

Analysis of Steel leaf Spring and C-Glass/Epoxy leaf Spring

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Abstract— Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. The Automobile Industry has shown increase interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance properties. The report describes static analysis of steel leaf spring and composite leaf spring. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a Light design calculations. Static Analysis of model of leaf spring is performed using ANSYS 11.0 The result of FEA is also experimentally to be verified. The stresses induced in the C-glass/Epoxy composite leaf spring are 69% less than that of the steel spring nearly. The load carrying capacity, and weight of composite leaf spring are compared with that of steel leaf spring. The design constraints are stresses and deflection. This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be similarly analyzed.

Index Terms—Composite, steel, stress, deformation, Cglass/Epoxy

I. INTRODUCTION

In order to see natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present time. It is known that the failure nature of steel leaf springs is usually common. It is very important to reduce accidents and to replace steel leaf springs by gradually failing FRP (fiber reinforced polymer) composite material. Weight reduction can be achieved primarily by the introduction of **Better Material, Design Optimization and Better Manufacturing Processes**. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the unsprung weight. This helps in achieving the vehicle with improved riding qualities. It is well known that springs are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs.

Compared to steel spring, the composite leaf spring is found to have 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf springs. Multi leaf springs used in the automotive vehicles normally consist of full length leaves and graduated length

leaves. Moreover the composite leaf spring has lower stresses compared to steel spring. Composite materials offers opportunity for substantial weight saving. Spring are design to absorb & store energy & then release it hence strain energy of material & shape becomes major factors in designing the spring. The spring allows the movement of wheel over obstacles & then after returns the wheel to its normal position.

Suspension System

The automobile chassis is mounted on the axles, not direct but some form of springs. This is done to isolate the vehicle body from the road shocks, which may be in the form of bounce, pitch and roll. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame body. All the part, which performs the function of isolating the automobile from the road shocks, is collectively called a suspension system. It includes the springing device used and various mountings for the same. Broadly speaking, suspension system consists of a spring and a damper. The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber.



Fig-1 Suspension System

Composite Materials - Composite materials are superior to all other known structure materials in specific strength and stiffness, high temperature strength, fatigue strength and other properties. The desired combination of properties can be tailored in advance and realized in the manufacture of a particular material. Moreover, the material can be shaped in this process as close as possible to the form of final products or even structural units. Composite materials are complex materials whose components differ strongly from each other in the properties, are mutually insoluble or only slightly soluble and divided by distinct boundaries.



Fig-2 Composite materials

Applications

- 1) An important consideration in the use of composites is light weight.
- 2) Assembling of various parts is usually done by adhesive bonding, using resins that are catalyzed to cure at room temperature in a short time.
- 3) In Railway carriages it is desirable to reduce the weight of rail car bodies as well as heavy transport vehicles, which in turn reduce power and braking requirements. It also reduces maintenance costs.
- 4) Fiber epoxy composites have been used in aircraft engine to enhance the performance of the system. The pilot's cabin door of aircrafts has also been made with fiber glass resin composites and these are now used in other transport systems.

II. LITERATURE SURVEY

Investigation of composite leaf spring in the early 60's failed to yield the production facilities because of inconsistent fatigue performance and absence of strong need for mass reduction.

Erol Sancaktar, Mathieu Gratton [1] have proposed Design and manufacture of a functional composite spring for a solar powered light vehicle is described. The objective is to provide an understanding of the manufacture, use, and capabilities of composite leaf springs produced by using unidirectional E-glass impregnated by an epoxy resin for light vehicle applications where the vehicle weight is of primary concern. and conclude that The spring can be sanded down on its convex side to achieve the desired spring rate. This method proved to be very effective in reducing the spring rate.

H.A.Qureshi [2] Present the general study on design ,analysis and fabrication of composite leaf spring and conclude that composite can be used for leaf spring for light truck and meet requirement with weight saving.(2001).

Mahmood M. Shokrieh, Davood Rezaei [3] used A four-leaf steel spring used in the rear suspension system of light vehicles is analyzed using ANSYS V5.4 software.and finally showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS.(2003).

