International Journal of Mechanical and Industrial Engineering

Volume 1 | Issue 1 Article 2

July 2011

Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA

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"Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA"

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Abstract - Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment positions. Another part has to be focused, is the automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. Therefore, analysis of the composite material becomes equally important to study the behavior of Composite Leaf Spring. The objective of this paper is to present modeling and analysis of composite mono leaf spring (GFRP) and compare its results. Modelling is done using Pro-E (Wild Fire) 5.0 and Analysis is carried out by using ANSYS 10.0 software for better understanding.

Keywords - Composite Leaf Springs, Glass Fiber Reinforced Plastic (GFRP), Static load condition.

I. I. INTRODUCTION

Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. To improve the suspension system many modification have taken place over the time. Inventions of parabolic leaf spring, use of composite materials for these springs are some of these latest modifications in suspension systems. This paper is mainly focused on the implementation of composite materials by replacing steel in conventional leaf springs of a suspension system. Automobile-sector is showing an increased interest in the area of composite material-leaf springs due to their high strength to weight ratio. Therefore analysis of composite material leaf springs has become essential in showing the comparative results with conventional leaf springs.

Advantages of leaf spring over helical spring are that the ends of the springs are guided along a definite path so as to act as a structural member in addition to shock absorbing device. This is the reason why leaf springs are still used widely in a variety of automobiles to carry axial loads, lateral loads and brake-torque in the suspension system.

In this analysis the conventional steel leaf spring is tested for static load condition and results are compared with a virtual model of composite material leaf spring. Leaf spring is modeled in Pro-E 5.0 CAD software and it is imported and simulated in ANSYS 10.0 for better understanding. Results of Composite Leaf Spring are compared on the basis of analysis reports produced by ANSYS software. The material used for conventional steel leaf spring is 60Si7 (BIS) and for composite leaf spring E - Glass/Epoxy material is used.

II. LITERATURE SURVEY

Many industrial visits, past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47, 50Cr4V2, 55SiCr7 and 50CrMoCV4 etc. These materials are widely used for production of the parabolic leaf springs and conventional multi leaf springs.

Leaf springs absorb the vehicle vibrations, shocks and bump loads (Induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly [1]. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system.

Many suspension systems work on the same principle including conventional leaf springs. However, for the same load and shock absorbing performance, conventional (steel) leaf springs use excess of material making them considerably heavy. This can be improved by introducing composite materials in place of steel in the conventional spring. Studies and researches were carried out on the applications of the composite materials in leaf spring [1,2]. A composite mono leaf spring with an integral eye was manufactured and tested for the static load conditions [2]. Fatigue life prediction was also done by authors so as to ensure a reliable number of life cycles of a leaf spring. Further, a leaf spring had been modeled in conventional way and simulated for the kinematic and dynamic comparatives [3]. Cyclic creep and cyclic deformation was also studied [4]. Efforts were taken for Finite Element Analysis of multi leaf springs. These springs were simulated and analyzed by using ANSYS 7.1[5]. Premature failure in leaf springs was also studied so as to suggest remedies on application of composite leaf springs. [6, 7, 8]

III. EXPERIMENTAL PROCEDURE

In this paper, a comparative analysis of conventional steel leaf spring is done with a virtual model of a composite leaf spring under static load condition only. Conventional leaf spring is first tested under static load condition by using Hydraulic Static Load Test Rig. Mounting of the leaf spring is done by keeping it in inverted manner on the test bed. Two eye ends are held in the clamping devices and load is applied from the top, at the center of leaf spring. The spring is loaded from zero to maximum load (i.e. 25 Kg) and again back to zero. The vertical deflection of the spring is recorded in the load interval of 5 Kg and specified as per the SOP prescribed by SAE. To measure the load dial indicator is used which is located beside the Test Rig and deflection is measured by strain gauges located at the clamping of the test rig.

IV. SPECIFICATION OF THE CONVENTIONAL LEAF SPRING

The test steel leaf spring used for experiment is made up of 60Si7. The composition of material is 0.56 C%, 1.80 SI%, 0.70 Mn%, 0.045 P%, 0.045 S%. Following are the parameters for the 60Si7.

