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Design and Fabrication of E-Glass /carbon/graphite epoxy hybrid composite leaf spring

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Abstract. The Automobile Industry has shown increase interest for replacement of steel leaf spring with that of composite leaf spring. Substituting composite materials for conventional metallic materials has many advantages because of higher specific stiffness, strength and fatigue resistance etc. This work deals with the replacement of conventional steel leaf spring with a hybrid Composite leaf spring using E -Glass/Carbon/Graphite/Epoxy. The hybrid composite is obtained by introducing more than one fiber in the reinforcement phase. The hybrid composite is fabricated by the vacuum bag technique. The result shows that introduction of carbon and graphite fiber in the reinforcement phase increases the stiffness of the composite.

1. Introduction

Leaf spring is a simple type of suspension element commonly used in wheeled vehicles. Steel leaf spring is generally high weight so the whole suspension system becomes bulky. Due to the high weight over steer and directional instability may occur during cornering of vehicle so the automobile industry was always looking for better material instead of conventional material. Composite is a material composed of two phases, matrix and reinforced phase here the two phases are distinctly identifiable constituents. The Composite material is not only used in automobile but all other industries like aerospace, marine, civil etc. The composite material gives more advantage than the conventional materials the main advantages of composite material is the weight reduction most of the industry looking to reduce the weight but not compromise the strength so composite is the suitable alternate for the current requirement. The suspension leaf spring is one of the potential items for weight reduction. The main function of the leaf spring is to absorb and store energy and then release it slowly. So, increasing the energy storage capability of a leaf spring makes it more compliant. The amount of elastic energy that can be stored by a leaf spring is given by [1] $S = \frac{1}{2}\frac{\sigma^2}{E}$ where σ is the max allowable stress induced into the spring and E is the modulus of elasticity, both in the longitudinal direction. The equation shows that a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material. Fortunately composite have these characteristics. There are many researcher analyses the composite material for the leaf spring application Rajendran I and Vijayarangan [2] presents an artificial genetic approach to optimize the composite leaf spring. The design variable thickness and width are optimized by the use of GA the result makes the impact on weight of the leaf spring 8% to steel leaf spring and 23.4% to composite spring. Quershi H.A Al [1] presents a paper which describes mechanical and geometrical properties of a single leaf, variable thickness spring of glass fiber reinforced plastic (GFRP).E.Mahdi and A.M.S Hamouda[3] described the effect of ellipticity ratio on the leaf spring performance and carbon-glass/epoxy hybrid composite leaf spring is fabricated and the result shows that adding four layers of carbon fiber control the load carrying capacity. Shishay Amare and Gebremeskel[4] explains the the E-glass epoxy composite leaf spring with the fatigue life of $221.16*10^3$ cycles. Satish K G et al.[5] presents a paper on Characterization of In-Plane Mechanical Properties of Laminated Hybrid Composites. Composite material behavior always depend on the various parameters like types of reinforcement, types of resin, fiber orientation , fiber thickness, fiber stacking sequence. Therefore the main objective of the present work is to analyze the effect of stacking sequence in laminated hybrid composite for a leaf spring application.

2. Leaf spring design

The firm is a single source to the world leading automobile manufacturer. The existing capacity of the supplier is 4800 units per month. But the manufacturer increases his demand to 6000 units per month as increases of their customer demand. Hence there is 41% gap to meet the demand.Here weight and initial measurement of four wheeler Mahindra Bolero Pik-up vehicle are taken

Weight of the vehicle	= 1000 kg
Maximum load carrying capacity	= 1150 kg
Total weight	= 2150
Taking factor of safety	= 2.4
Acceleration due to gravity	= 9.8
	= 2150 *2.4*9.8
	= 50568 kg

Since the vehicle is four wheelers, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight

$$F = \frac{50568}{4} = 12642\ N$$

Design load	= 12642 N
Straight length of the leaf spring (L)	=1680 mm
Design stress	= 490 MPa

Strength of material concept [4]

$$\sigma_{\max} = \frac{6FL}{bh^2} \quad (1)$$

$$\delta_{\max} = \frac{4FL^2}{Ebh^2} \quad (2)$$

Solving equation ot the above for ‘h’ (thickness of the leaf spring)

$$h = \frac{\sigma_{\max}}{E\delta_{\max}} \quad (3)$$

Rearranging the equation to get width ‘b’

$$b = \frac{6F(\frac{L}{2})}{\sigma_{max}h^2} \quad (4)$$

Therefore breath is taken as b = 104mm
Thickness = 20 mm
Camber Calculation [6]

$$\frac{C}{L} = 0.089 \quad (5)$$

Camber = 149 mm
The present work concentrates only a constant cross section because the accommodation of reinforcement fibers must be continuous and uniform distribution of resin is essential for analysis. Design model with the above dimensions are done with the help of CATIA.

