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Research Article

Computational Stress Analysis of a Composite Multi Leaf Spring

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Abstract

Today most of the industries are focusing on reducing the weight of the product while improving or keeping the same strength by using alternative design techniques to fulfill many advantageous aspects from the products. Automobile sector is one of the largest sectors in the globe and always trying to reduce the weight of the vehicles. Composite materials are the one of the families which is attracting as solutions to this issue. Among the many components of a vehicle leaf spring is selected for this research work. Leaf springs are crucial suspension elements in automobile, necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities. The main objective of this work is the computational analysis of a composite multi leaf spring for a light motor vehicle and its comparison with conventional steel spring. A new spring is designed and analyzed in this work showed 43.99 % weight reduction as compared to conventional spring in addition to reduction in stresses.

Keywords: *Composite material, glass fiber, leaf spring*

1. Introduction

In the year 1804, Obadiah Elliot used leaf spring first time. Initially use of the leaf spring was restricted to horse drawn chariot, afterwards they used them on railway rolling stock. Initial motor design community used leaf springs as it was easy to vary leaves and also the resilience of the desired degree can be achieved by changing the cross section of the leaf. For saving natural resources like petrol, diesel etc. and to manufacture energy efficient machines automobile industry today is focused on weight reduction. There are multiple ways of reducing component's weight. Some of them can be listed as replacement of material with better one, design optimization and introducing better quality manufacturing processes. As it is observed that conventional steel leaf spring fails abruptly due to fatigue loading, among the various components of vehicle leaf spring is considered for this research work.

Mostly leaf spring has dual purpose, firstly it acts as a load supporting member and secondly as an axel control member. One end of the spring is bolted to the frame; other end is attached to axle through attachment which is considered as free end of the spring. Almost all the good's carrier vehicles and few passenger vehicles have leaf springs as shown in Figure 1, either in front or rear suspension systems so that heavy loads can be supported and riding comfort can be improved.

Leaf springs are inserted between the wheels and the body in order to partially isolate the body from the axle. This allows the axel to move autonomously relative to the body. While vehicle is travelling on rough road, wheels move upward when travelling over a bump and leaf spring is deflected. The deflection of the spring stores the potential energy in the spring momentarily; which converts in to kinetic energy when released and causes oscillatory motion of the vehicle chassis and body. After few oscillations vehicle comes back to the equilibrium.

Fig.1 Truck equipped with leaf spring

It is well known that leaves are designed to absorb shocks, store energy and then release the stored energy. Hence, strain energy of material is an important parameter while designing leaf spring.

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Leaf springs are general classified in to three types,

1) Multiple leaf spring
2) Mono Leaf spring
3) Parabolic Single leaf spring

To meet the weight reduction objective as stated in above paragraph the composite materials is the substantial option because of its significant elastic strain energy storage capacity and high strength to weight ratio as compared to steel. Automobile industry has already using many vehicle components manufactured from composites like bumper, roofs of vehicle where significant weight reduction is achieved. The suspension leaf spring is one of the product in which weight reduction is possible. As it accounts 10%-20% of the unsprung weight. Some researchers have shown that weight of composite leaf spring is considerably reduced without any reduction in load carrying capacity. Patunkar, et al, studied a comparative analysis between steel leaf spring and a composite leaf spring is done under the same static load condition. Deflection and stresses of steel leaf spring and composite leaf spring are to be analyzed. Katke, et. al. 2016 have carried out the finite element analysis of mono leaf spring for the light motor vehicle. Only few researchers are working on the use of composite materials for suspension leaf spring and a lot of research is required on the composite springs. Hence, this work is related to comparative assessment of steel and composite leaf spring to be used for light motor vehicle.

2. Design of Leaf Spring

2.1 Composite Material

Composite materials are defined as the materials that compose two or more constituents which are combined on a macroscopic scale by means of mechanical and chemical bonds. The common/typical composite materials are made up of inclusions which are suspended into a matrix. The constituents of the material retain their identities into the composite material. Generally the components are physically identified and also there is an interface between them.
Most of the composite materials provide a combination of strength and modulus of elasticity which is either comparable with or better than any conventional metallic materials. As the specific gravity of composite materials is low, the ratio of strength to weight and ratio of modulus to weight of the composite materials are highly superior when compared to those of metallic materials.

Composite materials are considered to be superior to all the other known structure materials, specifically in stiffness and strength, strength at high temperatures, fatigue strength and other mechanical properties. The combination of the desired mechanical properties can be determined and tailored in advance and realized practically in the manufacture of that particular composite material. Furthermore, the composite material can be shaped through this process closely to the form of the final product or even the structural unit.
The first major use of composite material in the structural application is the corvette rear leaf spring in Commercial vehicles. Also structural chassis components of composite materials are being successfully tested and checked in the laboratories and they are currently being developed for future cars and vans, such as drive shafts/ propeller shaft and road wheels.