Table No.1 Specification of Existing Leaf Spring

Parameters	Value
Total Length of the spring (Eye to Eye)	1540 mm
Free Camber (At no load condition)	136 mm
No. of full length leave (Master Leaf)	01
Thickness of leaf	13 mm
Width of leaf spring	70 mm
Max^m Load given on spring	25 Kg
Young's Modulus of the spring	22426.09 Kgf/mm^2
Weight of the leaf spring	23 Kg

The leaf spring is used in the TATA SUMO vehicle, for Rear Suspension. Before testing of the leaf spring Shot Peening is done on all leaves.

V. SELECTION OF COMPOSITE MATERIAL

As mentioned earlier, the ability to absorb and store more amount of energy ensures the comfortable operation of a suspension system. However, the problem of heavy weight of spring is still persistent. This can be remedied by introducing composite material, in place of steel in the conventional leaf spring. Research has indicated that the results of E-Glass/Epoxy were found with good characteristics for storing strain energy [1]. So, a virtual model of leaf spring was created in Pro-E. Model is imported in ANSYS and then material is assigned to the model. These results can be used for comparison with the conventional steel leaf spring.

VI. MATERIAL PROPERTIES OF

VII. E-GLASS/ EPOXY

Table No.2 Properties of E-Glass/Epoxy material

Sr. No	Properties	Value
1	Tensile modulus along X-direction (Ex), MPa	34000
2	Tensile modulus along Y-direction (Ey), MPa	6530
3	Tensile modulus along Z-direction (Ez), MPa	6530
4	Tensile strength of the material, MPa	900
5	Compressive strength of the material, MPa	450
6	Shear modulus along XY-direction (Gxy), MPa	2433
7	Shear modulus along YZ-direction (Gyz), MPa	1698
8	Shear modulus along ZX-direction (Gzx), MPa	2433
9	Poisson ratio along XY-direction (NUxy)	0.217
10	Poisson ratio along YZ-direction (NUyz)	0.366
11	Poisson ratio along ZX-direction (NUzx)	0.217
12	Mass density of the material (ρ), Kg/mm3	2.6x10^3
13	Flexural modulus of the material, MPa	40000
14	Flexural strength of the material, MPa	1200

VIII. COMPARATIVE ANALYSIS OF LOAD AND DEFELECTION OF THE STEEL AND COMPOSITE LEAF SPRINGS

Table No.3 Comparative Analysis of Steel Leaf and Virtual Model of Composite Leaf Spring

		Conventional Steel leaf spring		**Virtual model of Composite Leaf Spring (FEA)**	
Sr. No.	Load (Kg)	Deflection (mm)	Stress (Kgf/mm^2)	Deflection (mm)	Stress (Kgf/mm^2)
1	5	31.127	17.818	24.23	59.102

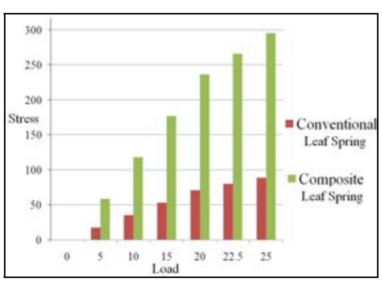
2	10	62.253	35.637	48.461	118.204
3	15	93.38	53.455	72.691	177.307
4	20	124.506	71.273	96.922	236.409
5	22.5	140.069	80.182	109.037	265.96
6	25	155.633	89.091	121.152	295.511

IX. COMPARATIVE ANALYSIS OF LOAD AND DEFELECTION OF THE STEEL AND COMPOSITE LEAF SPRINGS

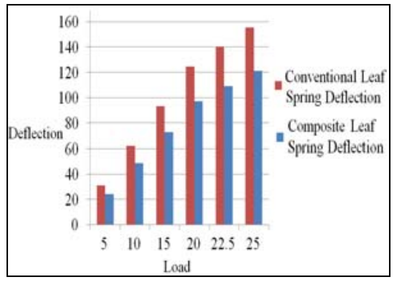
Table No.3 Overall Comparative Analysis of springs

Sr. No	Parameter	Expt. result	Analytical Result	FEA (ANSYS 10.0)
1	Load (Kg)	25	25	25
2	Max. Stress (Kgf/mm^2)	92	89.091	295.511
3	Max. Deflection (mm)	160	155.633	121.152
4	Max. Stiffness (Kg/mm)	0.156	0.1606	0.20
5	Weight (Kg)	23	---	3.59

Graph No.1 Comparison of Steel Leaf Spring and Composite Leaf Spring for Stress and Load



Graph No.2 Comparison of Steel Leaf Spring and Composite Leaf Spring for Load and Deflection



Graph No. 1 and 2 show the behavior of the leaf springs when subjected to load and its effect on Deflection and Stress.

