INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

COMPARATIVE ANALYSIS OF STEEL LEAF SPRING WITH FABRICATED FRP SPRING USING ANSYS

Rajan P [1], Salman Faris, N Vigneshwaran, and N Vinoth kumar E
1Assistant Professor, Department of Mechanical Engineering,
Agni College of Technology, Chennai, Tamilnadu, India
Email: rajan.mec@act.edu.in

Abstract: In the current scenario the Automobile industry majorly looks for weight reduction and thereby improving efficiency of the vehicle. The Leaf spring is one of the essential component of a vehicle suspension system. The main aim of this project is to design, Analyze and fabricate a composite leaf spring by Hand layup process. The ultimate purpose is to reduce weight and increase the strength of the leaf spring. An alternative advanced material (E-Glass Fibre) is used as the reinforcing material. The E glass fibre has made it possible to reduce the weight of leaf spring without any reduction of load carrying capacity. By means of weight reduction. We can achieve better stability and improve efficiency of the vehicle. Hand layup process was used to prevent crack and aging of composite material. Through Ansys software modelling and analysis of leaf spring was done. The load carrying capacity of the fabricated FRP Spring was tested in the UTM machine. The Fatigue analysis was carried out with the help of hydraulic fatigue testing machine. The test results of frp spring was compared with existing steel spring of same dimensions. Based on the results, the FRP Springs were found to have higher strength to weight ratio, High impact energy absorption, and longer product life and therefore it is suggested and recommended as a replacement for the existing steel leaf spring of the vehicle suspension system.

Keywords: E-Glass fibre, composites, leaf spring, Deflection

1 Introduction

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. 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 unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. [1]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. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs. The composite material offer opportunities for substantial weight saving but not always be cost- effective over their steel counterparts[6].Considering several types of vehicles that have leaf springs and different

Loading on them, various kinds of composite leaf spring have been developed. In some designs the thickness and width of the spring are fixed along the longitudinal axis. Merits of composite leaf spring.

- Reduced weight.

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

- Due to laminate structure and reduced thickness of the mono composite leaf spring, the overall weight would be less.
- Due to weight reduction, fuel consumption would be reduced.
- They have high damping capacity; hence produce less vibration and noise.
- They have good corrosion resistance.

The main problem in the automotive industry is weight of the car whereas increasing the strength and efficiency of automobile. Multi leaf spring creates problems such as producing squeaking sound, fretting corrosion there by decreasing the fatigue life [2]. Composite materials are one of the material families which are attracting and being solutions of such issue. The Automobile industry has shown great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials have high strength to weight ratio and good corrosion resistance properties.

Due to strength and stiffness, high temperature resistance, fatigue strength and other properties, composite materials are superior to all other known structural materials. Because of these superior properties of composite materials, the weight problem of automobile will be reduced by the development of leaf spring using hybrid composite materials. The desired combination of properties can be tailored in advance and realized in the manufacture of a material.

To conserve natural resources and economize energy, weight reduction has been the focus of automobile manufacturers in the present scenario. Weight reduction achieved primarily by the introduction of better material, design optimization and better manufacturing processes Suspension is the term given to the system that is an integral part of different mechanical components, which are springs, shock absorbers and linkages that connects a vehicle to its wheels. Suspension systems provides the following purposes contributing to the car s road holding/handling and braking for good active safety driving pleasure and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations. These goals are generally at odds, so the tuning of suspensions involves finding the right compromise.

It is important for the suspension to keep the wheel in contact with the surface as much as possible, because all the forces acting on the vehicle transmitted through the contact patches of the tires. The suspension protects body of the vehicle from damage and wear, and cargo or luggage may protect from damage. The primary function of the suspension system is to isolate the vehicle structure from shock and vibration that results from irregularities of the road surface. A spring, is characterized as an elastic body: its function is to distort during loading then recover to its original shape during unloading. In addition, it can be twisted, pulled, or stretched corresponding to loading directions [5]. All these effects may be recovered to the original shape during unloading.

