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Static and Fatigue Finite Element Analysis of Carbon - Epoxy Composite Leaf Spring

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Abstract

A lot of research has been performed on leaf spring of composite material to reduce spring as well as vehicle weight. This research paper represents the general study; and the finite element analysis of carbon epoxy reinforced leaf spring. A possibility of carbon-epoxy reinforced leaf spring of composite has been investigated to replace the steel spring. EN 45 steel rear leaf spring of a commercial vehicle has selected for the present study. Hand layup technique was used to make carbon epoxy reinforced composite leaf spring. Finite element based software ANSYS V16.2 was used to analyze the deflection, stress and fatigue strength of the steel and composite leaf spring. Results show that deflection of the composite leaf spring is more than the deflection of the steel spring and fatigue strength of leaf spring of composite material is more than the desire 100000 cycles.

Keywords: *Carbon epoxy composite leaf spring;Steel Leaf Spring; Finite Element Analysis (FEA);Fatigue Analysis; Static Analysis*

1. Introduction

Replacement of steel leaf springs by composite leaf spring is feasible because composite leaf spring possesses better mechanical properties even with less weight. Four-leaf steel spring of light weight commercial vehicle was examined with ANSYS V16.2 software. The E-glass-epoxy material was utilized for the examination and hand lay-up strategy was used for the manufacture of the spring. Stresses were restricted in the springs and along these lines considered as requirements. Tsai– Wu hypothesis chose as a standard. As per SAE principles leaf spring was viewed as two cantilevers. The leaf spring was inspected under the controlled stacking condition. The diversion of spring, static stacking is 120.7 mm, which is near the esteem 120.4 mm. Eye closes were joined to the spring with the assistance of darted joints or stuck to the spring. Distinctive joint plans were recommended by the manufacturer (Pardeep R., Vikram C.J. and Naveenchadran P., 2012). Steel leaf spring used as a part of the back suspension arrangement of the light vehicles was examined using ANSYS V5.4 program. Stress and diversion confirmed using existing logical and trial solutions. The improvement of fatigue strength by studying the residual stresses in the surface layers through shot peening. Computer aided model of leaf spring was prepared in CATIA and analysed in ANSYS (Shokreih M.M. and Rezeai D.,2003). Cyclic stress curves were determined using axial fatigue machine. After that S/N curves were plotted and laboratory testing was done on a test rig and bending stress was calculated using the formulae (Ravindra P. and Belkar S., 2014). The unpeened and peened material was under shots and each time fatigue life was recorded (Karthik J. P., Chaitanya K. L. and Tara Sasanka C., 2012). Leaf springs are suspension parts and used especially in business vehicles. Exhibiting and examination of composite mono leaf spring (GFRP) differentiated and steel spring by using ANSYS 10.0 software (Patunkar M. M. and Dolas D. R., 2011). The static and exhaustion examination of steel leaf spring and composite multi leaf spring made up of glass fiber sustained polymer were analyzed using life data examination. Exhaustion life of composite was more than that of steel leaf spring (Divagar S., Vignashwar M. and Selvamani S. T., 2016). CAD modeling software was dedicated for the specialized job of 3D-modeling. The model of the multi leaf spring

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structures also includes many complicated parts, which are difficult to make by any of other CAD modeling as well as finite element software. A stress-deflection analysis was performed using finite element analysis (FEA) (Mouleeswaran S. and Vijayaragan S.,2007). The complete procedure of analysis was done using ANSYS-11.
In the present study leaf spring of carbon fiber and epoxy resin was made and after that analysis was done on the ANSYS V16.2 software and Standards - IS 1135: 1995 and SAE HS - J788 were used for the analysis of the spring (Spring Design Manual, 1990).

2. Finite Element Analysis

Finite element based software ANSYS V16.2 was utilized for static and fatigue investigation of steel and carbon epoxy leaf spring. The target of this investigation is to discover the redirection of the leaf spring of steel and leaf spring of composite under given load. Limited component programming was used to discover weakness life of composite spring and steel leaf spring under weariness stack. The correlation consequence of leaf spring of steel with leaf spring of composite offers approval to utilization of the composite leaf spring instead of leaf spring of steel.

2.1 Static Analysis

The rear steel spring of Tata ace was considered as practical application. The dimension of steel spring of material EN45 are length 915mm, width 57 mm and thickness 7 mm. The geometrical modeling of steel spring was prepared in Solid works software. The properties of the EN45 material is given as under in Table 1.

