TECHNICAL REPORT

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Plain bearings — Testing of the tribological behaviour of bearing materials for oil lubrication application — Running-in under mixed lubrication conditions

Paliers lisses — Essai de propriétés tribologiques des matériaux pour paliers lubrifiés à l'huile — Aptitude au rodage dans des conditions de lubrification en régime mixte

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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 of 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 Technical reports type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.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 9993, which is technical report of type 2, was prepared by Technical Committee ISO/TC 123, *Plain bearings*.

Annex A of this Technical Report is for information only.

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Introduction

The surfaces of a journal and a bearing in the bearing designed for operation under hydrodynamic lubrication conditions are not always fully separated with a continuous oil film forming a hydrodynamic film. It causes severe wear and could cause bearing seizure. Wear of the bearing and the likelihood of its seizing are determined by a relative period of bearing operation under insufficient lubrication conditions, and by the relation of the friction surface areas operating under fluid and boundary lubrication and under direct contact.

The ability of a bearing to form a hydrodynamic and boundary oil film is ensured by its design and by the bearing material antifriction (tribological) properties, but mainly by their running-in ability. The higher the running-in ability and running-in time, the shorter the period of operation under alternating load during which mixed lubrication takes place and the greater is the range of the loads which ensure hydrodynamic and boundary effects.

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Plain bearings — Testing of the tribological behaviour of bearing materials for oil lubrication application — Running-in under mixed lubrication conditions

1 Scope

This Technical Report specifies a test procedure for evaluating the running-in ability of bearing materials under mixed lubrication conditions.

It does not apply to materials of hardness less than 10 HB and with overlay thickness less than 0,02 mm.

The test procedure helps to compare the running-in ability of the tested system, bearing material + mating surface material + lubricating oil, with the other combinations of the above components to help choose a system with the required properties of serviceability.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the edition indicated was 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 edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 468 : 1982, *Surface roughness — Parameters, their values and general rules for specifying requirements.*

3 Symbols and units

See table 1.

Table 1

Symbol	Description	Unit
u	Sliding velocity	m/s
f	Coefficient of friction	—
F_n	Normal force	N
p	Pressure	Pa
T_{oil}	Oil bath temperature	°C
C	Loading rate	Pa/min
C_1	$= 2 \times 10^5$	Pa/min
C_2	$= 5 \times 10^2$	Pa/min
R_{HT}, a	Temperature ratio constants	—
R_H	Hydrodynamic index of running-in ability	—

4 Definitions

4.1 running-in: Process of changing the rubbing surfaces geometry as well as the physical and mechanical properties of material surface layers during the initial period of friction, usually displaced under constant outside conditions as a decrease of friction force, temperature and wear intensity.

4.2 running-in ability: The property of the bearing material to reduce friction force, temperature and wear intensity during the running-in period.

4.3 hydrodynamic running-in ability: The property of the bearing material to restore or to maintain a hydrodynamic oil film during the running-in period.

4.4 hydrodynamic index of running-in ability, R_H: The ratio

$$\frac{p_2}{p_1}$$

where p_1 and p_2 are pressure values corresponding to the minimum of a function of a coefficient of friction and pressure at loading rates $C_1 = 2 \times 10^5$ Pa/min and $C_2 = 5 \times 10^2$ Pa/min respectively.

It characterizes the ability of materials to form a hydrodynamic oil film during friction under mixed lubrication conditions.

5 Principle

A rotating cylindrical specimen and a stationary specimen made of the tested bearing material are immersed in an oil bath heated up to the preset temperature. A rotating specimen is brought up to the preset angular frequency. A load is applied to the specimen at low and high speeds until seizure occurs. A coefficient of friction is constantly recorded during loading. The running-in ability of the bearing alloys is evaluated from the value of the appropriate coefficient of friction.

6 Equipment and materials

6.1 Equipment

The testing apparatus shall permit

— a rotation of a cylindrical specimen at a frequency which gives a linear velocity on its cylindrical surface of 1 m/s with an error not exceeding 5 %;

— the specimen to be maintained under an alternating force under a continuous pressure increase at the rates C_1 ± 10 % and C_2 ± 10 %, starting at a pressure of 10^{-3} Pa;

— continuous measurement of the specimen loading and of the coefficient of friction with the error not exceeding 5 %.

NOTE — Recording devices may be used for continuous recording of the friction forces moment and normal load; the error should not exceed 5 %.

Figure 1 shows the mounting of the specimens. The fixing mechanism for the stationary specimen shall position it as shown in figure 1.