The overall purpose of a leaf spring is to provide support for a vehicle. It also provides for a smoother ride absorbing any bumps or potholes in the road. Leaf springs are also used to locate the axle and control the height at which the vehicle rides and helps keep the tires aligned on the road. Because of its benefits, leaf springs are in high demand. Casual transportation is just one of the ways leaf springs have contributed to our transportation industry. These days, leaf springs are more popular with heavy commercial vehicles like trucks, SUVs, and vans.

MATERIALS AND ITS PROPERTIES

Rovings consist of straight continuous glass fiber strands or bundles of about 200 filaments; the number of strands depends on the end use, and these may be several kilometers long % uniaxially oriented fibers. Chopped Strand Mat (CSM) is a random fiber mat that provides equal strength in all directions and is used in a variety of hand lay-up and open- mold applications.[3] Chopped strand mat is produced by chopping continuous strand roving into short 1.5 to 3 inch lengths and dispersing the cut fibers randomly over a moving belt to form a “sheet” of random fiber mat.

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

2. Fabrication

Hand layup process Hand lay-up is the simplest method used for producing reinforced plastic laminates. Capital investment for hand layup processes is relatively low. In hand layup process (otherwise known as wet layup), high solubility resin is sprayed, poured, or brushed into a mold. The reinforcement is then wet with resin. The reinforcement is placed in the mold.

Depending upon the thickness or density of the reinforcement, it may receive additional resin to improve wet out and allow better drape ability into the mold surface. The reinforcement is then rolled, brushed, or applied using a squeeze to remove entrapped air and to compact it against the mold surface.

First the fibres (roving's and CSM) are cut into required sizes as per dimensions of leaf spring The wax polish is applied over the profile of leaf spring. This is applied for easy removal of frp leaf spring from the profile. After 39 applying within 5 minutes the applied wax polish is rubbed away from the profile. This is done because the wax polish is sticky, if it remains as a sticky over the profile it becomes another problem for removal of frp. So, just to the have a free removal contact the wax polish is applied over the profile. Releasing agent is necessary before doing the fabrication process as it helps the component to get released out of the mandrel easily without damaging the mandrel or the component fabricated. In the fabrication of composite leaf spring, plaster of paris is applied on the steel mandrel to protect the mandrel from damage. Wax polish is applied on the Plaster of Paris to get a smooth finish and for easy removal of the composite leaf spring. Apply a poly vinyl to form a smooth surface of FRP leaf spring. After applying wax polish and poly vinyl allow to dry for certain period of time. • A mixture of epoxy resin (Ly556) and hardener (Hy951) is prepared for 1kg of resin, 100 ml of hardener is used, until and unless the hardener is mixed with the resin, the resin remains in the liquid phase only. The hardener Hy951 is used for epoxy resin of grade Ly556 to harden the resin, by mixing 100ml of hardener in 1 kg of resin the hardening time of resin hardener mixture is 30 minutes.

Suppose we mix the hardener more quantity in the resin the time period for hardening the resin hardener mixture reduces. Now the Resin Hardener mixture is applied over the leaf spring profile. Depending upon thickness to be formed, Respective number of alternative layers of fiber is to be used.We used rovings of 0.75mm thickness and CSM of 0.38mm. To form a thickness of 8mm, we used 7 layers of rovings and 7 layers of CSM fibers. First the CSM layer is places over the resin coating on profile. After that again resin coating is applied over the CSM layer which is placed over the profile. Next the rovings layer is placed over the resin coating which is applied on CSM. The procedure is repeated till the required thickness is obtained. All the uni-directional roving fiber layers and CSM fiber layer which are cut using the template are arranged one over the other till 10 layers. Finally the wax polish is applied over the glass cloth and placed over the FRP leaf spring made on profile and place small weights over it to have a proper contact between and each layer of fiber to get cured and hardened. Curing means allowing hardening and forming a stiff contact between layer and layer. Removal of spring approximately 30minutes is required for resin setting and the composite leaf spring is removed from the mandrel without damaging the component.

