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Plain bearings — Testing under conditions of hydrodynamic and mixed lubrication in test rigs

Paliers lisses — Essai des paliers lisses dans les conditions de lubrification hydrodynamique et mixte dans des machines d'essai pour paliers

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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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 2, *Materials and lubricants, their properties, characteristics, test methods and testing conditions*.

This second edition cancels and replaces the first edition (ISO 6281:2007), which has been technically revised.

The main changes compared to the previous edition are as follows:

— editorial changes;

— reference to ISO 9045 has been replaced by ISO 4378 (all parts);

— Clause 1 has been edited to be in line with ISO drafting rules;

— the unit of the dynamic viscosity in Clause 4 has been modified.

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.

Plain bearings — Testing under conditions of hydrodynamic and mixed lubrication in test rigs

1 Scope

This document defines requirements for the testing of lubricated plain journal bearings in test rigs, running under conditions of hydrodynamic or mixed lubrication, during bearing and/or material development. It deals with both static and dynamic loading in solid and multi-layer journal bearings. It is not applicable to the testing of dynamic characteristics of lubricant film in journal bearings applied in calculation of vibration and stability of turbo-rotors.

NOTE It is intended that further details of test procedures be established when carrying out testing based on this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4378 (all parts), *Plain bearings — Terms, definitions, classification and symbols*

3 Terms and definition

For the purposes of this document, the terms and definitions given in ISO 4378 (all parts) and the following 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
wear rate
ratio of wear extent to the time interval during which it has developed

3.2
wear intensity
ratio of wear extent to the specified distance on which wear developed or to the volume of the work done

4 Symbols

See Table 1.

Table 1 — Symbols

Symbol	Description	Unit
a	length of period	s
B	bearing width	mm
F	bearing load	N
F^*	bearing load per unit bearing width	N/mm

Table 1 *(continued)*

Symbol	Description	Unit
f	coefficient of friction of journal bearing	—
t	time	s
U	sliding velocity	m/s
β	direction of bearing load	°
η	dynamic viscosity of lubricant	Pa · s
ω	angular velocity	rad/s

5 Test objectives for bearing properties

The test objectives for plain journal bearing test rigs operating under conditions of hydrodynamic or mixed lubrication are to obtain information, among others, on the following bearing properties, which can serve as critical variables when designing and applying the bearing (see the ISO 4378 series):

a) the running-in ability;

b) the wear resistance;

c) the compatibility between bearing and journal materials (resistance to adhesion);

d) the embeddability (foreign particles absorption);

e) the resistance to journal scoring and abrasion;

f) the conformability;

g) the deformability (compressive strength);

h) the resistance to erosion (cavitation erosion, fluid erosion, and particle erosion);

i) the static load carrying capacity;

j) the dynamic load carrying capacity (fatigue strength);

k) the friction characteristics;

l) the lubricant flow rate characteristics;

m) the temperature increase characteristics.

Of these bearing properties, the first group, a) to h), depends primarily on the mechanical and tribological properties of sliding materials under specified conditions. The second group, i) to m), depends primarily on hydrodynamic variables, and therefore also on

— viscosity as a function of temperature, pressure and shear rate,

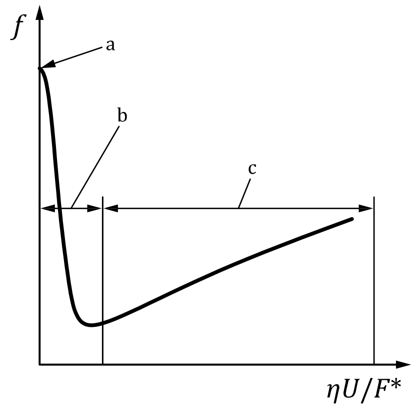
— energy dissipation in the lubricant film (shear heating and heat dissipation), and

— elastic and thermal deformation of the bearing and journal, and hence change of lubricant film thickness (thermo-elastohydrodynamic lubrication).

The determination of these bearing properties, or test objectives, requires lubrication conditions that can involve boundary, mixed or hydrodynamic lubrication — the three modes of lubrication regime. In certain cases, a repeated, time-dependent change between mixed and hydrodynamic lubrication can be required.

NOTE It is possible that specific test methods do not yet exist for all of the above-mentioned bearing properties.

