Design, Development and Analysis of Composite Mono Leaf Spring: A Review

Mujawar Ajij I[1]., Prof. S.D.KATEKAR[2]

1.ME Student, ME Design, Mechanical Engineering, Skn Sinhgad College of Engineering, Korti, Pandharpur, Solapur University, Maharashtra , India.

2. Professor of Mechanical Engineering, Skn Sinhgad College of Engineering, Korti, Pandharpur , Solapur University, Maharashtra , India.

Email: ajijmujawar1991@gmail.com

Abstract: Automobile industry has shown increased interest in the replacement of conventional materials with composites due to its property of high strength to weight ratio. Reducing weight while increasing or maintaining strength of products are getting to be highly important research is in this modern world. Composite materials are one of the material families which are attracting the researchers and giving solutions for such issues. This paper presents literature review on suitability of composite materials for leaf spring in automobile; compare its result with conventional steel leaf spring, design and analysis of composite leaf spring. Identify gaps in literature and present proposed research plan.

Key Words: Leaf Spring Glass Fiber Reinforced Material, Composite Material, FEA, ANSYS, Static and Dynamic Analysis.

Introduction:

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel. A composite is composed of a high performance fibers such as carbon, Kevlar, graphite or glass in a matrix material that when combined provides better properties compared with the individual materials by themselves. The composite materials are used in structural application areas, such as in aircraft, space, automotive, for sporting goods, and marine engineering. The various type of glass fibers available are Carbon fiber, C-glass, S-glass and E-glass. However, carbon epoxy material is better than other fibers but because of its high cost, it has limited applications. Favorable relation between cost and properties of a material can be obtained with E-glass fiber/epoxy.

The major step of composite in automotive business is extension of use in to truly structural application such as primary body structure and to chassis and suspension system. These are the area which has to sustain all major road load inputs and impact loads. Leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the un-sprung weight. This helps in achieving the vehicle with improved riding qualities. These are widely used in light motor vehicles, heavy duty trucks and in rail systems to absorb shock loads and vibration. Generally, leaf springs have been classified as mono- leaf spring and multi-leaf spring and based on the spring's ends: they are double-eye leaf springs and open-eye leaf springs. It is well known that springs are designed to absorb and store energy and then release it. It can be observed that material having lower modulus of elasticity and density will have a greater specific strain energy capacity. Thus, the introduction of Fiber Reinforced Plastics (FRP) made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. FRP materials have high elastic strain energy storage capacity, high strength-to-weight ratio, fatigue resistance.

Analysis:

Literature Review: Literature has been classified into three categories: composite materials for leaf spring, design and optimization of composite leaf spring, and analysis of composite leaf spring. Each one is explained in brief below.

A. Composite Materials for Leaf Spring: The composite material is having distinguishing characteristic such as, high strength to weight ratio, superior fatigue strength ,excellent corrosion resistance and higher natural frequency so it makes composite materials are excellent for leaf spring. (Beardmore P, Johnson1986).Application of composite material reduces the weight of spring without reducing load carrying capacity and stiffness in automobile suspension system. The leaf spring should absorb vertical vibration due to irregularities by means of variation in the spring deflection so that potential energy is stored in the spring as strain energy and released slowly (Daugherty, 1981; Breadmore, 1986; Morris, 1986; Corvi, 1990; G. Siddaratha, 2006).Table1 shows various composite materials proposed by researchers for leaf spring.

