INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

There are many physical systems such as engineering structures or machines which undergo severe vibration and need a reduction in vibration by using passive or active vibration absorbers. In the passive vibration absorber, structural modification is carried out by attaching an additional spring-mass-damper system to the vibrating main or primary system to reduce its vibration. Whereas in the active vibration absorber (AVA) various sensors and actuators are integrated with the passive vibration absorber to suppress the vibration of the primary system. The vibration absorbers are generally designed based on the assumption that the absorber structure possesses linear characteristics. However, an effective vibration absorber vibrates with a large amplitude leading to the dominance of structural nonlinearity. Thus, the linearity assumption regarding the elastic properties of the absorber substructure does not hold good in reality. Also, nonlinearity is inherently present in the main vibrating primary systems due to prolonged use, certain applications, or being subjected to various forms of external excitations. The available passive and active vibration absorbers also come up short to suppress the vibration in nonlinear primary systems under varied resonance conditions. Since the existence of nonlinearity in the primary systems and the absorber system are inevitable. It is observed from the literature that with the available passive or active vibration absorbers the vibration reduction of the primary system under varied resonance conditions is still high or limited to a very narrow range of operating frequencies. Also, complete vibration suppression of the nonlinear vibrating primary system is not achieved under various resonance conditions. The investigations of AVA with acceleration or combination feedbacks (displacement, velocity and acceleration) and its effectiveness in vibration suppression are also not explored. So, in the present thesis, a modified designed piezoelectric stack actuator based active nonlinear vibration absorber (ANVA) with various feedbacks and time delay is considered, where the frequency of the absorber can be actively changed to suppress the vibration of the primary system. In the modified designed ANVA the PZT (lead zirconium titanate) stack actuator is connected in series connection with a spring in the absorber configuration for a fail-safe design.

In this work, five problems related to the ANVA have been investigated considering the linear and nonlinear primary systems under various resonance conditions. In the first problem, the linear single degree of freedom (SDOF) spring-mass-damper primary system is subjected to an external harmonic excitation and its vibration suppression is carried out considering linear active vibration absorber (AVA) with acceleration feedback. Optimized parameters such as tuning ratio and damping ratio for the proposed AVA are obtained from the fixed-point theory (FPT) and genetic algorithm (GA). The optimal feedback gain is also evaluated maintaining Den Hartog's equal peaks in the frequency response and it is shown that with the active force the response amplitude of the primary system reduces close to its static deflection.

In the second problem, a similar system to the first problem is analyzed but here cubic nonlinear springs are considered. Also in this problem, the primary system is subjected to both external harmonic and base excitations. The active force by the ANVA is produced considering the time delay in the acceleration feedback. The modified harmonic balancing method (HBM), and Newton's method are used to study the system responses and stability. Fundamentally based on nonlinearity, presence and absence of PZT stack actuator (active force), delay and base excitation twenty different cases have been investigated. The system steady-state responses are investigated through the frequency responses, time responses, phase portraits, Poincare' sections, basin of attractions, force responses and different time delay effects in the feedback. The bifurcation and stability of the system are studied from various system parameters. It is shown that with the proposed ANVA significant vibration suppression for the nonlinear system is achieved and Den Hartog's equal peaks in the frequency response of the system are obtained when the primary system is subjected to both harmonic and base excitations.

In the third problem, a few modifications to the second problem are carried out by considering the undamped primary system subjected to external harmonic and parametric excitation. Here two types of ANVA are studied viz., traditional and non-traditional ANVA. The active feedback gain is produced by time delay in displacement, velocity and acceleration feedback. The method of multiple scales (MMS) is used to obtain the solutions which are found to be in good agreement with the linear, HBM and numerical methods. It is shown that with the proposed feedback gain by the ANVA, 100% vibration reduction in the primary system is achieved for the primary, principal parametric and simultaneous primary and principal parametric resonance conditions. Also, for a wide range of operating frequencies, the vibration of the primary system is reduced by changing the frequency of the absorber actively.

In the fourth problem, the previous problem (third problem) is modified considering the primary system subjected to external hard harmonic excitation, parametric excitation and base excitations. The ANVA is also modified considering time delay in the damper along with combinations of time-delayed displacement, velocity and acceleration feedback. The MMS is used to obtain the solution of the system for primary, principal parametric, sub and superharmonic resonance conditions considering 1:1, 1:2, 1:3 and 3:1 internal resonance condition. From the investigations on various active gains by different feedbacks and time delays, 100% vibration suppression of the nonlinear system is analyzed.

In the fifth problem, three different systems are studied. In the first system vibration suppression of the forearm tremor of the human hand with ANVA is carried out. In the second problem, a continuous beam system with various boundary conditions is considered as the primary system. The ANVA is attached to the beam which is subjected to a point load. The analyses are carried out to suppress the vibration of the beam at the first three modal frequencies with the displacement and velocity feedbacks by the ANVA. In the third problem, the ANVA is modified by a nonlinear rotational inertial double-tuned mass damper (RIDTMD) and influence of nonlinear stiffness in the system responses are studied. In all these systems HBM is used to obtain the solution of the governing equations of motion.

These studies will give a clear idea to the designer to know the safe operating zone and the system responses for various system parameters. From this research work, it is shown that one can completely suppress the vibration of the linear and nonlinear primary system for various resonance conditions. Also, the proposed ANVA is a fail-safe design i.e., when the active part fails due to electronic malfunction, then the passive optimal absorber can still protect the primary system from severe vibration.