2.2 Properties of Material

Table 1 shows the properties of steel and glass fiber used for finite element analysis,

Table 2 Properties of Material

Sr. No	Properties of Material	Steel	Glass Fiber
1	Tensile Modulus along X-direction (MPa)	200000	34000
2	Tensile Modulus along Y-direction (MPa)	200000	6530
3	Tensile Modulus along Z-direction (MPa)	200000	6530
4	Compressive Strength of material (MPa)	1306	450
5	Poisson's ratio	0.3	0.217
6	Mass Density of the material (g/cm^3)	7.8	2.66

2.3 Design Specifications of leaf springs

In this research work leaf springs are designed and analyzed for the light commercial vehicle having gross vehicle weight of 2250 kg. The design specifications of the developed model are as follows:

Table 2 Specifications of Leaf Springs

Sr. No.	Parameters	Steel leaf spring	Glass Fiber leaf spring
1	Total length of spring (mm)	1045	800
2	Number of full length leaf	01	02
3	Thickness of leaf (mm)	05	10.3
4	Width of leaf spring (mm)	60	60
5	Maximum load on spring (N)	5625	5625
6	Weight (kg)	7.07	3.96

3. Finite Element Analysis of Leaf Spring

The three dimensional model of the leaf springs was generated using CATIA V5. Finite element analysis is carried for both the multi leaf springs using ANSYS 16. As multiple leaves are to be used for the purpose of contacts generation solid shell element is used for meshing. Hence, the bending forces are accounted for and both the surfaces for the contacts are dealt with.

The boundary conditions used in analysis are given in Table 3.

Table 3 Boundary Conditions

Sr. No.	Along Axis	Translational Motion	
		Free	Fixed
1.	X- axis	At one eye end	At one eye end
2.	Y- axis	--	At Both eye ends
3.	Z- axis	--	At Both eye ends

3.1 Analysis of steel leaf spring

Figure 2 shows the loading for steel leaf spring. The load applied is 5625 N.

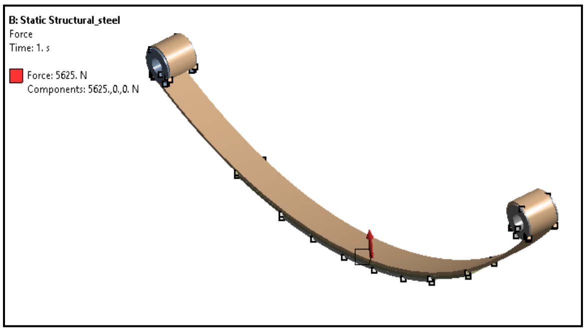

Fig. 2 Loading for steel multi leaf spring

Figure 3 below shows the meshed model for the assembly. Standard element size of 1 mm is used for the good results in the analysis.

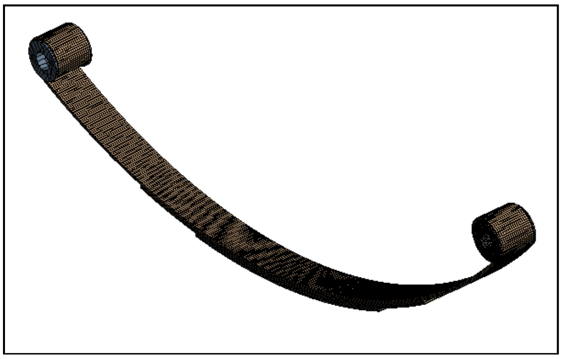

Fig. 3 Meshed model of steel multi leaf spring

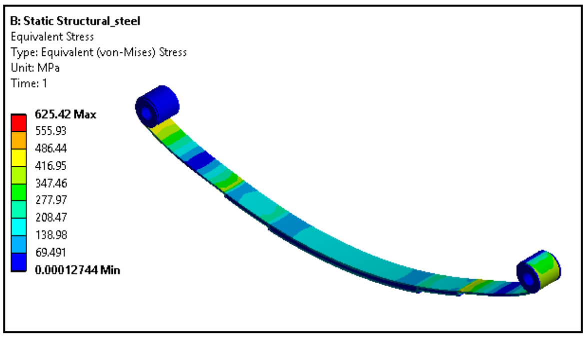

Fig. 4 Von Mises Stress plot for steel leaf spring

The meshed model is analyzed for results and the Figure 4 shows the stress plot for the steel leaf spring. From the figure, it is observed that the maximum stress experienced by the leaf spring is 625.41 N.

The deformation plot is shown in the Fig. 5. The maximum deformation underwent by the steel leaf spring is 112 mm.

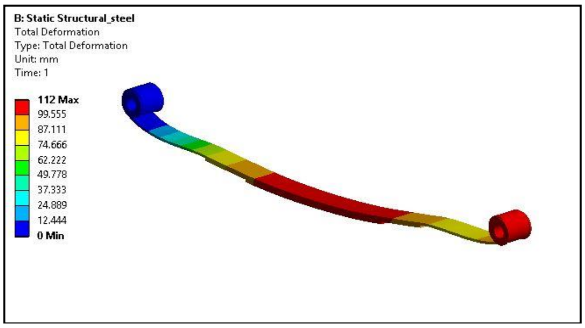

Fig. 5 Deformation plot for steel leaf spring

1.2 Analysis of Glass Fiber leaf spring

Figure 6 shows the loading conditions of the glass fiber leaf spring. The maximum load applied to the leaf spring is 5625N.

