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Design and Analysis of Mono Composite Leaf Spring by Varying Thickness using FEA

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Abstract: *Increasing competition and innovation in automobile sector tends to modify the existing products by new and advanced material products. Conservation of metals is an important issue these days. A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are universally accepted suspension components that are being still used widely in automobiles. Weight reduction is also given due importance by automobile manufacturers. The automobile industry has shown keen interest in the use of composite leaf spring in the place of conventional leaf spring due to its high strength to weight ratio. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. The objective of this paper is to present a general study on the Design and Analysis of composite (Glass Fibre Reinforced Composite- GFRC) leaf spring. Static analysis is performed out in FEA based software Ansys14.5 with design constrain as Stress, Deflection with varying thickness.*

Keywords: *Ansys 14.5, Mono composite leaf Spring, Glass Fiber Reinforced Composite (GFRC),*

I. Introduction

To meet the needs of natural resource conservation and energy economy, automobile manufacturers have been attempting to reduce the weight of vehicles in recent years[1] .The suspension spring is one of most important system in automobile which reduce jerk, vibration and absorb shocks during riding 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 [3]. 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 as it accounts for 10% - 20% of the un-sprung 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 the leaf spring without any reduction on load carrying capacity and stiffness[2]. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of vibrations in the spring and the energy absorbed is stored in spring as strain energy and then released slowly. Thus strain energy of material used for spring is the important property to be considered. The specific strain energy is inversely proportional to the density and Young's modulus. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Conventional leaf spring has less specific modulus strength. Conventional leaf spring are usally manufactured and assembled by using number of leaf made of steel and hence weight is more. Its corrosion resistance is more compared to composite leaf spring, it has less damping capacity. Hence, composite material becomes a very strong candidate for such applications[7]. 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.[5]

In present work an attempt is made to replace existing conventional leaf spring by mono composite leaf spring made of composite material Glass Fiber Reinforced Composite (GFRC).Conventional and Composite leaf spring is designed and analysis with constant width and varying thickness in Ansys14.5.

II. Materials

2.1Selection of material

Materials of the leaf spring should be consist of nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle[4]. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Composite material has less weight due to this fuel consumption would be reduced, high damping capacity due this produce less vibration and noise, they have good corrosion resistance, high specific modulus and strength and longer fatigue life. Hence, the composite materials have been selected for leaf spring design.

2.2Fibres selection

The commonly used fibers are carbon, glass, keviar, etc. Among these, the glass fiber has been selected based on the cost factor and strength. The types of glass fibers are C-glass, S-glass and E-glass. The C-glass fiber is designed to give improved surface finish. S-glass fiber is design to give very high modular, which is used particularly in aeronautic industries[4]. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

2.3Resins selection

Many thermo set resins such as polyester, vinyl ester epoxy resin are being used for fiber reinforcement plastics (FRP) fabrication. Among these resin systems, epoxies show better inter laminar shear strength and good mechanical properties Different grades of epoxy resins and hardener combinations are classifieds, based on the mechanical properties. Among these grades, the grade of epoxy resin selected is Dobeckot 520 F and the grade of hardener used for this application is 758. Dobeckot 520 F is a solvent less epoxy resin. This in combination with hardener 758 cures into hard resin. Hardener 758 is a low viscosity polyamine. Dobeckot 520 F, hardener 758 combinations is characterized by good mechanical and electrical properties, faster curing at room temperature and good chemical resistance properties.[4]

III. Mechanical Properties Of Material

3.1. Material for Steel leaf spring

The material selected for steel leaf spring is 55si2Mn90.[2]
The design parameters selected for steel leaf are listed in table 1.

Table-1: design parameters of steel leaf sprig

Properties	Value	Unit
Material	Steel (55si2Mn90)	-
Young's modulus	$2.1*10^5$	Mpa
Tensile strength	1962	Mpa
Yield Strength	1470	Mpa
Design Stress	600	Mpa
Density	7700	kg/m^3
Poisson Ratio	0.29	-
Total Length of spring(eye to eye)	1010	mm
Arc height at axle seat or Camber height	120	mm
Thickness of leaf spring	28,30,32	mm
Width of leaf spring	45	mm

3.2. Materials for Composite leaf spring

Based on the specific strain energy of steel spring and some composite materials, the E-glass/epoxy is selected as the spring material. The parameters for composite leaf spring material are listed in table 2.