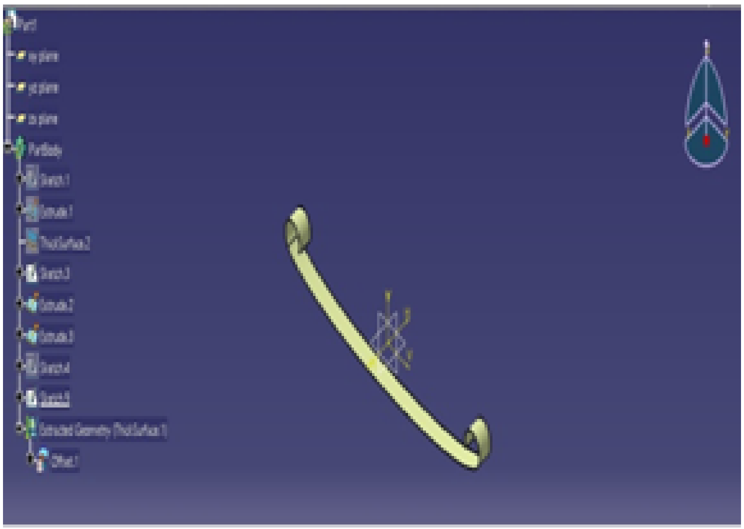

Figure 1. Leaf spring CATIA model

3. Hybrid composite

Hybridization in composite is obtained by introducing more than one fiber in the reinforcement phase in which two or more high-performance reinforcements are combined. The main aim to combine the properties of the different fibers is to get an average property, or even to create new or improved properties. The different reinforcement lamina is stacked with bottom to top order.

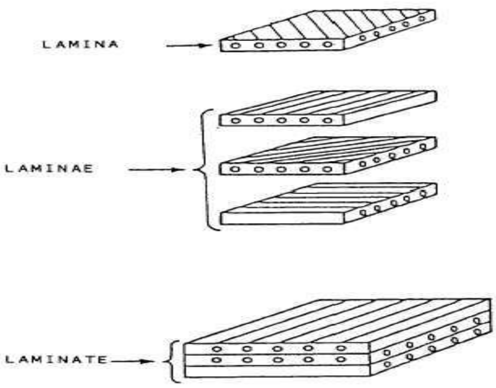

Figure 2. Lamina arrangements

4. Experimental Procedure

4.1 Polymers

In a polymer matrix composite structure the main function of matrix is binding the reinforcement in place and even distribution of stresses among the fibers under the applied force Epoxy resins are reasonably stable to chemical attacks and are excellent adherents having slow shrinkage during curing and no emission of volatile gases. Here L12 (3202) grade epoxy resin used as a matrix material.

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Figure 3. Epoxy resin

4.2 Hardener

Hardener is mainly used to cure the epoxy resin which causes a chemical reaction without changing its own composition. The catalyst initiates the chemical reaction of the unsaturated polyester and monomer ingredient from liquid to a solid state. When used as a curing agent, catalysts are referred to as catalytic hardeners. Hardeners are mainly used to increase the polymerization process. The curing time mainly depends on the hardener and epoxy mixing ratio. Here the mixing ratio is 100:10. This makes the fabrication process as per our requirements.

4.3 Mould preparation

The wooden mould is prepared for the fabrication process. The main difficulty in the wooden mould preparation is making the eye design here the loose pattern type wooden roll is used to make the eye design.

4.4 Vacuum bag moulding

The composite leaf spring is fabricated by vaccum bag moulding. First the woden mould is prepared and the E glass, carbon, Graphite fibers are placed on mould layer by layer in different sequence. The main advantage of vaccum bag moulding is the void formation within the composite can be avoided.

