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Extended Abstract

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Nonlinear resonance analysis

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Description of the universe in the scientific paradigm is based on conceptions of action and reaction. The main question then is, what sort of reaction should be expected to this or that action. Intuitively we expect bigger reaction to bigger action, and this is mostly the case. However, there exists a remarkable exception-the phenomenon of resonance first described by Galileo Galilei in 1638: "one can confer motion upon even a heavy pendulum which is at rest by simply blowing against it; by repeating these blasts with a frequency which is the same as that of the pendulum one can impart considerable motion". Nowadays resonance is generally regarded as a red thread which runs through almost every branch of physics; without resonance we wouldn't have radio, television, music, etc. Horrible destructions due to the occurrence of resonance in a particular system are also well known. The demand for a good mathematical description allowing to predict the appearance of a resonance and to deduce its quantitative characteristics, is obvious. Linear resonances are easily treatable by the linear Fourier analysis while for the description of nonlinear resonances a new branch of the mathematical physics has been recently developed (a book of speaker): "Nonlinear Resonance Analysis", with its own theory, computational methods, applications and open questions. In this lecture I shall demonstrate how nonlinear resonance analysis can be applied to a number of real systems, including largescale phenomena in the Earth's atmosphere and novel wave turbulent regimes, and explains a range of laboratory experiments. The dynamic nonlinear response and stability of slender structures in the main resonance regions are a topic of importance in structural analysis. In complex problems, the determination of the response in the frequency domain indirectly obtained through analyses in time domain can lead to huge computational effort in large systems. In nonlinear cases, the response in the frequency domain becomes even more cumbersome because of the possibility of multiple solutions for certain forcing frequencies. Those solutions can be stable and unstable, in particular saddle-node bifurcation at the turning points along the resonance curves. In this work, an incremental technique for direct calculation of the nonlinear response in frequency domain of plane frames subjected to base excitation is proposed. The transformation of equations of motion to the frequency domain is made through the harmonic balance method in conjunction with the Galerkin method. The resulting system of nonlinear equations in terms of the modal amplitudes and forcing frequency is solved by the Newton-Raphson method together with an arc-length procedure to obtain the nonlinear resonance curves. Suitable examples are presented, and the influence of the frame geometric parameters and base motion on the nonlinear resonance curves is investigated.

The dynamic nonlinear response and stability of slender structures in the main resonance regions are a topic of importance in structural analysis. In complex problems, the determination of the response in the frequency domain indirectly obtained through analyses in time domain can lead to huge computational effort in large systems. In nonlinear cases, the response in the frequency domain becomes even more cumbersome because of the possibility of multiple solutions for certain forcing frequencies. Those solutions can be stable and unstable, in particular saddle-node bifurcation at the turning points along the resonance curves. In this work, an incremental technique for direct calculation of the nonlinear response in frequency domain of plane frames subjected to base excitation is proposed. The transformation of equations of motion to the frequency domain is made through the harmonic balance method in conjunction with the Galerkin method. The resulting system of nonlinear equations in terms of the modal amplitudes and forcing frequency is solved by the Newton-Raphson method together with an arc-length procedure to obtain the nonlinear resonance curves. Suitable examples are presented, and the influence of the frame geometric parameters and base motion on the nonlinear resonance curves is investigated. A model of piezoelectric rectangular thin plates with the consideration of the coupled thermo-piezoelectric-mechanical effect is established. Based on the von Karman large deflection theory, the nonlinear vibration governing equation is obtained by using Hamilton's principle and the Rayleigh-Ritz method. The harmonic balance method (HBM) is used to analyze the first-order approximate response and obtain the frequency response function. The system shows non-linear phenomena such as hardening nonlinearity, multiple coexistence solutions, and jumps. The effects of the temperature difference, the damping coefficient, the plate thickness, the excited charge, and the mode on the primary resonance response are theoretically analyzed. With the increase in the temperature difference, the corresponding frequency jumping increases, while the resonant amplitude decreases gradually. Finally, numerical verifications are carried out by the Runge-Kutta method, and the results agree very well with the theoretical results.

Bottom Note: *This work is partly presented at 2nd International Conference on Physics August 28-30, 2017, Brussels, Belgium*