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Vibration Analysis of Composite Leaf Spring by Finite Element Method

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Abstract

Vibration is an oscillation wherein the quantity is a parameter that defines the motion of a mechanical system. The main causes of vibration are unbalanced forces in the machine, dry friction between the mating surfaces, external excitation, earthquakes, wind self-excited vibrations, misalignment of rotating shaft, looseness in rotating machinery, loose foundations and excessive bearing clearances, oil whirl in bearing. The harmful effects of vibrations are excessive stresses in machine parts and undesirable noise. Also due to high vibration there are looseness of parts and partial or complete failure of parts. This vibration phenomenon is used in some musical instruments, vibrating conveyors, shakers, vibrating screens, stress relieving. This vibration can be reduced by removing the causes of vibration, by vibration isolation. Also vibration can be controlled by using shock absorbers and by installing dynamic vibration absorbers. Using composite material also vibration reduce. Automobile suspension Leaf spring consist high vibration during motion. By binding the composite material to steel spring the vibration can be reduced. ANSYS software used for Finite Element Analysis for vibration analysis.
Keywords: Vibration, Composite Material, Natural Frequency, Mode Shape

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I. Introduction

A leaf spring is a simple form of spring, commonly used for the suspension in vehicles. A leaf spring which is an automotive component is used to absorb vibrations induced during the motion of vehicle. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There are single leaf springs and multi leaf spring used based on the application required. It also acts as a structure to support vertical loading due to the weight of the vehicle and payload. Under operating conditions, the behavior of the leaf spring is complicated due to its clamping effects and interleafs contact, hence its analysis is essential to predict the displacement and mode frequency the objective of this paper is to analyze the leaf spring for the constraints such as material composition, vibrations developed in the springs. And finally for both, the analytical results are compared with experimental results and verified. Vibration analysis is done and also how much damping will be required for the spring is determined. Mode frequency for the spring is also determined using ANSYS software. This Project Vibration analysis plays a very important role in the design of composite leaf spring, since the failure due to vibration is more prominent rather than material failure. The heavy & light vehicles need a good suspension system that can deliver a good ride and handling. At the same time, it needs to be lightweight and have an excellent fatigue life. Springs are crucial suspension elements in cars necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. Vertical vibrations and impacts are buffered by variations in the spring deflection so that potential energy is stored in spring as strain energy and then releases slowly. So increasing the strain energy capacity of the leaf spring ensures a more compliant suspension system. Therefore, material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Composite materials are now used extensively in the automotive industry to take the place of metal parts. So it is essential to provide hybrid composite leaf spring with reduced spring rate, which evenly distributes glass fibers and carbon fibers, graphite fiber throughout resin matrix. The hybrid composite materials offer the various advantages like maximum strength, minimum modulus of elasticity in the longitudinal direction, weight & vibration reduction, improved packaging, strain energy capacity, improved durability & fatigue life and cost reduction due to the use of glass fibers & carbon fibers over the conventional composites materials

II. Problem definition

Now-a-days vibration is very important factor for study in many fields because vibration cause many undesirable effects on machine. To reduce the effect of vibration and to reduce the repulsive effect of damper, is the main purpose of this project work.