Table-2: parameters of GFRC leaf spring

Properties	Value
Tensile modulus along X-direction (Ex), MPa	10370
Tensile modulus along Y-direction (Ey), MPa	6030
Tensile modulus along Z-direction (Ez), MPa	1530
Tensile strength of the material, MPa	800
Compressive strength of the material, MPa	450
Shear modulus along XY-direction (Gxy), MPa	2433
Shear modulus along YZ-direction (Gyz), MPa	1600
Shear modulus along ZX-direction (Gzx), MPa	2433
Poisson ratio along XY-direction (NUxy)	0.230
Poisson ratio along YZ-direction (NUyz)	0.039
Poisson ratio along ZX-direction (NUzx)	0.230
Mass density of the material (ρ), kg/m3	2100
Flexural modulus of the material, MPa	40000
Flexural strength of the material, MPa	1000

The specification of leaf spring [1] is as follows b=45mm t=30mm L=1010mm.

IV. Specification Of Problem

The objective of the present work is to design the E-glass/epoxy composite leaf spring for automobile suspension system and analyze it. This is done to achieve following

- To replace conventional steel leaf spring with E-glass/epoxy composite leaf spring.
- To achieve substantial weight reduction in the suspension by replacing steel leaf spring with composite leaf spring.
- A virtual model of both steel and mono composite leaf created in DM-design modular in Ansys14.5 constant width and varying thickness and for analysis by applying Static Loading condition. After analysis a comparison is made between existing conventional steel leaf spring and mono composite leaf spring in terms of deflection, Stress.

V. Results And Discussions

5.1Analytical Calculation

In present analysis at load 300kg.

$$\sigma = \left(\frac{6WL}{bt^2}\right), \quad \delta = \left(\frac{WL^3}{3EI}\right)$$

Table-3: Analytical Result of Conventional and composite Leaf Spring.

Thickness (mm)	Deformation (mm)		Stresses (N/mm^2)		Stiffness (N/mm)	
	Steel	Composite	Steel	Composite	Steel	Composite
28	154.52	128.97	877.97	252.75	19.04	22.81
30	120.32	104.85	743.10	220.18	24.45	28.06
32	99.33	86.40	653.27	193.51	29.62	34.06

5.2 FEA (Finite Element Analysis)

FEA tool is the mathematical idealization of real system. Its a computer based method that breaks geometry into element and link a series of equation to each, which are then solved simultaneously to evaluate the behavior of the entire system.[5]. Ansys14.5 software is commercially available software which is capable of analyzing the given part by means of structural, thermal, fluid ,harmonic analysis.

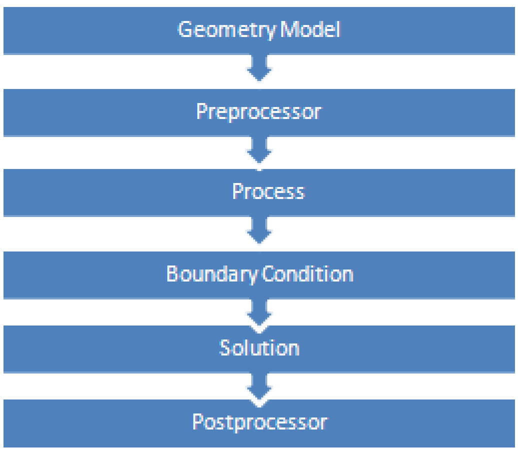
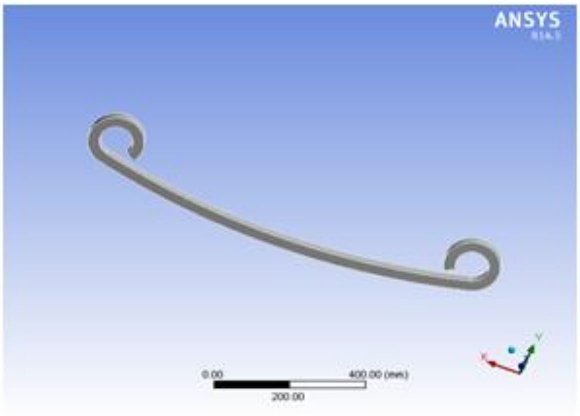


Fig.1.Typical FEA procedures by commercial software

5.2.1Geometry of leaf spring and Model meshing of leaf spring

This geometry has been created in Design modeler (DM) Ansys14.5as per dimensions as shown in fig3. The meshed model of mono leaf spring with an element size of 5mm brick mesh is as shown in fig 4



