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RESONANT DYNAMICS IN A ROTORDYNAMIC SYSTEM WITH NONLINEAR INERTIAL COUPLING

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ABSTRACT

The dynamical response of an unbalanced rotor is coupled to the underlying vibrations of the support through nonlinear inertial coupling, proportional to the magnitude of the unbalance. In the absence of the imbalance, and hence the inertial coupling, when the rotor is subject to constant torque its angular velocity increases linearly in time. In the presence of the imbalance and external torque, the angular velocity of the rotor is no longer an explicit function of time, rather it becomes another state variable in the system. With constant torque, modeling the spin-up of rotordynamic systems, when the angular velocity of the rotor approaches the natural frequency of the underlying support, a resonance occurs and the amplitude of the support vibrations can increase. For sufficiently large torques, in the presence of the unbalance the response of the coupled system is nearly identical to that of the balanced system. That is, the angular velocity of the system under constant torque increases almost linearly while the vibrations of the supporting system remain limited. In this case the angular velocity of the rotor passes through the resonance.

However, as the magnitude of the imbalance increases or the external torque decreases, the qualitative behavior of the system can change. Near the resonance between the rotational and translational motion, the system can become locked in resonance. That is, because of the inertial coupling despite the presence of the external torque applied to the rotor, its angular velocity does not increase. Rather, on average this value remains constant and instead the amplitude of the translational motions increases. This phenomena, known as the Sommerfeld effect, provides a mechanism for energy transfer from the rotational to the translational mode.

This work develops estimations of the regions in parameter space that lead to responses that become captured into resonance, rather than pass through the resonance. The response is modeled with a nonlinear, damped Jeffcott rotor and a reduced-order model is developed, valid near the resonance, that describes this resonant behavior. Analysis of this model leads to the desired relationships between torque, damping, and stiffness that deliminate systems that are captured into resonance from those that pass through the resonance. The predictions from the reduced-order model are verified against numerical simulations of the original equations of motion.

Keywords: Jeffcott rotors, Resonance Capture, Nonlinear Coupling, Spin-up