Numerical Simulation of an Automotive Multi-Leaf Spring Hybrid Stack up Design using ANSYS ACP

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***Abstract*— Automotive industry has altering the material of the Leaf Spring from steel to glass fiber composite because of the strength to weight ratio is much higher than steel. Hybrid composites joint the advantage of both steel and composites having high strength and fatigue properties. When compared to glass fiber composite, Hybrid composites have more Moisture resistant and high fatigue strength. In this work we studied the behavior of a Hybrid stack-up design of a Multi-Leaf Spring, in which the Leaf Spring plates are designed using steel and GFRP Layup together to form the Hybrid composite structure. And the load bearing capacity and stress distribution on the Leaf Spring are numerically simulated using ANSYS 16.2 software. 3D model of the leaf spring is done using catia V5. Composite pre-processing and post-processing are done using ANSYS ACP module. Finally the comparison between Fully Steel and Hybrid Multi-Leaf Spring with the aid of CAE simulated results from ANSYS 16.2 software. From the final results we found Hybrid composite leaf spring we can reduce the weight by 48.5 % on the same design.**

Index terms - Hybrid composites, Multi-Leaf Spring, ANSYS ACP, CAE simulation, Weight reduction

I. INTRODUCTION

In every automobile, i.e. four wheelers and trucks leaf spring is one of the main components and it provides a good suspension and it plays a vital role in automobile application. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. [1]

Ever increasing demands of high performance together with long life and light weight necessitate consistent development of almost every part of automobile. Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. [2]

The suspension leaf spring is one of the potential items for weight reduction in automobiles un-sprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings. [3]

A composite material is the combination of two or more materials that produce a synergistic effect so that the combination produces aggregate properties that are different from any of those of its constituents attain independently. This is intentionally being done today to get different design, manufacturing as well as service advantages of products. [5]

Hybrid structures enable the utilization of the most advantageous material properties of different material grades and incorporation of them into one structure. A typical desired material property combination of hybrid structures is low weight combined with good mechanical properties. The number of beneficial property combinations is numerous, since the constituent materials of a hybrid structure may have substantially different material properties. [6]

Fiber - metal laminates (FMLs) is a type of hybrid material which consists of alternating layers of thin metallic sheets bonded together with fiber reinforced layers. During the last decades the application of FMLs in various structures has become increasingly popular, especially in aerospace structures, for its improved fatigue and impact properties. [7]

By reviewing the above References [1 to 7], we came to know that composite materials are replacement of the conventional steel. But monolithic composite have some disadvantages also. Advantages of hybrid composites are follows:

- Better wear resistance
- Low thermal expansion coefficient
- Combination of high tensile strength and high failure strain
- Better impact and flexural properties
- Low notch sensitivity

To overcome the disadvantages monolithic composites we used the Hybrid Steel and GFRP for better strength and fatigue properties.

II. Problem Description

The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the un-sprung weight. [8]
The conventional steel leaf spring has some problems which are listed as follow: [5]

- Due to continuous running of the mini loader vehicle there is a decrease in the level of comfort provided by the spring.
- It is observed that the leaf springs tend to break and weaken at the eye end portion which is very close to the shackle and at the centre.
- The conventional steel leaf spring has higher weight, which also affect the fuel efficiency.

The combination of fiber and metal is also used to overcome the characteristics like corrosion, bearing strength, impact resistance and the repair ability of the composite materials. Hence the material has the property and characteristics of both the metal and composite. [9]

The Metal sheets and fibers are bonded together generally using adhesives like epoxy resin; the adhesion between the metal and fiber determine the mechanical properties of the composite materials. Epoxies are used to reduce the rate of fatigue crack growth and also reduce the growth of cracks in the fractured sheets by acting as a crack barrier. [9]

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III. Design and Modeling

Multi-leaf spring design is shown in the figure 1. The parameters required for the leaf spring design are:

- Diameter of eye "d" - mounting point diameter.
- Total Span "2L" - center to center distance of the two eye diameter.
- Camber of the Leaf spring "Y" - vertical distance measured between the eye centers to primary leaf center point.
- Thickness "t" - thickness of the single leaf spring plate.

