle such as Blue tempered and polished steel and forged alloy steel . According to results found in software analysis the best material for rear axle is forged alloy steel.
**KEYWORDS**— Suspension system, Finite element analysis, Leaf spring, Rear Axle Fatigue failure.

## INTRODUCTION
Traditionally, for light commercial vehicles, Engine is placed at front/middle giving huge space for traditional rear axle with differential inside .Propeller shafts are used to transfer drive from power pack to axle housing.

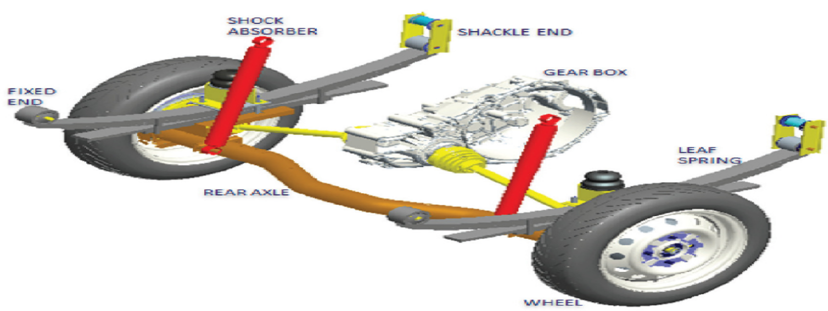



**Figure 1.Rear Suspension Concept for Rear Engine**

This project describes complete design of rear suspension with leaf spring application for rear engine vehicle as shown in Fig. 1 There is a need of high load carrying rear suspension to suit market requirement so necessary to use leaf spring type rear suspension.

## LEAF SPRING:
Springs are crucial suspension elements on vehicle, necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. A leaf spring, especially the

longitudinal type, is a reliable and persistent element in automotive suspension systems. These springs are usually Formed by stacking leafs of steel, in progressively longer lengths on top of each other, so that the spring is thick in the middle to resist bending and thin at the ends where it attaches to the body. A leaf spring should support various kinds of external forces, but the most important task is to resist the variable vertical forces. The automotive industry is exploring composite materials for structural components construction in order to obtain the reduction of weight without decrease in vehicle quality and reliability. To conserve the natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. Actually, there is almost a direct proportionality between the weight of the vehicle and its fuel consumption, particularly in city driving. The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density). Advanced composite materials seem ideally suited for suspension (leaf spring) applications. Their elastic properties can be tailored to increase the strength and reduce the stresses induced during application.

**REAR AXLE:**

The rear dead axle supports the weight of rear part of the vehicle, absorbs shocks which are transmitted due to road surface irregularities and also absorbs torque applied on it due to braking of vehicle. Rear axle was consists of wheel support plate, spring support plate and central tube as shown in Fig. 2. Once concept was finalized, cross section and thicknesses of different plates and tubes were finalized using finite element method.

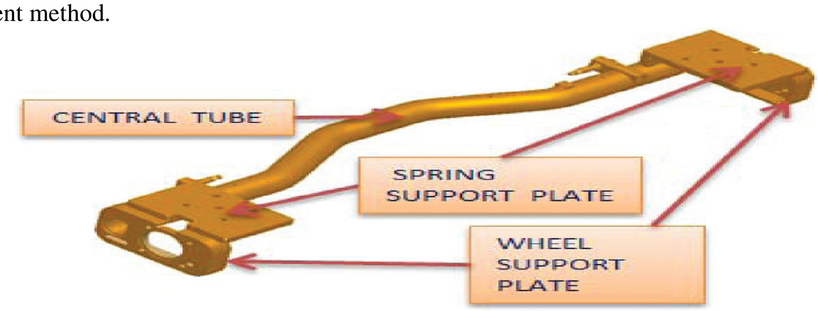



**Fig. 2 Rear Axle**

**PROBLEM STATEMENT**

A premature failure that occurred due to the higher loading capacity of the vehicle is studied. Leaf spring is major part of vehicle suspension system which is subjected to millions of varying stress cycles leading to fatigue failure. So it is necessary to obtain a spring with minimum weight that is capable of carrying given static external forces without failure.

