STATIC ANALYSIS OF COMPOSITE LEAF SPRING WITH NONLINEAR PARAMETERS

Yogesh Y. Kamble[1], Prof. Dr. S.H.Sawant[2].

[1]PG Student , [2]Professor ,Department of Mechanical Engineering,

Dr. J.J. Magdum College of Engineering, Jaysingpur.(India)

ABSTRACT

In this paper Numerical analysis of composite leaf spring is carried out to find out effect of nonlinearities. For Linear and Nonlinear Finite element analysis ANSYS software is used. Experimental set up is developed in order to find out load-displacement characteristics of Composite Leaf spring. Load- displacement characteristics are studied in order to find out nonlinearities present in composite leaf spring. The present work deals with the numerical analysis of composite leaf spring with nonlinear parameters. In this paper Material and Geometric nonlinearities are considered.

Keywords*: *ANSYS, Composite Leaf Spring, E-Glass/Epoxy, Nonlinearity.

I INTRODUCTION

Composite materials consist of two or more physically dissimilar and instinctively separable components called reinforcement and matrix. These two components can be mixed in a restricted way to achieve optimum properties, which are superior to the properties of each individual component. Composite materials have been widely used in automobile industry because of its high strength and modulus to weight ratio, low cost and flexibility in material and structure design. 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. Since the strain energy in the spring is inversely proportional to density and young’s modulus of the material, it is always suggested that the material for leaf spring must have low density and modulus of elasticity. Many research have been carried out in the direction to replace conventional steel leaf spring by composites [1]. CAE tools are widely used in the automotive industries. In fact, their usehas enabled the automakers to reduce product development cost and time while improving the safety, comfort, and durability of the vehicles they produce. The predictive capability of CAE tools has progressed to the point where much of the design verification is now done using computer simulation rather than physical prototype testing. Even though therehave been many advances in CAE and it is widely used in the engineering field, physical testing is still used as a final confirmation for subsystems due to the fact that CAE cannot predict all variables in complex assemblies, therefore the validation of CAE results is important [2].In this analysis the material of mono leaf spring is E- glass epoxy. There are four layers of material lay up by following way:

The E glass Epoxy is also type of fiber. SiO_2 54wt% ,$Al_2O_3$14wt% ,CaO+MgO 22wt% ,$B_2O_3$10wt%, Na_2O+K_2O less than 2wt%. The properties of E-glass epoxy material used for the analysis are as follows:

II MATERIAL PROPERTIES OF E-GLASS EPOXY

Sr. No.	Property	Value
1	Tensile Modulus Along X-Direction	34000MPa
2	Tensile Modulus Along Y-Direction	6530MPa
3	Tensile Modulus Along Z-Direction	6530MPa
4	Tensile Strength of Material	900MPa
5	Compressive Strength of Material	450MPa
6	Shear Modulus Along XY-Direction	2433MPa
7	Shear Modulus Along YZ-Direction	1698MPa
8	Shear Modulus Along ZX-Direction	2433MPa
9	Poisson Ratio Along XY-Direction	0.217
10	Poisson Ratio Along YZ-Direction	0.0366
11	Poisson Ratio Along ZX-Direction	0.217
12	Mass Density	$2.6*10^3$Kg/mm^3
13	Flexural Modulus	40000MPa
14	Flexural Strength	1200MPa

III NUMERICAL ANALYSIS

The Finite Element Method (FEM) is practical application often known as Finite Element Analysis (FEA) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as of integral equations. Finite Element Analysis is a simulation technique which evaluates the behavior of components, equipment and structures for various loading conditions including applied forces, pressures and temperatures. Thus, a complex engineering problem with non-standard shape and geometry can be solved using finite element analysis where a closed form solution is not available. The finite element analysis methods result in the stress distribution, displacements and reaction loads at supports etc. for the model. The three dimensional model of spring is drawn in CATIA V5 R16 environment. This geometry is imported to ANSYS environment. 20 node hexahedral element SOLID-95 used for meshing of the geometry. Meshing is done by Hexagonal Sweep. The geometry can be meshed by 10 node tetrahedron element as well but tetrahedron is stiffer as compared to hexahedron element so results in lower accuracy [3].In this paper linear and nonlinear analysis of composite leaf spring is carried out using ANSYS.

