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Plain bearings — Bearing fatigue —

Part 4:
Tests on half-bearings of a metallic multilayer bearing material

Paliers lisses — Fatigue des paliers —

Partie 4: Essais sur demi-coussinets en matériau antifriction métallique multicouche

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Foreword

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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 bearing*, Subcommittee SC 2, *Materials and lubricants, their properties, characteristics, test methods and testing conditions*.

This second edition cancels and replaces the first edition (ISO 7905-4:1995), which has been editorially revised.

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

— adjustments to ISO/IEC Directives, Part 2:2018 have been made;

— Annex A has been revised;

— the Bibliography has been revised.

A list of all parts in the ISO 7905 series can be found on the ISO website.

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 — Bearing fatigue —

Part 4:
Tests on half-bearings of a metallic multilayer bearing material

1 Scope

This document specifies a method for the determination of the endurance limit in fatigue of half-bearings of a multilayer bearing material.

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 4386-3, *Plain bearings — Metallic multilayer plain bearings — Part 3: Non-destructive penetrant testing*

3 Terms and definitions

No terms and definitions are listed in this document.

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 https://www.electropedia.org/

4 Symbols

The symbols used in this document are described in Table 1.

Table 1 — Symbols

Symbol	Description	Unit
A_1	coefficient of stress at the bearing backing	—
$a_{1,i}$	3 coefficients at the outside of the bearing back with i = 0, 1, 2	—
A_2	coefficient of stress at the surface of the lining	—
$a_{2,i}$	3 coefficients at the surface of the lining with i = 0, 1, 2	—
b	bearing width	mm
B_1	coefficient of stress at the bearing backing	—
$b_{1,i}$	3 coefficients at the outside of the bearing back with i = 0, 1, 2	—
B_2	coefficient of stress at the surface of the lining	—
$b_{2,i}$	3 coefficients at the surface of the lining with i = 0, 1, 2	—
E	Young's modulus	MPa
E_1	Young's modulus, steel bearing backing, $E_1 = 210 \cdot 10^3$	MPa

Table 1 *(continued)*

Symbol	Description	Unit
E_2	Young's modulus, lining	MPa
E_2*	dimensionless Young's modulus, $E*_2 = E_2/E_{2.0}$	—
$E_{2,0}$	Young's modulus of bearing used to construct curves in Figure A.2, $E_{2,0} = 50 \cdot 10^3$	MPa
E_3	Young's modulus, overlay	MPa
F	radial force at clamping end	N
$\bar{F}$	mean value of radial force	N
F_A	amplitude of radial force	N
N	number of cycles to failure	—
$\bar{r}$	radius of mean thickness $\bar{r} = (r_3 + r_4) \cdot 0,5$	mm
r_2	radius of interface between the bearing backing and lining	mm
r_3	radius of running surface (overlay thickness negligible)	mm
r_4	outer radius of bearing steel back	mm
s	total thickness of bearing	mm
$s*$	dimensionless total thickness, $s* = 2 \cdot [(r_4 - r_3)/(r_4 + r_3)]$	—
s_1	thickness of steel backing	mm
s_1^*	dimensionless steel backing thickness, $s_1^* = (r_4 - r_2)/(r_4 - r_3)$	—
t	time	s
σ	stress	MPa
$\sigma*$	dimensionless stress, $\sigma* = \sigma/\sigma_{nom}$	—
σ_{el}	stress amplitude	MPa
σ_{nom}	nominal stress, $\sigma_{nom} = (6 \cdot F \cdot \bar{r})/(b \cdot s^2)$	MPa
σ_1	stress at the outside of the bearing back	MPa
σ_1^*	dimensionless stress at the bearing steel back	—
σ_2	stress at the surface of the lining	MPa
σ_2^*	dimensionless stress, lining surface	—
σ_3	stress in overlay	MPa
ν_1	Poisson's ratio, steel backing	—
ν_2	Poisson's ratio, lining	—
ν_3	Poisson's ratio, overlay	—
ω	angular frequency of the radial load	s^{-1}
Δx	displacement	mm
$\overline{\Delta x}$	mean value of displacement	mm
Δx_A	amplitude of displacement	mm

