PERFORMANCE ANALYSIS OF COMPOSITE C SHAPE SPRING WITH STEEL LEAF SPRING

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ABSTRACT

In present industrial scenario suspension system is the most important parameter in all type of vehicle. The automobile world has keenly emphasized on progressive rate spring unit as an alternative to steel leaf spring, because of its good minor to maximum shock absorption and better part loading properties compared to leaf spring. This project work focuses on designing special C shape spring instead of leaf spring which serves the purpose of protection of the vehicle and comfort to the passengers. C shape and leaf spring are modelled with the help of Pro-E 4.0 software and FEA is done with the help of simulation software Ansys 17.1.FEA reading shows that the C shape spring not only has better bending strength but also deflection compared with existing suspension system. Hence provides better results as a suspension for the car and also use of composite material for C shape spring helps in reducing overall weight of the vehicle.

Keywords: - *Ansys, C shape spring, Deflection, FEA, Stress,*

1. INTRODUCTION

Automobile suspension system are designed to react and to maneuver forces induced by laterally (side loads on tilted vehicle) and longitudinally (acceleration, braking) by tires, to resist roll of chassis so that proper balance of the vehicle is maintained. It is used to keep the tires in minimum load variations. The role of suspension system is vital in vehicles, as it functionally support the vehicle weight. Also, for the occupant smooth riding i.e. cushioning effect. Protect the vehicle from damage and wear. To gain traction it helps in keeping firm contact of the wheels to the ground. Suspension separates the car body from dynamic vibrations and road shocks that can be transferred to the occupants. An advantage of leaf spring over the helical spring is that the ends of spring can easily be guided along the certain path with its deflection. Thus, the spring may act as a structural member and shock energy-absorption device. It can provide all the control for the wheels during acceleration, breaking, corning and general movements caused by the road surface.

Composite Material: Composite materials has superior strength and stiffness than all other known structure materials.

Also, it has high fatigue strength, temperature resistance strength, and other properties. The desired properties can be obtained by manufacturing particular material. Moreover, in this process the material can be shaped as to the form of final products. Composite materials are complex in nature as their components differ respect to each other in their properties, are insoluble or only little soluble and divided by defined boundaries.

From above study it is found that the C shape spring is design with the consideration that it is like a beam. Because of its accuracy ANSYS is selected for the analysis. Constant cross section design Composite C Shape Spring is made by hand layup technique. The specimen is experimentation is done by bending test on universal testing machine. In given references conclude that composite material not only reduces but also gives many other advantages such as flattering noise reduction, increasing ride comfort and zero maintenance.

2. LITERATURE REVIEW

2.1 Review papers

Anil Kumar and Ch. Ramesh did the experimental and analytical comparison in the multi-leaf steel spring and mono leaf spring of composite material. They had done the work on same load carrying capacity and stiffness. They found that at same load the defection in composite material leaf spring was minor to that of steel leaf spring for all composite materials. Value of stresses and deflection were nearly equals to theoretical result.[1]

M. V. Jadhav and Y. R. Kharde performed the experimental work on the leaf spring by using the composite materials like glass fibers C-glass and E-glass instead of the conventional steel material for leaf spring. They perform work on composite leaf spring under static loading condition. They used Pro-E 4.0 design software to make solid design and uses ANSYS 14.0 for the analysis. They found that composite mono leaf spring having constant stress at any thickness point in parabolic type thickness of the spring.[2]

Pankaj Saini and Ashish Goel stated that the comparative analysis between the conventional steel leaf spring and composite material like polymer reinforced with glass fiber i:e Carbon epoxy, E-glass based epoxy and Graphite epoxy used for designing leaf spring. They done the modeling in the Auto-CAD 2012 software and ANSYS 9.0 used for analysis. the static analysis results shows that maximum displacement of conventional steel leaf is 10.16 mm and that for E-glass based epoxy is 15 mm for Graphite epoxy is 15.75 mm and for carbon/epoxy 16.21 mm the values of stress for conventional steel leaf is 67 N/mm and 163.22 Mpa, 663.68 Mpa, and 300 Mpa, for composite material resp. Out of that graphite epoxy has more stress the conventional material steel leaf so E-glass based epoxy leaf spring can be replaced from stress and strain point of view.[3]