In finite element analysis 3D model of mono leaf spring is developed. After modeling of leaf spring the actual supporting boundary conditions are given i.e. fixed support and cylindrical support. In fixed support there is no any degree of freedom i.e. there is no displacement at any direction. But in cylindrical support only vertical excitation or motion is present and horizontal motion is restricted. This condition is real on TATA-SUMO leaf spring.

Fig.1 Cad Model of Leaf Spring

In ANSYS the Cad Model of composite leaf spring is developed. After that for analysis the Finite element model is generated. At the point of application of load the fine meshing is done. After meshing we get total 18054 No. of Nodes and 4198 No. of Elements.

Fig.2 Shows meshed model of composite leaf spring. Fig.3 shows displacement in y direction of linear composite leaf spring at 50N load.

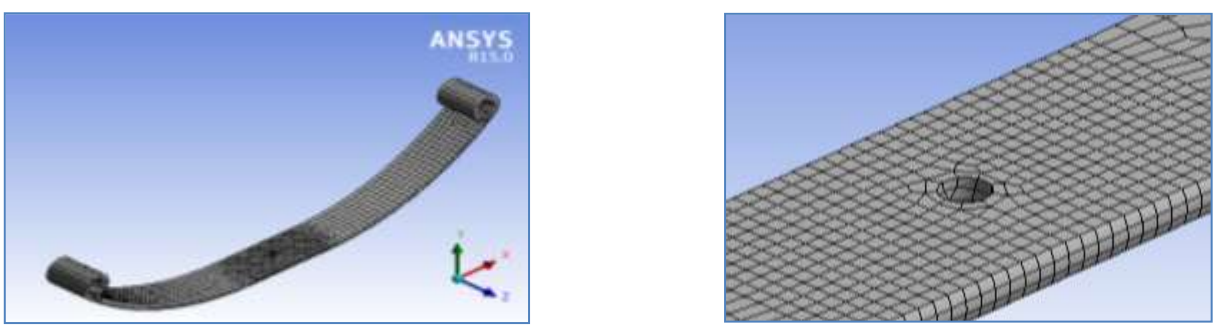


Fig.2 Meshed Model of Composite Leaf Spring

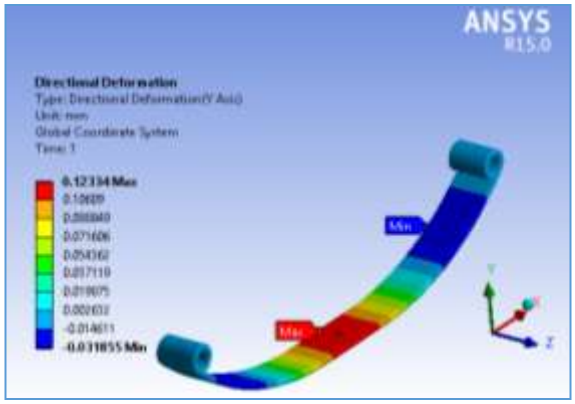


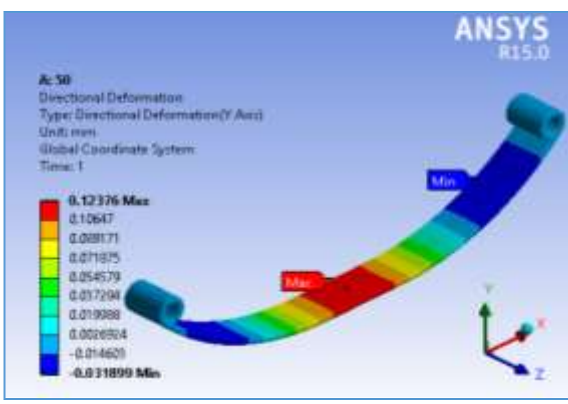
Fig.3 Directional Deformation at 50N of Linear Composite Leaf Spring.