X. FINITE ELEMENT ANALYSIS OF COMPOSITE LEAF SPRING USING ANSYS 10.0

All the analysis for the composite leaf spring is done by using ANSYS 10.0. For composite leaf spring the same parameters are used that of conventional leaf spring. For designing of composite leaf spring also the camber is taken 136 mm. The constraint is given at the two eye-rolled ends. One of the end is provided with translational movement so as to adjust with the deflection. This eye end is free to travel in longitudinal direction. This particular motion will help leaf spring to get flattened when the load is applied. Modelling is done without Roll Eye End because their DOF are constrained in specific directions. Produced results are very well compared with the realistic leaf spring and it's Experimental Procedure. The range of loads is applied and results are analyzed. The maximum principle stress is evaluated by software i.e. Von Mises Stress and Maximum Deflection is also observed. It is very much clear from the results produced by the ANSYS for Conventional Steel Leaf Spring, that red colored area indicated that eye end is the possible failure area for leaf spring. This failure at eye end is occurred when the load of 22.5 Kg is applied (ANSYS Result 1). It is also interesting to see the results for Composite Leaf Spring when same load is applied i.e. 22.5 Kg (ANSYS Result 3). Observation shows the absence of red colored area on Composite Leaf spring. Element Solid 46 is used for Composite Leaf Spring. Material is specified with 39 layers of fibers with the orientation (-45,90,+45). Entire volume is mapped meshed with hexahedral shape. ANSYS Result 1 and 2 represent the Stress and Deflection analysis of Conventional Steel Leaf Spring. ANSYS Result 3 and 4 represents the Stress and Deflection of E-Glass/Epoxy material respectively.

XI. CONCLUSION

Under the same static load conditions deflection and stresses of steel leaf spring and composite leaf spring are found with the great difference. Deflection of Composite leaf spring is less as compared to steel leaf spring with the same loading condition.

Conventional steel leaf spring was found to weigh 23 Kg. whereas E-Glass/Epoxy mono leaf spring weighs only

3.59 Kg. Indicating reduction in weight by 84.40% same level of performance.

Conventionl Leaf spring show failure at eye end only. At maximum load condition also Composite Leaf Spring shows the minimum deflection as compared to Steel Leaf Spring.

Composite leaf spring can be used on smooth roads with very high performance expectations.

However on rough road conditions due to lower chipping resistance failure from chipping of composite leaf spring is highly probable.

XII. ACKNOWLEDGEMENT

The authors would like to thank Prof. S. D. Deshmukh, Principal, JNEC, Aurangabad for his valuable guidance along with Mr. Harbaksh Singh of Ajanta Auto Pvt., Ltd for significant information on leaf springs and making available their test facility.

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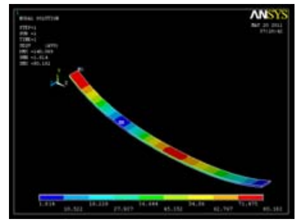
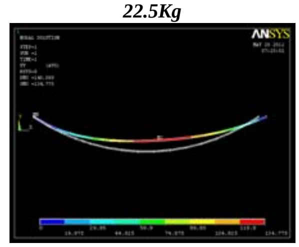
XIV. ANSYS 10.0 RESULTS FOR CONVENTIONAL AND COMPOSITE LEAF SPRING

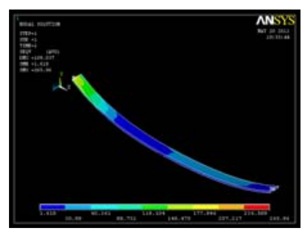
Von Mises Stress Analysis of Conventional Leaf Spring at 22.5Kg

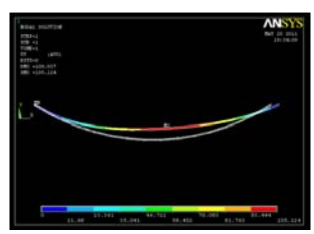


Deflection Analysis of Conventional Leaf Spring at 22.5Kg



Von Mises Stress Analysis of Composite Leaf Spring at 22.5 Kg





Deflection Analysis of Composite Leaf Spring at 22.5 Kg