M.A. Osipenko, R.N. Rudakov [4] Take the leaves have the same widths and different lengths (the lengths decrease upwards).and Each leaf has one end clamped and the other free.for that they gave loading is applied (upwards) to the

lower leaf. and finding the densities of the forces of interaction between the leaves and investigation of the interaction of spring leaves under joint bending allows one to understand the bending of two straight uniform leaves in full.(2003).

Gulur Siddaramanna Shiva Shankar, Sambagam Vijayarangan [5] have present a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. Also, general study on the analysis and design. A single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fiber reinforced plastic with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated and tested. Computer algorithm using C-language has been used for the design of constant cross-section leaf spring, and conclude that a spring width decreases hyperbolically and thickness increases linearly from the spring eyes towards the axle seat. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses and displacement. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85% lower with bonded end joint and with complete eye unit.(2006).

J.P. Hou, J.Y. Cherruault, I. Nairne, R.M. Mayer[6] present the design evolution process of a composite leaf spring for freight rail applications. Three designs of eye-end attachment for composite leaf springs are described. The material used is glass fiber reinforced polyester. Static testing and finite element analysis have been carried out to obtain the characteristics of the spring. Load-deflection curves and strain measurement as a function of load for the three designs tested have been plotted for comparison with FEA predicted values .and conclude Three eye-end designs of a double GRP leaf suspension have been evaluated by finite element analysis and static and fatigue testing. FEA and static test results show that the stress concentration at the tip of the fibers coming back along the leaf body.

B.Vijaya Lakshmi, Satyanarayana [7] have compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel leaf spring of a Heavy commercial vehicle are taken Same dimensions of conventional leaf spring are used to fabricate a composite multi leaf spring using E-Glass/Epoxy, C- Glass/Epoxy, S- Glass/Epoxy unidirectional laminates. Pro/Engineer software is used for modeling and COSMOS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using COSMOS. They concluded that E-glass epoxy is better than using Mild-steel as though stresses are little bit higher than mild steel, E-glass epoxy is having good yield strength value and also epoxy material components are easy to manufacture and this having very low weight while comparing with traditional materials. In that analysis S-glass is having better results while comparing with C glass, E-glass and mild steel. So better to use S-glass epoxy and also increased the number of leafs to reduce the stress for

structural stability and conclude that S-glass epoxy is the best material to manufacture leaf spring because of good structural stability low production cost and good efficiency.

Shishay Amare Gebremeskel[8] reducing weight of vehicles and increasing or maintaining the strength of their spare parts is considered. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials considering static loading only. shown that the resulting design and simulation stresses are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life.

Ghodake A. P., Patil K.N. [9] study the material selected was glass fiber reinforced plastic (GFRP) and the polyester resin (NETPOL 1011) is used against conventional steel. A spring with constant width and thickness was fabricated by hand lay-up technique which was very simple and economical. The numerical analysis is carried via finite element analysis using ANSYS software. Stresses, deflection and strain energy results for both steel and composite leaf spring material were obtained and conclude that the composite spring has maximum strain energy than steel leaf spring and weight of composite spring was nearly reduced up to 85% compared with steel material.

U. S. Ramakanth & K. Sowjanya[10] carried out on multi leaf springs having nine leaves used by a commercial vehicle. A Finite element approach for analysis of a multi leaf springs using ANSYS software is carried out. The model is generated using solid works and imported in ANSYS The material of the leaf springs is 65Si7 (SUP9), composite leaf springs and hybrid leaf springs. Fatigue analysis of leaf springs is carried out for steel leaf springs, and Static analysis for steel leaf springs, composite leaf springs and hybrid leaf springs and finds that the under same static load conditions the stresses in leaf springs are found with great difference. Stresses in composite leaf springs is found out to be less as compared to the conventional steel leaf springs, also a new combination of steel and composite leaf springs (hybrid leaf springs) are given the same static loading and is found to have values of stresses in between that of steel and composite leaf springs.

D. K. Damor, K. D. Kothari [11] describes design and experimental analysis of composite leaf spring made of long glass fiber reinforced thermoplastic. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken. The solid model of the leaf spring was made in Pro-E 5.0 and the analysis was done using ANSYS 13.0. And Conclude that using the composites material in automotive suspension leaf spring, reduce weight, increase the strength and stiffness therefore increase the performance of the automotive. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings.