**LITERATURE SURVEY**

Rajendran, S. Vijayaranganformulates and gives solution technique using genetic algorithms (GA) for design optimization of composite leaf springs is presented here. The suspension system in an automobile significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort, directional stability, etc. Leaf springs are commonly used in the suspension system of automobiles and are subjected to millions of varying stress cycles leading to fatigue failure. If the unsprung weight (the weight, which is not supported by the suspension system) is reduced, then the fatigue stress induced in the leaf spring is also reduced. Leaf spring contributes for about 10–20% of unsprung weight. Hence, even a small amount of weight reduction in the leaf spring will lead to improvements in passenger comfort as well as reduction in vehicle cost. In this context, the replacement of steel by composite material along with an optimum design will be a good contribution in the process of weight reduction of leaf springs. Different methods are in use for design optimization, most of which use mathematical programming techniques. This paper presents an artificial genetics approach for the design optimization of composite leaf spring. On applying the GA, the optimum dimensions of a composite leaf spring have been obtained, which contributes towards achieving the minimum weight with adequate strength and stiffness. A reduction of 75.6% weight is achieved when a seven-leaf steel spring is replaced with a mono-leaf composite spring under identical conditions of design parameters and optimization.[1]

**Table1. Specification of Existing Leaf Spring**

| Specifications | | |
|---|---|---|
| 1 | Total Length of the spring (Eye to Eye) | 1540mm |
| 2 | Free Camber (At no load condition) | 136mm |
| 3 | No. of full length leave (Master Leaf) | 01 |
| 4 | Thickness of leaf | 13mm |
| 5 | Width of leaf spring | 70mm |
| 6 | Maximum Load given on spring | 3850N |
| 7 | Weight of the leaf spring | 23kg |

Ramu I et al published Different methods for performing static and dynamic analysis of plate like structures. The finite element method (FEM) is widely used and powerful numerical approximate method. The finite element method involves modeling the structure using small inter connected elements called finite elements. The finite element method of structural analysis enables the designer to found stress, vibration and thermal effects during the design process and to evaluate design changes before the construction of a possible prototype. Thus assurance in the acceptability of the prototype is improved.[5]
Mahmood M Shokrieh Davood Rezaeistudied optimization of leaf spring. A four-leaf steel spring used in the rear suspension system of light vehicles is analyzed using ANSYS V5.4 software. The finite element results showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiber glass with epoxy resin is designed and optimized using ANSYS. He concluded from the results obtained that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. Compared to the steel spring, the optimized composite spring has stresses that are much lower, the natural frequency is higher and the spring weight without eye units is nearly 80% lower.[6]

**FINITE ELEMENT ANALYSIS**

Finite Element Method is a mathematical modeling tool involving discretization of a continuous domain using building-block entities called finite elements connected to each other by nodes for once and moment transfer. FEA analysis is done with the help of ABAQUS. Procedure for analysis is understood with help of following flow chart.

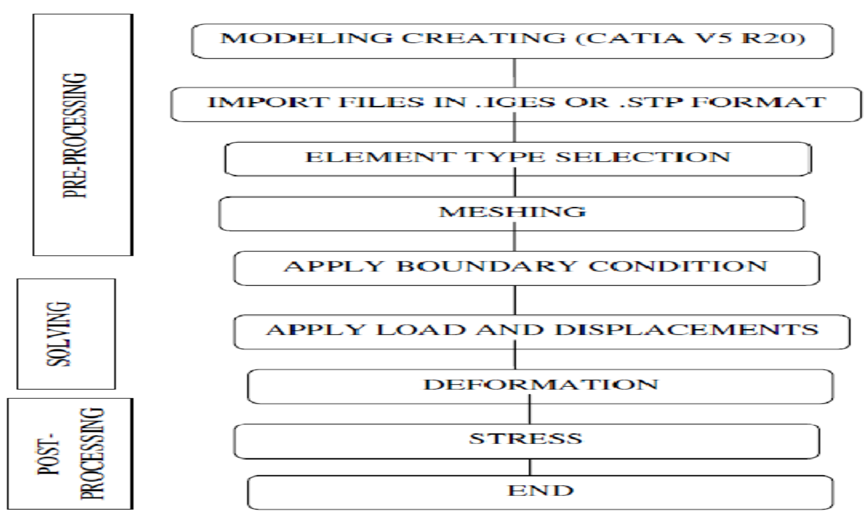
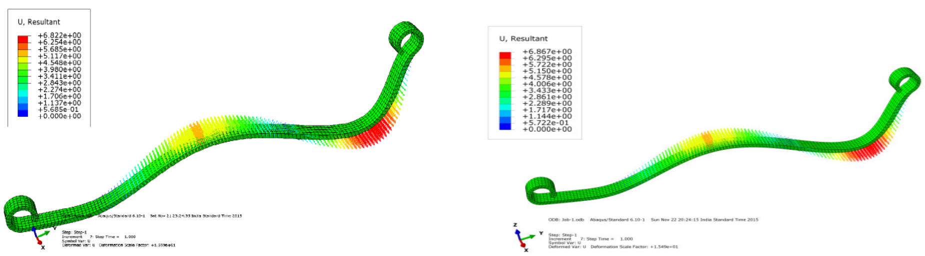