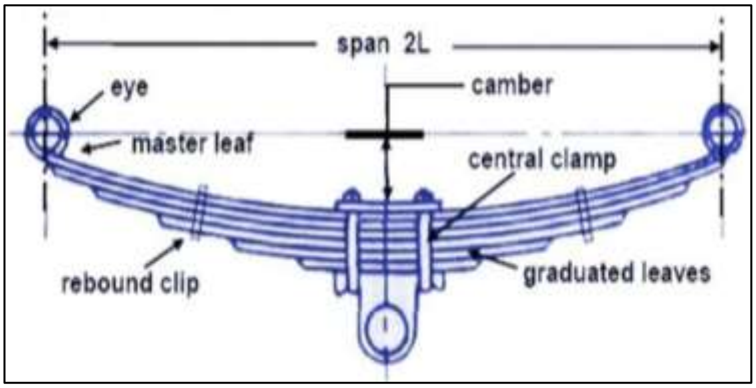


Fig. 1: Leaf spring

III. NEED OF COMPOSITE LEAF SPRING

Vibration analysis plays a very important role in the design of composite leaf spring. A leaf spring is a simple form of spring used for suspension in vehicles. Every heavy and light vehicle needs a good suspension system. A leaf spring is an automotive component used to absorb vibration induced during the motion of vehicle, so for that there should be light weight construction of leaf spring also it have good fatigue life. So for this composite leaf spring is better option over steel leaf spring. Nowadays composite materials are extensively used allover in industries. So it is essential to provide composite leaf spring with reduced spring rate. The composite materials have various advantages like maximum strength, minimum modulus of elasticity in the longitudinal direction, weight and vibration reduction, improved packaging, strain energy capacity, improved durability and fatigue life and cost reduction due to use of composite material. So composite leaf spring is more economical over steel leaf spring.

IV. OVERALL DISCUSSION ON RESEARCH

Vibration problems occure where there are rotating or moving parts in a machinery. Apart from the machinery itself, the surrounding structure also faces the vibration hazard because of this vibrating machinery. The common examples are locomotives, diesel engines mounted on unsound foundations, whirling of shafts, etc. The vibration occurs due to unbalanced forces in machine. These forces are produced from within the machine itself. Also due to dry friction between two mating surface. Vibration also occurs due to external excitation. This excitation may be periodic, random, or the nature of an impact produced external to the vibrating system. The effect of vibration are excessive stresses, undesirable noise, looseness of part and partial or complete failure of parts. A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Leaf springs absorb the vehicle vibrations, shocksand 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. Reduction of vibration done by using suspension system in case of vehicle. Leaf spring is commonly used suspension system in vehicles. There are steel leaf spring and composite leaf spring also. But nowadays for conserving natural resources and economize energy, weight reduction is the main focus of the automobile manufacturer. 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 unstrung weight. This gives vehicle an improved riding qualities. Springs absorbs and store energy and then release it. Hence strain energy of material is the major factor in designing a spring. The introduction of composite materials was made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. Since; the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. Composite materials are ideal for structural application where high strength to weight and stiffness to weight ratio are required. These materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. The composite material then has the properties of the two materials that have been combined. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses. Some of the properties that can be improved by forming a composite material are Strength, Fatigue life, Stiffness, Corrosion resistance, Thermal insulation, Weight, Wear resistance, Attractiveness, Thermal conductivity, Acoustical insulation. Naturally, not all of these properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another, e.g., thermal insulation versus thermal conductivity. Modern composites using fiber reinforced matrices of various types have created a revolution in high-performance structures in recent years. Advanced composite materials offer significant advantages in strength and stiffness coupled with light weight, relative to conventional metallic materials.

Fig. 2: Composite Leaf spring

Material Properties required for static and vibration analysis
Mode shape analysis (vibration analysis)
Case- simply supported
Load required for static analysis=3250N
Material properties of both composite and M.S Spring:

Table – 1
Material properties

Material	*Density Kg/m³*	*Youngs Modulus N/mm²*	*Yield tensile strength N/mm²*
Mild Steel	*$7.7x10^3$*	*$2.1x10^5$*	*1962*
E glass Epoxy	*$7.7x10^3$*	*$207x10^3$*	*1575*

Dimensions of spring
Length (Eye to eye) =1200mm
Thickness of Leaf spring=8mm
Width of Leaf spring=60mm
Dimension of clamping=80x40mm
Free casher load condition=120mm

V. FINITE ELEMENT MODELING

The main rule that involved in finite element method is “DEVIDE and ANALYZE”. The greatest unique feature which separates finite element method from other methods is “It divides the entire complex geometry into simple and small parts, called “finite elements”. These finite elements are the building blocks of the finite element analysis. Based on the type of analysis going to be performed, these elements divided into several types. Division of the domain into elements is called “mesh”. The forces and moments are transferred from one element to next element are represented by degrees of freedom (DOFs) at coordinate locations which are called as “nodes”. Approximate solutions of these finite elements give rise to the solution of the given geometry which is also an approximate solution.
The approximate solution becomes exact when

1) The geometry is divided into numerous or infinite elements.
2) Each element of geometry must define with a complete set of polynomials (infinite terms).