FIG 1: Roving glass fibre FIG 2: Handlayup method

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

Leaf spring material	= structural mild steel
No of leaves	= 5
Length of master leaf , 2L	= 950 mm
Length of 3rd leaf	= 750 mm
Length of 4th leaf	= 520 mm
Length of 5th leaf	= 320 mm
Width of leaves , b	= 50 mm
Thickness of leaves, t	= 6 mm
Inner eye diameter , d	= 31 mm
Outer eye diameter , D	= 43 mm

The composite leaf spring removed from the mandrel has the same dimensions as that of the steel leaf spring. Trimmimg and finishing generally we can remove the FRP leaf spring from the profile used, after 3 hours from the time of completion of leaf spring. After removing the FRP leaf spring from the profile, it should be cutted to proper shape of leaf spring with the help of hacksaw blade. The coarse teeth blade is used. Sharp edges produced during the fabrication process are removed by trimming them using a Grinding cutting tool. Surface finish is produced on the component using grinding machine. After cutting the leaf spring, the grinding operation is carried over leaf spring for the smooth finishing. For grinding the 36 grade 5 inch sand paper is used. Then the drilling is carried out over the leaf springs for fixing the center bolt. The sensitive drilling machine is used for drilling the hole of 10mm diameter for accommodating the center bolt.

INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

3 Design calculation

S.No	Property	Symbol	Value	Unit
1	Young's modulus	E	183.4	GPa
2	Poisson's ratio	μ	0.3	No unit
3	Density	P	2540	Kg/m^3

S.No	Property	Symbol	Value	Unit
1	Young's	E	183.4	GPa
2	Poisson's ratio	μ	0.3	No unit
3	Density	P	2540	Kg/m^3

Effective length of a leaf spring, 2L= 950 mm

L = 475 mm

Mass capacity of omni= 800 kg

Assume, factor of safety = 1.6

Total weight= 800 × 1.6 × 9.81

= 12556.8 N

Since, the vehicle is four wheeler a single leaf spring corresponding to one of the wheels take up one fourth of the total weight. Then,

Load on each wheel, W = 12556.8/4

= 3139.2 N

Load on each eye of the spring is = 3139.2/2

= 1569.2 N

Bending stress,

$$\sigma = \frac{6WL}{Nbt^2}$$
$$= \frac{6 \times 1569.2 \times 475}{5 \times 50 \times 6^2}$$
$$= 497.04 N/mm^2$$

$$\text{Deflection, } y = \frac{4WL^3}{Ebt^3}$$
$$= \frac{4 \times 1569.6 \times 475^3}{183.4 \times 10^3 \times 50 \times 6^3}$$
$$= 27.4\text{mm}$$

Weight calculation of leaves

Density of steel, $= 7850\text{kg/m}^3$

Density of e glass, $= 2540\text{kg/m}^3$

Weight of a leaf, $W = \rho V g$

Where, $V = 1 \times b \times h$

$$\text{weight of leaf spring } 1_a W_1 = 7850 \times (950 \times 50 \times 6) \times 10^{-9} \times 9.81$$
$$= 21.84\text{N}$$
$$\text{Weight of leaf } 2, W_2 = 7850 \times (900 \times 50 \times 6) \times 10^{-9} \times 9.81$$
$$= 20.79\text{N}$$
$$\text{weight of leaf } 3, W_3 = 7850 \times (750 \times 50 \times 6) \times 10^{-9} \times 9.81$$
$$\text{Weight of leaf } 4, W_4 = 7850 \times (520 \times 50 \times 6) \times 10^{-9} \times 9.81$$
$$= 11.55\text{N}$$

$$\text{Weight of leaf } 5, W_5 = 7850 \times (320 \times 50 \times 6) \times 10^{-9} \times 9.81$$
$$= 7.39\text{N}$$

$$W = W_1 + W_2 + W_3 + W_4 + W_5$$
$$= 21.94 + 20.79 + 17.33 + 11.55 + 7.39$$
$$= 79\text{N}$$

Weight of leaf 1, W1= 2540 × (950 × 50 × 6) × 10 -9 × 9.81

= 7.10 N

Weight of leaf 2, W2 = 2540 × (900 × 50 × 6) × 10 -9 × 9.81

= 6.72 N

Weight of leaf 3, W3 = 2540 × (750 × 50 × 6) × 10 -99 × 9.81

= 5.60 N

Weight of leaf 4, W4 = 7850 × (520 × 50 × 6) × 10 -9 × 9.81

= 3.73 N

Weight of leaf 5, W5 = 7850 × (320 × 50 × 6) × 10 -9 × 9.81

= 2.39 N

Total weight of steel leaf spring,
W = W1 + W2 + W3 + W4 + W5

= 7.10 + 6.72 + 5.60 + 3.73 + 2.39

= 25.54 N

Thus the weight of the leaf spring is 67.6 % reduced by composite leaf spring

TESTING AND ANALYSIS OF STEEL AND COMPOSITE LEAF SPRING

RESULT AND DISCUSSION

The table shows the comparison between the mass of the steel Leaf spring and composite mono-leaf spring.

