Bifurcation studies of a nonlinear mechanical system subjected to multi-frequency-quasi-periodic excitations

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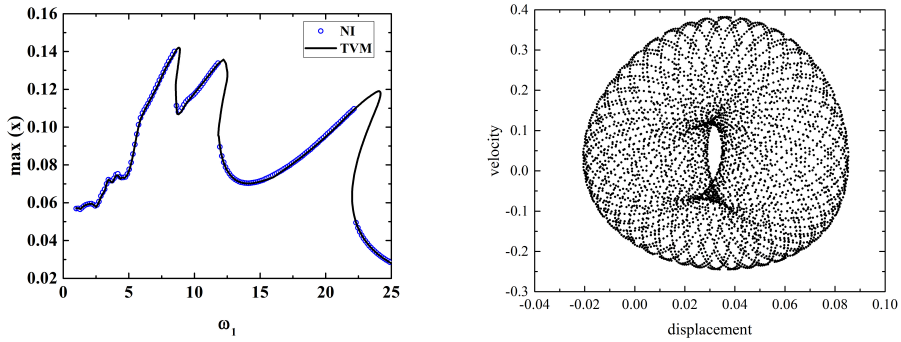
Abstract. The main objective of this paper is to present the nonlinear response characteristics of a mechanical system subjected to multi-frequency-quasi-periodic excitations. The analysis is performed using a duffing oscillator undergoing multiple frequency excitations with its frequency components are irrational multiples of each other. The effects of system parameters such as nonlinear stiffness and excitation amplitudes are analyzed using bifurcation diagrams and Poincaré maps. A time-domain technique called time variational method (TVM) is used to obtain the nonlinear, steady-state response of the system. It is an appropriate method for solving more than two-frequency excitations problems compared to other methods. Quasi-periodic motion leading to chaos are observed in the response through Poincaré maps and bifurcation diagrams.

Introduction

The engineering systems such as electronic circuits, vehicle suspensions, gears and multi-spool gas turbines are often subjected to multi-frequency-quasi-periodic excitations during their operation period. The presence of nonlinearities in the system adds complexity in the analysis and makes the system response unpredictable some times. It requires an extensive nonlinear dynamic analysis of such systems to prevent their unwanted failure during the worse operating conditions. Generally, the numerical integration schemes are employed to solve the nonlinear differential equations representing the system [1]. However, it is very time-consuming for the multi-degree of freedom (DOF) models since all the transients need to die out for obtaining the steady-state response. Some researchers [2] have used multi-harmonic balance method (MHBM) to acquire the frequency responses which is found to be very effective compared to numerical integrations. But, for more than two-frequency excitation problems, the use of MHBM becomes difficult since the conversion between time and frequency domains is appeared to be cumbersome. In such cases, the time variational method (TVM) which is based on time-domain analysis is suitable for predicting the nonlinear characteristics of the system very well [3]. In literature, there are not many studies that analyze the nonlinear characteristics of the mechanical systems undergoing more than two-frequency quasi-periodic excitations. Hence, in this paper, a detailed nonlinear analysis of a multi-frequency-quasi-periodic excitation problem is presented using frequency response curves, Poincaré maps and bifurcation diagrams.

Results and Discussions

The results are presented for a duffing oscillator subjected to three-frequency-quasi-periodic excitation. The frequency response diagram is shown in Fig. 1a which presents the effectiveness of the TVM in capturing the complete response of the system compared to numerical integration. Fig. 1b shows the Poincaré map of the response when $\omega_1 = 10\ rad/sec$. A torus like structure is observed indicating the quasi-periodic motions.



(a) frequency response (b) Poincaré map

Figure 1: Frequency response and Poincaré map of the three-frequency excitation problem

References

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