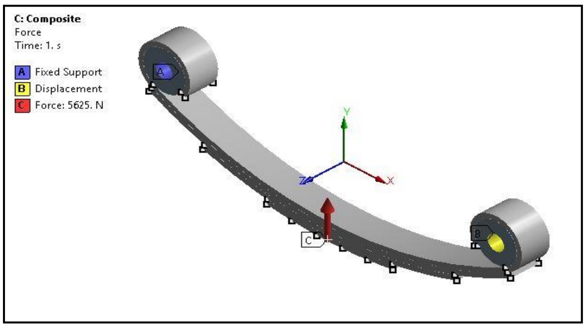

Fig. 6 Loading for Glass Fiber Leaf Spring

Figure 7 shows the meshed model for the composite leaf spring. Standard element size of 1 mm is used for the good results in the analysis.

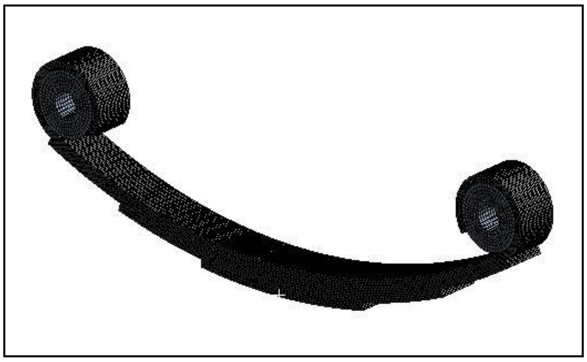

Fig. 7 Meshed model of glass fiber leaf spring

The meshed model of glass fiber leaf spring is analyzed for results and the Figure 8 shows the stress plot for the leaf spring. It is observed that the maximum stress experienced by the glass fiber leaf spring is 264.14 N.

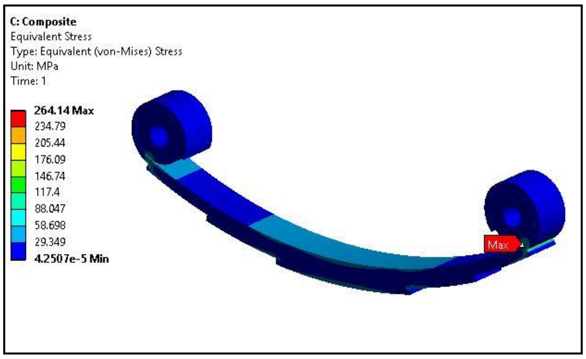

Fig. 8 Von Mises Stess Plot for Glass Fiber Leaf Spring

The deformation plot for glass fiber leaf spring is shown in the Fig. 9. The maximum deformation underwent by the steel leaf spring is 103.79 mm.

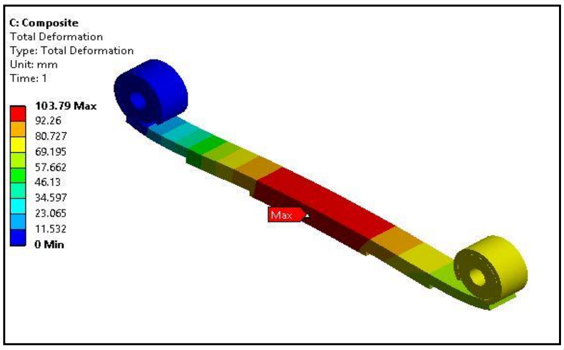

Fig. 9 Total deformation of Glass Fiber leaf spring

2. Results and Discussion

Results from the analytical calculations and FEA analysis are summarized and discussed in this section. Table 4 compares the results from analytical solution and FEA.

Table 4 Comparison of Analytical and FEA Results

Leaf Spring	Steel Leaf Spring		GFRP Leaf Spring	
Variable	Analytical	FEA	Analytical	FEA
Maximum von Mises Stress (MPa)	653	625.4	265	264.1
Total Deformation in Vertical Direction (mm)	118	112	110	103.7

The weight of the multi leaf spring using steel shows stresses up to 625.41 MPa while Glass Fiber leaf spring shows maximum stress of 264.14 MPa. Deformation in steel leaf spring is observed as 112 mm and 103.7 mm respectively. Weight of the leaf spring with GFRP material is observed as 3.96 kg whereas steel leaf spring weighed 7.07 kg.

Conclusion

All the stress and deformation values are within required limits for both conventional and composite leaf spring design. Results of analytical calculations and finite element analysis are in conformance with each other with the maximum error of 6 % for both composite as well as steel leaf spring Total of 43.99 % weight reduction can be achieved by using glass fiber as replacement material for steel leaf spring for multi leaf spring considered. Stresses observed in the composite leaf spring are much lesser than that of stresses observed in the steel multi leaf spring. Deformation of the steel leaf spring is slightly higher than its composite counterpart.

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