3.1 Nonlinear Finite Element Analysis

Nonlinear Analysis includes Material based non-linearity: Force (stress) Vs. Displacement (strain) curve is Nonlinear(polynomial).Geometric non-linearity: In real life, the stiffness [K] is a function of displacement [d].This means in a geometric nonlinear analysis, the stiffness K is re-calculated after a certain predefined displacement.Contact non-linearity: In Contact analysis, the Stiffness K also changes as a function of displacement (when parts get into contact or separate). Non-linear analysis deals with true stress and strain (unlike engineering stress and strain in linear static analysis)[4].

In this paper Material and Geometric nonlinearity is considered to find out load deflection characteristics and maximum equivalent stress contours (Von Misses Stress plots).

For maximum load acting on leaf spring 46.58 MPa equivalent stress is developed which is far below yield strength of material, hence design of composite leaf spring is also safe. Fig.4a shows directional deformation at 50 N of Linear Composite Leaf Spring and Fig.4b shows Maximum equivalent stress in Nonlinear Composite Leaf Spring.



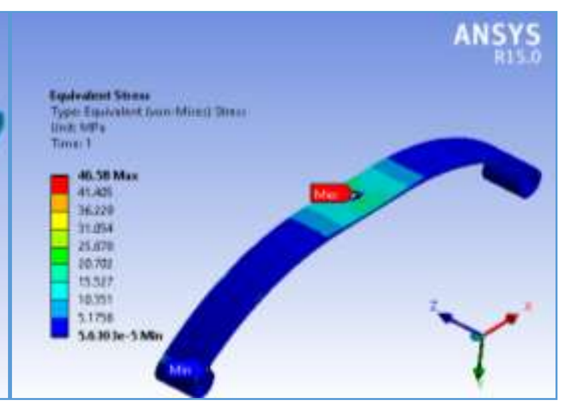


Fig.4a **Fig.4b**

Fig.4a- Deformation at 50N of Linear Composite Leaf Spring.

Fig.4b- Maximum Equivalent Stress in Non-Linear Composite Leaf Spring.

IV EXPERIMENTAL RESULTS

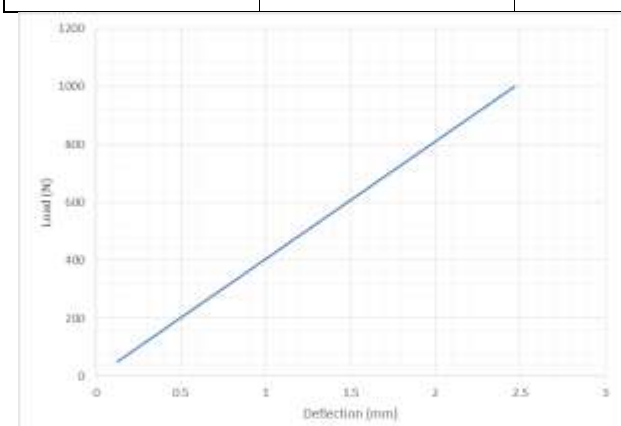
The experimentation is done by using universal testing machine. The loads are applied by using the universal testing machine. At various loads the deflection of composite leaf spring is measured. The following results are obtained during the experimental static analysis of composite leaf spring.

V RESULTS AND DISCUSSIONS

Table 1 shows the Comparative Load-displacement characteristics of Numerical Linear and Nonlinear Composite Leaf Spring and Experimental Analysis.