Table 1: Composite Materials Proposed for Leaf Spring

SN	Composite Materials	Researcher
1	S2-glass fiber/ Epoxy and E-glass/ Epoxy	W.J. Yu. Kim(1988)
2	E-glass/Epoxy	Mahmood Shokrieh (2003)
3	E-glass/Epoxy and carbon fiber/Epoxy	H.A. Al Qureshi (2001)
4	E-glass/Epoxy and Woven roving/ Epoxy	G GularSiddaramanna (2006)
5	E-Glass/Epoxy, C-Glass/Epoxy, S-Glass /Epoxy	B.Vijaya Lakshmi I. Satyanarayana(2012)
6	Glass Fibers	Frederick T. Wallenberger , James C.(2001)

B. Design and Optimization of Composite Leaf Spring: Usually leaf spring in vehicle is assumed as a simply supported beam which is subjected to both bending stress and transverse shear stress. Usually, three design approaches have been tried to accessed: (i) Constant thickness, varying width (ii) constant width, varying thickness and (iii) constant cross-section design. In 1981, a composite suspension of curved beam type was developed for family car (Daugherty 1981), in another design (Andrea Corrvi, 1990) the thickness of spring was kept constant and the theoretical details of composite mono leaf spring were reported using a program tool. Over a period of time GFRP double tapered beam and spring with variable thickness were designed and optimized for automobile suspension assuming similar geometrical and mechanical properties as that of multi steel (Yu and Kim, 1988; H. A. Qureshi, 2001). An optimal spring width decreases hyperbolically and thickness increases linearly from spring end towards the axle seat but deflection of composite spring was lower than steel leaf spring (M.M.Shokrieh2003). Researchers have employed a wide variety of methods and measures to investigate the performance parameters of composite leaf spring a brief summary are given below in table2.

Table 2: Performance Parameters of Composite Leaf Spring

Sr.No.	Tested performance parameter	Researchers
1	Fatigue Life and Natural Frequency	Gulur Siddarmanna 2006, M. Senthil Kumar 2007
2	Maximum Load, Stress, Deflection, Weight	Mahmood Shokrieh (2003), H.A.Al. Qureshi (2000), M.Raghvedra (2003), Pankaj Saini (2013), Parkhe

		Ravindra (2014)
3	Vonmisses stress, Normal stress	Vinkel Arora (2011)

C. Analysis of Composite Leaf Spring: The primary goal of analysis is to obtain information about the relevant performance parameters of leaf spring under different loading condition. These data can be of following: stresses, deflection, maximum and minimum stress induced, natural frequency and weight of spring. The leaf spring was analyzed by many researchers using analytical, numerical and experimental approach. In modern design, a wide range of software packages are being used, such as CATIA, PRO/Engineer, CAE, and ANSYS.

The Analysis of composite leaf spring has become essential for comparative evaluation with conventional steel leaf spring. The GFRP composite spring was subjected to static analysis to determine important attribute: deflection and bending stress. The result of analysis shows that impressive weight saving in leaf spring has been observed compared to conventional multi steel leaf spring (H.A.Qureshi, 2001, Pankaj Saini et.al Karthik. Badugu1, et.al 2013).

The main centre of attention was given to the effect of composite materials and orientation of fiber on the fatigue performance of spring. It is required that when spring is subjected to shock load the passenger seating in vehicle must get free form this vibration. In general, the road irregularities usually have maximum frequency of 12 Hz (Yu Kim, 1988). In order to provide comfort ride to the passengers in vehicle the leaf spring is designed in such a way that the natural frequency must be maintained within allowable limits to keep away from resonance. The natural frequency of composite leaf spring observed to be 1.2 times maximum road frequency and therefore resonance could not occur (M. Senthil Kumaret.al 2007, Shokerich, 2003, V. LaxmiNarayana, 2012).

Findings: A detailed and rigorous study has been carried out on the composite material leaf spring like E glass, Carbon Epoxy fiber only and the following observations were deduced:

1) Maximum work is done on E glass, Carbon Epoxy fiber composite material leaf spring.

2) Also few have work & studied with their vibration analysis using natural frequency.

3) It is seen that some of only work with S-glass fiber material for mono leaf spring, but they are only with finding out tensile testing only. But I should attention on S-glass fiber material with their design considerations, experimental work & also compare with steel leaf spring.