1. Mass of the leaf spring 79 N

2. Mass of the composite leaf spring 25.54 N

3. Percentage saving in mass 69.6 %

Above table shows that by using composite mono leaf spring 69.6 % saving in mass is achieved.

Load (N)	Deflection (mm)		Max stress (N/mm^2)	
	Steel	Glass fiber	Steel	Glass fiber
1000	59.32	52.94	703.12	200
2000	118.65	105.88	1406.25	400
3000	177.97	158.82	2109.37	600
4000	237.3	211.76	2812.5	800
5000	296.63	264.76	3515.65	1000
6000	355.95	317.58	4218.75	1200
7000	415.28	370.58	4921.87	1400
8000	474.63	423.52	5625	1600
9000	533.93	476.47	6328.12	1800
10000	593.26	529.41	7031.25	2000

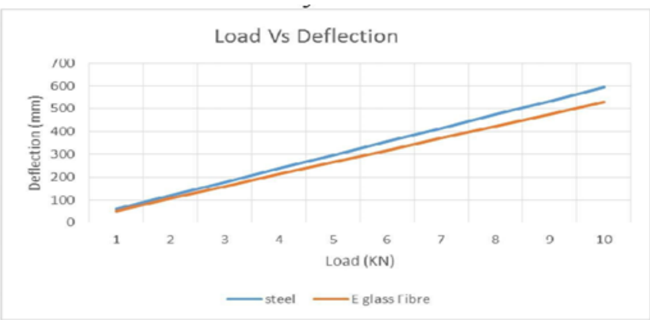


FIG 4.1 Plot of Load vs deflection

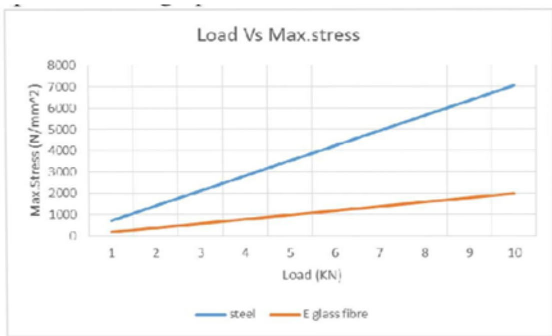


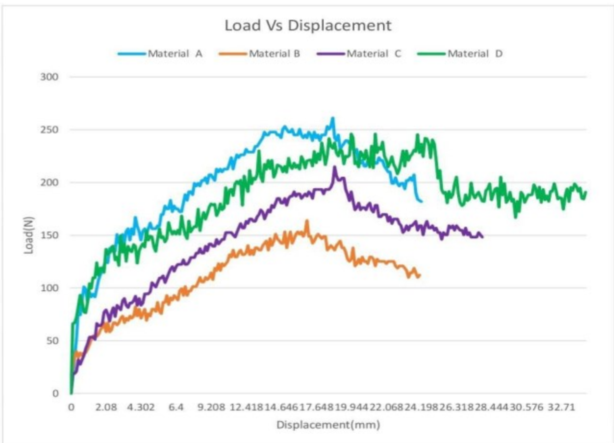
FIG 4.2Plot of Load vs Max stress

5 RESULT AND DISCUSSIONS

Flexural Test results

Material	Maximum Flexural Strength(σt) (MPa)	Standard Deviation	Maximum Flexural Module(E) (GPa)	Standard Deviation (GPa)
A	297.55	8.2	55.25	4.7
B	143.37	8.7	54.06	3.8
C	186.05	7.46	43.35	3.1
D	226.36	7.9	31.52	2

Engineers stress vs Engineering strain for bending test



INTERNATIONAL JOURNAL OF RESEARCH IN MECHANICAL, MECHATRONICS AND AUTOMOBILE ENGINEERING (IJRMMAE)
ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