A.V. Amrute and R. K. Rathore exchanged the conventional steel spring and used the E-glass based epoxy material leaf spring for experimental analysis of light commercial vehicle. They had done the CAE analysis of three full length leaves or strip. They found that under defined loading condition with same dimension of both leaf springs composite leaf has high strength to weight ratio, high stiffness lower weight reduces to 67.88% compared to leaf spring that means composite material spring is better option for the existing steel leaf spring.[4]

T. B. Sonawane and S. S. Sarode did V-shape and leaf spring comparative FEM analysis. They change the shape of leaf spring into V-shape spring with same width and thickness. Design of both spring is preferred using software Pro-E and using ANSYS the load is applied on both spring material selected for spring is 65si7 (65% Carbon and 7% Silicon). It observed that V-shape spring has more deflection i:e 16% and strain energy as 38.20% than that of steel material leaf spring from observation it find that V-shape spring can used only for part load condition only.[5]

3. OBJECTIVES

1. FEA and Experimental analysis of E-Glass/Epoxy Composite C shape spring.
2. Evolutions of stress value at different location for E-Glass/Epoxy C shape spring.
3. Evolution of greater load carrying capacity of E-Glass/Epoxy C shape spring compared with existing EN47 steel leaf spring.
4. Comparison of FEA and Experimental analysis results of E-Glass/Epoxy Composite C shape spring.

4. MATERIALS

4.1 Selection of Materials

Carbon, Kevlar, Glass etc. are commonly used fiber material. Selection of the glass fiber based on cost impact and strength required. The glass fibers are classified as E-glass, C-glass and S-glass. The C-glass fiber gives excellent surface finish. S-glass fiber gives very high modular strength, important in aeronautic industries. The E-glass fiber is nothing but a high quality glass. It is standard reinforcement fiber which satisfies mechanical property requirements. Hence, E-glass fiber is perfectly suitable for this application.

Fiber reinforcement plastics (FRP) are made from different resins like polyester, vinyl ester, and epoxy resin. Out of all resins, epoxies bears better mechanical properties and high inter-laminar shear strength. Hence, epoxide is perfectly suitable for given application. Epoxy resins with hardener pairs are classifieds, based on their mechanical properties.

Out of all, epoxy resin selected grade is Dobeckot 520 F and hardener grade used for given application is 758. Dobeckot 520 F is an epoxy resin without solvent. In this hardener 758 is cured into hard resin. Hardener 758 is a polyamine with low viscosity.

4.2 Design Selection

Types of spring design

1. Keeping Thickness Constant, Variable Width
2. Keeping Width Constant, Variable Thickness
3. Keeping Design of Cross-Section Constant

E-glass fibers are reinforced with Dubeckot 520F. Epoxy resin which chemically belongs to epoxide family serves as the matrix material. Commonly known as Bisphenol a Diglycidyl Ether. Hardener and low temperature curing epoxy resin are mixed in to each other in ratio of 1:10 by weight as recommended. The hardener and the epoxy resin are supplied by Dr. Nano NIC Ltd. E-glass fiber with epoxy resin has modulus of elasticity 53800 MPa and 17900 MPa respectively and has density of 2.6x10-6 kg/mm^3, 1.1x10-6 kg/mm^3 respectively. Weight percentage of E-glass fiber in composite is 60% for the samples.

5. METHODOLOGY

5.1 Analytical (Design of spring)

Leaf spring is considered first and designed as follows. Here, Weight and initial design data of measurements of "SWIFT DEZIRE" 4 wheeler.

Taking factor of safety (FOS) = 1.32
Number of full-length leaves (nf) = 1
Gravitational acceleration (g) = 9.81 m/s^2
Vehicle weight= 837 kg [6]
Load carrying capacity Max. = 1200 kg
Combined total weight= 837 + 1200 = 2037 kg;
Combined total weight = 2037 x 9.81 = 19982.97 ~ 20000
As the vehicle has 4-wheels, each leaf spring takes up 1/4th of the total weight.

