Stability analysis of hydrodynamic journal bearings using bifurcation and continuation methods

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ABSTRACT

Accurate prediction of rotor bearing system response and stability throughout the rotating speed range and under various operating conditions is of primary interest in an engineering context. It is known that rotors carried in fluid journal bearing may exhibit harmful unstable behaviour above certain critical speed. This instability may significantly affect machine performance and endanger its safe operation.

Exploring the dynamic behaviour of a hydrodynamic journal bearing, linearized analysis is usually used to determine stability boundaries. Nonlinear bifurcation and continuation methodology is required, however, to predict the presence and the size of stable or unstable limit cycles in the neighbourhood of the stability critical speed [1-2]. In recent research work, continuation methods have been developed so that limit cycles are computed by continuation algorithms and bifurcations of the limit cycles can also be detected in addition to the bifurcation of the equilibrium point [3].

In the present paper, a nonlinear dynamical model of a plain hydrodynamic cylindrical journal bearing for a perfectly balanced symmetric rigid rotor is derived and used. The fluid film hydrodynamic reactions are modelled by applying both the short and the long bearing approximation and using half Sommerfeld solution. Hopf bifurcation theory is utilised to predict the behaviour of the steady state equilibrium point of the journal center. Depending on bearing parameters, two cases may be encountered. The journal centre may undergo stable limit cycles, also known as periodic orbits, of increasing amplitudes at speeds above the threshold speed or unstable limit cycles at speeds below the threshold speed. Limit cycle continuation from the Hopf point have been applied to predict the periodic orbits and to detect the point at which these orbits bifurcate by folding. This paper shows that limit cycles themselves disappear beyond a certain rotor speed to exhibit a fold bifurcation giving birth to stable or unstable limit cycles surrounding the unstable subcritical or the stable supercritical limit cycles established by bifurcation theory for both short and long journal bearings. Numerical integration of the equations of motion is then carried out to verify and validate the results obtained using numerical continuation.

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