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An Overview of Disarray in Vibrational Analysis of Composite Leaf Spring Subjected to Harmonic Excitation with Nonlinear Parameters

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Abstract: *Most real-world phenomena exhibit nonlinear behavior. The behavior of steel leaf spring is nonlinear. It is having relatively high weight, and change in solid axle angle due to weight transfer specially during cornering of vehicle. That will lead to oversteer and directional instability under such situation it is very difficult for driver to control vehicle. These are some defect of metallic leaf spring so considering automobile development and importance of relative aspect such as fuel consumption, weight, ride quality, and handling development of new material is necessary in the automobile industry. In practice, engineering structures display a certain degree of nonlinearity, often due to a combination of nonlinear material properties, geometric effects, structural joints and nonlinear boundary conditions. Normally these effects are neglected by linearization in the intended working range. However, it becomes increasingly more important to take the nonlinear effects into account. This paper tries to give an idea about the previous researches and their finding about study of nonlinearity in spring.*

Keywords: *Composite Leaf Spring, Nonlinearity, E-Glass/ Epoxy, Tsai-Wu criterion.*

I. Introduction

Increasing competition and innovations in automobile sector tends to modify the existing products or replace 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 modifications 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 [1].

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 springs which are 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 [2].

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. Leaf springs probably are the oldest automobile suspension gadgets still in active use. Their simplicity and effectiveness might be contributing to this. The fact that a staggering amount of load is managed well while reducing the subsequent discomfort substantially adds to their reliability. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities[3, 11].

The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction in load carrying capacity and stiffness. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs. The composite material offer opportunities for substantial weight saving but not always be cost-effective over their steel counterparts [4].

There is an increasing awareness regarding highway traffic safety and automobile rollover accidents involving Sport Utility Vehicles (SUV'S). Among others, catastrophic rollover accidents of SUV draw

increasing attention to vehicle design and safety requirements. For this reason, accurate and efficient computer simulations of SUV models play an important role inthe design, performance evaluations and stability analysis of such vehicle systems. Most of SUV and trucks are equipped with leaf springs in either the front or rear axle suspension systems in order to improve the ride comfort and to support heavy loads. It is well known, however, that the suspension characteristics of leaf springs are highly nonlinear due to contact between spring leaves and hysteresis due to frictional effect [5].

Most real-world phenomena exhibit nonlinear behavior. There are many situations in which assuming linear behavior for physical system might provide satisfactory results. On other hand, there are circumstances or phenomena that require a nonlinear solution. A nonlinear structural behavior may arise because of geometric and material nonlinearities, as well as change in the boundary conditions and structural integrity.

II. Free Vibration Analysis of Composite Leaf Springs

A. L. Aishwarya et al.studied that the free vibration analysis of composite leaf springs clamped on one side. This has been done using a three dimensional finite element model in ANSYS version 12. The effects caused by the variation of width, friction between the leaves of the spring, relative movement of the leaves and the changes that occur in the natural frequency of the spring when the orientation of the fiber stacks by varying leaves have been discussed.The effect of friction has been studied by varying the values of friction in augumented method with the layer specification being no separation (always) for a 0l90l90l0 angular stack arrangement of fibers. In this paper they concluded that there is no significant effect of friction coefficient, no significant variation between friction and bonding cases, frictionless surfaces causes for reduction in frequencies and increase in leaf width improves natural frequencies.

III. Analysis of Composite Leaf Spring by Using Analytical and FEA

Ranjeet Mithari et al. [4] analyzed, a seven-leaf steel spring usedin passenger cars is replaced with a composite multi leaf spring made of glass/epoxy composites. The dimensions and the number of leaves for both steel leaf spring and composite leaf springs are considered to be the same. The primary objective is to compare their load carrying capacity, stiffness and weight savings. Finally, fatigue life of steel and composite leaf spring is also predicted using life data. The objective of the work is to calculate stresses, strength to weight ratio, dynamic loading condition, and stiffness and compare those with conventional steel leaf spring. For the accurate evaluation of above factor, they use Finite Element Method. In Static analysis, there is no variation of force with respect to time. Output in the form of stress, displacement, etc. with respect to time is not taken into account. Modal analysis of leaf spring is conducted to study the natural frequencies.