$\therefore$ 20000/4 = 5000 N

Here we have considered the Quarter Car Model for suspension
But, 2F = 5000 N

$\therefore$ F = 2500 N i.e. F = 254.84Kg

5.1.1 Analytical calculation for Steel Leaf Spring

The important aspect to understand is the force acting on the leaf spring and which is diagrammatically indicated as below.

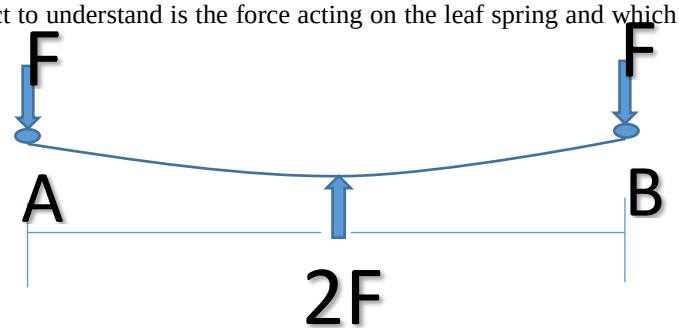

Fig. 5.1 Diagrammatic representation of loading condition of steel leaf spring

Table 5.1 Properties and Dimension of Leaf Spring

Sr. No.	Parameter	Value
1	Straight length (2L)	800 mm
2	Total length of the leaf	890 mm
3	Leaf thickness (t)	15 mm
4	Leaf width (b)	60 mm
5	Camber in mm	110 mm
6	No. of graduated leaves	0
7	Density of leaf material EN 47	7800 kg/m^3
8	Modulus of elasticity (E)	2.1x10^5
9	Tensile strength	1158 Mpa
10	Yield strength	1034 Mpa
11	Poisson's ratio	0.3

Deflection of Leaf spring

$$\delta = \frac{4FL^3}{Exbxt^3} \quad (1)$$

Bending Stress of Leaf Spring

$$\sigma_b = \frac{6FL}{bxt^2} \quad (2)$$

From the given formulae we can find out different values of stress with deflection for the leaf spring which are tabulated as follows.

Table 5.2 Analytical Readings **o**f Leaf Spring

Sr. no.	Central load	Cantilever load	Deflection (mm)	Stress N/mm^2
1	5000	2500	15.05	444.44

5.1.2 Analytical calculation for Composite C Shape Spring

From the material point of view a unidirectional E Glass/Epoxy Resin composite material is selected. It is selected due to its relative advantages stated in the literature review above, mainly high strength to weight ratio and high

capacity of storing strain energy in the longitudinal direction of the fibers. The diagrammatic representation of the C shape spring is given as follows.

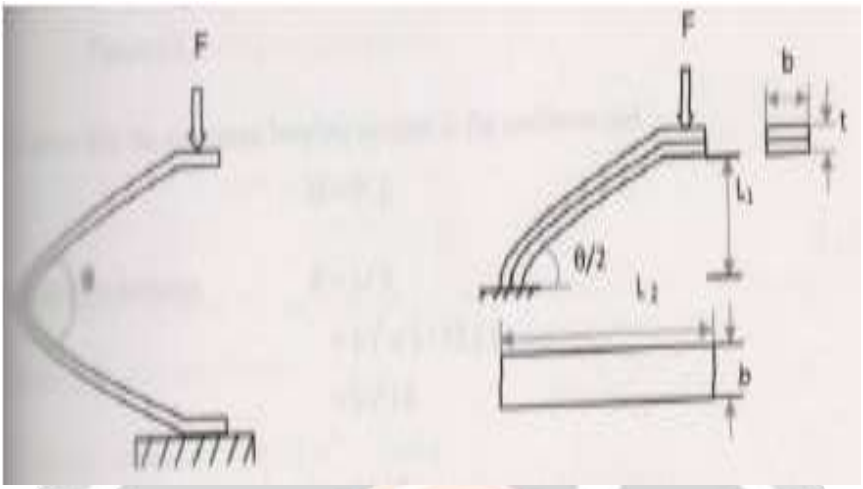

Fig. 5.2 Diagrammatic representation of loading condition and dimensions of composite c shape spring

Here, weight and force acting on V-spring is taken same as for leaf spring and design data or dimension of V-spring as follows.

