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Simulation of Steel and Composite Leaf Spring by Varying Thickness

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Abstract: *Finite Element analysis tools offer the tremendous advantage of enabling design teams to consider virtually any molding option without incurring the expense associated with manufacturing and machine time. The Ability to try new designs or concepts on the computer gives the opportunity to eliminate problems before beginning production. Additionally, designers can quickly and easily determine the sensitivity of specific molding Parameters on the quality and production of the final part. The leaf spring model is created by modeling software like pro-E , Catia and it is imported in to the analysis software and the loading, boundary conditions are given to the imported model and result are evaluated by post processor. The different comparative results of steel leaf spring and composite leaf spring are obtained to predict the advantages of composite leaf spring for a vehicle. The model of composite leaf spring is prepared and analyzed using ANSYS14.5 for the deflection and stresses under defined loading condition. The experimental and FEA result compared for validation. The dimension of conventional leaf spring is taken with varying load and thickness for evaluation of result and Static analysis is performed.*
KeyWords: *E-glass/epoxy composite, ANSYS14.5, Static Analysis.*

I. Introduction

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. It carries lateral loads, brake torque, driving torque in addition to shock absorbing [1]. 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 [2]. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring [3].

To meet the need of natural resources conservation, automobile manufacturers are attempting to reduce the weight of vehicles in recent years [4]. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness [5].

For weight reduction in automobiles as it leads to the reduction of un-sprung weight of automobile. The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% 0f the un-sprung weight [6]. The composite materials made it possible to reduce the weight of machine element without any reduction of the load carrying capacity. Because of composite material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel [7],[8]. FRP springs also have excellent fatigue resistance and durability. But the weight reduction of the leaf spring is achieved not only by material replacement but also by design optimization. The model of composite leaf spring is prepared and analyzed using ANSYS14.5 for the deflection and stresses under defined loading condition. The experimental and FEA result compared for validation. The dimension of conventional leaf spring is taken with varying load and thickness for evaluation of result and Static analysis is performed.

II. Material Properties And Design Specification

Glass fiber reinforced plastics is a composite material in which the volume fraction of fiber is 70% considering rule of mixture [9]. The low density and high specific strain of composites provides high specific strain energy capacity [10].

Table-1 :Properties Of Composite Leaf Spring.

Parameter	**Value**
Longitudinal Elastic Modulus, E_1	60.52 Gpa
Transverse elastic modulus, E_2	10.37 Gpa
Major poission's Ratio, V_{12}	0.230
Minor poission's Ratio , V_{21}	0.0390
In plane shear Modulus, G_{12}	4.014 Gpa
Density	2110 Kg/m^3

The glass fiber are earliest know fiber used in reinforcement. The main advantage of glass fiber reinforced composite is low cost, high strength, high chemical resistance and good insulating properties however the main disadvantage of glass fiber in composite is low elastic modulus poor adhesion polymer[11].

A .Selection of Fiber

Fig. 1- Fabricated composite Leaf Spring

Table 2: Properties of Fiber.

Sr.No.	Type of Fiber	Properties
1	Glass Fiber	-
a)	E-glass	High Stiffness, high buckling, weak in shear, low cost.
b)	S-glass	High Stiffness, high buckling, weak in shear, high cost.
2	Carbon fiber	High strength, high modulus, low density, high temperature resistance, considerably high cost.
3	Ceramic	High temperature resistance, low thermal conductivity.

From the above table we are choosing the E-glass fiber and resin epoxy choosing for fabrication of composite leaf spring

III. Result and Discussion

A. Experimental & Analytical Results

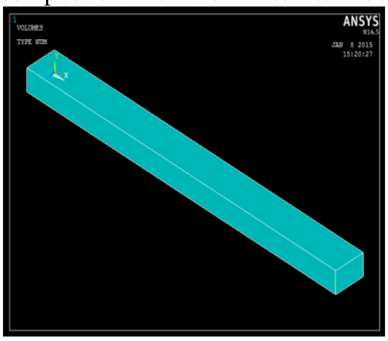
Experimental analysis of the leaf spring is done on Universal Testing Machine [12]. Glass fiber composite leaf spring is tested on the same. Load is applied at the center of the spring. The load is applied in a gradual intervals of 50kg. The table 3 shows experimental and analytical results at a load of 300kg.