S. D. Rathod, D. S. Shah, S. A. Ban [12] carried out computer aided design and analysis of a elliptical single leave leaf spring, with experimental design considerations and loading conditions. The material of the single leave leaf spring is 65Si7. The CAD model of the single leave leaf spring is prepared in Solid-Works and analyzed using ANSYS-14.0. The CAE analysis of the single leave leaf spring is performed for the deflection and stresses under defined loading conditions, using ANSYS-14.0. and finds when the leaf spring is fully loaded, a variation of 5.26 % in deflection is observed between the experimental and FEA result, and same in case of half load, which validates the model and analysis. On the other hand, bending stress in both the cases is also close to the experimental results.

Sorathiya Mehul, Dhaval B. Shah, Vipul Bhojawala [13] have describes static analysis of steel leaf spring and laminated composite Multi leaf spring. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a Light design calculations. Static Analysis of 3-D model of conventional leaf spring is performed

III. EXPERIMENTAL ANALYSIS

Electronic ranges of Universal Testing Machines are fast, accurate, & simple to operate. In these machines load and displacement are displayed on the digital display system in their respective engineering units. It is supported by windows based software which can store, retrieve readings as and when required.

The deflection and stress of both the spring for comparative study is taken on the Universal Testing Machine (UTM). In the experimental analysis the comparative testing of mono composite leaf spring and the steel leaf spring are taken.

Procedure for Testing

1. The spring to be tested is examined for any defects like cracks, surface finishing, etc.
2. Move the plunger up to desired height so that we can fix the fixture and leaf spring for test.
3. Fix the position of fixture. On the fixture place the specimen.
4. The load is applied at the centre of spring, the vertical deflection of the spring centre is recorded at desired interval.



Fig-3 Experimental setup



Fig-4 Spring is placed on setup



Fig-8 Result of steel leaf spring at 4500 N load



Fig-5 Result of composite leaf spring at 4500 N load

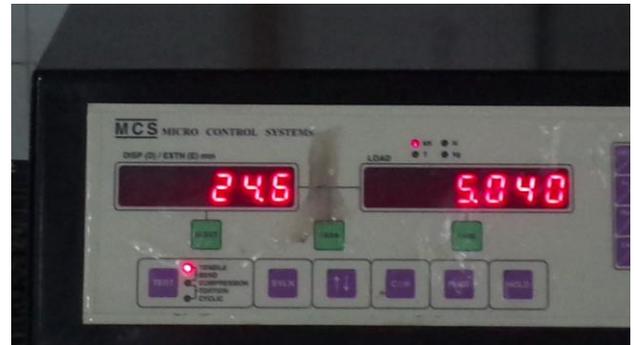


Fig-9 Result of steel leaf spring at 5000 N load



Fig-6 Result of composite leaf spring at 5000 N load



Fig-10 Result of steel leaf spring at 5500 N load



Fig-7 Result of composite leaf spring at 5500 N load

Table-1 Result of Composite leaf spring

| Sr. No | load (W) (N) | Bending stress (σ) (N/mm ²) | Deflection (δ) (mm) |
|--------|--------------|--|------------------------------|
| 1 | 4500 | 33.52 | 7.1 |
| 2 | 5000 | 52.88 | 11.2 |
| 3 | 5500 | 80.27 | 17.0 |

Table-2 Result of Steel leaf spring

| Sr. No | load (W) (N) | Bending stress (σ) (N/mm ²) | Deflection (δ) (mm) |
|--------|--------------|--|------------------------------|
| 1 | 4500 | 47.22 | 8.5 |
| 2 | 5000 | 136.66 | 24.6 |
| 3 | 5500 | 222.77 | 40.1 |

IV. Result and Discussion

Table-3 Comparison of Bending stress for both spring

| Sr. No | load (W) (N) | Bending stress (σ) (N/mm ²) | Bending stress (σ) (N/mm ²) |
|--------|--------------|--|--|
| | | Composite leaf spring | Steel leaf spring |
| 1 | 4500 | 33.52 | 47.22 |
| 2 | 5000 | 52.88 | 136.66 |
| 3 | 5500 | 80.27 | 222.77 |

