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Foil bearings — Performance testing of foil thrust bearings — Testing of static load capacity, bearing torque, friction coefficient and lifetime

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Design improvements commonly required for rotating machines such as turbines, generators, compressors and pumps include increases in speed and decreases in size. Foil bearings in turbomachinery operate by generating a self-acting air (or gas) film between surfaces in relative motion. A gap between a rotating shaft or runner and a foil surface compresses a gaseous lubricant to an elevated pressure, separating the relatively moving surfaces and providing a load-carrying capacity. The use of the surrounding air (or gas) as the bearing lubricant eliminates the need for an auxiliary lubrication system to deliver conventional oil lubricants. This permits drastic reductions in the weight, complexity and maintenance costs of foil bearing-supported turbomachines, in comparison to their rolling bearing-supported counterparts. It also permits higher shaft speeds by removing the $n \times d_m$ speed limits (where d_m is the mean diameter of bearing and n is the rotation rate) on rolling bearings.

Foil bearings — Performance testing of foil thrust bearings — Testing of static load capacity, bearing torque, friction coefficient and lifetime

1 Scope

This document specifies the method for comparing performance evaluation results for a foil thrust bearing that supports load with aerodynamic force generated by the rotation of a driving shaft and lubricates using air, not lubricating oil. The test procedure explained in this document measures and evaluates the static load capacity, bearing torque, friction coefficient and lifetime of the foil thrust bearing and compares the test results to those for different test conditions. The measured static load capacity can be varied depending on the capabilities of the test device used.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
thrust runner
runner
circular disc connected to the rotating shaft and facing the surface of the top foil

Note 1 to entry: The surfaces of the thrust runner should be machined smoothly enough to form the air film between the runner and the top foil.

3.2
take-off
stage aimed to secure the distance between the *thrust runner* (3.1) and the top foil by developing an aerodynamic pressure between them

3.3
clearance
shortest distance between the *thrust runner* (3.1) and the top foil

3.4
bearing torque
torque value developed by rotational friction between the *thrust runner* (3.1) and the top foil

Note 1 to entry: The measurement of the bearing torque is as described in 7.3.

3.5
load
load capacity
weight that can be delivered by a bearing under steady-state conditions

3.6
initial load
load (3.5) exerted on the rotating system in the beginning

Note 1 to entry: It should be lower than the static load capacity and the load at which the lifetime of the bearing is determined, as explained in 7.4 and 9.2.

3.7
reference load
load (3.5) expected to be supported by a bearing

Note 1 to entry: The calculation of the reference load is given in 7.2.

3.8
static load capacity
maximum *load* (3.5) value of a bearing in static state

Note 1 to entry: The measurement of the static load capacity is explained in 7.4.

3.9
friction coefficient
flow resistance caused by rotational friction between the *thrust runner* (3.1) and the top foil

Note 1 to entry: The measurement of the friction coefficient is described in Clause 8.

3.10
lifetime of bearing
total number of start–stop test cycles of the foil thrust bearing at which the coating layer disappears

Note 1 to entry: The measurement of the lifetime of bearing follows Clause 9.

4 Symbols

For the purposes of this document, the following symbols apply.

4.1 Basic characters — Roman alphabet

Table 1 — Symbol — Basic characters — Roman alphabet

Symbol	Description	Units
A	Area	Square millimetre
F	Force, load	Newton
H	Height	Millimetre
h	Humidity	Percentage
L	Lifetime	Number of start-stop cycles
M	Torque	Newton-millimetre
R_a	Surface roughness	Millimetre
r	Distance, radius	Millimetre
T	Temperature	Degrees Celsius
t	Thickness	Millimetre

4.2 Basic characters — Greek alphabet

Table 2 — Symbol — Basic characters — Greek alphabet

Symbol	Description	Unit
μ[a]	Friction coefficient	Non-dimensional
ω	Rotational speed	r/min
[a] The symbol f is also commonly used and accepted.		

4.3 Additional signs — Subscripts

Table 3 — Symbol — Additional signs — Subscripts

Subscription	Description
a	Air (surrounding), average, applied
b	Bump foil, bearing
f	Top foil, friction
fs	Top foil surface
i	Inner
inc	Increment
max	Maximum
n	Net
o	Outer
r	Radial, radius, runner, reference
R	Relative
to	Take-off
s	Steady-state, static
u	Upper
ua	Unit area
w	Working

5 Purpose of test

The primary purpose of the test is to measure and evaluate the static load capacity, bearing torque, friction coefficients and lifetime of a foil thrust bearing. These are the primary performance metrics of a foil thrust bearing as a mechanical element with specific dimensions. They are closely related to the performance of the mechanical systems in which foil thrust bearings are used.

6 Test conditions

6.1 General

The static load capacity of a foil thrust bearing should be tested, after the ambient pressure, temperature and humidity of the environment in which the bearing operates have reached a state of equilibrium. The bearing performance is determined by measuring the bearing torque and the rotational speed of the shaft. The take-off speed, which is the speed at which the runner floats on the top foil without making contact, should be determined. The bearing performance should be measured and compared at a rotational speed that is higher than the take-off speed.

6.2 Design of test apparatus

The bearing test apparatus should be designed to control the relative position of the bearing in relation to the runner. Excessive friction due to misalignment of the bearing can have a severe effect on the test results. It shall be avoided not only by maintaining a constant distance between the runner and the top foil, but also by preventing any disturbance that can affect the test results. A schematic illustration of the test apparatus is shown in Figure 1. The test load is applied by moving the loading plate to press against the runner, using a mechanical and/or pneumatic system.

6.3 Installation of sensors

The equipment used to measure the bearing torque and static load capacity of the foil thrust bearings is installed as shown in Figure 1. Using the measurement system shown in Figure 1, the bearing torque and applied load are measured and calculated as explained in 7.3. The rotational speed of the shaft is determined using a rotational speed meter. A thermocouple is installed inside the bearing to measure the temperature of the surrounding air (gas). A thermocouple should be welded to the top foil surface to measure the surface temperature of the top foil (see Figure A.1 and Figure A.2).

6.4 Test specimens

The bump foil, top foil and bearing plate should be designed and fabricated using materials appropriate for the intended use.