Journal of Sound and Vibration 412 (2017) 389–409

Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

Characterisation and calculation of nonlinear vibrations in gas foil bearing systems–An experimental and numerical investigation

Robert Hoffmann *, Robert Liebich

Chair of Engineering Design and Product Reliability, Berlin Institute of Technology (TU Berlin), Str. d. 17. Juni 135, 10623 Berlin, Germany

ARTICLE INFO

Article history:
Received 9 January 2017
Revised 27 September 2017
Accepted 28 September 2017
Available online XXX

Keywords:
Gas foil bearings
Nonlinear vibrations
Linearised method

ABSTRACT

This paper states a unique classification to understand the source of the subharmonic vibrations of gas foil bearing (GFB) systems, which will experimentally and numerically tested. The classification is based on two cases, where an isolated system is assumed: **Case 1** considers a poorly balance rotor, which results in increased displacement during operation and interacts with the nonlinear progressive structure. It is comparable to a Duffing-Oscillator. In contrast, for **case 2** a well/perfectly balanced rotor is assumed. Hence, the only source of nonlinear subharmonic whirling results from the fluid film self-excitation. Experimental tests with different unbalance levels and GFB modifications confirm these assumptions.

Furthermore, simulations are able to predict the self-excitations and synchronous and subharmonic resonances of the experimental test. The numerical model is based on a linearised eigenvalue problem. The GFB system uses linearised stiffness and damping parameters by applying a perturbation method on the Reynolds Equation. The nonlinear bump structure is simplified by a link-spring model. It includes Coulomb friction effects inside the elastic corrugated structure and captures the interaction between single bumps.

1. Introduction

Gas foil bearings (GFBs) have successfully been introduced into small turbo machinery for more than 40 years, e.g. air cycle machines, turbo compressors, turbochargers and compressors of fuel cells. Major advantages of compliant foil bearings are low drag friction, high speed operation, high temperature endurability and the omission of an oil system, [1]. In a bump type gas foil bearing the elastic bearing wall comprises a bump and a top foil made of thin sheet metal. Both foils are fixed with the bearing sleeve, e.g. by spot welds. Due to the eccentrically rotating bearing journal a fluid dynamic pressure field $p(z, \theta)$ is generated in the aerodynamic wedge and deforms the elastic structure $h(z, \theta)$ and an optimal film thickness is achieved, see Fig. 1. Thus, higher load capacities compared to rigid gas bearings are generated, [2]. The deformation of the foils may activate sliding contacts inside the elastic structure delivers additional damping and improves the dynamic behaviour compared to rigid gas bearings. Nevertheless, the low viscosity of the air film results in an overall low damping level, which is still a key issue because the poor damping ability may result in nonlinear vibrations. Those can significantly affect the rotor dynamic perfor-

* Corresponding author.
E-mail addresses: robert.hoffmann@posteo.de (R. Hoffmann), robert.liebich@tu-berlin.de (R. Liebich).

https://doi.org/10.1016/j.jsv.2017.09.040
0022-460X/© 2017 Published by Elsevier Ltd.