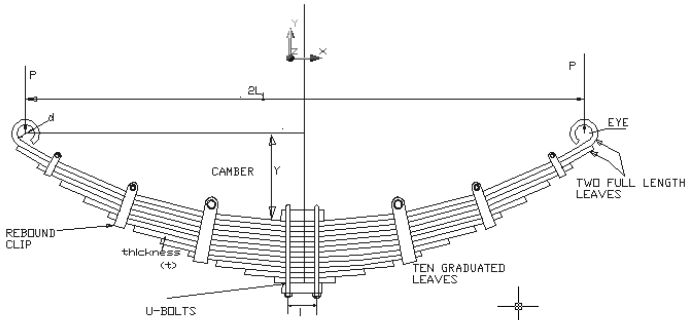

Figure 1 - Multi Leaf Spring Schematic view [12]

A. Design Parameters

The design parameters are chosen to suit for the LCV Multi Leaf Spring for the commonly acceptable range of values is shown in Table 1.

Number of Leafs	9
Total Span	1000 mm
Diameter of Eye	24 mm
Camber	150 mm
Width of the leafs	50 mm
Thickness of a leaf	5 mm

Table 1 - Design Parameters

B. Solid Modeling

The solid model of the Leaf spring with the chosen design parameter is shown in the fig 3.2. 3D modeling is done using software called CATIA V5.

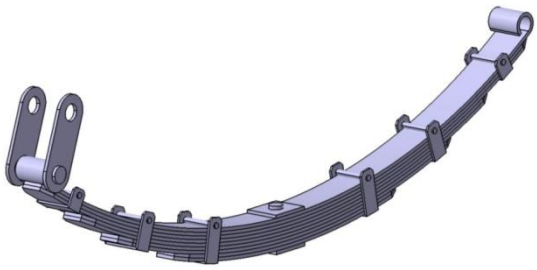

Figure 2 - 3D CAD Model of Multi Leaf Spring

IV. FEA Analysis

FEA is a computer based mathematically idealized real system, which breaks geometry into element. It links a series of equation to each element and solves simultaneously to evaluate the behavior of the entire system. This tool is very useful for problem with complicated geometry, material properties and loading where exact and accurate analytical solution is difficult to obtain. [10]

A. Assumptions for Analysis

- Automobile is assumed to be stationary.
- There are 4 Semi-elliptic leaf spring, two at front and two at rear axle.
- Static analysis is carried out for a single multi leaf spring with the safety factor of 2.
- Leaf spring Eye is fixed and load is applied on Bottom wheel mount.

B. Material Data

For monolithic 5 mm thick leaf sprig, the material used is 65Si7. Mechanical properties of 65Si7 are listed in table 2.

Parameters	Value
Density, **ρ**	7.86×10^{-6} Kg/mm^3
Young's Modulus, E	2.1×10^{5} MPa
Poisson's Ratio, **γ**	0.266
Tensile Strength Ultimate	1272 MPa
Tensile Yield Strength	1158 MPa

Table 2 - Mechanical properties of 65Si7

For Hybrid composite structure, 65Si7 metal and e-glass/epoxy UD is used. The adhesive material is epoxy resin. Mechanical properties of e-glass/epoxy UD laminate are listed in table 3.

Parameters	Value
Density, **ρ**	2×10^{-6} Kg/mm^3
Young's Modulus, E_1	0.45×10^{5} MPa
Young's Modulus, $E_{2,3}$	0.1×10^{5} MPa
Poisson's Ratio, γ_{yz}	0.4
Poisson's Ratio, $\gamma_{xy,xz}$	0.4
Tensile Strength Ultimate	1100 MPa
Compressive Strength Ultimate	675 MPa

Table 3 - Mechanical properties of e-glass/epoxy UD

C. Laminate Data

Hybrid laminate is stack up of 0.18 mm e-glass/epoxy layer with fiber direction along the length of the Leaf spring and 0.28 mm 65Si7 sheet. The stack up sequence is shown in the figure 3.