Table 5.3 Properties and dimension of c shape-spring

Sr. No.	Parameter	Value
1	Straight length (L_1) in mm	440
2	Total length of C-shape spring in mm	890
3	Thickness at end (t_1) in mm Thickness at center (t_2) in mm	10 30
4	Leaf width at end (b_1) in mm Leaf width at center (b_2) in mm	62 50
5	Total length between C-ends in mm in free condition	180
6	Density of leaf material E Glass/ Epoxy (kg/mm^3)	2.6×10^{-6}
7	Young's modulus in fiber direction, E1 (MPa)	39000
8	Young's modulus in transverse direction, E2 (MPa)	17900
9	Shear modulus, G12 (GPa)	8960
10	Tensile Strength in the fiber direction, (MPa)	1100
11	Compressive Strength (MPa)	515
12	Poisson's Ratio	0.217

Deflection of C shape spring

$$\delta = \frac{FL^3}{3ExI} \tag{3}$$

Bending Stress of C Shape Spring

$$\sigma_b = \frac{6FLxsin\theta}{bxt^2} \tag{4}$$

From given formulae we can find out different values of deflection and stress for the C shape spring which is tabulated.

Table 5.4 Analytical Readings **o**f C-Shape Spring

Sr. No.	Cantilever load (N)	Deflection (mm)	Stress (N/mm2)
1	3296.16	35.34	48.13

6. FINITE ELEMENT ANALYSIS

Modelling of leaf and C shape spring are done with the help of Pro-E 4.0 software and the simulation are done with the help of Ansys 17.1 software. Procedure followed in FEA are:

1. Domain discretization.
2. Applying Boundary conditions.
3. System equations formation.
4. System equations solution.
5. Post processing the results.

