ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

Fatigue Behaviour of Sandwich Composite Material Used in Automotive Leaf Spring

[1] Ramesh Sakhare, [2] Saurabh Bait, [3] Deepak Lambute, [4] Datta Mane, [5] A.S.Bhanage

[1][2][3][4][5] Marathwada Mitra Mandal's Institute of Technology, Pune, India

Abstract--- **In the present work, Sandwich composite structures have a high bending stiffness which make them very suited for automotive leaf spring. Sandwich composite the typical leaf spring configuration of mahindra SUV vehicle is selected for research. The static analysis gives the safe stress and with corresponding pay load .In this reasearch the sandwich composite materials like aluminium alloy (Al 5754 & Al 3003) and carbon epoxy (CFRP) are studied.**

Index Terms— **Sandwich composite, Leaf Springs, Static Test, Fatigue Test**

I. INTRODUCTION

In automotive suspension system, leaf spring components plays an important role. Leaf spring subjected to fatigue load as vehicle travels, particularly at eye point of rear axle. In steel materials leaf system, multi-leaf spring were used for strength, but it reduced the flexibility and also increase overall weight of vehicle. Now days, these steel materials were replaced by mono fiber reinforced composites such as glass/epoxy, carbon/epoxy etc. composites.

The suspension system is the one that helps the vehicle roll on the road at its smoothest best and surmount the irregularities. Springs are elastic bodies (generally metal) that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. .The vehicles need a good suspension system that can deliver a good ride and handling. At the same time, the component must have an excellent fatigue life. Fatigue is one of the major issues in automotive components. It must withstand numerous numbers of cycles before it can fail, or never fail at all during the service period.

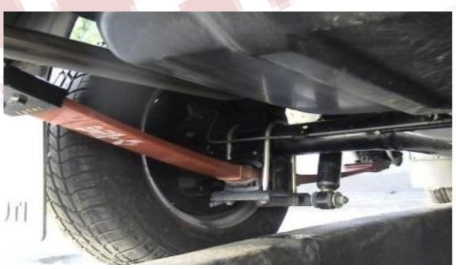


Figure 1: Mono Leaf Spring

A material with maximum strength and minimum modulus of elasticity in longitudinal direction is the most suitable material for a leaf spring; Important characteristics of sandwich composites that make them excellent for leaf spring Fatigue failure is the predominant mode of in-service failure of many automobile components. Fatigue behaviour of sandwich composite materials consisting carbon epoxy and aluminium alloys has been studied.

Stresses in sandwich composite was found to be same or less, in different researches performed earlier. Sandwich composite material can be chosen over steel due to its properties. Moreover according to researches performed earlier it was observed that sandwich composite leaf spring has advantages and better stiffness when compared to leaf spring material. Stresses were lesser for sandwich composite spring, deflection was found to be lesser as compared to conventional material, but stiffness and deflection depends on thickness of the leaf spring, as the thickness increases, the deflection reduces. Analysis performed that stresses sandwich composite leaf spring and weight was reduced to a high extent. In a long run a sandwich composite leaf spring with better mechanical properties and performance.

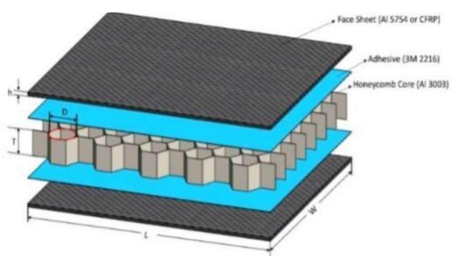


Figure 2: Sandwich composite specimen layers.

A sandwich composite is a special class of composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness

IFERP
connecting engineers... developing research
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 6, Issue 8, August 2021

provides the sandwich composite with high bending stiffness with overall low densty.

The main aim of this research is to design a mono sandwich composite leaf spring (a single leaf that acts as both the master leaf as well as the spring) and prove that it can be used as a replacement for the existing conventional leaf spring (the commonly used leaf spring that has multiple number of leaves).