Table 1. Mechanical properties of EN45

Property	Young's Modulus, E (GPa)	Poisson's Ratio	Tensile Strength (MPa)	Density (kg/m^3)
EN45	207	0.266	621	7850

After preparation of geometrical model and application of material properties, the geometrical model of steel spring was divided into small mesh elements. Meshing divide the whole leaf spring into small element parts. The minimum element of size 5 mm was considered for mesh generation as leaf spring contains sharp edges and curves. For the boundary conditions, it is assumed that both ends of leaf spring are designed as eye shape so that both ends are connected to the frame of the vehicle and a simple pin is used to connect leaf spring to the frame of body but it is restricted to translate and rotate in all other directions. So under the static analysis of steel spring, boundary condition are applied as mentioned above, spring is allowed to move only in x- direction when load is applied and all other side are restricted to move. The load is applied on centre of the steel spring and deflection induced in steel spring. The initial load applied on the spring is 1000 N after that 2000N, 3000N, 4000N, 5000 N and full load of 5400 N is applied on the spring to find the deflection. The deflection under full load of 5400 N during finite element analysis is shown in Fig.1. The result of deflection under different loads for spring is given in Table 2.

Load Applied (N)	Deflection in Steel Leaf Spring (mm)
1000	1.82
2000	2.17
3000	2.41
4000	2.63
5000	2.84
5400	3.18

Table 2. Deflection in steel leaf spring

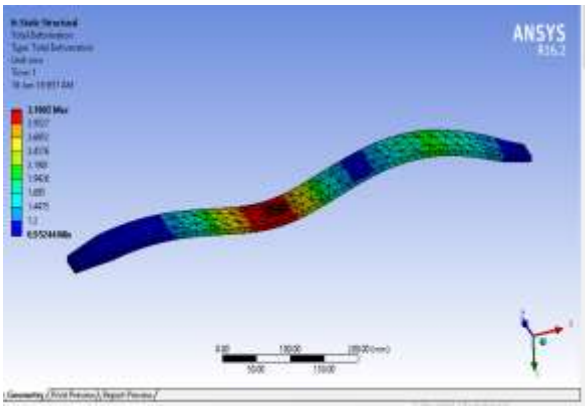

Fig.1. Static analysis of steel leaf spring under full load (5400 N)

For the analysis of leaf spring of composite material under static deflection by finite element method same procedure was adopted as used in the steel spring. The deflection in composite leaf spring under full load of 5400 N is shown in Fig.2. The result of deflection by finite element method of composite spring under different loads is shown in Table

Load Applied (N)	Deflection in Composite Leaf Spring (mm)
1000	2.31
2000	2.64
3000	3.13
4000	3.46
5000	3.85
5400	4.21

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3.

Table3. Deflection in composite leaf spring

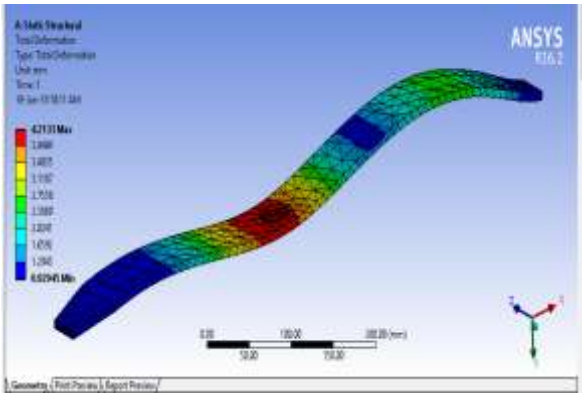

Fig. 2. Static analysis of composite leaf spring under full load (5400 N)

Comparison of results of deflection in leaf spring of composite material and steel show that leaf spring of composite has more deflection than steel leaf spring. Figure 3 shows deflection in composite and steel spring.

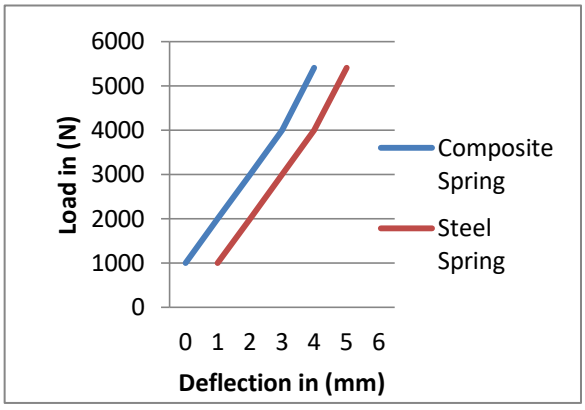

Fig 3. Load deflection curve of steel and composite leaf spring

2.2 Fatigue Analysis

Initially leaf spring is good in service but after long service period may fail due to repeated load on the spring. Fatigue analysis is carried out to find out the material capacity to withstand with the number of cycle without failure during its service time. After static analysis, fatigue analysis was also by ANSYS to find the fatigue strength of leaf spring of composite and steel. For the fatigue analysis of both spring, the same geometry was used in the static test analysis. During fatigue analysis the range of cyclic load was applied from 1000 N to 5400N on spring and result of stress and fatigue life was obtained as shown in the Table 4.

