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Nonlinear dynamics of a cable-stayed beam driven by sub-harmonic and principal parametric resonance

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Abstract

The nonlinear dynamics of a cable-stayed beam driven by the subharmonic resonance of the beam and the principal parametric resonance of the cable are investigated. Considering the combined effects of the nonlinear terms caused by the geometry of the cable and the coupled behavior between the modes of the beam and cable, a spatial discrete model of the cable-stayed beam is developed. The frequency response curves are determined by applying the method of multiple time scales to the model. The effects of some key parameters of the cable-stayed beam, namely the mass, stiffness, and sag-to-span ratios and the initial tension force, are discussed. The bifurcation and chaos of cable-stayed beams with different parameters are also studied to understand the effects of external excitation. The results show that these parameters have a considerable effect on the dynamic behavior of the cable-stayed beam, particularly that of the cable. Changes in the stiffness ratio and initial tension force also lead to more complex dynamics.

Keywords: cable-stayed beam, frequency response, principal parametric resonance, subharmonic resonance, nonlinear dynamics

1. Introduction

A cable-stayed beam consists of a flexible cable and a rigid beam; the former must be under only tensile stress and the latter can experience both tensile and compressive stress. The moment distribution of the beam can be improved by the elastic support from the cable when both are combined to form an overall structure. Given its simple structure, clear load-carrying path, and the mechanical properties of its flexible cable and rigid beam, cable-stayed beams are widely used in engineering projects, such as cable-stayed bridges, tower cranes, guyed masts, and suspended roofs. However, the length of the cable also increases as the spans of these projects increase; as a result, the nonlinear characteristics of the overall structure become very prominent and often play a decisive role. Furthermore, combining the cable and beam results in new mechanisms in the cable-stayed beam, such as internal and external resonance and combinations of these two types of resonance. Understanding the dynamics of the cable-stayed beam from the perspective of nonlinear dynamics is therefore very important.

Previous investigations have focused on the nonlinear dynamics of a single beam [1-5] or cable [6-9]. From the perspective of the overall structure, a Ritz-type coupled model was presented experimentally by Fujino et al. [10, 11] to investigate cable–beam interactions. Based on this model, Gattulli et al.[12]