Table. 1: Comparative Load-displacement Characteristics

Sr.No.	Load (N)	Linear Displacement	Non-Linear	Experimental
1	50	0.12334	0.12376	0.12776
2	100	0.24667	0.24838	0.28838
3	150	0.37001	0.37387	0.38238
4	200	0.49334	0.50024	0.51215
5	250	0.61668	0.6175	0.62575
6	500	1.2334	1.27375	1.35458
7	700	2.4667	3.2295	3.65451



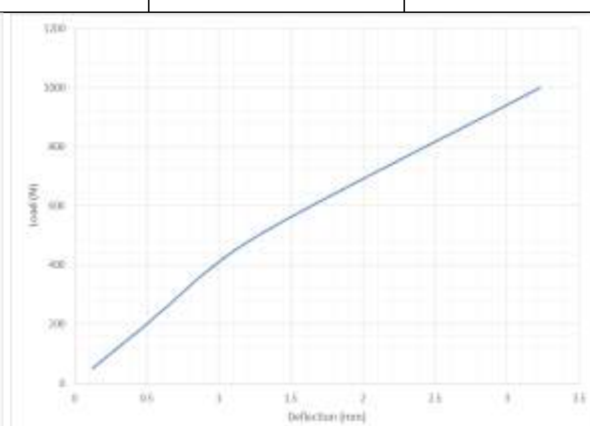


Fig.5a **Fig.5b**

Fig.5a- Load Deflection Characteristics of Linear Composite Leaf Spring.

Fig.5b- Load Deflection Characteristics of Nonlinear Composite Leaf Spring.

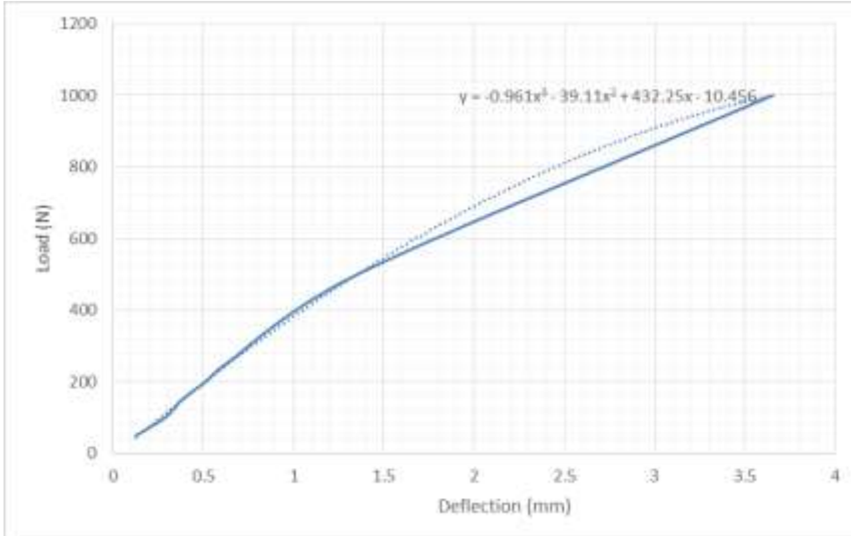


Fig.5c-Experimental Load Deflection Characteristics of Composite Leaf Spring.

From Experimental Load-Displacement Characteristics it is observed there is good agreement between load-deflection characteristics of Nonlinear Composite leaf Spring and Experimental Load-Deflection results, therefore in order to find out non-linear effects included in the spring force fs, it is modeled as third order polynomial function as

$$Fs = k0 + k1\Delta x + k2\Delta x^2 + k3\Delta x^3$$

Where the co-efficients are obtained by fitting the experimental data, which resulted in k_3 = -0.961 N/mm^3, k_2 =-39.11 N/mm^2, k_1= 432.25 N/mm and k_0 = -10.465 N. Hence, in order to model the nonlinearities in Leaf spring above equationwill be used, which includes the nonlinear effects in spring.

V CONCLUSION

Comparative Nonlinear static analysis of Composite Leaf spring used in Medium utility vehicle is carried out. Nonlinearities present in spring are found out. The numerical results from Nonlinear Finite Element Analysis showed in general a good agreement with the experimental values. However, differences appear indicating the necessity to improve the model input data and the experimental procedure. By using nonlinear analysis we can simulate real life conditions which were not possible in linear analysis, hence it is essential to use nonlinear analysis to get real life results.

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