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Fatigue Analysis of Composite Leaf Springs - A Review

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Abstract:- The purpose of this paper is to provide a review of work that has been carried out in analyzing composite leaf springs. Leaf springs made of fibre reinforced composites exhibit much more advantages when compared with steel leaf springs. Most importantly, polymer composites increase the performances of vehicles by decreasing the weight of the leaf spring and also by providing corrosion resistance. This paper summarizes the fatigue analysis of composite leaf springs by considering the results obtained by some of the research works.

Keywords:- *Composites, Leaf Spring, Fatigue Life.*

I. INTRODUCTION

The automotive industry is not new to the use of composite leaf springs. The leaf spring actually has roots in the horse-drawn carriage. Leaf springs are made to absorb vertical vibrations brought on by irregularities on the road. Potential energy can be stored as strain energy and subsequently released gradually over time, thanks to variations in the spring deflection. Composites have a high strength-to-weight ratio, fatigue resistance, and natural frequency, which make them ideal for use in leaf spring applications. Vibration noise is less likely to be transmitted to nearby structures when internal dampening in the composite material improves the material's ability to absorb vibration energy. The leaf spring was transversely mounted, meaning that at each axle it traversed the width of the vehicle. The coil springs that were located high in a spring pocket on the frame were removed as a result. As a result, the car's handling is improved because it may sit lower to the ground.

A transverse composite leaf spring spans the width of the vehicle and bears down on the bottom arm. The spring is actually always pressed up against the subframe. By directing shock loads into the frame side, this design does away with the need for a separate rear anti roll bar, which is required for vehicles with normal suspension kits. It's also said that the camber curve of the spring enhances tire contact with the road during cornering.

In longitudinal leaf springs, composites may also be used in place of steel to lighten the spring's weight. Until now, only low-volume production models of glass and carbon reinforced composite leaf springs have been available for purchase. The first resins chosen in the automotive industry were epoxy systems, which had already shown their worth in the aerospace industry.

The initial, propagating, and unstable crack propagation on material that strongly influences fatigue damage or fatigue life is the cause of the failure of leaf spring structure steel. One of the main problems in materials engineering is fatigue life, since it indicates how long a material will last. Materials' fatigue lives can be computed using simulation and experimentation. This paper examines the same topic, drawing on a few research papers as a source.

II. DETAILS OF REVIEW

Here, we take a look at some research that compares the various attributes of conventional and composite leaf springs. The composite materials that are chosen are CFRP1 and GFRP2. A two-dimensional plane strain finite element model (FEM) was used to do a stress analysis, and ANSYS was used for all computations.

- *CFRP Leaf Spring v/s SAE 5160 Chromium Steel[1] Leaf Spring.*

A work titled "Flexural and fatigue of a composite leaf spring using finite element" was carried out by T.G. Loganathan. This model is analyzed using the ANSYS program. After positioning the piles in a particular orientation, the composite leaf spring is first designed in Design Modeler as a surface and then transformed into a solid model. Once the composite model has been constructed, steel leaf springs need to be given boundary conditions that provide the same limitations as in a real-world application.

Although the vehicle can carry a variety of loads, it is vital to understand the fatigue strength of the leaf spring. We can now comprehend the fatigue strength of a leaf spring with the aid of the facts in paper[1].

- *Fatigue Life:*

In stress life analysis, loading has a constant amplitude and indicates the number of cycles a leaf spring will go through before failing from exhaustion. The fatigue total life (SN) approach is utilized for life prediction when a leaf spring is subjected to high cycle fatigue conditions, where stresses are primarily elastic. Four ways are commonly used in ANSYS Workbench for fatigue analysis: Goodman's

