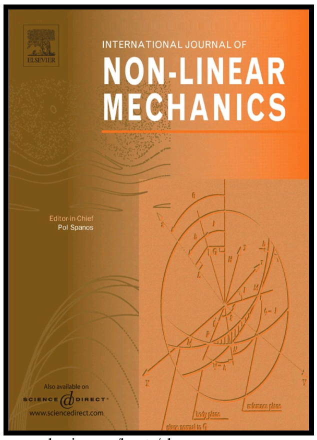

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Abstract

The dynamics of a modified Jeffcott rotor is studied, including rotor torsional deformation and rotor-stator contact. Conditions are studied under which the rotor undergoes either forward synchronous whirling or self-excited backward whirling motions with continuous stator contact. For forward whirling, the effect on the response is investigated for two commonly used rotor-stator friction models, namely, the simple Coulomb friction and a generalised Coulomb law with cubic dependence on the relative slip velocity. For cases with and without the rotor torsional degree of freedom, analytical estimates and numerical bifurcation analyses are used to map out regions in the space of drive speed and a friction parameter, where rotor-stator contact exists. The nature of the bifurcations in which stability is lost are highlighted. For forward synchronous whirling fold, Hopf, lift-off, and period-doubling bifurcations are encountered. Additionally, for backward whirling, regions of transitions from pure sticking to stick-slip oscillations are numerically delineated.

Keywords: Jeffcott rotor, bifurcations, drill-string dynamics, nonlinear oscillations, torsional vibrations

1. Introduction

The focus of this paper is on the dynamics of a modified version of the Jeffcott rotor [1], including the geometric nonlinearity originating from torsional-lateral coupling and friction due to rotor-stator contact. Such a rotor, which can undergo elastic torsional deformations in addition to the rigid body rotation about its drive axis has been studied previously, see [2] and the references within.

A key motivation for this simplified single-rotor model is its application in understanding the dynamics of rotary drill-strings, which are slender rotating structures that are used to drill for petrochemicals and in other geothermal applications. These structures are rather different from typical rotating machines, because they typically have large torsional deformations and can also feature significant imbalance and eccentricity originating from curvature in the string. Moreover, rotor-stator contact is often designed to be a key part of such devices through the introduction of stabilizing disks.

Previously, Edwards *et al.* [3] performed a parametric study of a rotor-stator system similar to the one presented here and mapped out regions of impacting motions and quasi-periodic behavior.