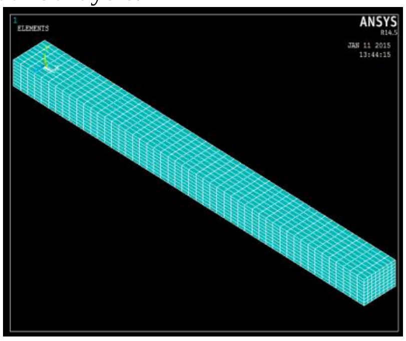
Table -3: Experimental & Analytical Results At -Load 300kg For Stress And Deflection Of GFRC

Thickness mm	Analytical result		Experimental result	
	Deflection mm	Stresses N/mm^2	Deflection mm	Stresses N/mm^2
30	128.97	252.75	92	252.10
32	104.85	220.18	75	220.15
34	86.40	193.51	61	193.30

B. 3D-Finite Element Analysis (FEA)

For 3D finite element analysis of present work is done in Ansys 14.5 using a 3D element suitable for composite analysis known as "SOLID 186" and is an 20-noded element useful for structural analysis of composite which facilitates near about 250 layers.





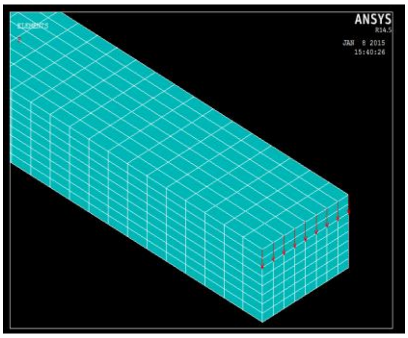
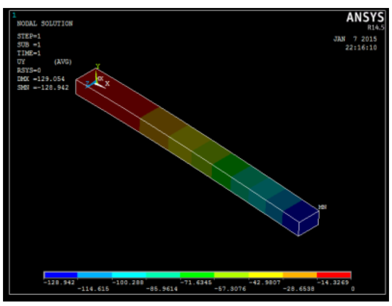
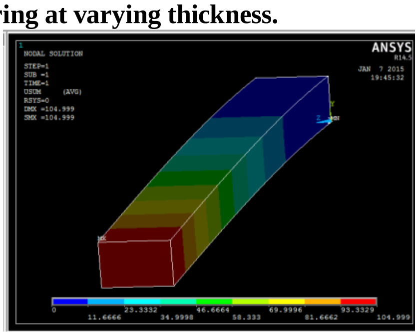


Fig-2: 3-D Model of leaf spring **Fig-3: Meshed model of leaf spring** **Fig-4: Fixed support with load**

For the leaf spring is consider as cantilever beam with one end fixed and at other end load applied shown in fig4.

C. Deflection for composite leaf spring at varying thickness.





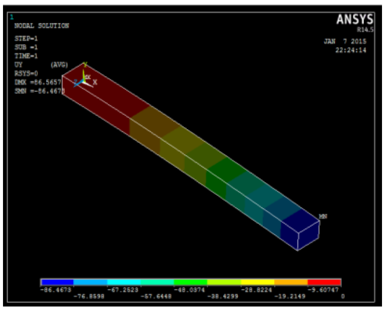


Fig-5: Deflection of Composite leaf leaf spring at thickness 30mm **Fig-6: Deflection of Composite leaf spring at thickness 32mm** **Fig-7: Deflection of Composite spring at thickness 34mm**

Fig-5,6,7 shows the deflection result of composite leaf is less as compared to conventional leaf spring.

Table-4: Fea Results At Load 300kg Deflection Of Composite Leaf Spring At Thickness 30mm, 32mm And 34mm.

Thickness mm	Deflection mm	
	Steel	Composite
30	152.52	129.054
32	119.49	104.999
34	96.33	86.565