Table 4. Stress in leaf springs during fatigue test

Load Applied (N)	Stress in Steel Spring (MPa)	Stress in Composite Spring (MPa)	Fatigue Life Spring (Cycles)
1000	86.9	52.75	100000
2000	123.40	76.20	100000
3000	151.50	92.02	100000
4000	175.58	109.30	100000
5000	196.98	122.91	100000
5400	205.01	128.11	100000

It was found from the analysis that steel and composite leaf spring has fatigue life of more than 100000 cycles. Fatigue analysis performed on both springs under full load i.e. 5400 N is shown in Fig. 4. and Fig. 5.

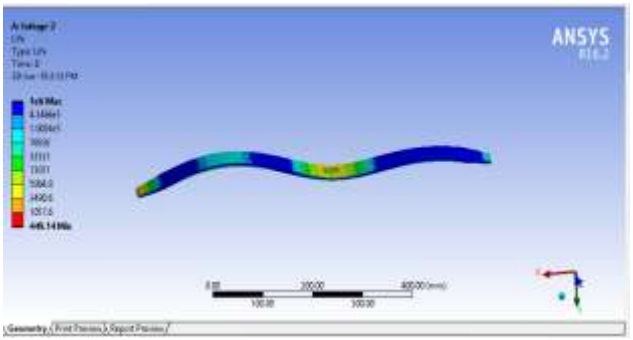

Fig. 4. Fatigue analysis of steel leaf spring under full load of 5400 N

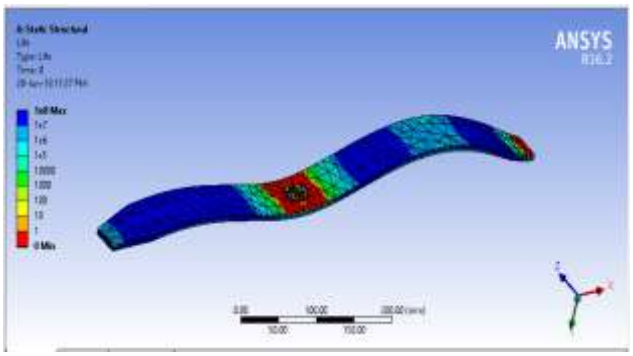

Fig. 5. Fatigue analysis of composite leaf spring under full load of 5400 N

From the analysis of leaf spring of composite and steel material it can be concluded that leaf spring of composite material has less stress as compared to the leaf spring of steel. The comparison curve of stress produced during analysis of leaf spring of composite and steel material is shown in Fig. 6.

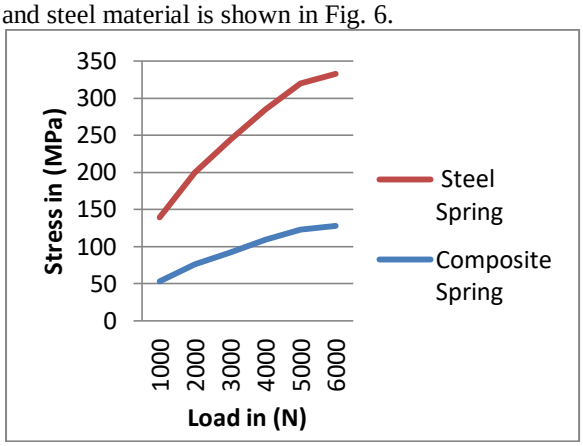

Fig. 6. Stress produced during finite element analysis

3. Conclusions

Carbon epoxy reinforced leaf spring of composite was successfully manufactured by hand-layup technique. Finite element analysis of the carbon-epoxy reinforced leaf spring of composite material and steel spring was successfully carried out under static and fatigue loads. The small difference in deflection result was obtained during the same static load condition. The leaf spring of composite produces less stress as compared to the steel leaf spring. The fatigue-life cycle of leaf spring of steel and leaf spring of composite has obtained life of more than the designed value i.e. 100000 cycles. So, leaf spring of composite can be replaced in place of steel leaf spring with good result expectations.

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