II. LITERATURE REVIEW

Anand kumar predicted the mono composite leaf spring of MARUTI Omni rear suspension system for strength & weight reduction. The analysis is done by using ANSYS software. The comparison of steel and composite leaf spring was done. They concluded that the results of the analytical & experimental analysis are almost same & they use composite material instead of steel, they have to change dimensions. Here they have changed the thickness stresses & deflection. They concluded composite leaf spring have much low stress & deflection than that of steel leaf spring.composite leaf spring reduced weight up to 80% compare to steel leaf spring [1].

Anil Kumar studied on design optimization of leaf spring. The objective of this paper is to replace the multi-leaf steel spring by three capacity & stiffness. It is possible to reduce the weight of the leaf spring without any reduction on load carrying capacity &stiffness. They concluded that optimize conventional steel leaf spring have weight 23 kg. Composite leaf spring weight is only 3.59 Kg.so weight reduction in 84.40% composite leaf spring can be used on smooth road with very high performance. On rough road condition due to lower chipping resistance failure from chipping of composite leaf spring [2].

Y. N. V. SanthoshKumar, presented Work on design analysis of composite leaf spring. They also discussed that the advantages of composite materials like higher specific stiffness & strength, higher strength to weight ratio. This work deals with the replacement of conventional steel leaf spring with mono composite leaf spring using E-Glass/Epoxy. For this they selected design parameters & analysis of it. Main objective of this work is to minimize weight of composite leaf spring compare to conventional steel leaf spring. The leaf spring was designed in Pro-E & the analysis was done using ANSYS Metaphysics. From these results they observed that the composite leaf spring weighed only 39.4% of the steel leaf springs for the analyzed stresses. it was proved that all the stresses in the leaf springs with good factor of safety. It was found that the perpendicular orientation of fibers in the laminate offered goodstrength to the leaf spring [3].

B.Srikanth Gound presented a leaf spring is which designed & modeled in 3D modelling software Pro-E. Present used material for leaf spring is steel. In this project the material is replaced with composites since they are less dense than steel & have good strength. The composites used are E Glass Epoxy &Aluminium reinforced with boron carbide. Modelling is done in pro/ E. The weight is reduced almost by 267kgs when aluminum reinforced with boron carbide is used & almost by 246kgs when E Glass is used [4].

Yogesh Nikam showed some of the general study on the design, analysis & fabrication of composite leaf spring. Leaf springs are one of the popular suspension components they are frequently used, especially in commercial vehicles. The suspension system included in a vehicle significantly affects the behaviour of vehicle, vibration characteristics including ride comfort &stabilityetc. Many materials are used for leaf spring but it is found that fiberglass has better strength & lighter in weight as compared to steel forleaf spring. In this paper author is reviewed few papers on use of different optional materials & effect of material on leaf spring performance [5].

V.K. Aher predicted the fatigue life of steel leaf spring along with analytical stress deflection calculation. This present work describes static & fatigue analysis of a steel leaf spring of a light commercial vehicle. The non-linear static analysis of 2D model of the leaf spring is performed using NASTRAN solver compared with analytical results. The pre-processing of the model is done by using HYPERMESH software. The stiffness of the leaf spring is studied by plotting load versus deflection curve for various load application [6].

K. Diwarkarstudied on reduction of bending stress & weight of the leaf spring. In this study, composite material is used & flat plates are replaced with tapered plates with uniform cross section. The optimised tapered leaf spring showed better result in bending stress & weight than the conventional leaf spring.the weight of conventional leaf spring is 16.7 kg, weight of tapered Steel leaf is about 18.5 &tapy e-glass leaf spring weight is about 4.7 kg [7].

Shishay Amare described & solves the major issue of vehicle weight though use of composite material E-Glass/Epoxy composite. Their work focuses on constant cross section design, weight reduction & design. The result shows that shear stress in much less than the shear strength t=3mpa & design is safe even for flexural failure. They focus on their work design of leaf spring used in three wheelers [8].