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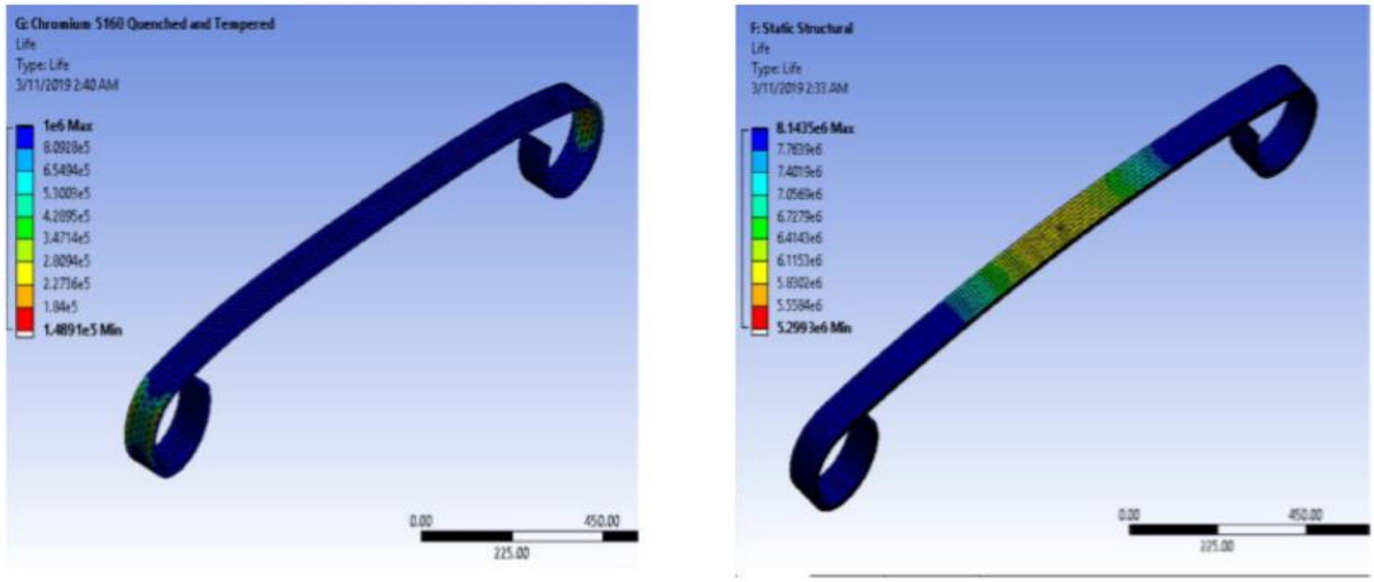
approach, Gerber's approach, Mean stress approach, and Soderberg's approach. These approaches use a 5000N load with a loading condition derived from engineering data and Goodman's theory. The outcomes are produced by ANSYS Workbench. Figure 1 makes it evident that the life of chromium SAE5160 steel is 1.491e5 and that of CFRP is 5.2993e6. Compared to steel, carbon fiber has more cycles.