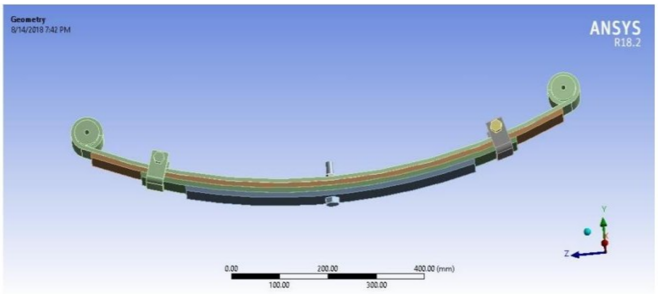


Figure 4-6: The browsed three-dimensional model of steel leaf spring

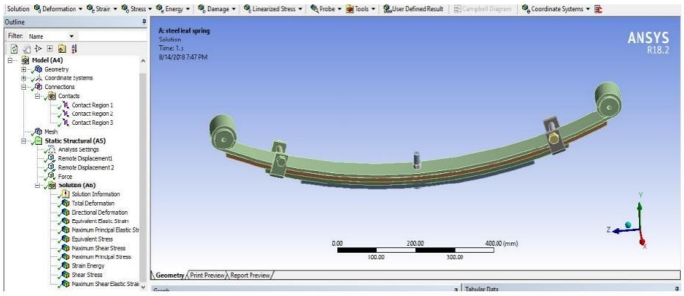


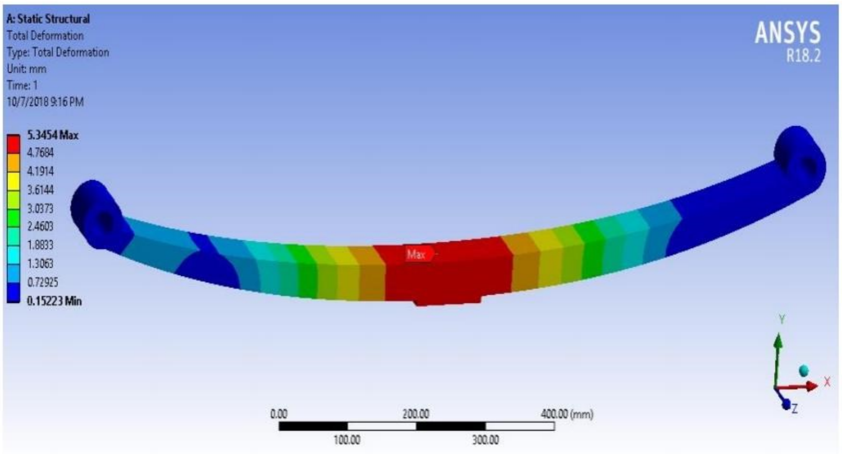
Figure 4-11: Generating solution of steel leaf spring

Finite Element Analysis of Steel and Composite LeafSprings

Static analysis of steel leaf spring

➢ Assumptions:

- Software to be used for ANSYS 18.2
- Model simplification for FEA.
- Meshing size is limited to computer compatibilities.
- Static analysis is considered.



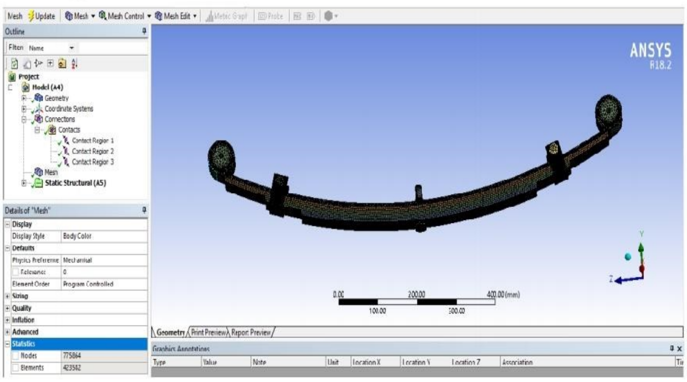


Figure 4-8: Meshed model of steal leaf spring

ISSN: 2454-1435 (Print) | 2454-1443 (online)
Volume 1 Issue 3 – www.ijrmmae.in – Pages 172-184

