

Development of leaf spring with E-glass/Epoxy composites for automobile vehicles

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Abstract

Now a days the industries of automobile very interesting to replace leaf spring which are made by steel instead of composite materials for the reason that of its good strength to weight ratio as well as corrosive ratio. This project work contributing design, analysis as well as development of leaf spring through composite materials for leaf spring in military jeep. Carbon epoxy 28 material is used in this work. Our main objective of this work is to replace steel for reducing weight of the leaf spring. Here stiffness is the main design constraint. The material designated is carbon fiber reinforced polymer that is called as E-glass/epoxy which is used to replace steel. The strength, weight and life comparative studies have been made for those two different materials. From the results clearly shows that when implementing composite materials 85% of the weight could be reduced than the steel. CATIA V5R20 and CATIA V5 software's are used for modeling and analyzing of the proposed leaf spring.

Keywords: Automobile Industry; design; composite leaf spring; CARBON; EPOXY28; E-glass; CATIA V5;

1. Introduction

The benefits of leaf springs than helical springs are the ending of spring leaf could be guided with specific path by the way of spring eye with its bush. It has arc shape when comparing with semi elliptical types of spring and made with rectangular cross sectional area. At the center point of this arc facilitate to seat the vehicle body

on it. In the application of heavy vehicles leaf spring construct with layer by layer stacked one by one by gradually decreasing its length. It also be served as a damping action and springing action.

Abdul Rahim et.al [1] developed spring stiffness based elliptical spring using composite material for improving its fatigue life with considering the parameters with shear stress. They proved their experiment and stated that mono elliptical spring made by composite could be utilized for light as well as heavy duty trucks including substantial reduction of weight. Jeffery et.al [2] studied the behavior of static as well as fatigue of steel as well as composite multileaf spring by the software of ANSYS V12.

They found that leaf spring from composite has lower bending stress and higher fatigue than steel spring and also they found E-glass/epoxy has better performance than vinyl ester. Dipendra Kumaret.al [3] made investigation of prismatic cantilever beam deflection through numerical analysis to find the different mechanical properties of materials with its free end and studying its displacement. They found that the improvement of mechanical properties are high economical than steel spring.

Jiashi et al [4] examined leaf spring with mono composite having rectangular cross section for commercial vehicle to measure stiffness and its maximum capacity of load carrying through hot molding method. Their experimental and FEA results

shows the 1.56% in stiffness and 0.82% in capacity load gives good agreement. Sampath et.al [5] investigated leaf spring for reducing its weight using Epoxy/E-glass with Epoxy carbon and found better comparison with different thickness steel leaf spring.

Ganeshet.al [6] investigated multi leaf spring with its load carrying capacity; stiffness as well as reduction of weight and found 22.46 kg mass reduction of reinforced epoxy with fibre glass comparing with SAE 9260 steel leaf spring. Syambabu et al [7] obtained a leaf spring along with least weight with composite as compared with steel leaf spring and made testing its accomplished static load as well as forces acting with externally to avoid failures. Pinaknath et al [8] proposed design as well as analysis of multi-layer composite leaf spring and made analysis with ANSYS12 software along with statics structural tool and found that E-Glass/Epoxy has 67.88% reduction in weight.

Through literature survey it could be seen that weight reduction has very general issues for increasing fuel efficiency as well as minimize the pollution from automobile. The weight reduction could be achieving to alternate spring from steel materials by the materials with composite. Furthermore materials from composite give lower stresses as well as deflection with greater fatigue life.

2. Construction of leaf spring

Figure 1 shows the general semi elliptical leaf spring in automobiles which is construct number of plates called leafs. This leaves have an initial curvature and cambered to straight by load.