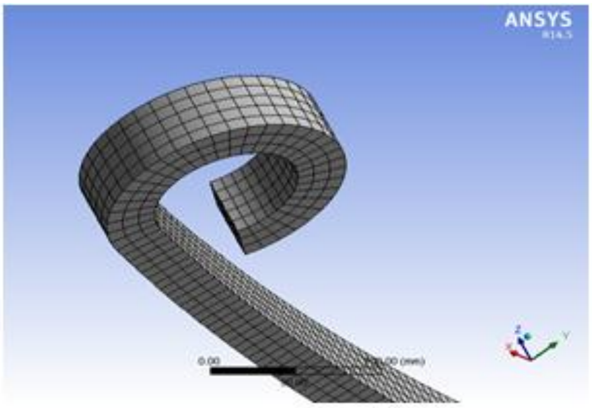


Fig.2. 3-D Model of leaf spring **Fig.3. Meshed model of leaf spring**

5.2.2 Fixed Support and cylindrical support.

For the leaf spring analysis one eye end of the leaf spring is fixed to the chassis of the vehicle and the fixed support at another eye end of the leaf spring model. and cylindrical support is applied to the other eye end of leaf spring model.

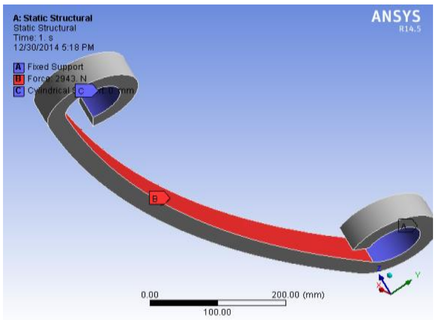


Fig.4. Fixed support and cylindrical support with load

5.3.FEA Results

5.3.1Deflection for composite leaf spring at varying thickness

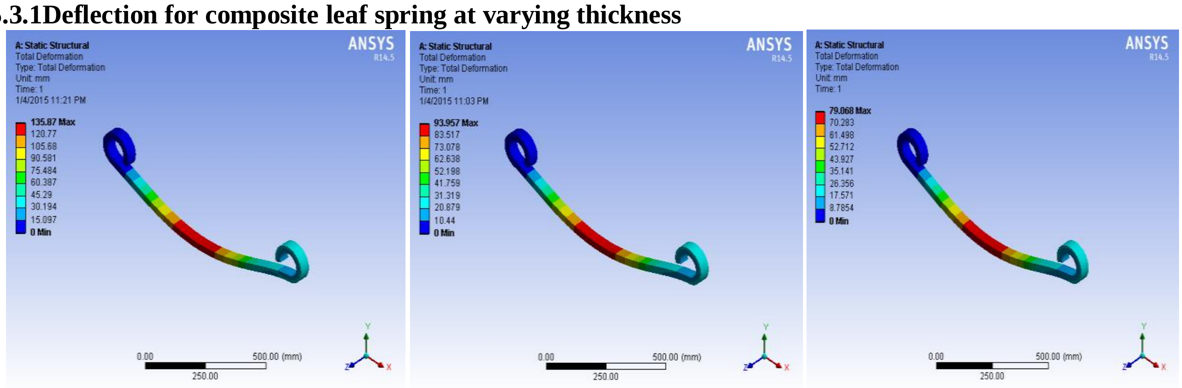


Fig. 5 deformation of Composite leaf spring at thickness 28mm,30mm and 32mm respectively

Table-4: FEA Result of deformation of Composite leaf spring at thickness 28mm,30mm and 32mm.

Thickness (mm)	Deformation (mm)		Stiffness (N/mm)	
	Steel	Composite	Steel	Composite
28	152.52	135.87	19.29	21.66
30	119.49	93.957	24.62	31.32
32	96.33	79.068	30.55	37.22

5.3.2.Stress for Composite Leaf Spring at varying thickness.

