Abstract

The flexible rotating shaft with rigid-disk has widely been used in numerous industrial and nonindustrial applications starting from daily used home appliances, transportation, shipping, heavy industries, aerospace, mining, power generation and many more. Identifying characteristics behaviour of the systems and analysing its stability in working environment is very important subject impacting design, control, maintenance and safety. Linear analysis of such systems explores only fundamental characteristics behaviour of the systems, and it becomes difficult to predict the reasons behind a violent behaviour and the catastrophic failure of the system under critical working conditions while presence of the nonlinearities within the system causes undesirable behaviour of the system that may further lead to working instability. To address this need, nonlinear approach becomes more inevitable to indicate and detect the causes of nonlinearities. Thus, objective of this research is to perform nonlinear analysis of the rotating system mounted on flexible bearings with nonlinearity due to large deformation of the shaft and bearings to study the effect of mass unbalance, axial load, rotor-stator interaction and moving base on the system's stability, bifurcation and prediction of chaotic behaviour.

Dynamic model of a flexible rotating system consisting of a flexible shaft with geometric eccentricity, a rigid disk loaded with an unbalance mass and characterized with the nonlinear curvature, axial stretching effect and gyroscopic effect has been developed. A mathematical model of the rotor bearing system is developed using Galerkin's principle and the extended Hamilton's principle. Free vibration analysis of the nonlinear rotor bearing system is performed to analyse the effect of nonlinearity on the characteristics behaviour of the system with influence of the disk parameters. Further the study is extended to analyse the forced vibration with the effect of an unbalance mass, a pulsating axial loading and moving platform excitation. Effect of the nonlinearity is monitored considering the different resonance conditions of these different excitations and analyzed the stability for corresponding behavior of the system. A perturbation technique has been used to obtain a set of nonlinear algebraic equations that govern the overall dynamics of the system. The system stability has been studied by investigating the bifurcation and route to chaos upon changing the design parameters such as geometric eccentricity, mass unbalance and disk parameters under the resonance conditions. The present system exhibits a complex behaviour travelling with periodic, quasi-periodic, period-doubling and chaotic on a gradual change of design variables. These complex behaviours have been studied in detail with the illustration of time history, phase trajectories, bifurcation diagrams and Poincare's map for the each category. Qualitative assessment of bifurcation diagrams has been studied to explore the boundaries of the stable and unstable behaviours and essential dynamics of the systems. Then, the perturbation results are compared with results obtained using direct integration of the equations of motion to verify its compliance. The results are then portrayed using different vibration analyzing tools for better understanding.

Further, a non-dimensional equation of motion for the rotor-bearing model is formulated considering the inextensibility condition of the shaft axis. The model is analysed considering nonlinear effect due the inextensible condition under excitations due to an unbalance force, combined effect of an eccentricity and unbalance mass, contact phenomena between the disk and casing. A set of nonlinear algebraic equations have been derived from the nonlinear governing equation to obtain system responses and their stability upon changing the design variables i.e., unbalance and disk parameters under resonance condition due to imbalance and geometric eccentricity as well as rubbing model parameters.

Large and violent vibrations are major problems in the light-weight and flexible rotor system. Thus, external damping always needed for effectively controlling and reducing the vibration. The viscoelastic material can provide means to reduce the vibrations and act as a mechanical damper. To analyses influence of viscoelastic properties on the nonlinear behavior of the system, a material for the shaft is considered as viscoelastic. Results are then portrayed using different vibration analyzing tools for better understanding.

...