Fig. 6.1 Model of EN47 Leaf Spring in Pro-E 4.0

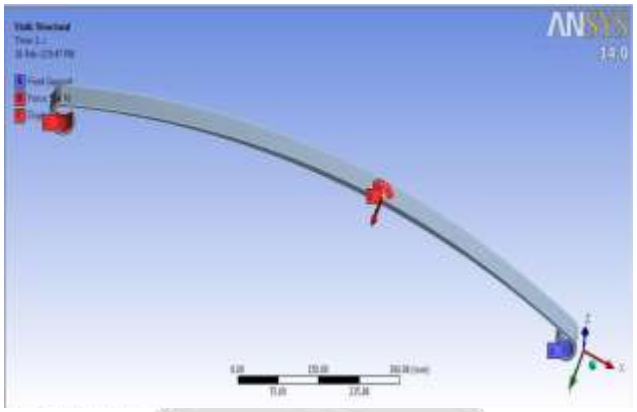

Fig. 6.2 Boundary Conditions and Loading for EN47 Leaf Spring

Fig. 6.3 Meshing of EN47 Leaf Spring

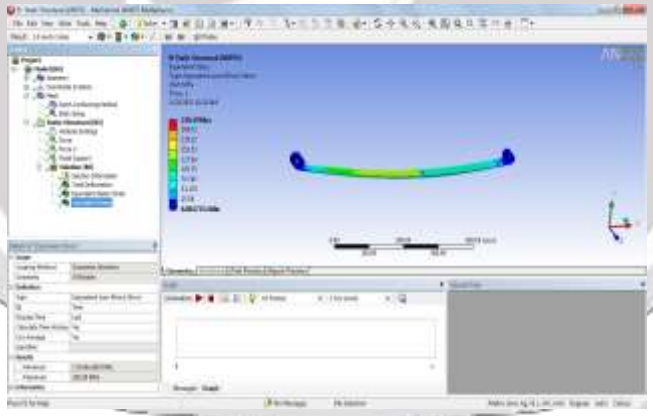

Fig. 6.4 Equivalent Von Mises Stress for EN 47 Leaf spring

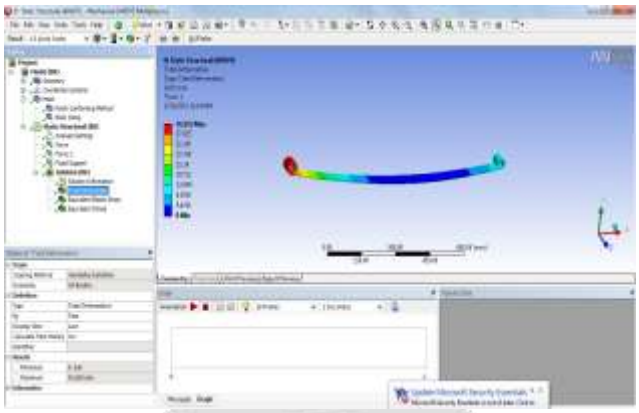

Fig. 6.5 Total Deformation of EN47 Leaf spring

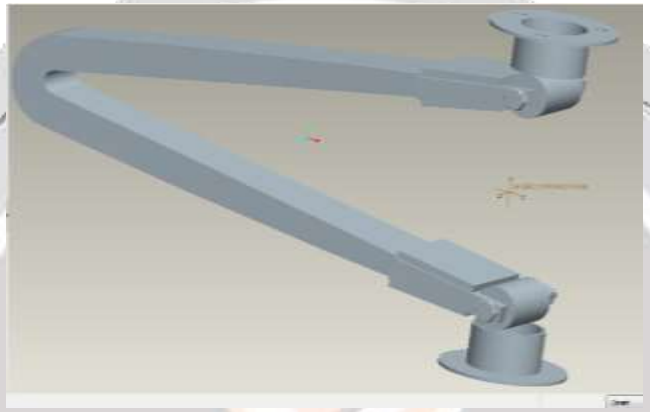

Fig. 6.6 Model of Composite C Shape Spring in Pro-E 4.0

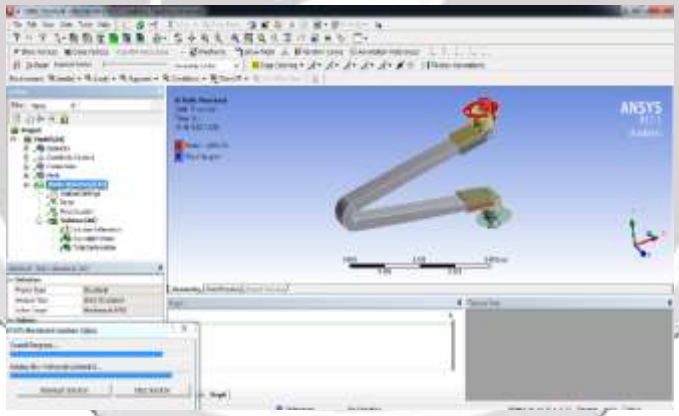

Fig. 6.7 Boundary Conditions and Loading of Composite C Shape Spring

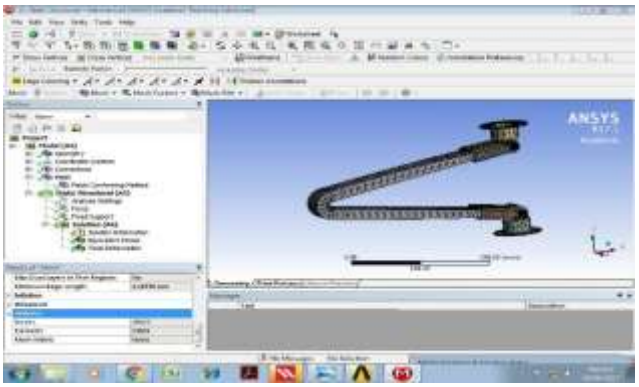

Fig. 6.8 Meshing of Composite C Shape Spring

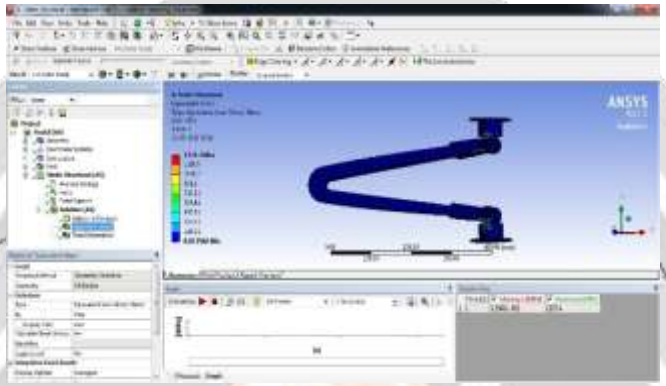

Fig. 6.9 Von Mises Stress for Composite C Shape Spring

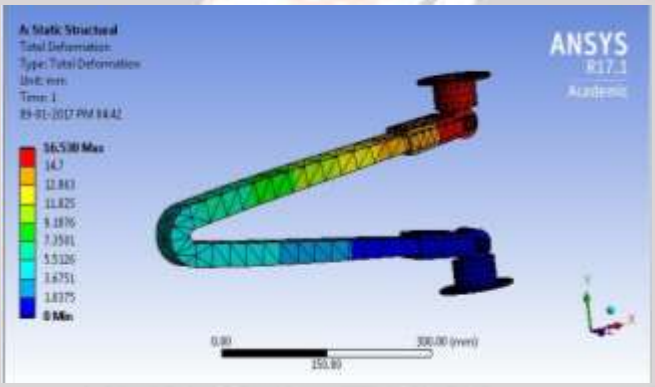

Fig. 6.10 Von Mises Stress for Composite C Shape Spring

Table 6.1 FEA Readings **o**f Leaf and C-Shape Spring

Load N	Leaf Spring (EN 47)		C Shape(E Glass/Epoxy)	
	Deflection (N)	Stress (N/mm^2)	Deflection (N)	Stress (N/mm^2)
3296	39	805	45	18

The force in z-axis doesn't produce any displacement. In FEA because of forces in y and x axis stress was created. Static stress values variation is quite high because spring's starting position is different than in the FEA. In the FEA, spring deformation is same to ideal deformation. The deviation between analytical and FEA results can be considerate acceptable. Where up to load of 3296.16N where deflection and stress value of EN47 and E-