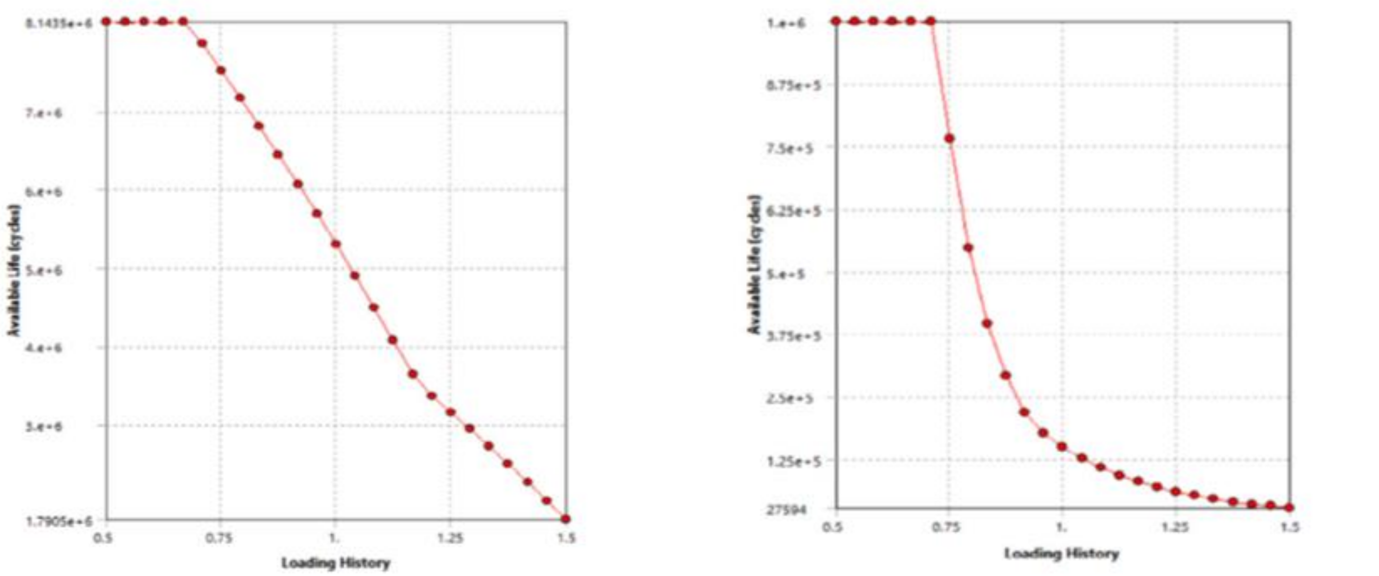


(a) Fatigue life of Chromium SAE5160 (b) Fatigue life of CFRP

Fig 1 Fatigue Life

- *Fatigue Sensitivity:*

The fatigue results vary depending on the stress at the key position on the leaf spring model, as shown in Fig 2. Sensitivity is typically seen in factories of safety, life, or harm. The fatigue sensitivity plots for SAE5160 steel and CFRP material are shown in Figures 2(a) and (b), respectively.



(a) Fatigue sensitivity plot for CFRP (b) Fatigue sensitivity plot for SAE 5160 steel

Fig 2 Fatigue Sensitivity

Finite element analysis was used to examine the composite leaf spring's flexural and fatigue behavior. This work revealed that the SAE5160 Chromium Steel (10.16 kg) weighs more than the CFRP Material (5.9 kg). Comparatively speaking, CFRP deforms less than SAE 5160 Chromium Steel. Therefore, compared to SAE 5160 steel, CFRP has a higher degree of stiffness. More fatigue life is provided by CFRP material than by SAE1560 chromium steel.

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➢ *GFRP Leaf Spring v/s SAE 5160 Steel[2] Leaf Spring.*

A work titled "Static analysis and fatigue life prediction of steel and composite leaf spring for light passenger vehicles" was carried out by M Senthil Kumar and S Vijayarangan. This paper presents the stress analysis of a leaf spring utilizing experimental, analytical, and FEM along with fatigue life. An electro-hydraulic leaf spring test equipment is used to evaluate composite leaf springs. Four Composite leaf springs were produced and put through testing. For purposes of comparison, the spring with the highest stress values and the least stiffness has been taken into consideration. Its reduced volume fraction during the fabrication process or incomplete curing could be the cause of the stiffness and stress fluctuations. By substituting the Composite leaf spring (4.3 kg) with the Steel leaf spring (13.5 kg), a weight reduction of 68.15% is accomplished.

- *Load–Deflection of Steel and Composite Leaf Springs*

Theoretically, a light passenger car with a 175 mm camber height would require a static force of 3250 N to flatten the leaf spring. In order to ascertain the load-deflection curves, a static vertical force of 3250 N is applied (Fig. 3).

The spring constants of an epoxy/glass composite leaf spring range from 34.57 to 53.59 N/mm. As a result, every composite leaf spring's spring constant data point exceeds the design value of 20 N/mm. The combination of lower density E-glass and epoxy composite is the cause of the improved rigidity.