The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. It has developed simultaneously with the increasing use of high-speed electronic digital computers and with the growing emphasis on numerical methods for engineering analysis. This method started as a generalization of the structural idea to some problems of elastic continuum, is well-established numerical method applicable to any continuum problem, stated in terms of differential equations or as an extranet problem.
The fundamental areas that have to be learned for working capability of finite element method include

1) Matrix algebra.
2) Solid mechanics.
3) Variational methods.
4) Computer skills.

Matrix techniques are definitely the most efficient and systematic way to handle algebra of finite element method. Basically, matrix algebra provides a scheme by which a large number of equations can be stored and manipulated. Since vast majority of the literature on the finite element method treats problems in structural and continuum mechanics, including soil and rock mechanics, the knowledge of these fields became necessary.

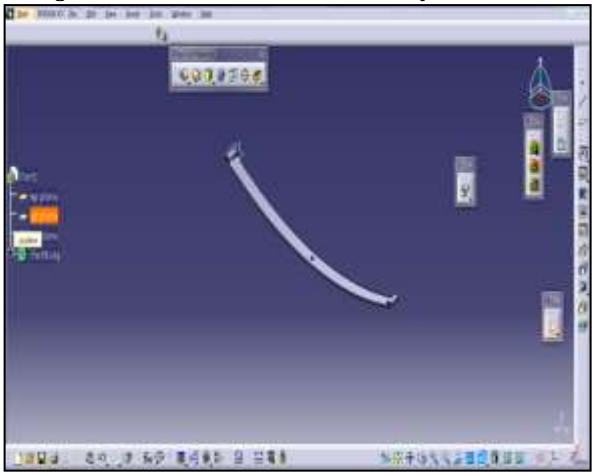


Fig. 3: 3D Model Master leaf

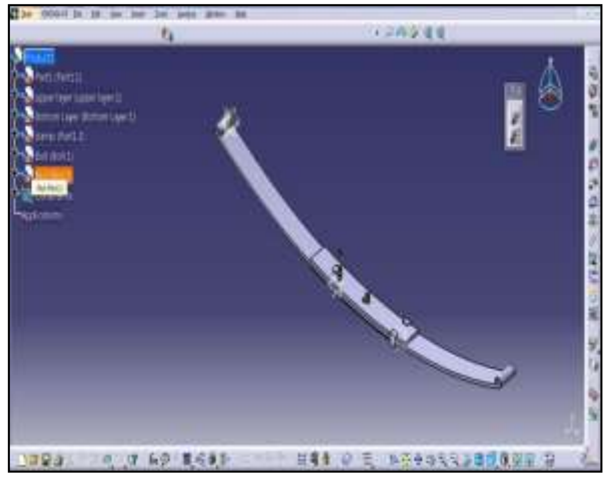


Fig. 4: 3D Model Composite leaf

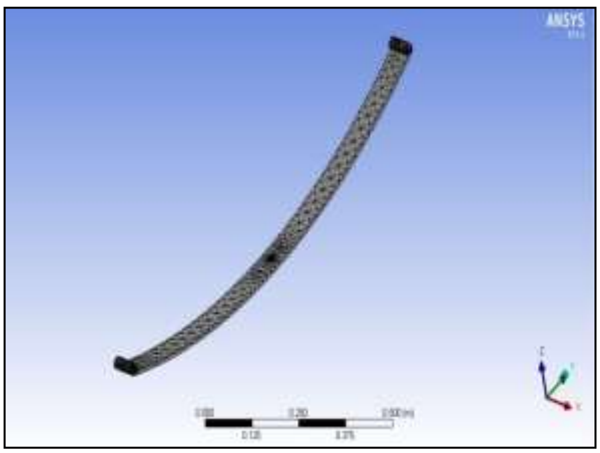


Fig. 5: Meshing of master leaf

Fig. 6: Meshing of composite leaf

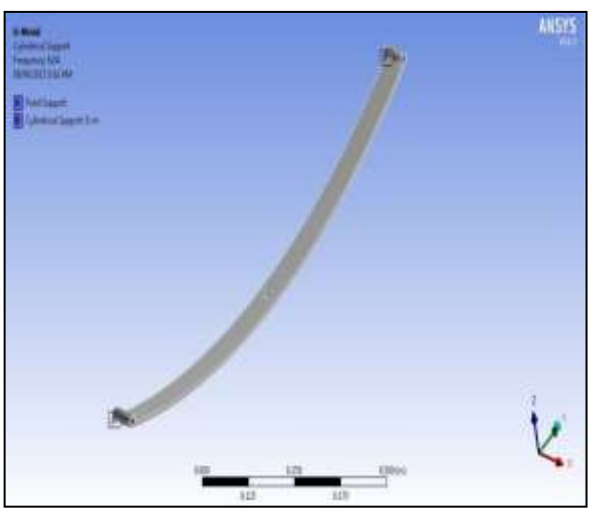


Fig. 7:Boundary conditions

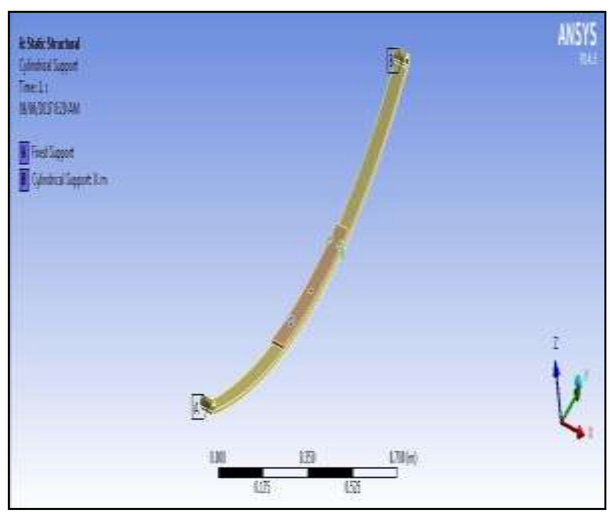


Fig. 8: Boundary conditions