Table 3: Summary of Major Work on Analysis of Composite Leaf Spring

Sr.No	Research Objectives	Researchers
1	To Optimize geometry of composite leaf spring.	M.M. Shokrieh (2003) H.A.Al. Qureshi(2000)
2	To design and analyze GFRP mono leaf spring.	M.Raghvedra (2003), Gulur Siddaramanna(2006)
3	To compare load carrying capacity, stiffness, strength and weight of spring.	Vinkel Arora(2011), Vijaya Laxmi (2012)
4	Design and Analysis of E-glass/Epoxy composite mono leaf spring.	Sushil B. Chopade , Prof. K.M.Narkar , Pratik K Satav (2015)

Conclusion:

This review paper provides a brief summary on the work carried out for material selection, design, analysis and optimization of composite leaf spring. All the above parameters on composite leaf spring were discussed and compared with existing steel leaf spring for vehicles. The composite mono leaf springs were modelled by considering constant and varying cross-section area, with unidirectional S-glass fiber/epoxy for each lamina of a laminate. The different analysis namely static analysis, fatigue analysis, modal and shock analysis were performed using analytical, numerical and experimental approaches on steel as well as composite leaf spring by many researchers. Sometimes apart from experimental method a wide range of software packages such as CATIA, PRO/Engineer, CAE, ANSYS were used. Finally from various research papers, it is concluded that compared to conventional mono and multi steel leaf spring for vehicle the composite leaf spring have lesser stresses, weight, noise, vibration, harshness characteristic and increasing in fatigue life, strength and comfort ride. Also, Past Research has indicated that the results of E-Glass/Epoxy were found with good characteristics for storing strain energy. As a result this indicates that composite leaf spring is lighter and more economical than the conventional steel spring. Therefore, it is concluded that composite leaf spring is an effective replacement for the existing steel leaf spring in light passenger vehicle.

References:

1. Mahmood M. Shokrieh, Davood Rezaei, "Analysis and optimization of a composite leaf spring", Composite Structures *pp.* 317–325 2003.
2. RanjeetMithari, "Analysis of Composite Leaf Spring by Using Analytical & FEA" International Journal of Engineering Science and Technology Vol. 4 No.12 December 2012.
3. Gulur Siddaramanna, Shiva Shankar, SambagamVijayarangan.; Mono Composite Leaf Spring for Light Weight Vehicle – Design,End Joint Analysis and Testing, Materials Science, pp. 220-225 ,2006.
4. SushilB.Chopade, Prof.K.M.Narkar, Pratik K Satav "Design and Analysis of E-Glass/Epoxy Composite Monoleaf Spring for Light Vehicle" IJIRESET Vol. 4, Issue 1, January 2015.
5. B.Vijaya Lakshmi, I. Satyanarayana "Static and Dynamic Analysis on Composite Leaf Spring in Heavy Vehicle" International Journal of Advanced Engineering Research and Studies, Vol. II/80-84/ Issue I/ 2012.
6. M. Raghavedra, Syed AltafHussain, V. Pandurangadu, K. PalaniKumar "Modeling and Analysis of Laminated Composite Leaf Spring under the Static Load Condition by using FEA" International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.4, pp-1875-1879 ISSN: 2249-6645 , July-Aug. 2012
7. 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 May 2013.
8. Jadhav Mahesh V, ZomanDigambar B, Y R Kharde, R RKharde "Performance Analysis of Two Mono Leaf Spring Used For Maruti 800 Vehicle" International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-2, Issue-1, December 2012.
9. Al-Qureshi, H.A., "Automobile leaf springs from composite materials", Journal of Materials Processing Technology, Vol. 118(1-3), pages58-61. [doi:10.1016/S0924-0136(01) 00863-9]
10. Manjunath H.N, Manjunath.K, T.Rangaswamy "Static Analysis and Fatigue Life Prediction of Composite Leaf Spring for A Light Commercial Vehicle" IJER Volume No.3 Issue No.7