Abstract

The current research work addresses two interesting systems related to rotating beams. The first dynamical system under consideration is an articulated uniform beam rotating in vacuum under vertical hub excitation along the axis of rotation. The study considers the ensuing parametric instabilities in the considered system. Parametric excitation manifests in the form of time-varying parameters of a dynamical system. Interestingly, more often than not, these time-varying parameters are time periodic in nature and possess inherent frequency/frequencies of oscillation. In an externally forced system, response grows increasingly large when the frequency of the external forcing is close to the system natural frequency/frequencies. In contrast, a parametrically excited system may show large responses under the effect of parametric resonance even when the excitation frequency does not coincide with the system natural frequency/frequencies. In the current study, the effect of parametric excitation on a simple articulated uniform rotating beam in vacuum is considered. The autonomous form (in the absence of base excitation) of the system possesses a non-trivial equilibrium point which is a function of rotation speed and the acceleration due to gravity. In the absence of damping, the considered equilibrium point is neutrally stable and happens to be stabilize in the presence of positive structural damping. However, on application of the hub excitation, the equilibrium point is annihilated, but the system still oscillates in the near neighborhood of the equilibrium point (corresponding to the autonomous system). The ensuing oscillations can be rendered unstable owing to parametric resonance through tuning of the excitation. The linearization of the system close to the equilibrium point leads to the celebrated Mathieu equation with external forcing. The stability surface dividing the stability-instability region of the resulting Mathieu equation is derived by invoking the Floquet theory.

The nonlinear stability boundaries are constructed using Poincaré maps, and are compared with the linear stability boundaries. In order to validate the theoretical study, an experimental model is designed. Although, the primary resonance is captured sufficiently well, the higher and lower order parametric resonances are nuanced due to the presence of damping. However, the experimental results do in fact indicate the existence of these parametric resonances on the parameter plane.

The second part of the study is concerned with the existence and bifurcations of nonlinear normal modes (NNMs) of a flexible beam rotating in vacuum with both transverse and longitudinal deflection. The nonlinear strain-displacement relation is considered while deriving the equations of motion which are coupled through quadratic and cubic nonlinearities. The discretized form of nonlinear coupled equations of motion is derived considering coupling between the first mode of transverse and longitudinal oscillations resulting in nonlinearly coupled oscillators. The effect of slenderness ratio, rotation speed and the system energy is considered on the evolution of the ensuing NNMs and sub-harmonics and the cascade of bifurcations experienced by these modes are explored.