The apparatus shall include an oil bath of not less than 400 cm^3 capacity with a device for heating the oil and with a temperature control in the range from 20 °C to 120 °C to within ± 2 °C.

6.2 Materials

The flushing fluids shall be petrol and acetone.

The dimensions of the stationary specimen are shown on figure 2. Surface roughnesses R_a and R_z should correspond as far as possible to the surface roughness of the tested bearing components.

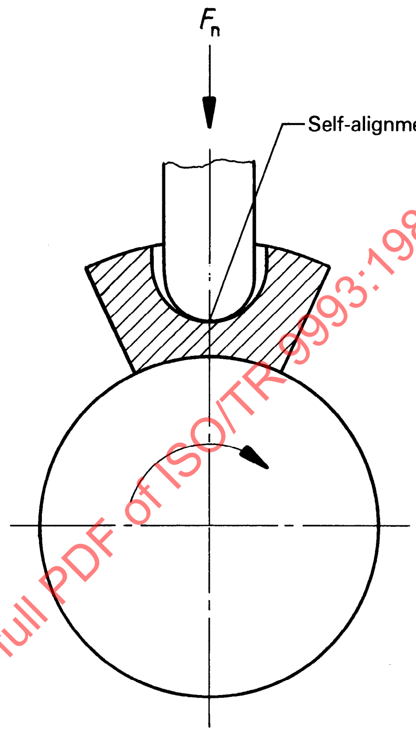
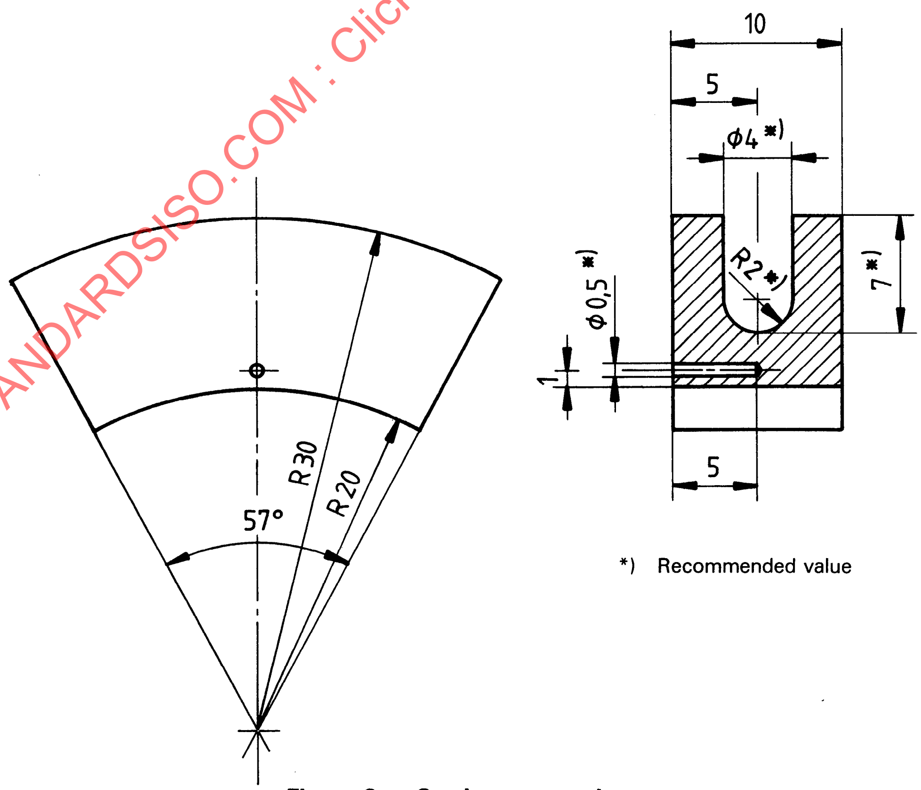


Figure 1 — Mounting of specimens

Dimensions in millimetres



*) Recommended value

Figure 2 — Stationary specimen

7 Preparation for the tests

7.1 Give a suitable finish to the stationary specimen surface using a special tool to give a surface fit to the rotating specimen in the apparatus over not less than 90 % of the nominal contact area. Control the fit by checking the mark of the contact.

NOTE — The surfaces may be worked with emery paper to give a proper fit.

7.2 Remove burrs from the friction surface of the rotating and the stationary specimens. Blunt the sharp edges and chamfer the ends. Flush the surfaces successively with petrol and acetone. Measure the surface roughness parameters R_a and R_z of the specimens.