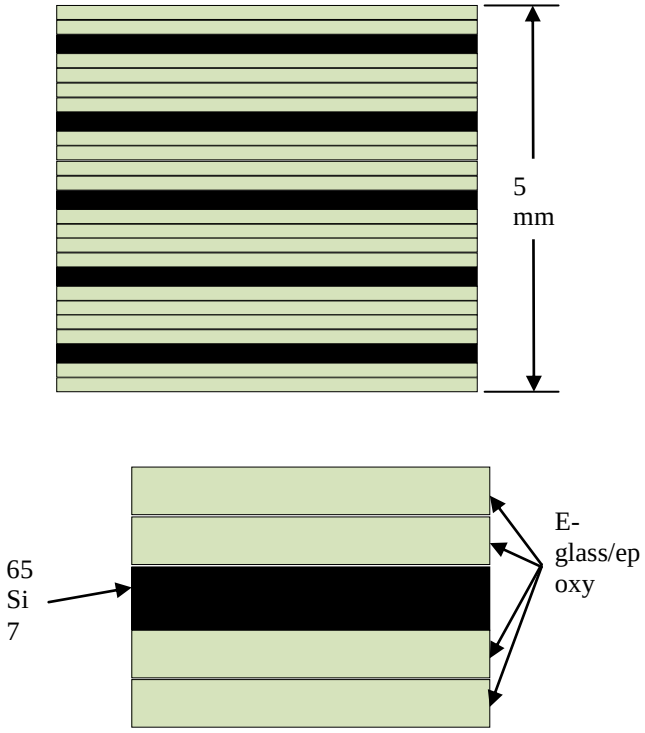

Figure 3 - 3D CAD The stack up sequence

This laminate having 1 mm thickness, sequence is repeated for 5 times to get the 5 mm thickness Leaf spring.

D. Load Data

A four wheeler light commercial vehicles are categorized under the grass weight ratting of 4500 kg. [11] We can take the vehicle under 3000 kg range leaf spring

Total Weight = 3000 kg

Acceleration due to gravity (g) = 9.81 m/s^2

Therefore; Total Weight Force = 3000*9.81 = 29430 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one 4th of the total weight.

Implies: 29430/4, F = 7358 N.

Therefore load acting on the Wheel mount is approximately equal to 7400 N

By taking the safety factor 2, Load acting on Wheel mount = 15000 N

V. STATIC STRUCTURAL ANALYSIS

Static structural analysis boundary conditions are shown in the fig 5.1. Load acting on the leaf spring is applied as force.

The same mesh and load setups are used for both steel and hybrid composite leaf spring model. Laminate pre-processing for the composite material is done using Ansys ACP module. Boundary conditions for static structural analysis are Right side eye is free to rotate and left side joint given 15 deg of

rotation and the load is applied on the bottom used for the above result images.

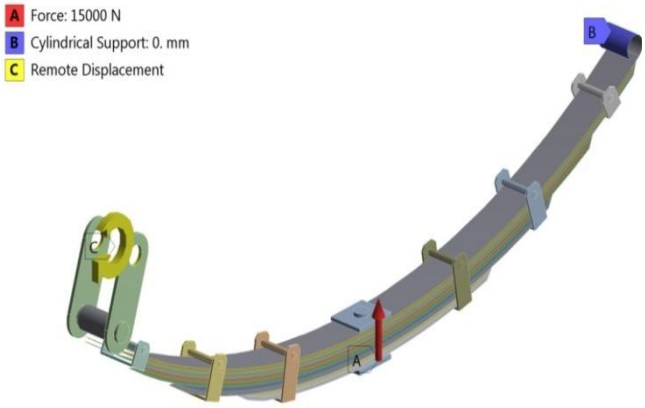

Figure 4 - Leaf Spring with Boundary Conditions

Results obtained from the Ansys Structural analysis are shown in the figure 5, 6, 7 and 8.