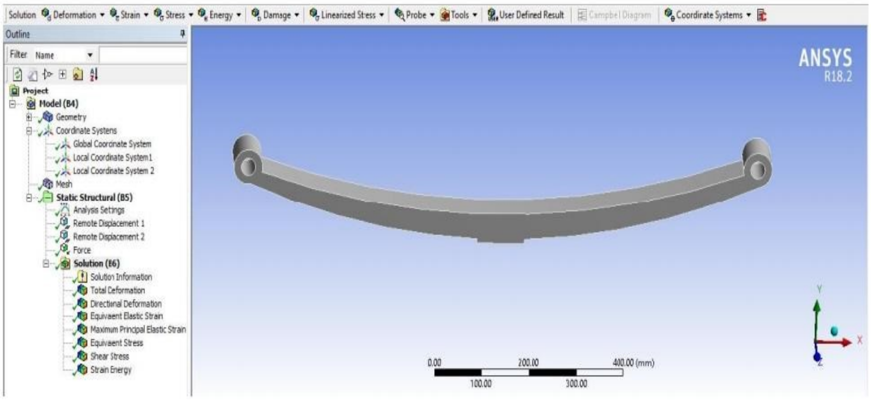
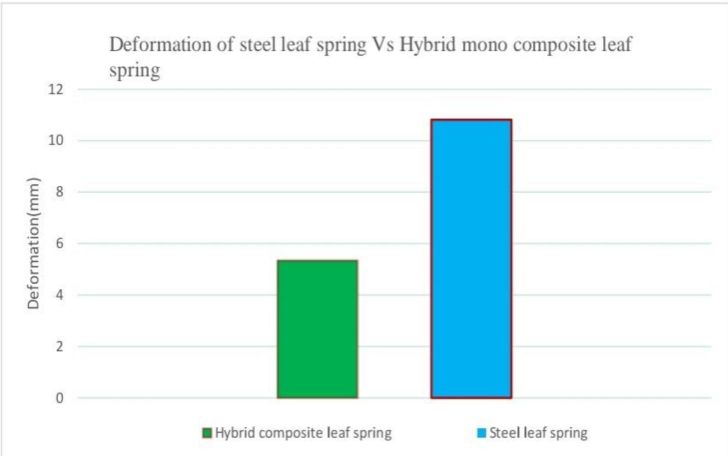
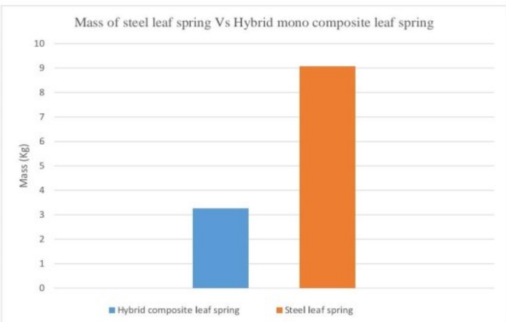
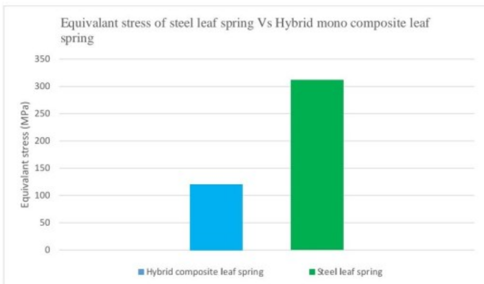


Figure 4-17: Generating solution of hybrid composite leaf spring







Weight reduction

The mass of laminated hybrid composite material leaf spring = 3.24 Kg

The mass of conventional steel leaf spring = 9.06 Kg,

Now the percentage reduction of mass becomes: (9.06-3.24)÷ 9.06 ×100 = 64.23%

The weight of the leaf spring is reduced about 64.23% by replacing conventional steel leaf spring with a laminated hybrid composite material leaf spring.

The smaller mass of the laminated hybrid composite material leaf spring helps to make the vehicle lightweight, so that efficiency, running speed and fuel consumption of the vehicle is improved.

