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

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

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Contents

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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 main task of ISO technical committees is to prepare International Standards. In exceptional circumstances a technical committee may propose the publication of a technical report of one of the following types :

— type 1, when the necessary support within the technical committee cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development requiring wider exposure;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical reports are accepted for publication directly by ISO Council. Technical reports types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical reports type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 6281, which is a technical report of type 2, was prepared by Technical Committee ISO/TC 123, *Plain bearings.*

The reasons which led to the decision to publish this document in the form of a technical report type 2 are explained in the introduction.

Annexes A, B, C and D of this Technical Report are given for information only.

Introduction

Test rigs for plain bearings, using different test systems, are used all over the world. The wide range of practical applications with different requirements led to the design of numerous test rigs for plain bearings. Unfortunately, since the conditions of lubrication in these test rigs are usually not well defined, the test results obtained with one rig cannot generally be directly compared with results obtained on another test rig, nor can the results be related to practical applications. Different test rigs may even produce different rankings.

This Technical Report aims to improve the comparability and the transferability of the results by a better definition of the operating conditions, in particular with regard to conditions of lubrication.

The following parameters can be used to describe the lubrication adequately:

a) the minimum lubricant film thickness, its distribution as a function of time and of location in the bearing under dynamic loading;

b) the maximum lubricant film pressure;

c) the distribution of pressure in the peripheral and the lateral directions as a function of time under dynamic loading conditions and the resulting (alternating) stresses in the bearing material;

d) the maximum and the mean lubricant film temperature, the coefficient of friction and the variation of these parameters as a function of time.

Since tribochemical reactions may occur between lubricant and material, it is also necessary to characterize the lubricant in as detailed a way as possible.

It was therefore decided to first specify uniform guidelines for the testing of plain bearings.

During the ISO/TR 123/SC 2 meeting in Vienna on 12 October 1984 it was decided to make this method known in the form of a Technical Report. Further experience will be gathered with a view to publishing an International Standard.

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

1 Scope

This Technical Report establishes guidelines for the testing of oil-lubricated plain bearings without flange in bearing test rigs, running under conditions of full hydrodynamic lubrication and mixed lubrication, where the load is carried to a greater or lesser extent by mechanical contact.

This Technical Report deals with both static and dynamic loading in solid and multi-layer bearings.

Annex B gives examples of four types of test rigs.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 3448 : 1975, *Industrial liquid lubricants — ISO viscosity classification.*

ISO 3675 : 1976, *Crude petroleum and liquid petroleum products — Laboratory determination of density or relative density — Hydrometer method.*

ISO 7146 : — [1], *Plain bearings — Terms, characteristics and causes of changes in appearance and damage.*

ISO 7902-1 : — [1], *Hydrodynamic plain journal bearings under steady-state conditions — Circular cylindrical bearings — Part 1: Calculation procedure.*

3 Test objectives

The test objectives with plain bearing test rigs operating under conditions of mixed or full hydrodynamic lubrication may be to obtain information on the following properties:

A: running-in characteristics

B: wear resistance

C: compatibility between bearing and shaft material (resistance to scuffing)

D: embeddability

E: resistance to shaft scoring (which may result from contamination with solid particles)

F: static-load-carrying capacity

G: deformability

H: conformability

I: dynamic-load-carrying capacity (fatigue strength)

J: resistance to erosion (cavitation erosion, fluid erosion, particle erosion)

K: resistance to corrosion

The determination of these properties requires operating conditions which may result in the immediate establishment of full hydrodynamic lubrication conditions or in mixed lubrication conditions. The operating conditions needed for some objectives may imply repeated, time-dependent change between full hydrodynamic and mixed lubrication.

In any case, it is necessary to give a clear description of the operating conditions and to relate them unambiguously to the lubrication conditions (see clause 6).

NOTE — Specific test methods exist for only some of the above properties.

1) To be published.

4 Test requirements

The operating conditions can be defined adequately only if the test rig and the test procedure comply with the following requirements:

a) a simple mechanical construction;

b) simple dismantling procedures; it should preferably be possible to inspect the bearing *in situ*;

c) application of special measuring techniques: if possible, continuous wear measurements should be performed by means of radio nuclide techniques or X-ray fluorescent analysis of the lubricant; it should be possible to measure lubricant film thickness, lubricant film and bearing temperatures and pressure distributions in the lubricant film and torque;

d) well defined dimensions of the test bearing: it should have a high dimensional stability and little shaft deflection. In special cases it should be possible to vary the dimensional stability or the shaft deflection;

e) adequate lubricant supply to be ensured without impairing the oil pressure build-up;

f) hydrodynamic conditions should be well defined and experimentally verifiable;

g) a clear distinction should be made between mixed and full hydrodynamic lubrication conditions;

h) the entire temperature and stress range that may occur in practice should be covered in the tests;

i) in case of dynamic loading, the bearing periphery should be stressed as uniformly as possible.

