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Foil bearings — Guidelines for testing of the performance of foil journal bearings — Testing of load capacity, friction coefficient and lifetime

Paliers-feuilles — Lignes directrices pour les essais de performance des paliers radiaux à feuilles non lubrifiés — Essais de la capacité de charge, du coefficient de friction et de la durée de vie

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13939 was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings*.

Introduction

Foil bearing is a special type of plain bearing; at the time of publication of this International Standard, no International Standards on foil bearings exist. This International Standard is an attempt to elaborate a test method for the basic performance of a foil bearing.

Foil bearings — Guidelines for testing of the performance of foil journal bearings — Testing of load capacity, friction coefficient and lifetime

1 Scope

This International Standard describes a method of comparing the performance test results of foil journal bearings, which are lubricated by air (gas) and supported by hydrodynamic force generated by the rotation of the rotating shaft. The test procedure proposed in this International Standard aims to predict and evaluate the static load capacity, friction coefficient and lifetime of the foil journal bearing, and compare the results with those occurring under different test conditions, i.e. dimensions of a foil bearing, rotational speed of a shaft, pressure and humidity of surroundings and so on. The magnitude of the static load capacity can change according to the test setting, as the test conditions can be changed.

The test method described in this International Standard has the following application coverage:

a) the criterion of the static load capacity is the steady-state, i.e. it is applied in a limited operating condition with a uniform magnitude, load direction and rotational speed;

b) the evaluation procedure can be applied only if the foil journal bearing is under a uniform rotating inertia at an arbitrary rotational speed;

c) the dynamic load with a time-variant magnitude and direction is not taken into consideration;

d) for the purposes of this International Standard (these guidelines), the configuration of a typical foil journal bearing is presented in Annex A.

2 Symbols

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

2.1 Basic characters — Roman alphabet

Table 1 — Symbol — Basic characters — Roman alphabet

Symbol	Description	Unit
C	Clearance, coefficient	Micrometres, Non-dimensional
D	Diameter	Millimetres
d	Diameter	Millimetres
e	Eccentricity	Micrometres
F	Force	Newton
H	Height	Millimetres
h	Humidity	Percentage
L	Length, lifetime	Number of revolutions
p	Pressure	Newton per square millimetre
Ra	Surface roughness	Micrometres
r	Distance	Millimetres
T	Temperature, torque	Degrees Celsius, Newton-metres
t	Thickness	Millimetres
F_w	Mass, load	Newton

2.2 Basic characters — Greek alphabet

Table 2 — Symbol — Basic characters — Greek alphabet

Symbol	Description	Unit
ε	Eccentricity ratio	Non-dimensional
μ	Friction coefficient	Non-dimensional
ω	Rotational speed	Revolutions per minute

2.3 Additional signs — Subscripts

Table 3 — Symbol — Additional signs — Subscripts

Subscript	Description
a	Air (surrounding), average, applied
ah	Air in bearing housing
b	Bump foil, bearing
f	Top foil, friction
fs	Top foil surface
h	Housing
max	Maximum
n	Net
r	Radial, radius
R	Relative
to	Take-off
s	Steady-state, static

2.4 Additional signs — Superscript (shown on X)

Table 4 — Symbol — Additional signs — Superscript

Superscript	Description (shown on X)
$\bar{X}$	Non-dimensional value

3 Purpose of test

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

4 Test conditions

4.1 General

In order to compare the static load capacity, the test should be performed 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 obtained by measuring the bearing torque and the rotational speed of the shaft. In this case, the take-off speed, at which the shaft floats on the top foil without contact, may be observed. Bearing performance should be measured and compared at a rotational speed which is higher than the take-off speed.