Fig.3 Flowchart F or FEA Analysis

**LEAF SPRING:**

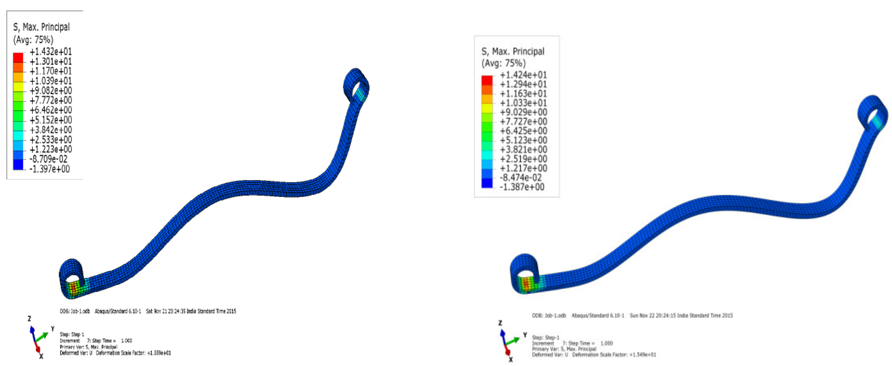
**Table2. Material Properties of material used for analysis**

| Sr No | Properties | Value | |
|---|---|---|---|
| | | Oil tempered carbon steel | manganese silicon steel |
| 1 | Density(Kg/m$^3$) | 7862.67 | 7860 |
| 2 | Tensile strength(MPa) | 2234 | 1758 |
| 3 | Modulus of elasticity(GPa) | 200 | 190-210 |
| 4 | Thermal Conductivity( W/mK) | 52.0 | 41.9 |
| 5 | Poisons Ratio | 0.29 | 0.27-0.30 |
| 6 | Rockwell Hardness | C42-55 | C48-51 |



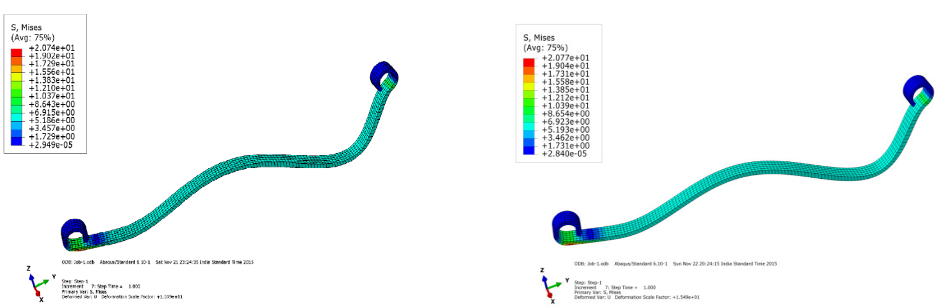

**Oil tempered carbon Steel Manganese silicon spring steel**

**Fig 4. Total Deformation of leaf spring**




**Oil tempered carbon Steel Manganese silicon spring steel**

**Fig 5. Maximum principal stresses of leaf spring**




**Oil tempered carbon Steel Manganese silicon spring steel**

**Fig 6. Von Misses stresses of leaf spring**

**Table3. Abaqus Result comparison for leaf spring**

| Material | Max Deformation (e-2) | Mass(Kg) | Max. Principal stress(e+1) | Von misses stress (e+1) | Max. Principle Strain (e-5) |
|---|---|---|---|---|---|
| Oil Tempered carbon steel | 6.822 | 23 | 1.432 | 2.07 | 5.017 |
| Manganese Silicon Spring Steel | 6.867 | 23 | 1.424 | 2.08 | 5.107 |

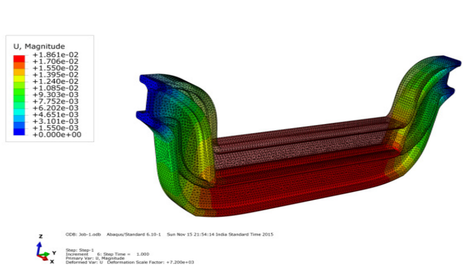
**REAR AXLE**:

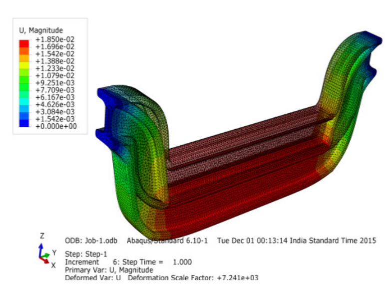
**Table 4.Specification of Existing Rear Axle**

| Specifications | | |
|---|---|---|
| 1 | Outer Diameter (mm) | 63 |
| 2 | Inner Diameter (mm) | 53 |
| 3 | Thickness (mm) | 05 |
| 4 | Load (N) | 23000 |
| 5 | Rear axle weight (Kg) | 4600 |

**Table 5.Material Properties**

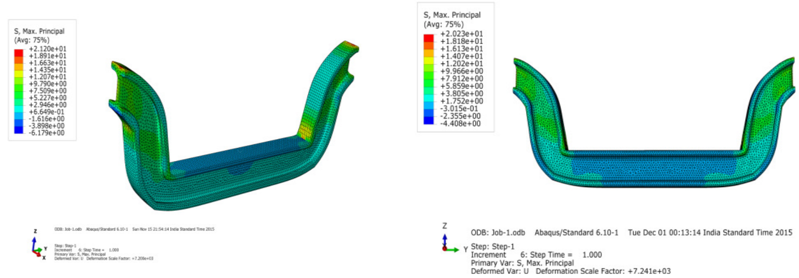
| Sr No | Properties | Value | |
|---|---|---|---|
| | | Forged Alloy Steel | Blue tempered & polished steel |
| 1 | Tensile Strength(MPa) | 745 | 139 |
| 2 | Yield Strength(MPa) | 470 | 84 |
| 3 | Rockwell Hardness | C95 | C31-55 |
| 4 | Thermal conductivity(W/mK) | 44.5 | 350 |
| 5 | Coefficient of thermal Expansion(um/m) | 12.3 | 6.7 |
| 6 | Shear Modulus (GPa) | 80 | 110 |
| 7 | Density (Kg/m$^3$) | 7834 | 7862 |





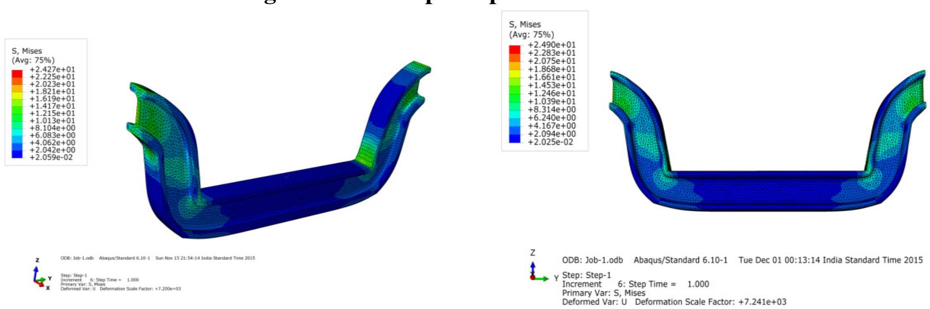
**Blue Tempered and polished steel** **Forged alloy steel**

**Fig 7. Total Deformation for Rear axle**



**Blue Tempered and polished steel Forged alloy steel**

**Fig 8. Maximum principal stresses for Rear axle**



**Blue Tempered and polished steel Forged alloy steel**

**Fig 9. Von Misses stresses for Rear axle**

**Table 6. Abaqus Result Comparison for Rear Axle**

| Material | Max Deformation (e-2) | Mass(Kg) | Max. Principal stress(e+1) | Von misses stress (e+1) | Max. Principle Strain (e-5) |
|---|---|---|---|---|---|
| Forged Alloy Steel | 1.85 | 4600 | 2.023 | 2.427 | 8.779 |
| Blue tempered & polished steel | 1.861 | 4600 | 2.12 | 2.427 | 8.779 |

## CONCLUSION

The study demonstrated that Oil Tempered carbon steel can be used for leaf springs and Forged Alloy Steel for light weight vehicles and meets the requirements, together with substantial weight savings. The 3-D modeling of leaf spring and rear axle is done and analyzed using Abaqus According to software analysis oil tempered carbon steel is best material for leaf spring For light duty vehicles. As it having less maximum deformation, von misses stress and maximum principle strain as compared to Manganese Silicon Spring Steel. Similarly for rear axle forged alloy steel is best as compared with Blue tempered & polished steel. A comparative study has been made for leaf spring and rear axle material with respect to weight, cost and strength.

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