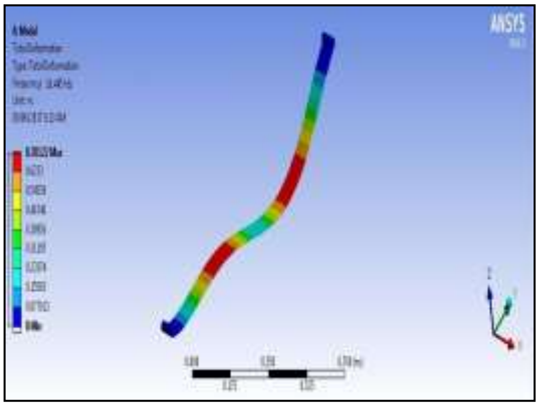


Fig. 9: Mode 1 of master leaf

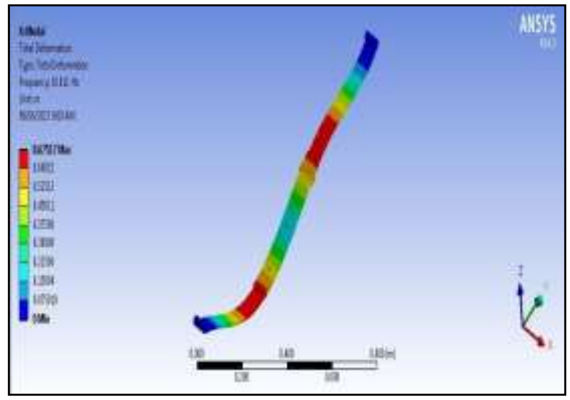


Fig. 10: Mode 1 of composite leaf

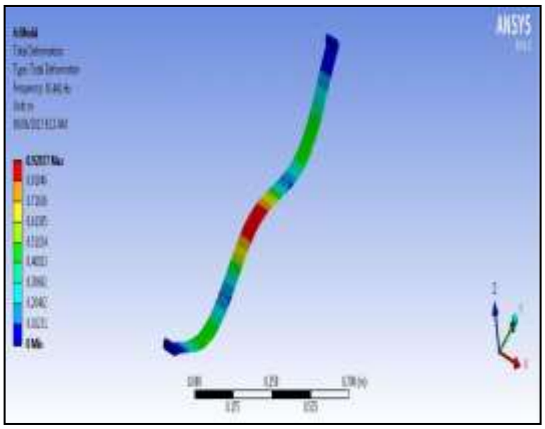


Fig. 11: Mode 2 of master leaf

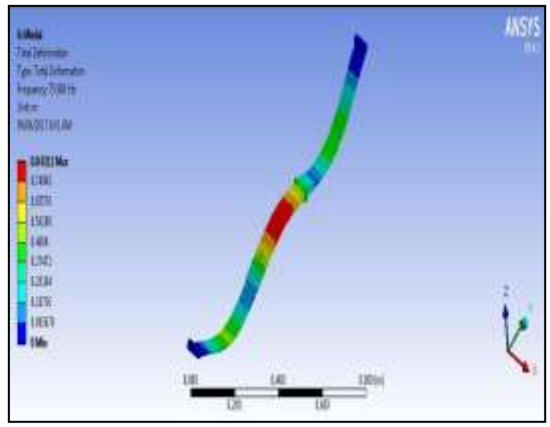


Fig. 12: Mode 2 of composite leaf

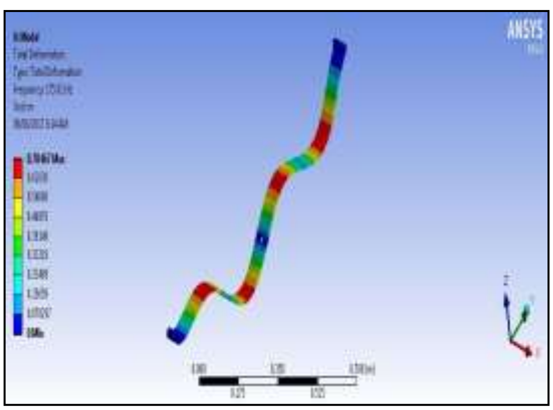


Fig. 13: Mode 3 of master leaf

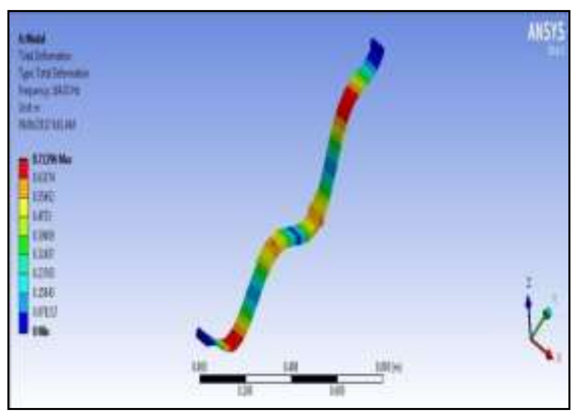


Fig. 14: Mode 3 of composite leaf

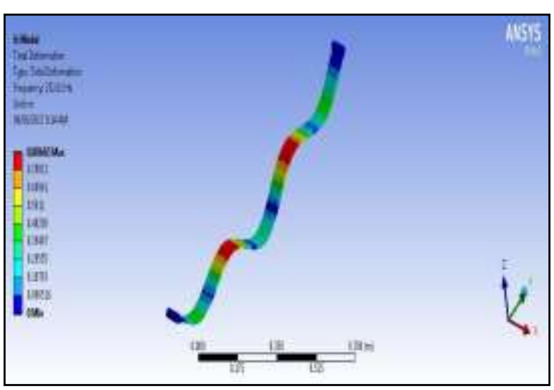


Fig. 16: Mode 4 of master leaf

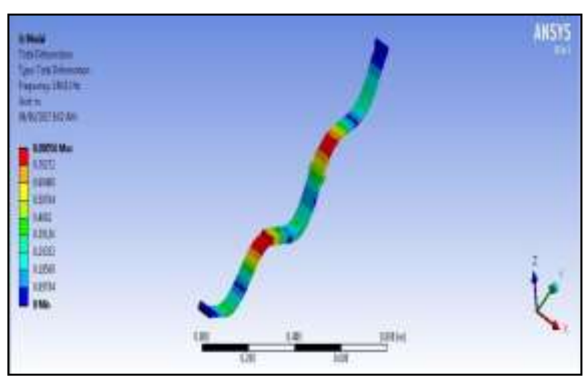


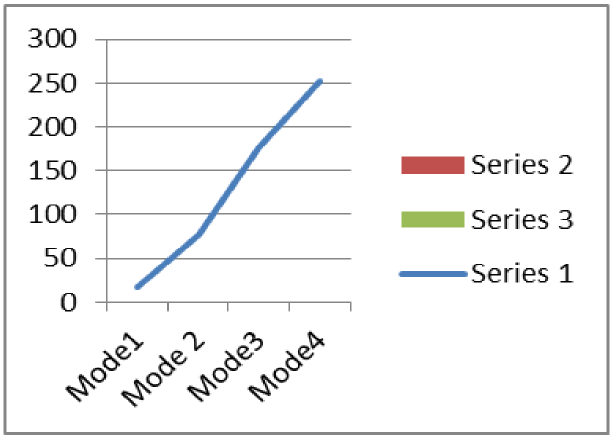
Fig. 17: Mode 4 of composite leaf

Table – 2
Frequency modes

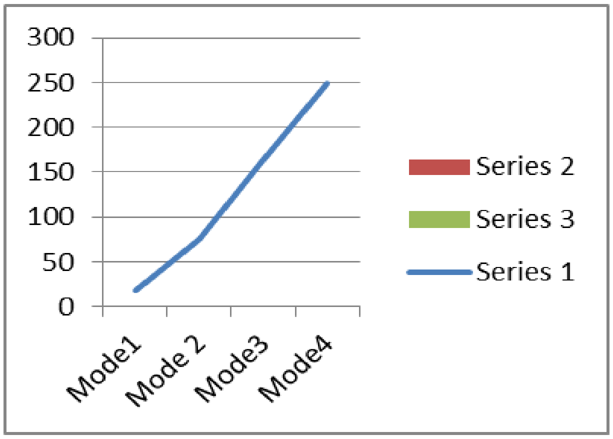
	Frequency(hz)			
	Mode1	Mode2	Mode3	Mode4
Master leaf	16.445	76.441	175.81	252.01
Composite leaf	18.811	75.988	164.03	249.81

VI. RESULT

A. Graph of mode vs frequency:



Graph 1: Mode vs freq for master leaf



Graph 2: Mode vs freq for composite leaf

VII. CONCLUSION

The composite leaf spring is designed according to constant cross-section area method. The 3-D model of the composite leaf spring is analyzed using finite element analysis. The results of the FEM analysis are verified with the test results. A comparative study has been made between composite and steel leaf springs with respect to weight, riding quality, cost and strength. 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 convectional leaf springs.

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