IV. Modeling and Analysis Of Composite Leaf Spring Under The Static Load Condition by Using Fea

M. M. Patunkar and D.R.Dolas [6] done analysis of composite leaf spring. 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.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.

V. Analysis and Optimization of a Composite Leaf Spring

Mahmood M Shokrieh and DavoodRezaei [7] studied, a four-leaf steel spring used in passenger cars replaced with a composite spring made of glass/epoxy composites. The main objective was the shape optimization of the spring to give the minimum weight. They concluded that static loading and full bump is not sufficient to design a composite leaf spring. So, a stress analysis was performed using finite element method. All the calculations were done using the version 5.4 of ANSYS [9]. In the finite element modeling, every leaf was modeled with eight-node 3D brick elements (SOLID 45) and then five node 3D contact elements (CONTACT 49) were used to represent contact and sliding between adjacent surfaces of leaves. The focus was on to obtain a spring with minimum weight that is capable of carrying given static external forces by constraints limiting stresses (Tsai–Wu criterion) and displacements.

VI. Experimental Investigation and Numerical Analysis of Composite Leaf Spring

K. K. Jadhao et al. [8] worked on design, fabrication, experimental testing and analysis of composite spring made up of E-glass fiber, chopped strands mat and epoxy resin (general purpose resin) with constant width and thickness throughout its length.They calculated experimental values of the stresses and deflection

by testing the leaf springs under static loading condition. These results are also compared with FEA. The weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring. They compared performance of existing steel leaf spring with the fabricated composite leaf spring. Testing has been done for unidirectional E-Glass/Epoxy mono composite leaf spring. Since the composite leaf spring is able to withstand the static load, they concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring.

VII. Design and Analysis of Composite Leaf Spring

Y.N.V. Santhosh Kumar and M. Vimal Teja [9] in their paper discussed that the composite structures for conventional metallic structures has many advantages because of higher specific stiffness and strength of composite materials. The automobile industry has shown increased interest in the replacement of steel spring with fiberglass composite leaf spring due to high strength to weight ratio. There work deals with the replacement of conventional steel leaf spring with a Mono Composite leaf spring using E-Glass/Epoxy. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring. The leaf spring was modeled in Pro/E and the analysis was done using ANSYS Metaphysics software.

VIII. Analysis and Comparison of Vehicle Dynamic System with Nonlinear Parameters Subjected To Actual Random Road Excitations

Prof. S. H. Sawant and Dr. J. A. Tamboli published a paper on Analysis and Comparison of Vehicle Dynamic System with Nonlinear Parameters Subjected to Actual Random Road Excitations. Paper investigates the importance of effects depend upon the degree of nonlinearity and so the effect on the response. In this paper, nonlinearity in mass, spring and damper are considered and compared for their individual and relative significance. Also, it is studied how nonlinearity affects the response compared to linear system. The theories of non-linear dynamics are applied to study non-linear model and to reveal its non -linear vibration characteristics. Thus this paper deals with comparison between simulation results obtained for passive and semiactive linear systems with nonlinear mass, spring and damper. The excitation is taken as actual random road excitation to achieve improved performance. Thus,the emphasis is to study the nonlinearities in mass, spring and damper for passive suspension system performance and compare the relative significance [10].

IX. Conclusion

From the literature survey it is seen that the Design and analysis of composite leaf spring, has started from developing theories related to design and development of composite leaf spring and is now moving towards optimizing various spring parameters according to applications. Theories are used to calculate the natural frequencies and mode shapes. In order to carryout vibrational analysis of composite leaf spring it is necessary to carryout analysis with nonlinear parameters.

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