The design and static structural analysis of steel leaf spring and composite leaf spring has been carried out. Comparison has been made between hybrid composite leaf spring with steel leaf spring having same design and same load carrying capacity. The stress and displacements have been calculated analytically as well using ANSYS 18.2 for steel leaf spring and hybrid composite leaf spring. From the static analysis results, it is found that there is a maximum deformation of 10.81.mm in the steel leaf spring and the corresponding displacements in hybrid composite leaf spring is 5.33 mm.

From the static analysis results, the von-mises stress in the steel leaf spring is 311.15 MPa and in hybrid composite leaf spring is 120.65 Mpa. These indicates that composite material A has higher resistance to the applied load.

A comparative study has been made between steel and hybrid composite leaf spring with respect to strength and weight. Hybrid composite leaf spring reduces the weight by 64.23% over steel leaf spring. The size optimization has been carried out for further mass reduction of composite leaf spring. The stresses in the composite leaf spring are much lower than that of the steel. Of course, the reduction is attributed to lower elastic modulus and better geometric (free of notch) characteristics of the composite materials.

6. REFERENCES

[1]. Springer, George S., Kollar, Laszloa P. Mechanics of Composite Structures. Cambridge University Press, New York, 2003.

[2]. AL-Qureshi, H. A. Automobile leaf springs from composite materials, Journal of Processing Technol., 2001.

[3]. Prof. N.P.Dhoshi, Prof .N.K.INGOLE, Prof .U.D.GULHANE. Analysis and Modification of Leaf Spring of Tractor Trailer Using Analytical and Finite Element Method.IJMER. 2002; 1(2): pp-719-722.

[4]. G. Goudah, E. Mahdi, A.R. Abu Talib, A.S. Mokhtar, et al.Automobile Compression Composite Elliptic Spring. IJET. 2006; 3(2): pp-139-147.

[5]. M. M. Patunkar, D. R. Dolas. Modelling and Analysis of Composite Leaf Spring under theStatic Load Condition by using FEA.IJMIE. 2011; 1(1): pp- 1-4.

[6]. Dixit, S.; Goel, R.; Dubey, A.; Ahivhare, P.R.; Bhalavi, T. Natural fibre reinforced polymer composite materials- A review. Polym. Renew. Resour. 2017, 8, 71–78

[7]. Arun Kumar, D.T.; Kaushik, V.P.; Raghavendra, R.P.S. Tensile and impact properties of jute/glass and jute/carbon fiber reinforced polypropylene. J. Polym. Compos. 2016, 4, 35–39.

[8]. W. Ren, B. Peng, J. Shen, Y. Li and Y. Yu, "Study on Vibration Characteristics and Human Riding Comfort of a Social Equipment Cab", Hindawi Journal of Sensors, Vol. 2018, pp. 1-8, Feb 2018.

[9]. W. Shi, C. Liu, Z. Chen, W. He and Q. Zu, "Efficient Method for Calculating the Composite Stiffness of Parabolic Leaf Springs with Variable Stiffness for Vehicle Rear Suspension", Hindawi Mathematical Problems in Engineering, Vol. 2016, pp. 1-12, Feb 2016.

[10]. D. Kumar and A. Kalam, "Design, Analysis and Comparison between the Conventional Materials with Composite Materials of the Leaf Springs", Fluid Mechanics Open Access, Vol. 3, Issue 1, pp. 1-20, 2016.

[11]. Harshit, S, Kumar and A. Verma, "Design and Simulation of Leaf Spring for TATA-ACE Mini Loader Truck using FEM", International Journal of Interdisciplinary Research, Vol. 2, Issue 10, pp. 1421-1427, 2016.

[12]. P. Shinde, P. Talekar, Y. Kamble and S. Desai, "Vibration Analysis of Composite Leaf Spring used for Passenger Car", International Conference on Recent Innovation in Engineering and Management, pp. 762-769, Mar 2016.

[13]. Ramakanth, U.S.; and Sowjanya, K. (2013). Design and analysis of automotive multi-leaf springs using composite materials. International Journal of Mechanical Production Engineering Research and Development, 3(1), 155 -162.

xvii. Ashok, D.; Mallikarjun; and Mamilla, V.R. (2012). Design and structural analysis of composite multi leaf spring. International Journal of Emerging Trends in Engineering and Development, 2(5), 30-37.