5 Test procedures

The actual test procedures depend on the properties to be determined. In order to ensure that test results obtained on different test rigs are mutually compatible, and that results obtained on test rigs are applicable in practice, it is necessary to establish the parameters describing the degree of hydrodynamic lubrication during the test. The test rig, the test programme, the test conditions, the test bearing and, possibly, other factors which may influence lubrication, should therefore be described in detail. The characteristic parameters which should be known for each of the test objectives set out in clause 3 are given in 5.1 to 5.3.

The characteristics which should be determined for each objective are given in 5.4 to 5.7.

5.1 Characteristic parameters for test objectives A, B, C, D and E

5.1.1 The minimum lubricant film thickness determined by means of calculation of measurement.

5.1.2 The variation of the lubricant film thickness as a function of time, and the local development of small film thicknesses in the bearing as a function of the parameters given in 5.1.2.1 to 5.1.2.6.

5.1.2.1 Parameters describing the surface topography of both sliding partners, for example

$$\lambda = \frac{h_{min}}{\Sigma R_a}$$ (for test objectives A and B)

where

h_{min} is the minimum lubricant film thickness;

ΣR_a is the sum of surface roughnesses of the sliding partners.

5.1.2.2 The particle size and the hardness of contaminating particles (for test objectives D, E and, possibly, J).

5.1.2.3 Parameters describing the surface topography and the hardness of both sliding partners immediately before intentionally reducing the minimum lubricant film thickness (for test objective C).

5.1.2.4 Possible deviations in the geometry of the sliding partners (shaft deflection and local pressure marks in the plain bearing) (for test objectives G and I).

5.1.2.5 The sliding velocity and the shear rate at minimum clearance.

5.1.2.6 The temperature of the lubricant film and of the bearing and, if necessary, the temperature distribution.

5.2 Characteristic parameters for test objectives F, G, H and I

5.2.1 The maximum lubricant film pressure.

5.2.2 The variation in the lubricant film pressure in the peripheral and the lateral directions.

5.2.3 The variation in the distribution of the lubricant film pressure in the peripheral and the lateral directions as a function of time.

5.2.4 The maximum static strain in the bearing material.

5.2.5 The maximum dynamic strain in the bearing material, in terms of mean and alternating strain, depending on the point of application, and as a function of 5.2.5.1 to 5.2.5.3.

5.2.5.1 The construction of the bearing and the static strength values of the individual layers of bearing material (for test objectives F, G and H).

5.2.5.2 The construction of the bearing and the dynamic strength values of the individual layers of bearing material in the appropriate temperature ranges (for test objective I; see also annex C).

5.2.5.3 The temperature of the lubricant film and of the bearing and, if necessary, the temperature distribution.

5.3 Characteristic parameters for test objective J

5.3.1 The variation in the lubricant film thickness as a function of time and location in the bearing.

5.3.2 The distribution of speed in the clearance gap, characterized for example by the maximum shear rate in the minimum clearance and its variation as a function of time and of location in the bearing, related to the construction of the bearing and deviations in the geometry of the bearing as related to the location and the degree of the wear damage.

5.4 Characteristics for test objectives A, B, C, D and E

5.4.1 Duration of the periods during which wear may occur (for test objective A).

5.4.2 Change of the contact geometry as a function of time (parameters describing the micro- and macro-shape of the surfaces) (for test objectives B and C).

5.4.3 Wear as a function of time.

5.4.4 Decrease in wall thickness or weight loss.

5.4.5 Endurance of the upper layer of bearing material, in case of multilayer bearings (for test objective B).

5.4.6 Overall endurance of the bearing, number of revolutions at which bearing damage has reached a predefined maximum value (for test objectives D and E).

5.5 Characteristics for test objectives F, G, H and I

5.5.1 Number of revolutions at which plastic deformation has reached a predefined maximum value (for test objectives F, G and H).

5.5.2 Number of revolutions at which the first crack occurs (for test objective I).

5.6 Characteristics for test objective J

5.6.1 Number of revolutions at which erosive attack has reached a predetermined maximum value.

5.6.2 Erosive attack as a function of time.

5.7 Characteristics for test objective K

5.7.1 Number of revolutions at which corrosive attack has reached a predefined maximum value.

5.7.2 Corrosive attack as a function of time.

5.7.3 Corrosion-free comparative tests, performed under the same operating conditions (lubricant film thickness, shear rate, etc.) with a non-corrosive lubricant.