Table-4 Comparison of Deflection for both spring

| Sr. No | load (W) (N) | Deflection (δ) (mm) Composite leaf spring | Deflection (δ) (mm) Steel leaf spring |
|--------|-----------------|--|--|
| 1 | 4500 | 7.1 | 8.5 |
| 2 | 5000 | 11.2 | 24.6 |
| 3 | 5500 | 17.0 | 40.1 |

IV. CONCLUSION

The conclusion of the work is to minimize stress and deformation in C-Glass/Epoxy composite leaf spring compared to steel leaf spring for automobile suspension system. This is done to achieve the following-

1. It can be observed from the comparison that the bending stress induced in the C-Glass/Epoxy composite leaf spring is **64%** less than the conventional steel leaf spring for the same load carrying capacity.
 2. It can be observed from the comparison that the deformation induced in the C-Glass/Epoxy composite leaf spring is **57%** less than the conventional steel leaf spring for the same load carrying capacity.
- This design helps in the replacement of conventional steel leaf springs with composite mono-leaf spring with better ride quality.
 - To achieve weight reduction in the suspension system by replacing steel leaf spring with mono composite leaf spring.
 - From the study it is seen that the composite leaf spring are lighter and more economical than that of conventional steel leaf springs for similar performance. Hence, the composite leaf springs are the suitable replacements to the conventional leaf springs.

REFERENCES

- [1] Erol Sancaktar, Mathieu Gratton “Design, Analysis, And Optimization Of Composite Leaf Springs For Light Vehicle Applications” (1999) 195-204.
- [2] H.A. Qureshi [2] “Automobile leaf spring from composite material” Journal of material processing technology 118 (2001) 58-61.
- [3] Mahmood M. Shokrieh, Davood Rezaei “Analysis and optimization of a composite leaf spring” Composite Structures 60 (2003) 317-325.

[4] M.A. Osipenko, R.N. Rudakov “A contact problem in the theory of leaf spring bending” International Journal of Solids and Structures 40 (2003) 3129-3136.

[5] Gulur Siddaramanna Shiva Shankar, Sambagam “Mono Composite Leaf Spring For Light Weight Vehicle – Design, End Joint Analysis And Testing” ISSN 1392-1320 Materials Science (Medžiagotyra). Vol. 12, No. 3. 2006.

[6] J.P. Hou, J.Y. Cherruault, I. Nairne, R.M. Mayer “Evolution of the eye-end design of a composite leaf spring for heavy axle loads” 78 (2007) 351-358

[7] B. Vijaya Lakshmi, Satyanarayana “Static And Dynamic Analysis On Composite Leaf Spring In Heavy Vehicle” International Journal of Advanced Engineering Research and Studies IJAERS/Vol. II/ Issue I/Oct.-Dec., 2012/80-84.

[8] Shishay Amare Gebremeskel “Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle” Double Blind Peer Reviewed International Research Journal Volume 12 Issue 7 Version 1.0 Year 2012.

[9] Sorathiya Mehul, Dhaval B. Shah, Vipul Bhojwala” Analysis Of Composite Leaf Spring Using FEA For Light Vehicle Mini Truck” Issn 0975 – 668x | Nov 12 To Oct 13 | Volume – 02, Issue – 02.

[10] Ghodake A. P., Patil K.N. [11] “Analysis of Steel and Composite Leaf Spring for Vehicle” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684 Volume 5, Issue 4 (Jan. - Feb. 2013), PP 68-76.

[11] U.S. Ramakant & K. Sowjanya [12] “Design And Analysis Of Automotive Multi-Leaf Springs Using Composite Materials” International Journal of Mechanical Production Engineering Research and Development (IJMPERD) ISSN 2249-6890 Vol. 3, Issue 1, Mar 2013, 155-162

[12] D. K. Damor, K. D. Kothari “A Review On Design And Analysis Of Long Fiber Reinforced Thermoplastic Leaf Spring” Indian Journal Of Research Volume : 2 | Issue : 3 | March 2013.

[13] 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.

[14] S. D. Rathod, D. S. Shah, S. A. Ban “Comparative Study Of Single Leaf Spring In Cae Tool And Experimental Data Of Leaf Springs In Automotive Vehicles” International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) ISSN 2249-6890 Vol. 3, Issue 3, Aug 2013, 1-8

[15] Bhandari V.B. (2001), “Design of machine element”, 3rd Edition, McGraw Hi Education India Pvt. Ltd.