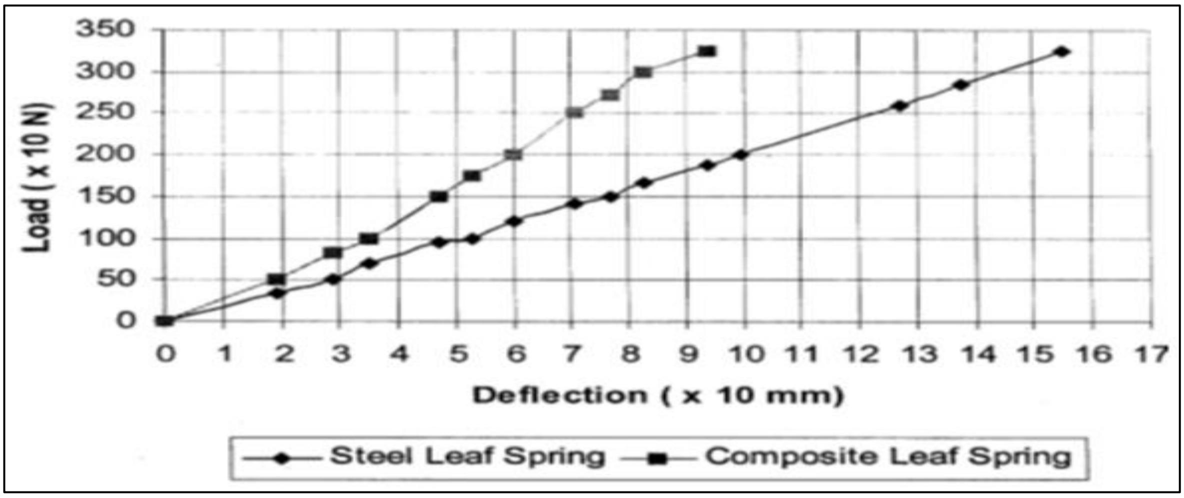

Fig 3 Steel and Composite Leaf Springs - Load–Deflection Curves

- *Variation of Experimental Stress of Steel and Composite Springs*

A leaf spring is examined in the context of transverse loading. The composite material utilized in this investigation has a lower longitudinal compressive strength than its longitudinal tensile strength. Thus, longitudinal compressive stress serves as the failure criterion stress. For Composite leaf springs, the maximum longitudinal compressive stress is 222 MPa (Fig. 4). The highest stress that can arise in a steel leaf spring under the same force is 680.05 MPa (Table 2, Fig. 4). Stress created in Composite Leaf Spring is 67.35 percent less than that developed in SLS. The yielding stress of steel is 1175 MPa, while the compressive strength of fiber glass/epoxy is 610 MPa. Therefore, the safety factor achieved by a Steel leaf spring is 1.73, whereas that of a Composite leaf spring is 2.75.

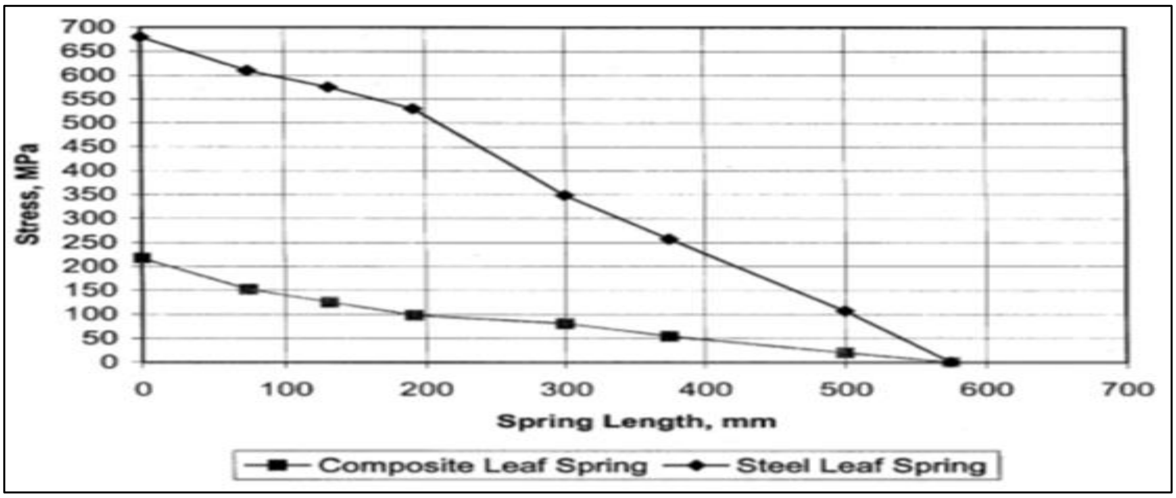

Fig 4 Variation of Experimental Stress of Steel and Composite Springs

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Table 1 Stress analysis of Steel Leaf Spring using Experimental, analytical and FEM