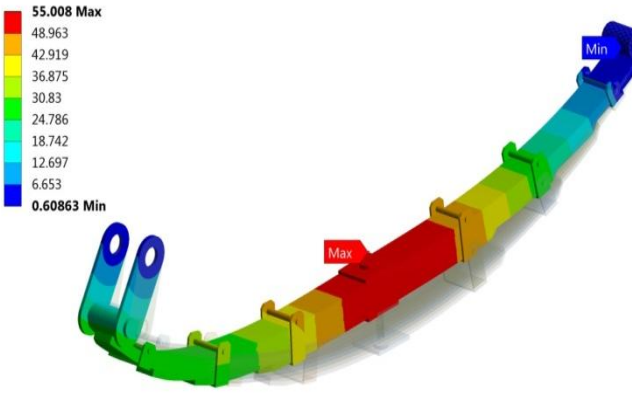

Figure 5 - Total Deformation of Steel Leaf spring in mm

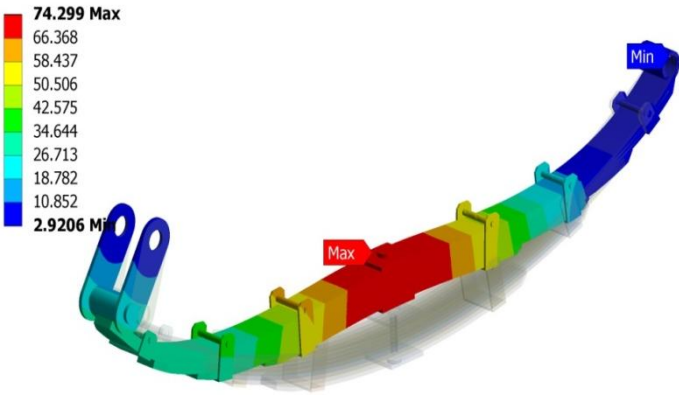

Figure 6 - Total Deformation of Hybrid Composite Leaf Spring in mm

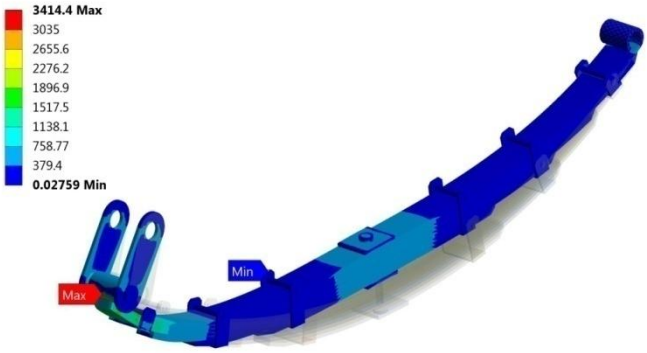

Figure 7 - Equivalent Stress of Steel Leaf Spring in MPa

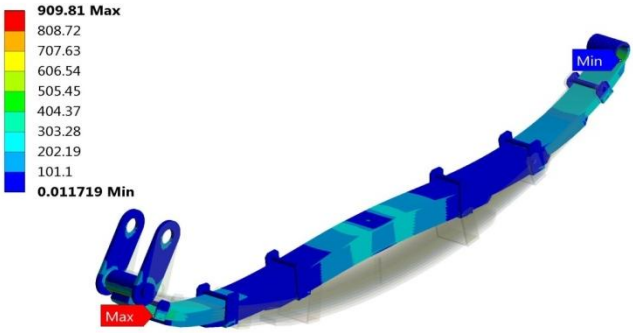

Figure 8 - Equivalent Stress of Hybrid Composite Leaf Spring in MPa

B. Results

Design and Analysis of both steel and hybrid composite leaf springs are done and the results are listed in Table 4.

Parameter	Steel leaf spring	Hybrid Composite Leaf Spring
Weight , kg	16.3	8.4
Load, N	15000	15000
Equivalent Stress, MPa	3414	1056
Total Deflection, mm	55	74.2

Table 4 - Results

VI. CONCLUSION

From the above results when we replace the conventional steel leaf spring with the conceptual Hybrid composite leaf spring we can reduce the weight by 48.5 % on the same design. And comparatively the strength and fatigue life of the

structure is higher than the monolithic FRP. This thesis can be extended for the dynamic loading and fatigue behavior of the Hybrid multi-Leaf Spring Design in the near future.

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