Dev Dutt Dwivedi had done design and analysis of composite leaf spring ANSYS14.5 has been used to conduct the analysis. Static structural tool has been used of

ANSYS. A three layer composite leaf spring with full length leave. E- Glass/ Epoxy material has been used. Conventional steel leaf spring results have been compared with the results obtained for composite leaf spring. A wide amount of study has been conducted in his paper to investigate the design & analysis of leaf spring & leaf spring fatigue life. Results demonstrate that composite leaf spring deflection for particular load is less compared to conventional leaf spring. composite leaf spring is lighter in weight compared to conventional steel leaf [9].

Edward Nikhil Karlus adds some effort to reduce the mass of the leaf spring to perform optimization of the mono parabolic leaf spring with the help their shape parameters taken were mass deflection & the maximum stress, where as the input shape parameters. The optimization of the PLS has been done with the help of adaptive single objective optimization algorithm. The outcome of his work gives better & lighter design for the automotive designer to modify the design. By the reduction of weight & controllable stress & deflection, the mass of optimized carbon- Epoxy composite leaf spring is to lesser than that of steel leaf spring. Which means the proposed new optimized carbon-Epoxy composite material and shape can be used to satisfy the second objective [10].

Dasari Ashok Kumar Observed main aim of the project is to find the effects of replacement of the leaf spring and composite leaf spring made of E-Glass Epoxy is carried out.The analysis is performed in three phases. They are by varying the load applied on the leaf springs, by varying the normal penalty stiffness of contact pair, by varying the thickness of the composite leaf spring [11].

Dr. P. V. Jadhav investigated Design & Analysis of Sandwich Composite Leaf Spring for Hmv. Best technique to reduce weight of the design is to find alternate material, to optimize the shape of the design or to improve manufacturing process used [12].

Sarfaraz Husain investigated the objective is to find the stresses and deformation in the leaf spring via making use of static load on it.the three materials, steel (SUP9), Glass epoxy and Carbon epoxy which are of great interest to the transportation industry.The study in this chapter is subdivided into number of categories on the basic of work done in past.The purpose of this paper is to predict the fatigue life of steel leaf spring along with analytical stress and deflection calculations. To design and analyse a composite leaf spring with different material for an automobile like conventional steel and new carbon epoxy, glass epoxy [13].

Sandeep Bhatta charjee Predictated to review the paper about fabrication and analysis of composite leaf spring. The numerical analysis is carried via finite element analysis using ANSYS software.The use of composite materials for suspension leaf spring reduces the weight of conventional multi leaf steel leaf spring by nearly 75%.This achieves the vehicle with more fuel efficiency and improved riding qualities [14].

Mr.Rathod Jairam The objective of this dissertation is to analyze experimentally and by finite element method the mechanical behavior of composite material used for leaf spring.There are several methods allowing to do so, each having its particular characteristics and applications, depending on the type of system analyzed, the quality of the data that is required, the time that is available for the measurements for instance [15].

Hai Fang predicted innovative steel-GFRP sandwich panel was introduced in this study. Experiments were conducted to investigate the effects of the steel and GFRP facesheets on the overall structural performance in bending.The transformed section method is used for the theoretical calculation of the sandwich panel [16].

III. SPECIFICATION AND MATERIAL PROPERTIES OF LEAF SPRING

Table1: Specification of exiting leaf spring.

Mahindra Modal - SUV300

Parameter	Value
Overall length	1150mm
Lengthof Leaf Spring(eye to eye)	990mm
Thickness (h)	8mm
Width (b)	50mm
No of leaves	1
Centre load	2150kg
Factor of safety	1.33
Kerb weight	1450kg
Gravity	9.813m/s^2

Table2: Mechanical properties of the adhesive, and the Al-5754 and Al-3003 alloys.

Materials	Young's Modulus	Poisson's Ratio	Tensile Strength (MPa)
Al-5754 Face Sheet	70.3 GPa	0.33	245
Al-3003 Core	68.9 GPa	0.33	131

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 6, Issue 8, August 2021

Table3: Mechanical properties of the carbon fiber Reinforced plastic (CFRP) composite.