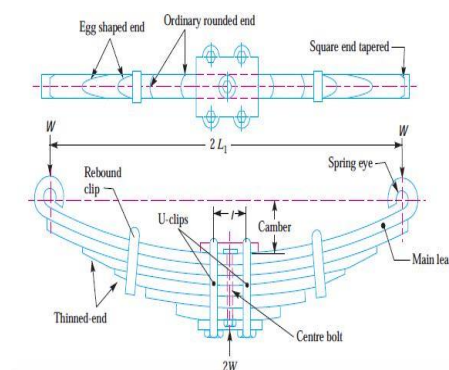


Figure 1: Semi elliptical leaf spring

The leaves have connected are held together through around a band shrunk its center by means of bolt which insert center hole of all leaves. The lengthy leaf is called as main leaf with end form shape of eye to facilitate fitting on vehicle chassis with spring pins using spring buses by means of shackle and hanger.

2.1 Design calculation of leaf spring

Traditional design techniques of leaf springs have large depending on its application. The purposes of springs have absorbing energy then release it related to the performance and function and its design mainly depends on the capacity of load carrying as well as deflection.

Step 1: Steel spring as 50 Cr 1 V 23

Its composition is 0.45% C; 0.1-0.3% Si; 0.6-0.9 % Mn; 0.9-1.2 % Cr

Step2: Basic leaf spring data:

Total length i.e. Eye to Eye = 1250 mm

Number of full length leaves (n_f) = 02

Number of graduated leaves (n_g) = 04

Leaf thickness, t = 7 mm

Width, $b = 60 \text{ mm}$
 Young's modulus (E) = $2 \times 10^5 \text{ N/mm}^2$
 From center 110 mm wide
 Strength in tensile side, $\sigma_t = 1900\text{--}2400 \text{ N/mm}^2$
 Strength at Yield, $\sigma_y = 1800 \text{ N/mm}^2$

Total load = 2850 Kg
 BHN is $500 - 580 \text{ HB}$ including when hardening as well as tempering.
 Step 3: Basic requirement of load:

Maximum capacity = 2850 Kg
 $= 2850 \times 10$
 $= 28500 \text{ N}$

The Vehicle has equipped with 4 numbers of spring assembly with semi elliptical shaped. Therefore the total acting load is $8500 / 4 = 7125$.

Step 4: estimation of load as well as effective length. Consider as the given leaf spring has a beam with cantilever and load acts as its both ends and divided into two since its consider as the beam of cantilever.

$$2 \times W = 7125 \text{ N}, W = 7125/2, W = 3562.5 \text{ N}$$

To carrying with holding of spring by using U bolt with the distance of 110 mm . The effective spring length l is 110 mm .

$$2 \times L = 2 \times L_1 - l$$

$$2 \times L = 1250 - 2/3 (110)$$

$$2 \times L = 1176.67$$

$$L = 1176.67/2$$

$$L = 588.34 \text{ mm}$$

Step 5: stress development in spring

Material is $50 \text{ Cr } 1 \text{ V } 23$
 Properties of the material are:

Tensile strength, $\sigma_t = 190 - 240 \text{ Kg/mm}^2$
 $= 1900 - 2400 \text{ N/mm}^2$

Yield strength, $\sigma_y = 180 \text{ Kg/mm}^2 = 1800 \text{ N/mm}^2$

Modulus of elasticity, $E = 200000 \text{ N/mm}^2$

BHN is $500\text{--}580 \text{ HB}$ for hardening as well as tempering.

Factor of safety is taken as 1.5 especially for Automobile applications.

Tensile strength, $\sigma_t = \frac{1900}{1.5}$

$$= 1266.66 \text{ N/mm}^2$$

Yield strength, $\sigma_y = \frac{1800}{1.5}$

$$= 1200 \text{ N/mm}^2$$

The Bending stress in the leaf spring is:

$$\sigma_b = \frac{6 \times W \times L}{n \times b \times t^2}$$

$$\sigma_b = \frac{6 \times 3562.5 \times 588.34}{6 \times 60 \times (7)^2}$$

$$\sigma_b = 712.91 \text{ N/mm}^2$$

So our results shows the lower stress of the leaf spring compared with allowable design, the proposed design is safe.

$$y = 6 \times W \times L^3$$

$$n \times E \times b \times t^3$$

$$y = \frac{6 \times 3562.5 \times 588.34^3}{6 \times 200000 \times 60 \times 7^3}$$

$$Y = 176.26 \text{ mm}$$

Step 6: Pin calculation

$$p_b = 8 \text{ N/mm}^2$$

Length of eye, $l_1 = 60 \text{ mm}$.