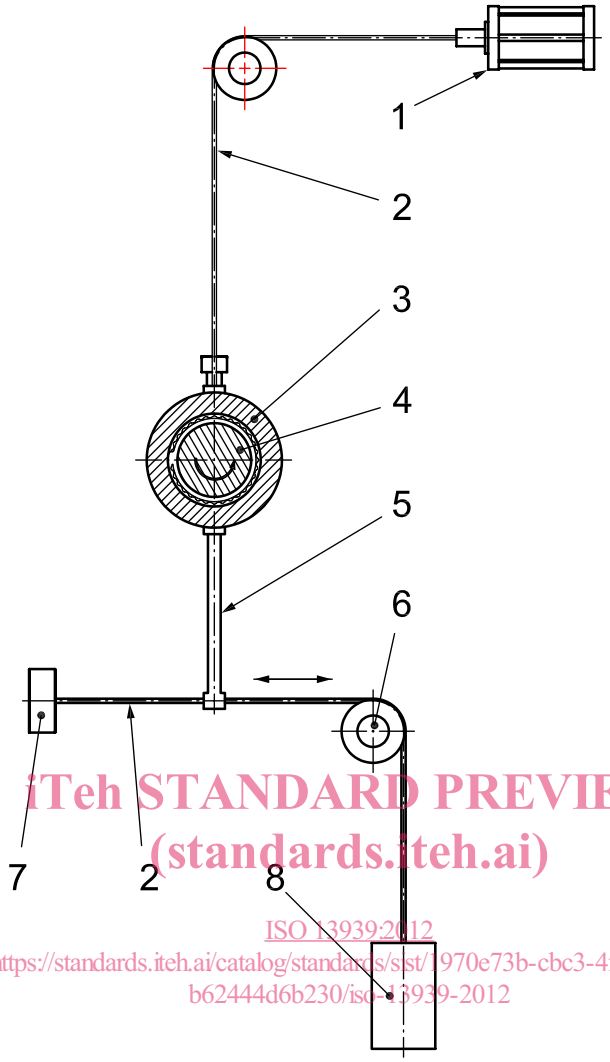
4.2 Design of test facility

The bearing test facility should be designed to control the relative position of the bearing in relation to the shaft. The bearing housing may be connected to a separate supporter, such as a spring or springs. Otherwise, a vibration-proof facility may be applied in order to prevent perturbation, which can have a severe effect on the test results. Also, excessive friction can have a severe effect on the test results due to misalignment of the bearing.

4.3 Installation of sensors

The equipment to measure the bearing torque and static load capacity of the foil journal bearings may be installed as shown in Figure 1. Using the measurement system clarified in Figure 1, the bearing torque and applied load may be measured and calculated as explained in 4.4.

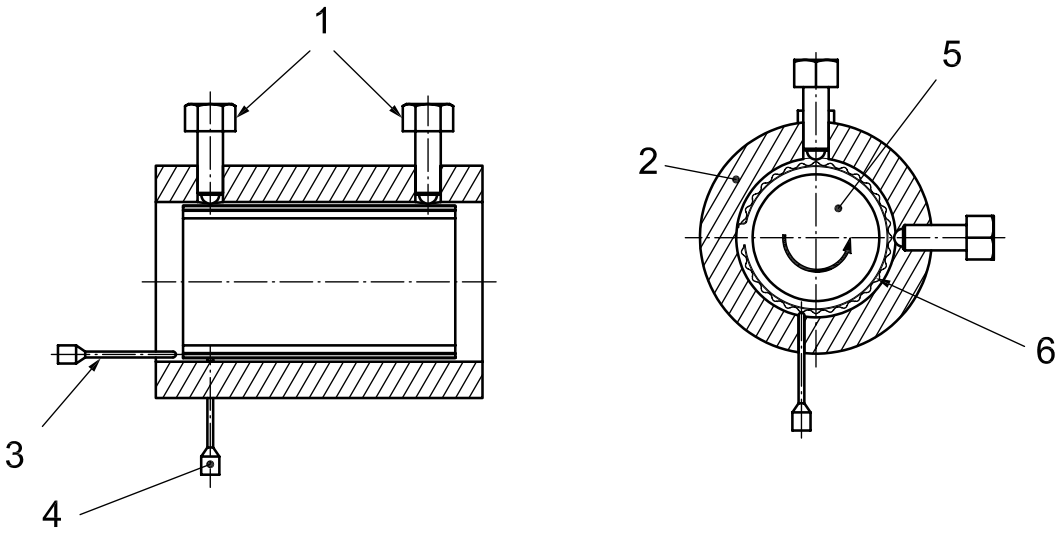
As shown in Figure 2, the displacement sensors are installed at right angles to each other at both ends of the bearing housing. The displacement of the shaft centre may be observed by measuring and comparing the values arrived at. The rotational speed of the shaft may be obtained by applying a fast Fourier transform (FFT) algorithm to the measured displacement data or by the use of a rotational speed meter. A thermocouple is installed inside the bearing housing to measure the temperatures of surrounding air (gas). To measure the surface temperature of a top foil, the thermocouple should be welded to the top foil surface.



Key

1 applied load
2 cable
3 deadweight housing
4 shaft
5 torque rod
6 pulley
7 load cell
8 counterweight preload

Figure 1 — Measurement system for the bearing torque and applied load



Key

1 displacement sensor
2 deadweight housing
3 thermocouple for measuring air temperature
4 thermocouple for measuring top foil surface temperature
5 shaft
6 top foil

Figure 2 — Installation of sensors

4.4 Calculation of bearing torque and loads

The friction force, F, may be measured using a load cell linked to the torque rod installed on the outside of the housing. Then, the bearing torque, T, generated by the rotation of the shaft is obtained as the product of the friction force, F, and the distance, r, between the two centres of the housing and load cell, as given by Formula (1):

$$T = F \times r \tag{1}$$

where

T is the bearing torque;

F is the friction force;

r is the distance between the housing centre and the sensor-linked location of the torque rod.

The net load, $F_{w,n}$, exerted on the foil journal bearing, as shown in Figure 1, is obtained by subtracting the applied load, $F_{w,a}$, measured from the load cell installed between the housing and the loading apparatus to the mass of the housing, $F_{w,h}$. Where the load is applied in the lower direction, the net load, $F_{w,n}$, is obtained by adding the mass of the housing, $F_{w,h}$, to the applied load, $F_{w,a}$.

4.5 Test specimens

The housing, bump foil, top foil and shaft comprising the foil journal bearing may be designed and fabricated according to the purpose of use.