Figure 1 depicts the typical relation between the dimensionless number $\eta U/F^*$ representing a normalized speed, and the coefficient f of friction of the journal bearing, where η, U and F^* denote dynamic viscosity of the lubricant, sliding velocity and bearing load per unit bearing width ($F^* = F/B$), respectively. It shows the three regimes of boundary, mixed and hydrodynamic lubrication and qualitatively indicates the dependence between these important parameters.



Key

a Boundary lubrication.

b Mixed lubrication.

c Hydrodynamic lubrication.

Figure 1 — Three modes of lubrication regime

6 Test rigs

6.1 General recommendations

It is often more practical and efficient to investigate the bearing in a test rig than in an actual application. The design of the bearing test rig should be such as to simulate as far as possible all the relevant characteristic parameters (e.g. geometric, dynamic, hydrodynamic, thermal, and thermodynamic) of the actual application.

In addition, the following is recommended for the test rig.

a) A simple mechanical construction.

b) Simple dismantling and assembly procedures for the test objects; with well-defined positioning of the bearing and housing; preferably it should be possible to inspect the test bearing *in situ*. In addition, the test rig should be equipped with an emergency stop mechanism, both for safety reasons and to allow the inspection of the sliding surface before the onset of catastrophic damage.

c) A well-defined dimensions for the test bearing.

d) A high dimensional stability with little shaft deflection. The test rig should be as rigid as possible, with a high natural frequency. In special cases, however, it can be necessary to vary the dimensional stability or the shaft deflection in order to simulate the operating condition of the actual application.

e) An appropriate lubricant supply condition. When the lubricant flow within the bearing clearance needs to be simulated exactly, the circumferential and axial position of the lubricant supply in the test rig should be the same as in the actual application.

f) Well-defined and experimentally verifiable lubrication conditions.

g) The regime of laminar or turbulent flow should be the same in the test rig and in the actual application.

h) The rig should replicate as far as possible the temperature and stress range that can occur in practice.

i) Appropriate measuring techniques or equipment should be employed.

6.2 Generic types of test rig

Generic types of test rig for plain journal bearings are shown in Figure 2 and Figure 3. Figure 2 a) and Figure 2 b) depict the rotational motion of the journal, where a combination of both is also possible. In practice, many more patterns of journal motion other than rotation can occur, such as inclination, bending, axial, conical and their combinations. In addition, the bearing itself can rotate, oscillate or even move in space instead of, or together with, the journal, as with a crank-pin bearing. In any case, the relative motion of the journal to the bearing shall be known (measurable) exactly. However, constant rotational speed of journal and the parallel movement of journal to bearing are the simplest and most preferable for testing.

Figure 3 shows patterns of the bearing load. In the case of statically loaded journal bearing [Figure 3 a)], the magnitude, F, and the direction, β, of the bearing load are constant. In a special case of dynamically loaded bearing, F is constant, but β increases or decreases with time [Figure 3 b)]. In the general case of dynamically loaded bearing [Figure 3 c)], both or at least one of F and β change(s) with time, while the remaining variable can be constant. The change of form of F (also β) is then arbitrary, such as sinusoidal with or without constant offset, curving steeply up and downwards, as, for example, in engine bearing loading.

With regard to the loading of the test bearing, it is often more practical to load the test bearing directly supported by the journal [Figure 4 a)], than to load the test bearing indirectly through the journal [Figure 4 b)]. For static loading, a dead weight system, with or without lever, or hydraulic or pneumatic actuation can be used. For dynamic loading, a rotating or vibrating mass system, with or without lever, an electromagnetic exciter, and hydraulic actuation, can be applied. Dynamic loading by means of a mass fixed to the journal seems to be simple, but the amplitude of the bearing load is then determined primarily by the rotational speed of the journal. Therefore, it is not easy to change the load amplitude independently of the rotational speed. Furthermore, the magnitude and direction of the bearing load shall be precisely measured, and it is important to let the journal move freely inside the bearing clearance without hindrance from the loading mechanism.

Besides such bearing test rigs operating under hydrodynamic or mixed lubrication, as described above, many other kinds of test apparatus and test methods may be used to investigate the tribological or mechanical properties of bearing materials, including coefficient of friction, mechanical strength, hardness, elasticity, plasticity and bond strength. The study of the tribological properties of boundary films has also led to the development of other test apparatus and methods; these are, however, outside the scope of this document (see ISO 4384-1, ISO 4384-2, ISO 4385, ISO 7148-1, ISO 7148-2, ISO 7905-2, ISO 7905-3, and ISO 7905-4).

NOTE The testing of the resistance to corrosion of bearing materials by the lubricant is the subject of ISO 10129.