Glass/Epoxy leaf spring 805Mpa and 18Mpa for analytical reading and 444.44MPa and 48.13MPa for FEA and experimental reading shows stresses in E-Glass based Epoxy leaf spring lower as compare to EN47 leaf spring.

7. CONCLUSION

The analytical, FEA analysis of statistical behavior of E glass fiber with Epoxy resin based composites leads to the following conclusions:

1. E-Glass fiber with Epoxy resin Composite C shape spring withstands for greater load carrying capacity as compared to EN47 material leaf spring for the similar conditions and result also in agreement with published results.
2. The analytical, FEA results were compared and showed good agreement.
3. Deflection and stresses of EN47 steel leaf spring and E-Glass/Epoxy C shape spring are varying and showed E-Glass/Epoxy C shape spring has less stress value under the same static loading condition.

8. REFERENCES

[1] M. M. Patunkar D. R. Dolas "Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA" International Journal of Mechanical and Industrial Engineering, Volume 1 Issue 1-2011, pp-1-4.

[2] Shishay Amare Gebremeskel, "Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle" Global Journal of Researches in Engineering Volume XII Issue VII Version I, 2012, pp-21-30.

[3] R B Charde and Dr. D V Bhope, Investigation of stresses in master leaf of leaf spring by FEM and its experimental verification, International journal of engineering science and technology, ISSN:0975-5462, Vol.4 No. 02 Feb. 2012,pp-633-640.