Load on eye:

$$W = d \times l_1 \times p_b$$

$$d = \frac{W}{l_1 \times p_b}$$

$$d = \frac{3562.5}{60 \times 8}$$

$$d = 7.42 \text{ mm}$$

$$d = 8 \text{ mm}$$

$$d = 8 \text{ mm}$$

Safe factor is 2.

Bending moment calculation

Length of the pin = Length of the eye + (2 × Clearance)

Clearance is 2.50 mm per side

$$l_p = 60 + (2 \times 2.50)$$

$$l_p = 65 \text{ mm}$$

Bending moment maximum on pin

$$M = \frac{W \times l_p}{4}$$

$$M = \frac{3562.5 \times 65}{4}$$

$$M = 57890.62 \text{ N.mm}$$

Pin modulus

$$Z = \frac{\pi \times d^3}{32}$$

$$Z = 0.0982 \times d^3 \text{ mm}^3$$

$$Z = 0.0982 \times d^3 \text{ mm}^3$$

Pin bending stress, $\sigma_b = \frac{M}{Z}$

$$\sigma_b = \frac{3562.5}{0.0982 \times d^3}$$

$$43 = \frac{3562.5}{0.0982 \times d^3}$$

$$d = 29.93 \text{ mm}$$

$$d = 30 \text{ mm}$$

The diameter of the eye internal surface is 30mm

Shear stress in the pin is:

$$W = \frac{2 \times \pi \times d^2 \times \tau}{4}$$

$$\tau = \frac{W \times 4}{2 \times \pi \times d^2}$$

$$\tau = \frac{3562.5 \times 4}{2 \times \pi \times (30)^2}$$

$$\tau = 2.52 \text{ N/mm}^2$$

The stresses of tensile as well as shear stress are lower than that of allowable stress so design is safe.

Step 7: Length of spring calculation

Ineffective length is 110 mm

$$= \frac{\text{length in effective}}{n-1} + \frac{2(\text{Ineffective length})}{3}$$

$$= \frac{[2 \times 588.34] \times 1 + 73.33}{6-1}$$

$$= 308.66 \text{ mm}$$

Length of the 2nd leaf

$$= \frac{[2 \times L] \times 2}{n-1} + \frac{2(\text{Ineffective length})}{3}$$

$$= \frac{[2 \times 588.34] \times 2 + 73.33}{6-1}$$

$$= 544 \text{ mm}$$

Length of the 3rd leaf

$$= \frac{[2 \times L] \times 3}{n-1} + \frac{2(\text{Ineffective length})}{3}$$

$$= \frac{[2 \times 588.34] \times 3 + 73.33}{6-1}$$

$$= 779.34 \text{ mm}$$

Length of the 4th leaf

$$= \frac{[2 \times L] \times 4}{n-1} + \frac{2(\text{Ineffective length})}{3}$$

$$= \frac{[2 \times 588.34] \times 4 + 73.33}{6-1}$$

$$= 1014.67 \text{ mm}$$

Length of the 5th leaf

$$= \frac{[2 \times L] \times 5}{n-1} + \frac{2(\text{Ineffective length})}{3}$$

$$= \frac{[2 \times 588.34] \times 5 + 73.33}{6-1}$$

$$= 1250 \text{ mm}$$

- But 5th and 6th leaves have full length leaves and 6th leaf as consider as called as master leaf.
- Length of the master leaf calculated as:

$$\text{Length of master leaf} = 2 * L_1 + \pi (d + t) \times 2$$

$$= 1250 + \pi (30+7) \times 2$$

$$= 1482.48 \text{ mm}$$

Step 8: Radius calculation,

R = Initial bend radius

y = Camber of the spring

$$y(2 \times R - y) = (L_1)^2$$

$$176.26 (2 \times R - 176.26) = (625)^2$$

$$R = 1196.22 \text{ mm}$$

2.2 The existing material

Spring steel has wide range of steels which is widely used for manufacturing of springs prominently in automotive as well as industrial suspension applications. It contains 0.45-0.55% of Carbon and 0.50% of Silicon and 0.50-0.80% of Manganese, 0.06% of Phosphorous 0.06%, Chromium 0.80-1.20%, Sulphur 0.06% and Vanadium 0.15% min.

