An Overview of Disarray in Undamped Dynamic Vibration Absorber Subjected to Harmonic Excitation with Nonlinear Parameters

Amit A. Hingane, S. H. Sawant

ABSTRACT: ***Vibration is omnipotent, universal and multifaceted phenomena. Vibration absorption is a method of adding a tuned spring-mass absorber to a system to create anti-resonance at a resonance of the original system. Most real-world phenomena exhibit nonlinear behavior. In these paper overviews of various works are done. This paper tries to give an idea about the previous researches & their finding about study of nonlinearity in spring and mass, Static analysis of spring and study related to vibration absorber and its application.***

KEYWORDS: Vibration Absorber, Resonance, Nonlinear behavior.

I. INTRODUCTION

In vibration analysis, a dynamic vibration absorber is a tuned spring-mass system which reduces or eliminates the vibration of harmonically excited system. Rotating machines such as engines, motors and pumps often incite vibration due to rotational imbalances. A dynamic absorber can be affixed to the rotating machine and tune to oscillate in such a way that exactly counteracts the force from rotating imbalance. This reduces the possibility that a resonant condition will occur which may cause rapid catastrophic failure. [1]

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. A nonlinear spring has a nonlinear relationship between displacement and spring force. A graph of spring force vs. displacement for a nonlinear spring will be more complicated than a straight line, with a changing slope. As nonlinear springs have different load-deflection characteristics than the linear spring there will be difference in the amplitude of main mass obtained by theoretical and experimental methods. Nonlinearity in mass and spring will be considered. The nonlinearity in mass arises when mass moves with certain velocity, which is due to change in mass density of the fluid around it. Nonlinearity in spring is due to large deflection of it, which is geometric nonlinearity.

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Mr.Amit A. Hingane, Department of Mechanical Engineering, Dr.J.J.Magdum College of Engineering, Jaysingpur, India.

Prof. Dr. S. H. Sawant, Department of Mechanical Engineering, Dr.J.J.Magdum College of Engineering, Jaysingpur, India.

By considering all above facts, this paper tries to cover literature which deals with vibrational analysis of undamped dynamic vibration absorber subjected to harmonic excitation with nonlinear parameters.

II. STUDY ON HELICAL COMPRESSION SPRING OF VARYING WIRE DIAMETER

Sanket M.Modi and Shrirang P chavan in year 2012 studied helical compression spring of varying wire diameter. Helical springs are often used in mechanical systems. They can be designed in such a way that they show nonlinear behavior. This means that the spring stiffness is not constant but depends on the compression. This nonlinear behavior occurs when the number of active coils decreases or increases with varying compression. The nonlinear behavior of a spring can be achieved by varying wire diameter, pitch and mean spring diameter. For this research, a helical compression spring of varying wire diameter with a constant pitch and a constant mean spring diameter is used. Finite element analysis results of modeled spring are compared with manufactured spring.

The helical compression spring with variable wire diameter was analyzed in this paper. Then the stiffness of spring was calculated from the FE analysis and testing of spring, the following conclusions are drawn.

a) The spring studied in research shows feature of nonlinear which was found in testing of spring.

b) From the test validation, they found that there is good consistency between the results of FE simulation and test. The results and research method in this paper can be reference for the optimization of the helical spring with variable wire diameter, further improving the performance of the vehicle suspension [1].

III. A FINITE ELEMENT ANALYSIS OF THE BARREL-SHAPED HELICAL SPRING ON THE VEHICLE REAR SUSPENSION

Zuo Shuguang et al. analyzed the barrel shaped helical spring on the rear suspension of passat b5. The accurate 3D model of spring is built. Then the stiffness of spring is calculated by finite element analysis. The results of FE analysis are validated by experimental method. The barrel shaped spring used is showing nonlinear phase during compression which can improve the stability of vehicle [2].

IV. MODELING, VERIFICATION, OPTIMAL DESIGN OF NONLINEAR VALVE SPRING

Yu cheng su, Dr.Yuyi lin submitted a thesis on Modeling, Verification, Optimal Design of Nonlinear Valve Spring.

The objective of their study was optimal design of helical spring based on dynamic criteria. The most important dynamic performance criterion of a helical spring is the resonance behavior, including dynamic stress, coil closing, and surge. More design variables are also making the description of dynamics more complex. In this study, predictive dynamic models for variable pitch angle, wire diameter, and spring radius are derived by fundamental mathematics and mechanics principles. These models are nonlinear partial differential equations, in general more complex than the well-known and commonly used wave equation. Numerical solution of these dynamic models is also called dynamic simulation.

In this study, finite difference method combined with moving boundary solutions are applied to obtain the dynamic response. Dynamic responses as a time domain, discrete data from various models are compared with data from physical dynamic experiments to verify the accuracy of the models, and to improve the parameters in the dynamic models. Fast Fourier Transform (FFT) is utilized as a tool to evaluate severity of resonance in different models and in optimization process. To verify that the use of finite difference in the simulation process is providing stable and reliable results, the numerical solutions are compared with solutions obtained using ABAQUS-MATLAB programs. Results in terms of system eigenvalue calculation obtained by different programs, either commercial or Finite Difference Method (FDM), showed very good agreements. Numerical optimization results obtained in this study also showed that it is worthwhile to introduce more design variables to increase the flexibility in an optimal design process for obtaining better results [3].

V. VIBRATION ISOLATION USING NONLINEAR SPRINGS

M.I.Friswell, Y.xia presented a paper on Vibration Isolation Using Nonlinear Spring. Their work deals with basics of vibration isolator, linear vibration isolation and nonlinear vibration isolation mounts. There are two significant problems with HSLDS mounts that this paper aims to address. Current approaches to realize the required nonlinear characteristics are often inconvenient and various design based on beam type structures will be investigated. Second, the weight of the supported equipment, the environment, or the structural stiffness may change, requiring the mount to be semi-active and to tune its nonlinear characteristics.