Mate-rial	E_1 (GPa)	E_2 (GPa)	v12	G12 (GPa)	XT,YT (MPa)	XC, YC (MPa)	S (MPa)
CFRP Face Sheet	3.4	83.5	0.05	6.8	1008	953	125

Static Calculation

The values for static calculation were observed from Murat Yavuz Solmaz [10]. According to this paper Flexural tests were performed in accordance with the ASTM C393 standard at a 1 mm/min loading rate using Shimadzu Universal test equipment with a 250 KN load cell. During three-point bending tests, a load was applied with a 30 mm-diameter cylinder. The span length between the 30 mm-diameter support was 80mm.

The following are the material properties of the given leaf spring. Material = Aluminium alloy Al5754 and GERP

Young's Modulus = 68.9 GPa

Density = 2700kg/m^3

Poisson's ratio = 0.3 and

tensile strength = 1368 MPa

Force calculations

1) Total weight acting downwords = Gross vehicle weight×Gravity

= 2150×9.81

= **21091.5 N**

2) Load on one suspension = 21091.5/4

= 5272.87 ≈ 5300

But 2F = 5300

F = 2650N

3) Span length 2L = 990mm

L = 495mm

4) Bending stress

$$\frac{M}{I} = \frac{\sigma}{Y} = \frac{E}{R}$$

$$\therefore \sigma = \frac{MY}{I}$$

$$\sigma = \frac{3PL}{2bh^2}$$

$$\sigma = \frac{3 \times 2650 \times 495}{2 \times 50 \times 8^2}$$

$$\boldsymbol{\sigma = 614.88\,N/mm^2}$$

5) Deflection (δ)

$$\delta = \frac{\sigma L^2}{4Eh}$$

$$\delta = \frac{614.88 \times 495^2}{4 \times 68.9 \times 10^3 \times 8}$$

$$\boldsymbol{\delta = 68.33mm}$$

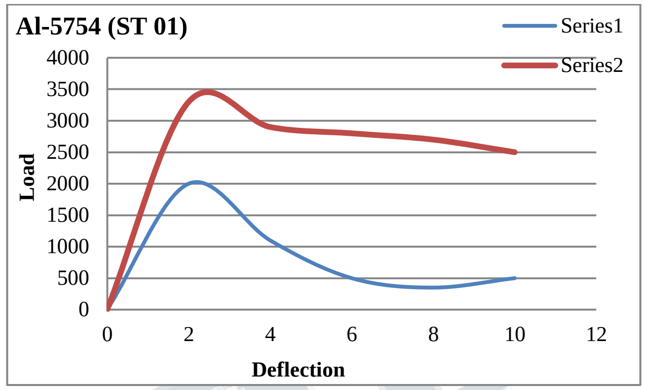


Figure 3: Load v/s Deflection Al-5754(ST 01)

Table 4: Comparative Load v/s Deflection

Specimens	Max Load	Deflection(mm)
Al-3003 (ST 01)	3480	2.5
Al-5754 (ST 02)	3100	2.7
CFRP (ST03)	3800	4

Fatigue Design Calculation

The values of static test were taken from Murat YavuzSolmaz [10]. According to this paper, the tests were conducted on Shimadzu Servo-Hydraulic test equipment with a 100 kN load cell. For fatigue calculation, the stress ratio R – 0.1 were used. The fatigue calculation were considered for flexural loading (3 Point Bend) loading.

Fatigue tests were performed for aluminum, the 3M 2216 adhesive and the composite materials, for values below static damage loads. Figure 5 shows stress vs. cycles to failure graphs for the Al 5754 face sheet, the 3M 2216 adhesive and the CFRP under tensile loading. During fatigue tests, a load was applied on the specimen. The span length between the 300 mm-diameter supports middle of the specimen.