Parameters	Experiment	Analytical	FEM
Load, N	3250	3250	3250
Maximum stress, MPa	680.05	982.05	744.32
Maximum deflection, mm	155	133.03	134.67
Maximum stiffness, N/mm	20.96	24.43	24.13

Table 2 Stress analysis of Composite Leaf Spring using Experimental, analytical and FEM

Parameters	Experiment	Analytical	FEM
Load, N	3250	3250	3250
Maximum stress, MPa	222	310.82	215.46
Maximum deflection, mm	94	59.20	60.65
Maximum stiffness, N/mm	34.57	54.89	53.59

- *Fatigue Life.*

The following is the result of the steel leaf spring's fatigue life calculation: The fatigue testing machine's stroke ranges from 0-200 mm; the SLS's starting deflection is 100 mm; the experiment measures the initial stress at 420 MPa; the final SLS deflection (camber) is 175 mm; and the maximum stress at the final position is 805 MPa. According to Figure 5, the anticipated fatigue life cycle of a steel leaf spring is less than 10,000 cycles.

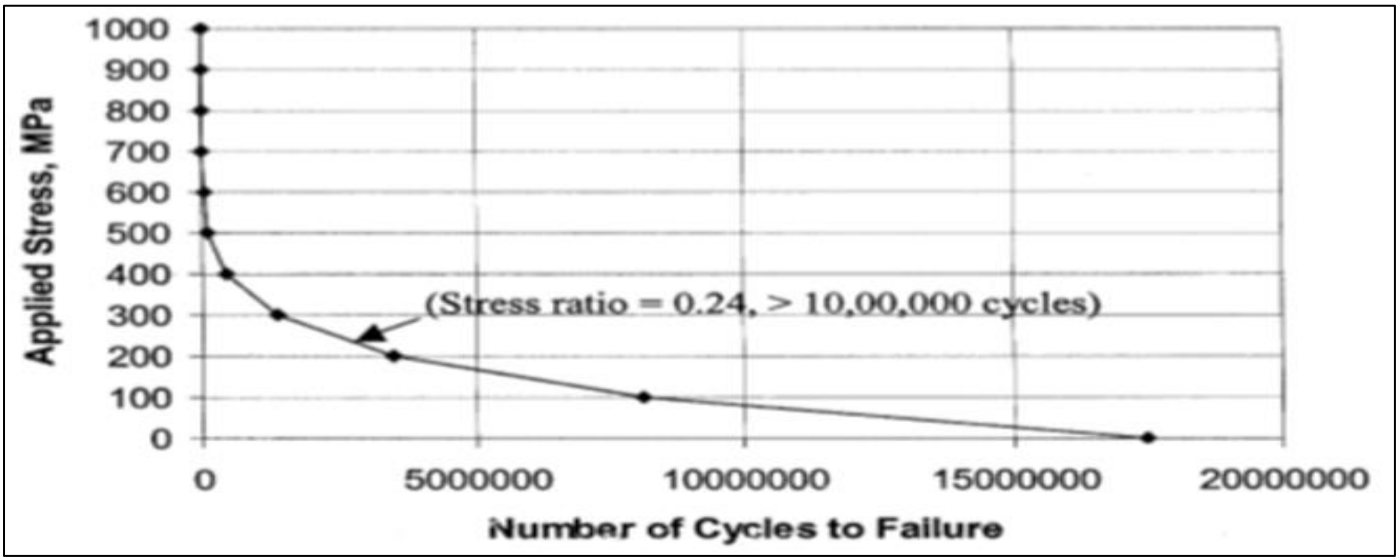

Fig 5 Composite Leaf Spring - S-N curve

A composite multi-leaf spring made of glass fiber-reinforced polymer has been designed and experimentally analyzed. Compared to the current Steel leaf spring, the Composite leaf spring exhibits lower stress (67.35%), greater rigidity (64.95%), and a higher natural frequency (126.98%). The E-glass/Epoxy multi leaf spring weighs only 4.3 kg, compared to the conventional multi leaf spring's approximate 13.5 kg weight. This results in a weight reduction of 68.15%. In addition to being lighter than steel leaf springs, composite leaf springs are expected to have a longer fatigue life. It has been found that composite leaf springs work well in place of the current steel leaf springs. It was discovered that the analytical and FEM simulated models of the Steel Leaf Spring and Composite Leaf Spring were comparatively stiffer than the real experimental design models.

III. CONCLUSION

Based on the various research works, it is found that the composite leaf spring has a significantly lower weight than traditional leaf springs while maintaining a higher fatigue life and high rigidity. In order to achieve higher performance with less fuel consumption, it is therefore preferred in the automotive industry to replace steel leaf springs with fiber reinforced composites.

REFERENCES

[1]. T.G. Loganathan, K. Vinoth Kumar and S. Kumar, Flexural and fatigue of a composite leaf spring using finite element. 2214-7853/ 2019 Elsevier Ltd.