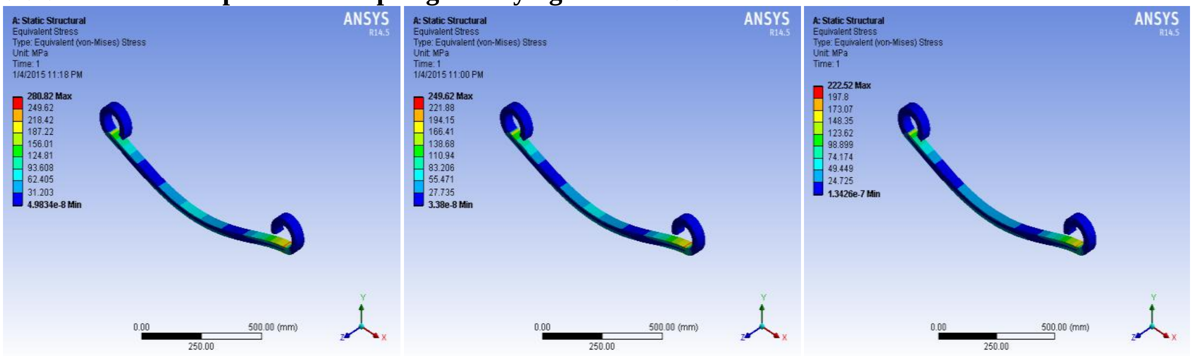


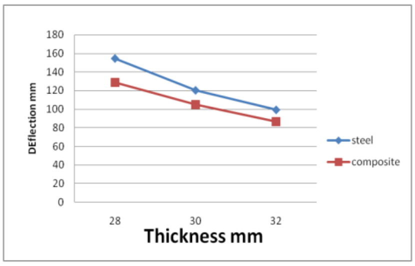
Fig. 6. Stress of Composite leaf spring at thickness 28mm,30mm and 32mm respectively

Table-5: FEA Result of Stresses of Composite leaf spring at thickness 28mm,30mm and 32mm

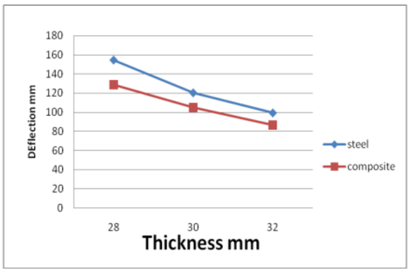
Thickness (mm)	Stresss (N/mm^2)	
	Steel	Composite
28	875.97	280.82
30	741.29	249.62
32	651.27	222.62

VI. Graphical comparison of Conventional and composite Leaf spring

6.1Thickness Vs Deflection

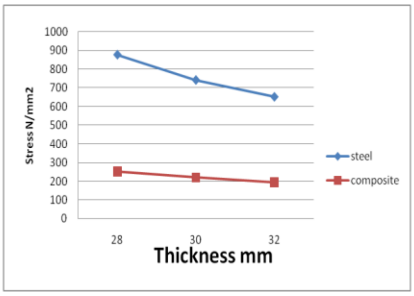


Graph1: Analytical Result

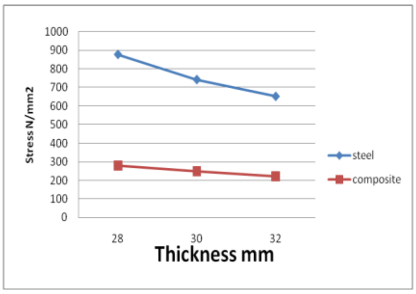


Graph2: FEA Result

6.1Thickness Vs Stresses

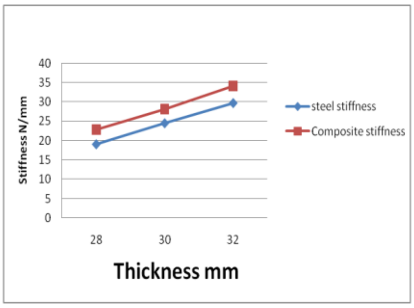


Graph3: Analytical Result

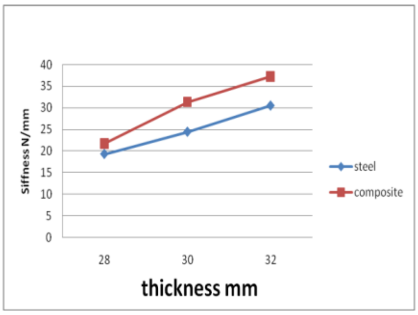


Graph4: FEA Result

6.2Thickness Vs Stiffness



Graph5: Analytical Result



Graph6: FEA Result

VI. Conclusion

In present research work at static loading condition by varying thickness stress and deflection of GFRC is found having difference as compared to conventional leaf spring. the analytical result were compared with FEA of varying thickness shows good agreement with stress and deflection. Study demonstrated that composite can be used for leaf spring meet the requirements.

VII. Future Scope

a) Analysis of leaf spring is done by varying width and varying thickness
b) Harmonic analysis with finding and compression of first five natural Frequencies.
c) As this analysis is under static load condition, so one can go for the analysis of composite & steel leaf spring under dynamic loading condition
d) Analysis is also done by another Software like Simulation, Hypermesh etc

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