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Commissioning of a Novel Test Apparatus for the Identification of the Dynamic Coefficients of Large Tilting Pad Journal Bearings

Forte P.*[a], Ciulli E.[a], Maestrale F.[b], Nuti M.[b], Libraschi M.[c]

[a] *Department of Civil and Industrial Engineering, University of Pisa, Largo Lazzarino, 56122 Pisa, Italy*
[b] *AM Testing, Via Padre Eugenio Barsanti 10, Loc. Ospedaletto, 56121 Pisa, Italy*
[c] *BHGE, Via Felice Matteucci 2, 50127 Florence, Italy*

Abstract

This paper describes the commissioning of a novel test bench for the static and dynamic characterization of large tilting pad journal bearings, realized within a collaboration of the Department of Civil and Industrial Engineering of the University of Pisa, BHGE and AM Testing.

The adopted test bench configuration has the test article (TA) floating at the mid-span of a rotor supported by two rolling bearings. The TA is statically loaded vertically upwards by a hydraulic actuator and excited dynamically by two orthogonal hydraulic actuators with multiple frequency sinusoidal forces. The test rig is capable of testing bearings with a diameter from 150 to 300 mm. It includes very complex mechanical, hydraulic, electrical and electronic components, and needs, for the whole plant, about 1 MW of electric power.

The commissioning of the testing system involved several aspects and presented various issues. This work focuses on measuring systems and data acquisition of high-frequency data (forces, accelerations and relative displacements) and on data processing for the identification of the bearing dynamic coefficients. The identification procedure is based on the linearity assumption and the principle of superposition, operating in the frequency domain with the fast Fourier transforms of the applied forces and displacement signals. First results, referred to a 4-pad bearing, are in satisfactory agreement with theoretical ones.

* Corresponding author. Tel.: +39-050-2218046; fax: +39-050-2218065.
E-mail address: p.forte@ing.unipi.it

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1. Introduction

Tilting pad journal bearings (TPJBs) are commonly used in turbomachines for their stability characteristics at high speed and low load operating conditions.

Assuming linear and synchronous behavior the dynamic characteristics of the bearings can be expressed by stiffness and damping matrices (**K** and **C**), 2x2, which are fundamental in the study of rotor dynamics. Mathematical models are validated and calibrated by comparing the theoretical results with experimental ones obtained on specific test stands by applying dynamic loads (harmonic forces, impulsive or random) to the bearing or to the rotor and measuring their relative relative displacement. For a review on experimental apparata and procedures refer to the work of Dimond et al. (2009). The most common test bench configuration has the test bearing floating at mid-span of a fixed rotor supported by two rolling bearings. The bearing is loaded statically and it is dynamically excited by two independent actuators in two orthogonal directions. Examples of such configured test benches are described by Childs and Hale (1994), Ha and Yang (1999), Wygant et al. (2004), Ikeda et al. (2006), Bang et al. (2010). Less common is the configuration of two identical fixed test bearings that support the rotor free to move more like a real configuration, as adopted by Chatterton et al. (2014) and Dang et al. (2016), although limited to smaller bearing diameters.

Unfortunately the dynamic bearing coefficients are not directly scalable with diameter. That justifies the effort of developing a new test facility for the dynamic characterization of large TPJBs to extend the ranges of test parameters and support the development of products of industrial interest.

At the University of Pisa a new testing platform, unique in Europe for size and power, was designed and set up within a collaboration between the Department of Civil and Industrial Engineering of the University of Pisa, BHGE and AM Testing with Tuscany Region funds. For details of the design process refer to Forte et al. (2016). The test bench commissioning ended in early 2017. This paper illustrates the major features of the test facility and the first experimental results.

Nomenclature

A	stator acceleration component
c	damping coefficient
C	damping matrix
D	relative displacement component
$\boldsymbol{D}$	relative displacement vector
D	relative displacement matrix
F	force component
$\boldsymbol{F}$	force vector
F	force matrix
H	impedance matrix
k	stiffness coefficient
K	stiffness matrix
M	stator mass
Δ	difference
ω	angular frequency
subscripts:	
af	anti-phase
b	bearing
s	stator
f	in-phase
u,v	directions of dynamic actuators