[2]. M Senthil Kumar and S Vijayarangan, Static analysis and fatigue life prediction of steel and composite leaf spring for light passenger vehicles. Journal of Scientific & Industrial Research Vol 66, February 2007, pp 128-134.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24AUG1662

[3]. Breadmore P & Johnson C F, The potential for composites in structural automotive applications, Composite Sci & Technol, 26 (1986) 251-281.
[4]. Morris C J, Composite structures for automobiles, Composite Structures, 5 (1986) 233-242.
[5]. Daugherty R L, Composite leaf springs in heavy truck applications, Int Conf Composite Materials, Proc of Japan – US Conf, Tokyo, 1981, 529-538.
[6]. Yu W J & Kim H C, Double tapered FRP beam from automotive-suspensions leaf spring, Composite Structures, 9 (1988) 279-300.
[7]. Rajendran I & Vijayarangan S, Optimal design of a composite leaf spring using genetic algorithms, Int J Computers & Structures, 79 (2001) 1121-1129.
[8]. Corvi A, A preliminary approach to composite beam design using finite element analysis, Composite structures, 16 (1990) 259-275.
[9]. Springer G S & Kollár L P, Mechanics of Composite Structures (Cambridge university press, New York) 2003.
[10]. Hawang W & Han K S, Fatigue of composites – Fatigue modulus concept and life prediction, J Com Materials, 20 (1986) 154-165.
[11]. Yasushi M, Prediction of flexural fatigue strength of CFRP composites under arbitrary frequency, stress ratio and temperature, J Com Materials, 31 (1997) 619-638. 12 ANSYS 7.1 (Ansys Inc, New York) 1997.
[12]. Eliahu Zahavi, The Finite Element Method in Machine Design (Prentice Hall, Englewood cliffs, N.J, 07632).
[13]. Design and application of leaf springs, in Spring Design Manual, HS-788, AE-11 (Society of Automotive Engineer) 1990.
[14]. Ryan W E, Method of making a molded fiber reinforced plastic leaf spring, US pat 4,560,525 (24/12/1985)
[15]. Richrad D S, Mutzner J E & Eiler J F, Method of forming a composite leaf spring with fabric wear pad, US pat 4,894,108 (16/1/1990).
[16]. Nickel H W, Bushing construction for a fiber reinforced plastic leaf spring, US pat 4,565,356 (21/1/1986).
[17]. Rajendran I & Vijayarangan S, Design, analysis, fabrication and testing of a composite leaf spring, J Instn Engr, 82 (2002) 180-187.
[18]. Mahmood M S & Davood R, Analysis and optimization of a composite leaf spring, Composite structures, 60 (2003) 317325.
[19]. Rajendran I, Studies on isotropic and orthotropic leaf springs, Ph D Thesis, Bharathiar University, India, 2001