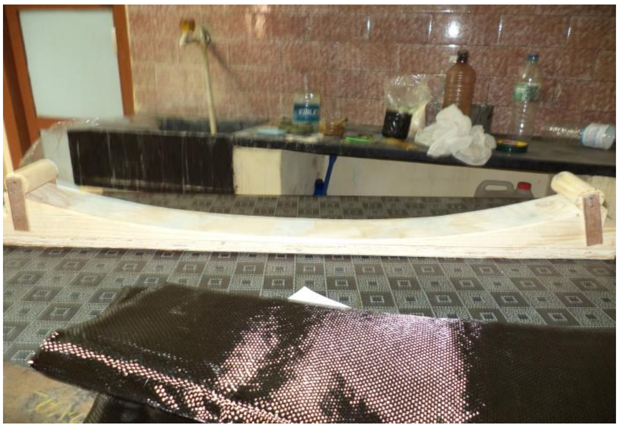
Figure 4. wooden mould

5. Result and discussion

The deflection for the load application in various stacking sequence is tabulated. Initial analysis for the first sequence is arranged as first 10 layers of glass fiber and other 10 layers of carbon from bottom to top layer.

Table 1 Deflection for Various Lamina Stacking Sequence

Sl. no	Layer sequence	Deflection mm
1	1-10 glass ,10-20 carbon	133.7
2	1-10 glass ,10-20 graphite	125.9
3	1-10 carbon ,10-20 graphite	100
4	1-5 Glass,6-10 carbon,11-15 glass, 16-20 carbon	141.9
5	1-5 Glass,6-10 graphite, 11-15 glass, 16-20 graphite	135.7
6	1-5 Carbon, 6-10 glass, 11-15 carbon, 16-20 glass	132.5
7	1-5 Graphite, 6-10 glass, 11-15 graphite, 16-20 glass	124.488
8	1-5 graphite, 6-10 carbon, 11-15 graphite, 16-20 carbon	104.653
9	1,4,7,10,13,16,19 –glass, 2,5,8,11,14,17,20 – carbon, 3,6,9,12,15,18 – graphite	125.335
10	1,4,7,10,13,16,19 – carbon, 2,5,8,11,14,17,20 – graphite, 3,6,9,12,15,18 – glass	106.297
11	1-3 ,10-12,19,20 glass, 4-6, 13-15 – carbon, 7-9, 16-18 –graphite	145.49
12	1-3, 10-12,19-20 – carbon , 4-6, 13-15 – graphite, 7-9, 16-18 glass	107.97
13	1-3, 10-12, 19,20 – graphite, 4-6, 13-15 – glass, 7-9,16-18 – carbon	104.02
14	1,2,7,8,13,14,19,20 – glass, 3,4,9,10,15,16 – carbon, 5,6,11,12,17,18 -Graphite	126.435
15	1,2,7,8,13,14 – carbon, 3,4,9,10,15,16 – graphite, 5,6,11,12,17,18 – glass	105.74

The deflection of the leaf spring is shown in fig. The glass fiber having the youngs modulus value of 43000 MPa[7] in the x-direction but when its compared to carbon 177000 MPa so it makes the laminate as stiff as compared to laminate containing only glass fiber. Here the woven fibers are used so it makes the composite with minimum deflection range. The vacuum bag technique also used to remove the excessive resin that will avoid the matrix cracking and voids in the composite is reduced.