2.3 The proposed material

2.3.1 Carbon epoxy

The flexural test has conducting on specimen by ASTM as shown in Figure 2. The experiments have conducted by test with three points.

The deflection has been calculated through its cross head position.

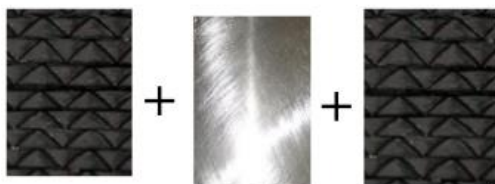


Figure 2: Flexural specimen

Prepared specimen and after testing is Figure 3. With the temperature 25% including humidity of 50% all experiment have been conducted.



Figure 3: Fractured specimen after the testing

The group of carboxylic has been generated with the surface of nano tubes by HNO₃ treatment for creating DWCNTs. OX-DW CNT. Usually 350 mg of P-DWCNT is dispersed with 50 ml of HNO₃ with 45 minutes and it's refluxed at 115 °C for 3 h. After that filtration cellulose nitrate filter has 0.45 µm and neutralization, OXDW CNT dispersed at DMF 0.5 mg of OXDWCNT per ml of DMF in ultrasound by 40

minutes as well as vigorous stirring at 1 h. 50 mg with HDA and 50 mg of EDC added to 250 mg of OXDWCNT in DMF with stirring 24 h. After filtration Nano tubes are getting by PTFE filters. Various epoxy resin/carbon nano tube are preparation from 0.20 to 0.50 wt% with NH₂DWCNT and the composition of epoxy resin is 52 wt% of resin, 47 wt% of hardener and 1 wt% of catalyst.

2.3.2 Materials properties

The carbon content of leaf spring is 0.90 to 1.0% carbon.. The properties are high strength as well as load carrying capacity.

2.3.3 Carbon / graphite fibers

The benefits are greater strength including modulus as well as low coefficient of thermal expansion as well as high fatigue strength.

2.3.4 Glass fibers

It is available with low cost than other materials. It possesses high strength, more chemical resistance as well as better insulating properties. It has some disadvantages There disadvantages are low elastic modulus with poor adhesion to polymers, low fatigue strength and high density, which increase weight as well as size. Also form crack.

3 Results and discussion

Software namely CATIA V5 is utilized for modeling the proposed with UUID (Universal Unique Identifier) back up. It has 128 bit capacity to assign object within the DCE i.e. Distributed Computing Environment cell for unique. The schematic view of Composite Leaf Springs is shown in Figure 4.



Figure 4: Schematic view of Composite Leaf Springs

During design of spring structure for determining characteristics of vibration should be considered using model analysis. It further more acts on initial point for next additional dynamical and analytical information like harmonic response to entire transient of dynamic analysis. It is one of the basic analysis and CATIA V5 is a more computational and time savings than the other statically analysis. Figure 5 illustrates levels of stress on the tube of rear axle at the critical point.

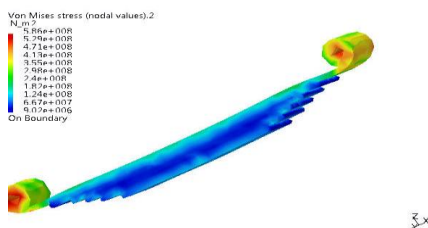


Figure 5: Stress levels on the rear axle tube at the point of critical locations

Table 1 and 2 are showing materials of spring and its elements qualities. In the techniques of numerical the major modification is an additional step named as mesh generation. It is the technique which is used to divide complex model with minor elements which develop solvable in the situation at very complex. The following

details are the process terminology to software. This FEM method shows very clearly with sensitive of the stiffness of the spring bush with stress level at the center and considering the optimum value of the components of the rear axle to reduce the stresses. The various spring bushes and its stiffness are the critical place of tube of rear axle.