6 Test criteria

A distinction has to be made between the characteristic aspects of the test rig (6.1), the test programme (6.2), the test conditions (6.3), the test bearing, including the journal (6.4), the hydrodynamic parameters (6.5) and the test results (6.6). The characteristic aspects of the test rig, the test programme, the test conditions and the test bearing are of importance when carrying out the test; the characteristic aspects of the hydrodynamic parameters and the test results are important when comparing and applying the results.

During testing, the bearing and journal materials may undergo changes (for example as a result of diffusion processes). This shall be documented by metallo-graphic study of cross-sections of the worn surfaces.

6.1 Test rig

The following details shall be given:

a) designation;

b) principle (main features);

c) construction;

d) design limits;

e) auxiliary equipment, for example filters;

f) location and number of test bearings;

g) method of load application;

h) method of friction measurement;

i) method of wear measurement;

j) location of temperature-measuring points;

k) any additional equipment, for example filter.

6.2 Test programme

The following characteristics shall be specified:

a) mean load;

b) load level;

c) frequency of load level;

d) time and point function of cyclic load factor;

e) speed (number of revolutions);

f) time function of the periodically irregular rotational movement of journal and plain bearing;

g) sliding velocity;

h) duration of stress;

i) rest periods.

6.3 Test conditions

The following conditions concerning the lubricant, lubricant supply and temperatures shall be given.

6.3.1 Lubricant

a) type;

b) chemical composition;

c) viscosity/temperature relationship (see ISO 3448);

d) density (see ISO 3675);

e) contamination (dirt particles, abrasive material).

6.3.2 Lubricant supply

a) type (spray lubrication, ring lubrication, force feed lubrication, etc.);

b) supply pressure;

c) manner in which the oil is introduced in the bearing clearance (oil duct bore, oil pocket or oil groove; their size and location);

d) lubricant flow rate;

e) total quantity of lubricant and retaining time in oil reservoir;

f) filtering method.

6.3.3 Temperatures

a) oil inlet temperature;

b) oil outlet temperature;

c) bearing temperature;

d) variations of temperatures with time, if applicable;

e) locations of temperature-measuring points;

f) ambient temperature;

g) temperature in the oil reservoir.

6.4 Test bearing and journal

The following details concerning the test bearing and the journal shall be given.

6.4.1 Test bearing

6.4.1.1 Material properties

a) standard designation;

b) chemical composition;

c) manufacturing method;

d) heat treatment;

e) structural condition;

f) hardness;

g) 0,2 % elongation limit;

h) compression strength;

i) Young's modulus;

j) coefficient of thermal expansion.

6.4.1.2 Dimensions, finishing method and roughness

a) internal diameter;

b) external diameter;

c) wall thickness;

d) functional width;

e) functional internal diameter;

f) bearing clearance at room temperature before test and during operation;

g) finishing method of bearing inner surface;

h) surface roughness, R_a;

i) housing bore;

j) thickness of steel backing.

6.4.2 Journal

6.4.2.1 Material properties

a) standard designation;

b) chemical composition;

c) manufacturing method;

d) heat treatment;

e) structural condition;

f) hardness;

g) Young's modulus.

6.4.2.2 Dimensions, finishing method and roughness

a) diameter;

b) length;

c) deflection during test run;

d) misalignment;

e) surface finishing method;

f) surface roughness, R_a.

6.5 Hydrodynamic parameters

a) minimum lubricant film thickness, h_{min};

b) variation in the lubricant film thickness as a function of time and of location in the bearing;

c) maximum lubricant film pressure;

d) distribution of the lubricant film pressure in the peripheral and the lateral directions;

e) variation of the distribution of the lubricant film pressure as a function of time;

f) maximum static strain in the material;

g) maximum dynamic strain in the material (mean and alternating stress);

h) maximum shear rate;

i) variation of shear rate as a function of time and of location in the bearing;

j) coefficient of friction;

k) coefficient of friction as a function of time.

The hydrodynamic parameters can be measured, except for the variation of shear rate as a function of time and of location in the bearing. However, it is possible to calculate the parameters, for example using ISO 7902-1.

It should be noted that the reliability of calculations or measurements of hydrodynamic parameters increases with the simplicity of bearing geometry and manner of loading.

6.6 Test results

a) description of damage (see also ISO 7146);

b) degree of damage;

c) volume of material removed by wear;

d) wear rate or wear distribution per unit of time;

e) endurances (amplitude of alternating loads — to be converted to tangential stresses);

f) duration of test (number of load cycles);

g) characteristic parameters for the description of micro- and macro-shape after testing;

h) the dynamic load endured at 4×10^7 load changes without surface crackings or break-outs in the bearing;

i) test conditions, speed, oil inlet temperature and the measured bearing temperature.

When applying measuring results in practice, different designs and operating conditions shall be taken into account.