Table 5: Calculated fatigue Load

Maximum load value (N)	Percent of Max Load	Fatigue Load (N)	Designation
2000	90% of max load	1800	FT 01
2000	75% of max load	1500	FT 02
2000	50% of max load	1000	FT 03
2000	30% of max load	600	FT 04

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 6, Issue 8, August 2021

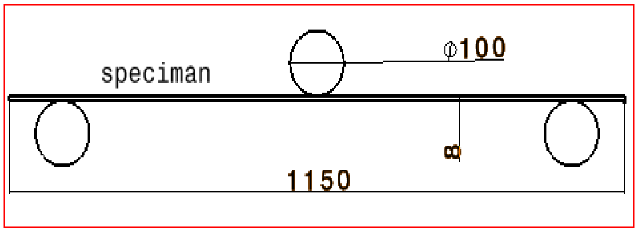


Figure 4: Drafting of 3 point bending

Fatigue Calculation

Specimen 1(Al5754 ST01)

Max load Value = 2000N

Endurance Limit

Se'= 0.5×max load

Se'= 0.5×2000

Se' = 1000N

Se= ka× kb×kc×kd×ke×kf×Se'

=0.69×0.77×0.89×0.62×1×1000

Se=293.17 N

Fatigue load = 1800 (FT 01)

R = 0.1

R = Fmin/Fmax

Fmin = 0.1×1800

Fmin = 180N

Load Amplitude

Fa = (Fmax-Fmin)/2

= (1800-180)/2

Fa=810 N

Mean load

Fm= (Fmax+Fmin)/2

= (1800+180)/2

Fm = 990 N

Goodman Theory

$$\frac{\mathrm{Fa}}{\mathrm{Se}} + \frac{\mathrm{Fm}}{\mathrm{Max\ load}} = \frac{1}{\mathrm{FOS}}$$

$$\frac{810}{293.17} + \frac{990}{1800} = \frac{1}{\mathrm{FOS}}$$

FOS = 0.304

Gerber Theory

$$\frac{\mathrm{Fa}}{\mathrm{Se}} + \left(\frac{\mathrm{Fm}}{\mathrm{Max\ load}}\right)^2 = \frac{1}{\mathrm{FOS}}$$

$$\frac{810}{293.17} + \left(\frac{990}{1800}\right)^2 = \frac{1}{\mathrm{FOS}}$$

FOS=0.329

Minol rule

$$\frac{\log_{10}\mathrm{max\ load} - \log_{10}\mathrm{Se}}{3} = \frac{\log_{10}\mathrm{fatigue\ load} - \log_{10}\mathrm{Se}}{6 - \log_{10}\mathrm{N}}$$

$$\frac{\mathrm{Log}_{10}(2000) - \log_{10}(293.17)}{3} = \frac{\log_{10}(1800) - \log_{10}(293.17)}{6 - \log_{10}(\mathrm{N})}$$

N=1428.47≅1428 cycle

Table No: 4 (Al-5754 (ST 01a))

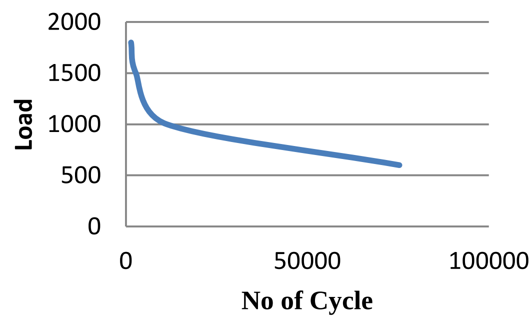
Max Load =2000 N

IV. RESULTS AND DISCUSSION

The coordinate of the fatigue diagram displays the load amplitude v/s no of cycles. We were calculated the fatigue analysis of the specimens that shown in graphical representation. The fatigue calculation were performed at 90%, 75%, 50% and 30% of the static load for the specimen, The applied fatigue loads were found to be 1800N, 1500N, 1000N and 600N respectively.

Figure 5 Shows cycles to failure values corresponding to different fatigue load for the Specimen Al-3003 (ST 01a).The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material AL-3003 for specimen ST01 is 75380 cycle

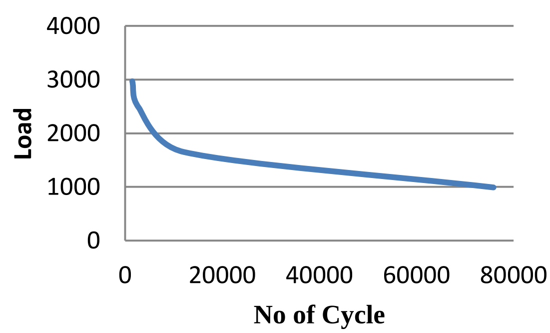
Figure 5:(Al-3003 (ST 01a))



.