[4] Mouleeswaran senthil kumar, Sabapathy Vijayarangan, "Analytical and experimental studies on fatigue life prediction of steel And composite multi-leaf spring for light passenger vehicles using Life data analysis" Materials Science, ISSN 1392–1320, Vol. 13, No. 2. 2007, pp-141-146.

[5] Mahmood M. Shokrieh and Davood Rezaei, "Analysis and optimization of a composite leaf spring", Composite Structure 60 (2003), pp-317-325.

[6] Dara Ashok, M.V. Mallikarjun and Venkata Ramesh Mamilla, Design And Structural Analysis Of Composite Multi Leaf Spring, International Journal of Emerging trends in Engineering and Development, ISSN 2249-6149, Issue 2, Vol.5 (July 2012), pp-30-37.

[7] Kumar Krishan and Aggarwal M.L., A Finite Element Approach for Analysis of a Multi Leaf pring using CAE Tools, Research Journal of Recent Sciences, ISSN 2277-2502, Vol. 1, Feb. (2012), pp- 92-96.

[8] M.Venkatesan and D.Helmen Devaraj, Design and Analysis of Composite Leaf Spring in Light Vehicle, International Journal of Modern Engineering Research (IJMER), ISSN: 2249-6645, Vol.2, Issue.1, Jan-Feb 2012, pp-213-218.

[9] Yogesh G. Nadargi, Deepak R. Gaikwad and Umesh D. Sulakhe "A performance evaluation of leaf spring replacing With composite leaf spring", International Journal of Mechanical and Industrial Engineering, ISSN No. 2231 –6477, Vol-2, Iss-4, 2012, pp-65-68.

[10] Kumar Dewangan, Manas Patnaik, Narendra Yadav, "Minimization of Stress of a Parabolic Leaf Spring by Simulated Annealing Algorithm", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, Vol. 2, Issue 4, July-August 2012, pp.457-460.

[11] Kumar Krishan and Aggarwal M.L, Computer Aided Fea Comparison of Mono Steel and Mono Grp Leaf Spring, International Journal of Advanced Engineering Research and Studies, E-ISSN 2249–8974, IJAERS/Vol. I/ Issue II/January-March, 2012, pp-155-158.

[12] Y. N. V. Santhosh Kumar and M. Vimal Teja, Design and Analysis of Composite Leaf Spring, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012, pp-97-100.

[13] Yogesh G. Nadargi, Deepak R. Gaikwad and Umesh D. Sulakhe, "A performance evaluation of leaf spring replacing With composite leaf spring", International Journal of Mechanical and Industrial Engineering, ISSN No. 2231 –6477, Vol-2, Iss-4, 2012, pp-65-68.

[14] Malaga Anil Kumar, T. N. Charyulu, Ch. Ramesh, "Design Optimization of Leaf Spring", International Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 2, Issue 6, November- December 2012, pp.759-765.

[15] Jadhav Mahesh V, Zoman Digambar B, Y R Kharde, R R Kharde, "Performance Analysis of Two Mono Leaf Spring Used For Maruti 800 Vehicle", International Journal of Innovative Technology and Exploring Engineering, ISSN: 2278-3075, Volume-2, Issue-1, December 2012, pp. 65-67

[16] Pankaj Saini, Ashish Goel, Dushyant Kumar, "DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING FOR LIGHT VEHICLES" International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 5, May 2013, pp. 1-10

[17] Ashish V. Amrute, Edward Nikhil Karlus, R.K. Rathore, and "Design and Assessment of Multi Leaf Spring", International Journal of Research in Aeronautical and Mechanical Engineering ISSN (ONLINE): 2321-3051 Vol.1 Issue.7, November 2013, pp: 115-124.

[18] T. B. Sonawane, S. S. Sarode, M. D. Shende, A. P. Ghodake, D. P. Chavan, "Comparative FEM Analysis of V-Shape and Leaf Springs for Improved Suspension with Part Loading Functionality" IOSR Journal of Mechanical and Civil Engineering Volume 11, Issue 1 Ver. V (Feb. 2014), PP 53-57.

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