7.3 Place the rotating and the stationary specimens in the testing apparatus. Supply oil to the apparatus. There should be enough oil to submerge both specimens completely. Rotate the rotating specimen.

NOTE — For testing, it is preferable to use the oil that will be used in practice for the actual combination of bearing materials.

7.4 Apply a load of 10 MPa. Continue running-in until the coefficient of friction (friction forces moment) is stabilized but for at least 120 min.

8 Test procedure

8.1 Heat the oil in the oil bath up to 30 °C ± 2 °C and at the same time begin the running-in of the specimen in accordance with 7.4.

8.2 Start the loading device to ensure a continuous increase of load at rate C_1. Constantly record the value of the coefficient of friction.

NOTE — A constant recording of the friction force and the load instead of the coefficient of friction is allowed.

8.3 Continue testing in accordance with 7.1 and 7.2 until the coefficient of friction rises sharply or scratches, hollows or build-ups not more than 5 µm deep (or high) appear on the surface of the specimens.

8.4 Replace the specimens and prepare the new specimens in accordance with clause 7 and 8.1. Start the loading device to ensure a continuous increase of load at rate C_2. Constantly record the value of the coefficient of friction. Continue the test in accordance with 8.3.

8.5 Repeat the operations given in 8.1, 8.2, 8.3 and 8.4 at temperatures in the oil bath of 60 °C and 90 °C.

8.6 Repeat the operations given in 8.1 to 8.5 not less than three times using new specimens.

8.7 Replace the specimens and prepare the new specimens for the tests given in 8.6. Heat the oil in the oil bath up to the temperatures given in 8.5. Start the loading device to ensure a continuous increase of load at rate C_2. Constantly record the values of surface temperature and of the coefficient of friction. Continue the tests until seizure occurs.

9 Independent test variables

In the process of comparative testing, the following independent test variables should be kept constant:

— method of machining and finishing of the harder (usually steel) rotating specimen material;

— initial surface roughness (R_a, $R_{a;max}$) of the rotating specimen.

10 Expression of results

10.1 From the results of each of the tests of 8.2, 8.4 and 8.6 on not less than three specimens, calculate the arithmetic mean of the pressures corresponding to the minimum coefficient of friction at each loading velocity and at temperatures T_1, T_2 and T_3.

10.2 From the value found in 10.1, determine the hydrodynamic index of running-in ability, R_H, for each of the oil temperatures in the oil bath.

10.3 Linearize the graph of the hydrodynamic index of running-in ability, R_H, as a function of the oil temperature in the oil bath using the equation

$$R_H = R_{HT} + a\,T_{oil}$$

NOTE — The R_{HT} and a parameters are used as running-in indices. The higher the values of R_{HT} and the lower is the value of a, the higher is the running-in ability of the material.

11 Description of materials, oil and test conditions

Unless agreed otherwise, for description of materials, oil, test conditions and test results, the following data shall be supplied.

11.1 Bearing material

Type

Chemical composition, in percent

Heat treatment

Parameters of surface roughness, R_a and R_z

Hardness

Method of applying the surface layer

11.2 Material of mating component

Type

Chemical composition, in percent

Heat treatment

Parameters of surface roughness, R_a and R_z

Hardness

Method of applying the surface layer

11.3 Oil

Type (including information on viscosity and, if possible, on additives)

11.4 Cover gas

Type

Relative humidity, in percent

11.5 Operating variables

Loading rate, C, in pascals per minute

Sliding velocity, u, in metres per second

Temperature of the oil bath, T_{oil}

11.6 Test results

The following parameters shall be supplied and inserted in table 2:

a) Hydrodynamic index of running-in ability, R_H

b) Temperature ratio constants, R_{HT} and a

Table 2

	Bearing material	Material of the mating part
Transferred material		
Reaction layer		
Scratches — none — several (1 to 3) — many		

Annex A
(informative)

Bibliography

ISO 4381 : 1981, *Plain bearings — Lead and tin casting alloys for multilayer plain bearings.*

ISO 4382-1 : 1982, *Plain bearings — Copper alloys — Part 1: Cast copper alloys for solid and multilayer plain berings.*

ISO 4382-2 : 1981, *Plain bearings — Copper alloys — Part 2: Wrought copper alloys for solid and multilayer plain bearings.*

ISO 4383 : 1981, *Plain bearings — Metallic multilayer materials for thin-walled plain bearings.*

ISO 4384-1 : 1982, *Plain bearings — Hardness testing of bearing metals — Part 1: Compound materials.*

ISO 4384-2 : 1982, *Plain bearings — Hardness testing of bearing metals — Part 2: Solid materials.*