A result confirmation that the levels of stress levels become improve at the stiffness lower reason of vibration of the spring on the shackle fitting so maximum stiffness is considered. However reason for the production constrain it is not possible for making bush along with stiffness 300Kg/mm therefore cup washer has been designed for getting more assembly stiffness at the direction of lateral direction even with minimum shore of bush with hardening rubber.

Table 1: Materials and its qualities

ELEMENT QUALITY:

Criterion	Good	Poor	Bad	Worst	Average
Stretch	5151 (98.45%)	81 (1.55%)	0 (0.00%)	0.175	0.572
Aspect Ratio	4188 (80.05%)	1008 (19.27%)	36 (0.69%)	6.991	2.163

Materials.1

Material	Carbon Epoxy 28
Young's modulus	70N_m2
Poisson's ratio	0.25
Density	1.6kg_m3
Yield strength	110N_m2
Coefficient of thermal expansion	28_Kdeg

Primarily process of analysis has been done with the whole vehicle model that contains of rear axle, spring as well as its bushes and its frame to get the

effect of all parts on stress level of the rear axle. Due to the minimum reduction of this model developing and correlating with the entire vehicle model for giving minimum values of the stresses for making various iterations for designing the effect related to the cost of the rear axle with reducing time has been tabulated in Table 2.

Table 2: Stress iteration and cost effective with time reduction

Value	Dof	Node	x (mm)	y (mm)	z (mm)
7.3801e-003	Tx	1640	1.7976e+001	7.5326e+000	-2.6884e+001
2.2664e+000	Ty	1407	9.0488e+000	4.3366e+001	-2.2283e+001

Minimum pivot

Value	Dof	Node	x (mm)	y (mm)	z (mm)
1.6900e-002	Tz	1640	1.7976e+001	7.5326e+000	-2.6884e+001
2.8605e-002	Ty	570	2.0250e+001	-5.5160e+000	-3.5247e+001
3.6091e-002	Tz	570	2.0250e+001	-5.5160e+000	-3.5247e+001
4.0261e-002	Tz	537	-2.4967e-001	1.6414e+001	-2.2752e+001
4.2128e-002	Ty	537	-2.4967e-001	1.6414e+001	-2.2752e+001
4.4428e-002	Tz	773	2.0000e+001	-9.5699e+001	1.4136e+001
4.4583e-002	Tz	1425	5.3128e+000	6.0764e+001	-2.1136e+001
4.8391e-002	Ty	773	2.0000e+001	-9.5699e+001	1.4136e+001
4.8448e-002	Ty	528	-1.4967e-001	5.0648e+000	-2.0160e+001

The outline of composites supports for designing a superior system of suspension including better ride quality and could be achieved without compensate of excess cost and quality as well as reliability. The relationship with the specific strain energy could be expressed as it has well known and the springs are designed for absorbing and furthermore energy storage and release with slowly. The ability of storage capacity of strain energy absorption and ensures the very comfortable system of suspension for automobile vehicles.

4 Conclusion

The proposed leaf spring gives huge amount of weight reduction at the same time strong enough using single composite including design. It is illustrated that the proposed designs with simulation stresses have more strength of the material which is satisfying the maximum stress failure criterion.

From the static analysis results it has been noted that vonmises stress of steel is 352.917 MPa, stress of E-glass / Epoxy is 178.356 MPa. This composite mono leaf spring reduces the weight nearly 84% of EGlass/Epoxy.

From fatigue analysis results, usage factor of E-glass / Epoxy has very minimum when comparing with steel. So, it is a benefit for replacing steel leaf spring using E-glass/Epoxy.

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