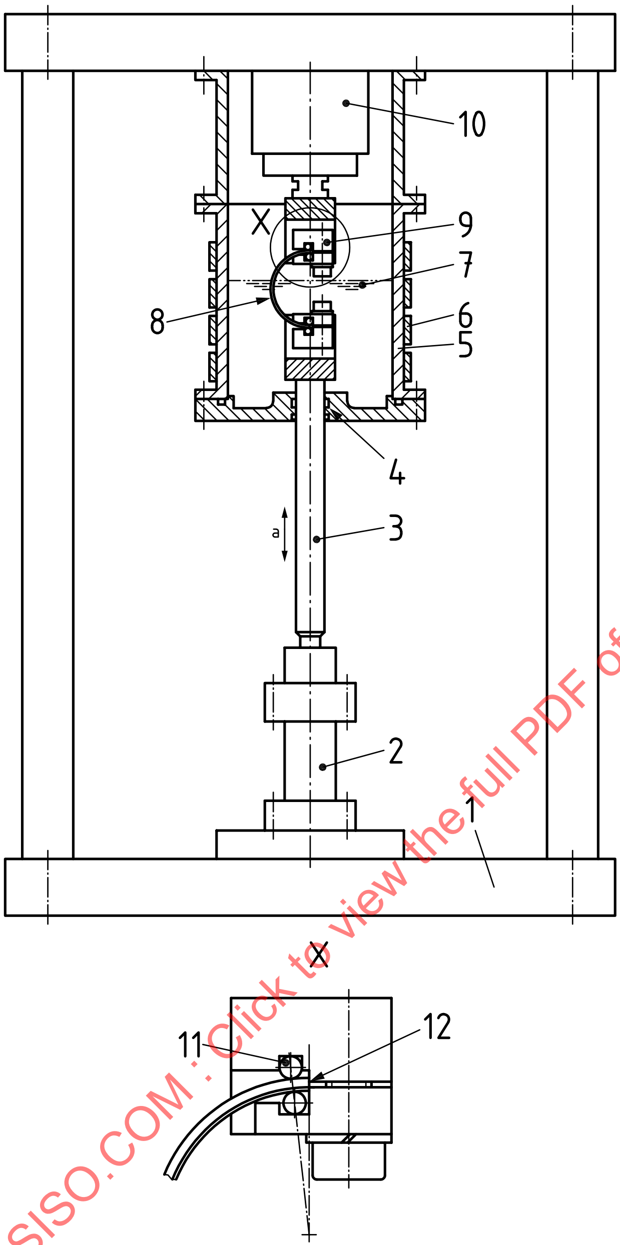
5 Test specimens

The test specimen shall be half bearings ready for use. Normally, as a result of the loading conditions, the major stresses are located in the crown area of the bearing. Care should be taken before and during the test not to damage the surface mechanically or by corrosion. The advantage of this method is the presence of residual stress associated with the bearing manufacturing process.

6 Test methods

The test principle is illustrated in Figure 1. The specimens shall be clamped at one end and loaded at the other end by force or displacement applied radially at the relief parting line runout. The load shall fluctuate from tension to compression within the running surface. Additionally, a tensile or compressive prestress can be applied in order to evaluate dependency upon mean stress. The test equipment is preferably located in a chamber containing a lubricant at fixed levels of temperature with a tolerance of ±2 °C. Alternatively, tests can be conducted in air at fixed levels of temperature with a tolerance of ±2 °C.

Surface stress on the back surface of the bearing at mid-peripheral length is used as nominal stress and can be measured by a strain gauge at this position. The required stress in the lining can be calculated if the steel and lining thicknesses and Young's moduli are known. Alternatively, the radial force at the clamping end F can be measured by a load cell or calculated from cantilever beam theory and the value of stress in the lining calculated according to Annex A. The values are critically dependent upon the lining and steel thickness which shall be determined by microsection after the tests. The test frequency shall have a range of 50 Hz to 80 Hz. Crack detection shall be performed by dye penetrant method in accordance with ISO 4386-3 or by microscope.



Key

1	frame	7	testing fluid
2	hydraulic cylinder	8	half bearing
3	connecting shaft	9	hinged clamping beam
4	seal	10	load cell
5	sample receptacle	11	rollers on radial line
6	strip heater	12	fulcrum clamping beam

a $F = \bar{F} + F_A \cdot \sin(\omega \cdot t)$ or $\Delta x = \overline{\Delta x} + \Delta x_A \cdot \sin(\omega \cdot t)$.

Figure 1 — Test principle

The amplitude shall be controlled by force, *F*, or displacement, *Δx*.

7 Evaluation and presentation of test results

The endurance limit stresses should be presented in the form of σ_{el}-N curves at a predetermined temperature with a tolerance of ±2 °C against a detailed description of the bearing material. Normally σ_{el}-N curve testing is terminated for practical considerations at $50 \cdot 10^6$ stress cycles. The endurance limit stress can be quoted at a specified number of cycles, for example, $3 \cdot 10^6$, $10 \cdot 10^6$, $25 \cdot 10^6$ or $50 \cdot 10^6$. A specimen without failure during fatigue testing to a specified endurance should be identified in the report. Due to the scatter of test results normally experienced and the statistical nature of the fatigue limit, the results should be evaluated based on a statistical method.