Figure 6 Shows cycles to failure values corresponding to different fatigue load for the Specimen Al-3003 (ST 01b). The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material AL-3003 for specimen ST01b is 75844 cycle.

Figure 6:(Al-3003 (ST 01b))



ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

Figure 7 Shows cycles to failure values corresponding to different fatigue load for the Specimen Al-5754 (ST 02a). The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material AL-5754 for specimen ST02a is 75380cycle.

Figure 7:(Al-5754 (ST 02a))

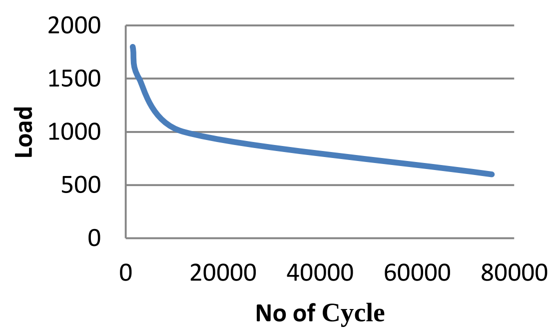


Figure: 8 Shows cycles to failure values corresponding to different fatigue load for the Specimen Al-5754 (ST 02b).The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material AL-3003 for specimen ST02b is 81349 cycle.

Figure 8:(Al-5754 (ST 02b))

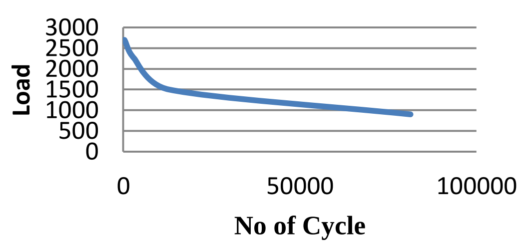
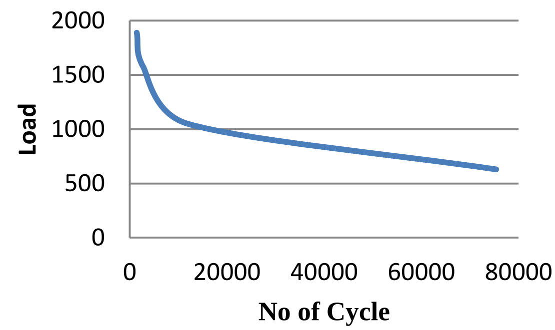


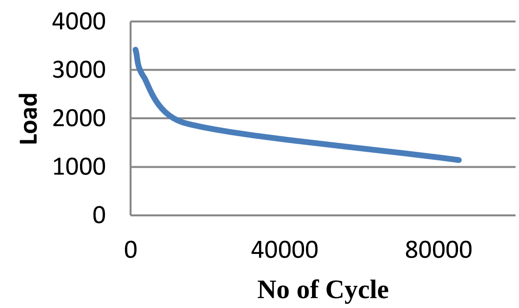
Figure: 9 Shows cycles to failure values corresponding to different fatigue load for the Specimen CFRP (ST03a).The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material CFRP for specimen ST03a is 75382 cycle.

Figure 9:(CFRP (ST03a))



Figure; 10 Shows cycles to failure values corresponding to different fatigue load for the Specimen CFRP (ST03b). The Fatigue calculation executed at different load amplitudes. The fatigue prediction according to No of cycles of the material CFRP for specimen ST03b is 85287 cycle.

Figure 10:(CFRP (ST03b)



V. CONCLUSION

1. The lifetime predictions were confirmed by the fatigue calculation. From the test result fatigue life of the specimen increases when load is dcreases.
2. The sandwich composite materials aluminium alloys and carbon epoxy material gives better strength under the max fatigue loading.
3. From the results, it is observed that the mono sandwich composite leaf springs are more effective and it has good load carrying capacity.
4. This study will help to understand more the behavior of the leaf spring and give information for the Manufacturer to improve the fatigue life of the spring. It can help to reduce cost and times in research and development of new product.

ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 6, Issue 8, August 2021

REFERENCES

[1] Mr. Anand Kumar A. Satpute, Prof. S.S Chavan. Mono Composite Leaf Spring – Design and Testing. INDIAN JOURNAL OF APPLIED RESEARCH. Volume: 3 | Issue: 7 | July 2013.

[2] Anil Kumar, T.N.Charyulu, Ch.Ramesh. Design Optimization of Leaf Spring. IJERA, Vol. 2, Issue 6, November- December 2012.

[3] Y. N. V. Santhosh Kumar, M. VimalTeja “Design and Analysis of Composite Leaf Spring” Dept. of Mechanical Engineering, Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada. (2012)

[4] B.Srikanth Gound (2015) “Design optimization of a heavy vehicle leaf spring the material E-Glass Epoxy and Aluminum reinforced with boron carbide”,SSRG International Journal of Mechanical Engineering (SSRG-IJME) – volume 2 Issue 10.

[5] Yogesh Nikam, Dr.Avinash Badadhe, (2016) “Design analysis and failure modes of leaf spring”International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03 Issue: 10.

[6] V.K. Aheret. al. “Fatigue Life Prediction of Multi Leaf Spring used in the Suspension System of Light Commercial Vehicle”, International Journal on Theoretical and Applied Research inMechanical Engineering (IJTARME), 2012.

[7] K. Diwarkar 'Design & Analysis Of A Tapered Composite Leaf Spring'. "international journal of advanced trends in engineering & technology" (IJATET), 2018.

[8] Shishay Amare Gebremeskel. Design, simulations, and prototyping of single composite Leaf Spring for Light Weight Vehicles. Global Journal of Researches in Engineering Mechanical and Mechanics Engineering Volume 12, Issue 7, Version 1.0, Year 2012.

[9] Dev Dutt Dwivedi, V.K.Jain, (2016) “Design and Analysis of Automobile leaf spring” ISSN (PRINT): 2393-8374, (ONLINE):2394-0697,VOLUME-3ISSUE-1

[10] Edward Nikhil Karlus, (2014.) “Optimization of Mono Parabolic leaf spring”International Journal of Advances in Engineering & Technology, IJAET. ISSN: 22311963

[11] Murat Yavuz Solmaz and TolgaTopkaya, Mechanical Engineering Department, Engineering Faculty, Fırat University, 23100 Elazı ˘g, Turkey 2. Mechanical Engineering Department, Engineering and Architecture Faculty, Batman University, 72100 Batman, Turkey; tolga.topkaya@batman.edu.tr(2012)

[12] Manjunath HN, Manjunath K, T

[13] Rangaswamy " Static analysis and fatigue life prediction of steel and composite leaf spring for light commercial vehicles". International Journal of Engineering Research 3: 422-425, 2007.

[14] Syambabu Nutalapati, Dr. P.V Jadhav Design and Analysis of Leaf Spring by Using Composite Material for Light Vehicles, International Journal of Mechanical Engineering and Technology (IJMET), Volume 6, Issue 12, pp. 36-59, Dec 2015

[15] V.K. Aher et. al. “Fatigue Life Prediction of Multi Leaf Spring used in the Suspension System of

[16] Light Commercial Vehicle”, International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME), 2012.

[17] Sandeep Bhatt Chatrjee, M. Raghavedra et. al. “Modelling and Analysis of Laminated Composite

[18] Leaf under the Static Load Condition by using FEA”, International Journal ofModern Engineering Research (IJMER) Vol.2, Issue.4, pp-1875-1879, July-Aug 2012.

[19] ”International Journal of Innovative Research in Science, Engineering and Technology Vol. [2].W.J. Padgett “A Multiplicative Damage Model for strength of Fibrous composite Materials” IEFE transactions on reliability, VOL. 47, No. 1, March 1998.

[20] W. Prachasaree, A. Sangkaew, S. Limkatanyu, and H. V. S.GangaRao, “Parametric study on dynamic response of fiber reinforced polymer composite bridges,” International Journal of Polymer Science, vol. 2015, Article ID 565301, 13 pages, 2015.