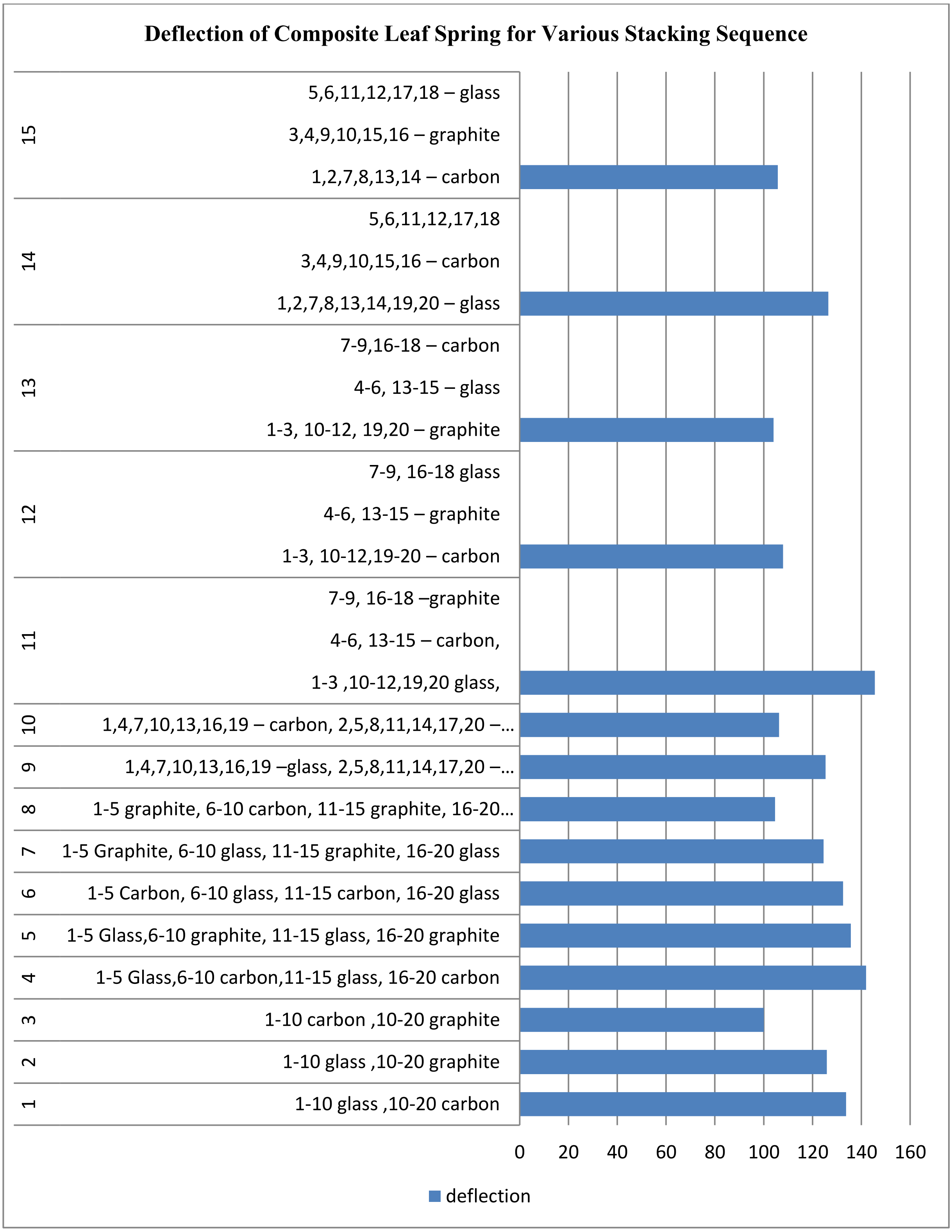

Figure 5. Deflection of Composite Leaf Spring for Various Stacking Sequence

7. Conclusion
The result shows that the introduction of carbon and graphite fibers in the reinforcement phase increases the stiffness of the composite leaf spring. The composite of $[\{0/90/0\}^{gr}\{90/0/90\}^{e\text{-}gl}\{0/90/0\}^{ca}\{90/0/90\}^{gr}\{0/90/0\}^{e\text{-}gl}\{0/90/0\}^{ca}\{90/0/90\}^{gr}]$ stacking sequence gives the more appropriate result over other and it shows that carbon and graphite fiber in the principle direction makes more effective instead of shear direction.

8. References
[1] Al-Qureshi H A 2001 Automobile leaf springs from composite materials *Journal of Material Processing Technology* **118(1)** 58-61.

[2] Rajendran I and Vijayarangan V 2001 Optimal design of composite leaf spring using genetic algorithm *computers and structures* **79(11)** 1121-1129

[3] Mahdi E, Hamouda A M S 2013 An experimental investigation into mechanical behaviour of hybrid and nonhybrid composite semi elliptical springs *Materials and design* **52** 504–513.

[4] Shishay Amare Gebremeskel 2012 Design,Simulation and prototyping of single composite leaf spring for light vehicle *Global Journal of Researches in Engineering Mechanical and Mechanics Engineering* **12(7)** 0975-5861.

[5] Satish K G, Siddeswarappa B, and Mohamed Kaleemulla K 2010 Characterization of In-Plane Mechanical Properties of Laminated Hybrid Composites *Journal of Minerals & Materials Characterization & Engineering* **9(2)** 105-114.

[6] ManasPatnaik, Koushik L P and Manoj Mathew 2012 Determination of Camber and Leaf Span of a Parabolic Leaf Spring for Optimized Stress and Displacement Using Artificial Neural Networks *International Journal of Modern Engineering Research* **2(11)**

[7] PankajSaini, AshishGoel and Dushyantkumar 2013 Design and analysis of composite leaf spring for light vehicles *International journal of innovative research in science, Engineering and technology* **2(5)** 2319-8753