The results in this paper have demonstrated that the linear stiffness and the point of inflection in the force displacement characteristic for the beam isolator may be tuned by prescribing the displacement and rotation at the ends of the beam [4].

VI. 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 reactive significance [5].

VII. DESIGN OF A NONLINEAR VIBRATION ABSORBER

Maxime Geeroms, Laurens Marijns of Ghent University, Department EESA, Belgium carried out work on nonlinear vibration absorber. They found that linear vibration absorbers can only capture certain discrete frequencies. Therefore the use of nonlinear vibration absorbers which can capture a whole range of frequencies is investigated as an alternative. Such a nonlinear vibration absorber has some special characteristics. For example there is certain frequency-energy dependence. To investigate nonlinear dynamical systems there is a need for new methods. The harmonic balance method is such a method and is discussed. The idea is to substitute a Fourier series expansion of the solution variables into the system equations and 'balance' them. Furthermore two realizations of a nonlinear energy sink as an example of a nonlinear vibration absorber are discussed. One based on the restoring force in a wire, the other one by forcing a linear spring to follow a certain path. As will be discussed, an analog principle can be used for the realization of a Duffing type of nonlinear absorber [6].

VIII. THE EXPERIMENTAL PERFORMANCE OF A NONLINEAR DYNAMIC VIBRATION ABSORBER

Yung-sheng Hsu, Neil S Ferguson have investigated the physical behaviour and effectiveness of a nonlinear dynamic vibration absorber (NDVA). The nonlinear absorber considered involves a nonlinear hardening spring which was designed and attached to a cantilever beam excited by a shaker. The cantilever beam can be considered at low frequencies as a linear single degree-of-freedom system. The nonlinear attachment is designed to behave as a hardening Duffing oscillator. The nonlinearity of the attachment is due to the particular geometrical configuration undergoing a large amplitude response. The experiment investigated the potential for vibration reduction of the system. Analytical and numerical results are presented and compared. From the measured results it was observed that the NDVA had a much wider effective bandwidth compared to a linear absorber. The frequency response curve of the NDVA has the effect of moving the second resonant peak to a higher frequency away from the tuned frequency so that the device is robust to mistuning.

This paper has also investigated the influence of the NDVA parameters on the vibration reduction. The nonlinearity resulted in a much wider effective bandwidth compared to that for a linear absorber with similar mass and damping. It was found that the frequency response curve of the NDVA has the effect of moving the second resonant peak to a higher frequency away from the tuned frequency, so that the device is robust to mistuning. Experimental results have been presented to compare with the model derived [7].

IX. ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF A TUNED UNDAMPED DYNAMIC VIBRATION ABSORBER IN TORSION.

Prof. H.D. Desai and Prof. Nikunj Patel published a paper on Analytical and Experimental Investigation of a Tuned Undamped Dynamic Vibration Absorber in Torsion. In this paper design and development of experimental setup for determining the response characteristics of torsional, tuned, undamped, dynamic vibration absorber is presented. A mathematical model for the absorber with base excitation is developed and the theoretical values of the torsional amplitude are calculated for different values of excitation frequency. The theoretical and experimental results are correlated.

The theoretical and experimental results are superimposed for both the single degree of freedom system and absorber respectively. From these graphs it can be observed that a correlation exists between theoretical and experimental results but due to nonlinearities exists in the system itself, the experimental and theoretical results doesn’t exactly matches [8].

X. DESIGN AND DEVELOPMENT OF A PENDULUM TYPE DYNAMIC VIBRATION ABSORBER FOR A SDOF VIBRATING SYSTEM SUBJECTED TO BASE EXCITATION

Irshad M. Momin Dr. Ranjit G. Todkar published a paper on Design and Development of A Pendulum Type Dynamic Vibration Absorber for A Sdof Vibrating System Subjected to Base Excitation

The use of centrifugal pendulum for dynamic vibration absorber design (CPVAs) is a proven method for reducing undesired torsional vibrations in rotating systems. These devices are in use for many years, most commonly in light aircraft engines, helicopter blade rotors etc. These devices have also been reported for reduction of rectilinear vibrations. Pendulum type dynamic vibration absorbers use impact forces for effective reduction of rectilinear vibrations describing modeling method and transient state analysis in view of spring impact absorbers, floating impact absorbers and pendulum impact absorbers. Bond graph technique for modeling of SDOF vibrating system excited by rotating unbalance at the sprung mass using a pendulum type dynamic vibration absorber is reported in the recent literature. This paper deals with the modeling and design procedure for a centrifugal pendulum type dynamic vibration absorber (CPVA) subjected to base excitation. This paper presents a detailed analysis and experimental investigations of the effect of parameters affecting the motion transmissibility of the sprung mass such as size of the pendulum mass, eccentricity of the pendulum pivot with respect to axis of rotation of the pendulum assembly, mass ratio (ratio of the pendulum mass to the sprung mass), gear ratio (the ratio of the pendulum rotational frequency to the excitation frequency) and the frequency ratio (the ratio of the excitation frequency to the natural frequency of the SDOF system). It has been proved that the CPVA is effective in reduction of motion transmissibility of the sprung mass of the SDOF system with the proper selection of the affecting parameters [9].

XI. CONCLUSION

By the literature review it is seen that importance of nonlinear anaysis and various methods of static analysis of spring. In earlier recherchés linear parameters of vibration absorber were considered but in practice the spring and mass behaves with nonlinear characteristic. So it is important to consider the nonlinearities of spring and mass while designing the vibration absorber.

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