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Parametrically Excited Rotating Shafts on Gas Foil Bearings

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Abstract: The possibility of applying parametric excitation in a flexible rotating shaft utilizing controllable-adjustable gas foil bearings is investigated in this paper. The gas foil bearings are investigated on introducing periodic variation of impedance gas forces through a theoretical and simplistic concept of time periodic variation of nominal clearance between top foil and rotor surface. The embedded excitation mechanism is not discussed in this paper. The potential to introduce parametric anti-resonance and modal interaction and extent the threshold speed of instability (Hopf bifurcation) at higher speeds is of major interest in this work. Collocation method is implemented for the evaluation of limit cycles of the parametrically excited system (periodically forced), and the stability of motion is assessed for the various frequencies of excitation through Floquet multipliers. Continuation method is applied for the computation of limit cycles of motion and the respective stability as the parameter of excitation frequency changes (bifurcation parameter). It is found that the parametrically excited system may operate in stable trajectories in higher rotating speeds than the reference system without excitation. Various rotor-bearing designs are investigated with respect to key design parameters (rotor slenderness, bearing geometry, bump foil stiffness and damping).

Keywords: parametric excitation, gas foil bearings, continuation and stability of limit cycles

1. Introduction

Parametric excitation has been investigated on its potential to introduce anti-resonance and modal interaction, extending the stability margins of mechanical structures [1-2]. Recently, oil bearings with adjustable geometry were utilized to apply parametric excitation in rotors through time-periodic variation of the journal bearing's radial clearance [3-4].
The motivation of this work lies on the rising need for oil-free rotor-bearing systems, with gas foil bearings to have vital role [5-6]. The potential to utilize the principle of parametric excitation in such system is checked in this paper in preliminary stage through simplistic assumptions for rotor geometry (flexible rotor carrying three masses) and simplistic gas-foil-bearing model with linear bump foil stiffness and damping [7], applied through a theoretical change in nominal clearance. The change in nominal clearance can be achieved using piezo-actuators [8] and the implementation is left for future investigations. The work aims primarily to detect the sensitivity of resulting gas forces when nominal bearing clearance varies by 0-50%. The corresponding limit cycle motions of a balanced rotor (still non-autonomous due to parametric excitation) are investigated for stability after computed through collocation scheme. A code for pseudo-arc-length continuation of limit cycles is programmed to evaluate the solution branches and the respective stability of the system as the parameter of excitation frequency changes.

2. Results and Discussion

A two-segment rotating shaft mounted on two gas foil bearings and carrying three lumped masses is modelled with FEM. The equations of motion are written for the 12 DOFs with gyroscopic coupling to be considered. Gas foil bearings follow the modelling in [7] and further physical coordinates are introduced defining the deformation of the top foil at each bearing. The state space representation of the motion equations renders the state vector **x** including physical coordinates and gas pressure distribution at each bearing. The non-autonomous (periodically forced) dynamic system is defined in Eq. (1) where Ω_{ex} is the excitation frequency of each top foil (equal for both bearings), acting as primary bifurcation parameter. The dynamic system is converted to autonomous by adding to the equations of motion a nonlinear oscillator with the desired periodic forcing as one of its solution components.

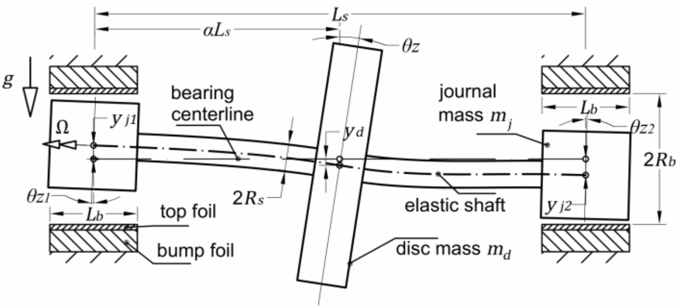

Fig. 1. Flexible rotor supported by two gas foil bearings.

$$\dot{\mathbf{x}} = \mathbf{f}\left(\mathbf{x}, \Omega_{ex}, t\right) \tag{1}$$

Results include limit cycles of motion in regards to Ω_{ex} for various key design characteristics of the system. Stability and bifurcations of equilibriums (fixed points) and of limit cycles are investigated at the cases of parametric resonances for certain Ω_{ex} .

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