D. Stress for Composite Leaf Spring at varying thickness

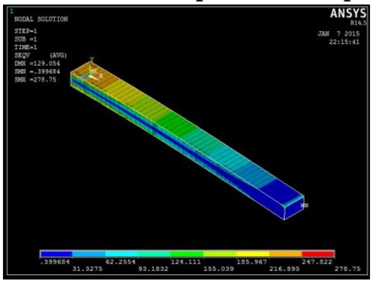


Fig-8: Stress of Composite leaf spring at thickness 30mm

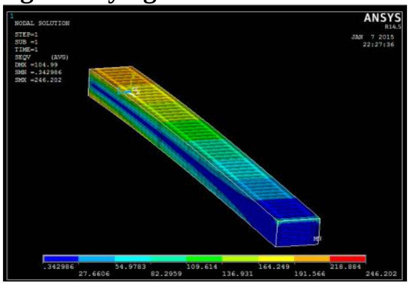


Fig-9: Stress of Composite leaf spring at thickness 32mm

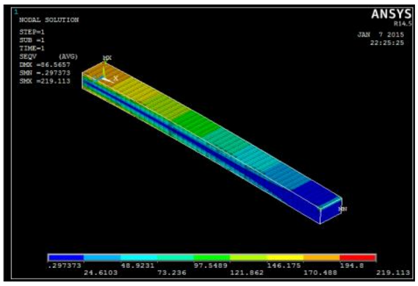


Fig-10: Stress of Composite leaf spring at thickness 34mm

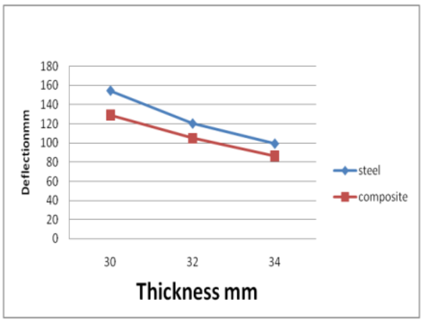
Fig- 8,9,10 shows the stresses result of composite leaf spring much lower as compared to conventional leaf spring at various thicknesses.

Table-5: FEA Results At Load 300kg Stresses Of Composite Leaf Spring At Thickness 30mm,32mm and 34mm

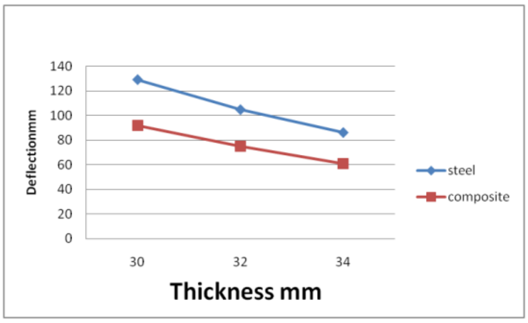
Thickness mm	Deflection mm	
	Steel	Composite
30	875.97	278.85
32	741.29	246.20
34	651.27	219.11

E. Graphical comparison of conventional and composite leaf spring.

a) Thickness Vs Deflection

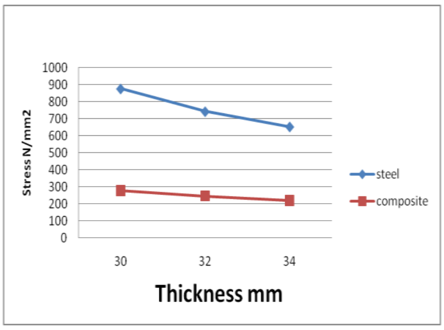


Graph-1: FEA Result

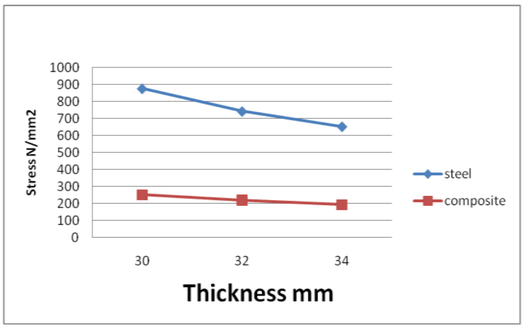


Graph-2: Experimental Result

b) Thickness Vs Stresses



Graph-3: FEA Result



Graph-4: Experimental Result

The above graph shows the great difference between the conventional leaf spring and composite leaf spring .

IV. Conclusion

Composite leaf spring is successfully fabricated by hand lay-up technique. The experimental and FEA results of deflections and stresses of leaf spring are calculated and results are found to be in good agreement with each other. With increase in thickness of composite leaf spring the deflection and stress decreases and are significantly less compared to the conventional leaf spring. The stiffness of composite leaf spring is increases with increase in thickness and is higher than conventional leaf spring.

Since the composite leaf spring is able to withstand the static load it is concluded that there is no objection from strength point of view in the process of replacing conventional leaf spring by GFRC. The weight of leaf spring is reduced considerably about 75% by replacing conventional leaf spring by GFRC with varying thickness. Thus the unsprung mass is achieved to large extent. Stresses in composite leaf spring are much lower than that of conventional leaf spring.

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