Forced response of a vertical rotor with tilting pad bearings

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Long Abstract

Introduction

Tilting pad journal bearings (TPJB) have been used in rotating machines since the early 1900's and describing the bearing coefficients dynamically has been studied extensively over the last 60 years. In 1964 Lund [1] published a paper where he introduced the pad assembly method and the Reynolds equation solution to solve the bearing coefficients. Over the last 50 years bearing theory has evolved, Timothy et.al [2] published a review of tilting pad bearing theory and current state of the art now include inertia effects, pad motions, thermal and mechanical deformations. However, modelling the bearing coefficients dynamically using e.g. Reynolds equations takes time and if rotordynamical studies are to be performed simplified and accurate methods are preferred. Nässelqvist et.al [3] proposed a method to describe the bearing coefficients dynamically as function of eccentricity and load angle.

In vertical machines the bearing coefficients are dependent on shaft position and the eccentricity in the bearing, this will introduce periodic coefficients which depends on the number of pads. Studies of a vertical Jeffcott rotor with two 4-pad bearings shows that higher frequency components at $3 \times \Omega$ and $5 \times \Omega$ exist in the unbalance response, see Figure 1. In this paper the effects of these higher frequency components are studied where the aim is to analyse if these higher frequency components could excite the machine and cause resonance problems.

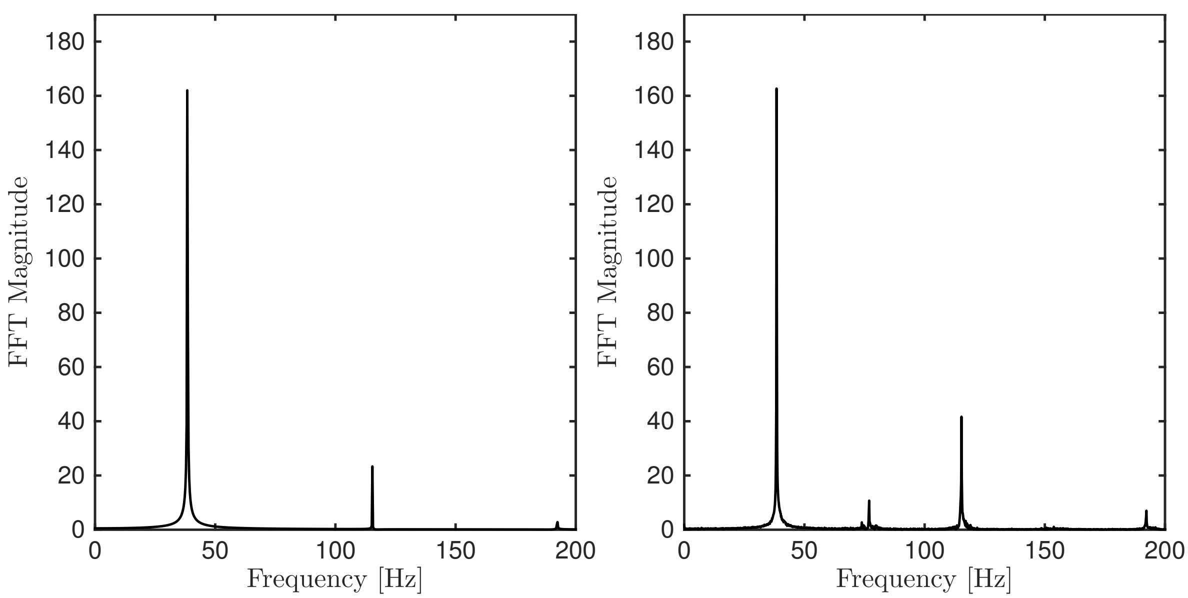

Figure 1. Fourier transform of the bearing load from simulations (left) and experiments (right).

1. Methods

Simulations of a vertical rotor with TPJB's are performed with a unbalance load f_{ub} and excitation force $f(t) = F_0 sin(\omega_{dr} \cdot t)$ where different ω_{dr} is studied to see if multiples of the natural frequencies could cause resonance problems due to the periodic coefficients in the bearing. The rotor is modelled using Timoshenko beam elements with consistent mass matrix and the bearing coefficients are evaluated at each time-step as function of eccentricity and load angle according to [3]. The equation of motion can thus be written in matrix form as:

$$\mathbf{M}\ddot{u} + (\mathbf{C} + \mathbf{C_T} + \Omega\mathbf{G})\dot{u} + (\mathbf{K} + \mathbf{K_T})u = f_{ub} + f(t) \quad (1)$$

where $\mathbf{M}$ is the mass matrix, $\mathbf{C}$ is the damping matrix, $\mathbf{G}$ is the gyroscopic matrix, $\mathbf{K}$ is the stiffness matrix, $\mathbf{K_T}$ and $\mathbf{C_T}$ is the bearing coefficients, Ω is the rotational speed, f_{ub} is the unbalance load and $f(t)$ is the excitation load.

From these simulations, displacements and loads can be compared for different excitation frequencies ω_{dr} to see if resonance peaks can occur for other frequencies than the natural frequencies. Since the 4-pad bearing setup shows a large frequency component at $3 \times \Omega$ then the region where $3 \cdot \omega_{dr} = \omega_n$ is of interest to study, where ω_n is the natural frequencies of the system.

References

[1] JW Lund. Spring and damping coefficients for the tilting-pad journal bearing. *ASLE transactions*, 7(4):342–352, 1964.

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[3] Mattias Nässelqvist, Rolf Gustavsson, and Jan-Olov Aidanpää. Experimental and numerical simulation of unbalance response in vertical test rig with tilting-pad bearings. *International Journal of Rotating Machinery*, Vol. 2014(No. 309767), 2014.