Another presentation of the endurance limit stress can be affected by means of the Haigh diagram which plots stress amplitude against mean stress. Metallographic examination provides detailed evidence of the damage mechanism, corrosive attack and diffusion resulting from thermal effects.

Annex A
(informative)

Evaluation of stress

A.1 Evaluation of stresses

A half-bearing system is described in Figure A.1 by radial dimensions, r_4, thickness, s_1, and related to Young's modulus, $E_{2,0} = 50 \cdot 10^3$ MPa, and to nominal stress, σ_{nom}.

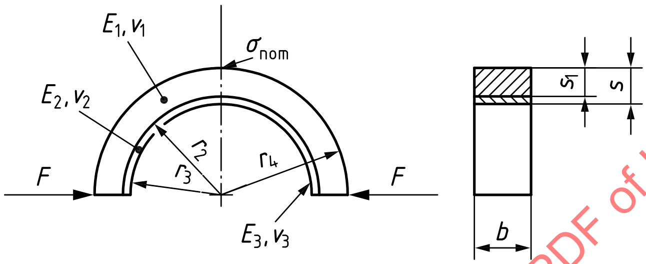


Figure A.1 — Half-bearing system

The bearing stress calculations are given in Figure A.2 for a two-layer bearing. The data used to construct the charts in Figure A.2 were based on a bearing having a Young's Modulus of $50 \cdot 10^3$ MPa.

A.2 Worked example

A.2.1 General

Given data for a half-bearing:

$b = 30$ mm

$E_1 = 210 \cdot 10^3$ MPa

$E_2 = 69 \cdot 10^3$ MPa

$E_3 = 22 \cdot 10^3$ MPa

$F = 100$ N

$r_2 = 49{,}10$ mm

$r_3 = 48{,}52$ mm

$r_4 = 51{,}50$ mm

It is assumed that since the overlay (PbSn11) is relatively thin (0,02 mm), it does not affect the stresses in the other layers. All values in this example are calculated to three decimal places.

A.2.2 Calculation of related dimensions

To correct for the actual Young's modulus:

$E_2{*} = E_2/E_{2,0}$

$E_2{*} = 69 \cdot 10^3/50 \cdot 10^3$

$E_2{*} = 1,380$

To calculate the dimensionless steel thickness:

$s_1^* = (r_4 - r_2)/(r_4 - r_3)$

$s_1^* = (51,50 - 49,10)/(51,50 - 48,52)$

$s_1^* = 0,805$

To calculate the dimensionless total thickness:

$s{*} = 2 \cdot [(r_4 - r_3)/(r_4 + r_3)]$

$s{*} = 2 \times [(51,50 - 48,52)/(51,50 + 48,52)]$

$s{*} = 0,060$

To calculate the radius of mean thickness:

$\bar{r} = (r_3 + r_4) \cdot 0,5$

$\bar{r} = (48,52 + 51,50) \times 0,5$

$\bar{r} = 50,01$ mm

A.2.3 Calculation of nominal stress

$\sigma_{nom} = (6 \cdot F \cdot \bar{r})/(b \cdot s^2)$

$\sigma_{nom} = (6 \times 100 \times 50,01)/[30 \times (51,50 - 48,52)^2]$

$\sigma_{nom} = 112,630$ MPa

A.2.4 Coefficients *a* and *b*

Using Figure A.2 and the dimensionless steel thickness, s_1^*, the coefficients *a* and *b* can either be calculated or read from the charts.

Running surface:

$a_{2,0} = 0{,}014$ $a_{2,1} = 0{,}488$ $a_{2,2} = -0{,}083$

$b_{2,0} = 0{,}031$ $b_{2,1} = 0{,}335$ $b_{2,2} = -0{,}077$

Bearing back:

$a_{1,0} = 1{,}553$ $a_{1,1} = -0{,}281$ $a_{1,2} = 0{,}046$

$b_{1,0} = -0{,}441$ $b_{1,1} = -0{,}090$ $b_{1,2} = 0{,}032$

A.2.5 Calculation of coefficients *A* and *B*

Running surface:

$$A_2 = a_{2,0} + a_{2,1} \cdot E_2^* + a_{2,2} \cdot E_2^{*2}$$

$$A_2 = 0{,}014 + 0{,}488 \times 1{,}380 - 0{,}083 \times 1{,}380^2$$

$$A_2 = 0{,}529$$

$$B_2 = b_{2,0} + b_{2,1} \cdot E_2^* + b_{2,2} \cdot E_2^{*2}$$

$$B_2 = 0{,}031 + 0{,}335 \times 1{,}380 - 0{,}077 \times 1{,}380^2$$

$$B_2 = 0{,}347$$

Bearing back:

$$A_1 = a_{1,0} + a_{1,1} \cdot E_2^* + a_{1,2} \cdot E_2^{*2}$$

$$A_1 = 1{,}553 - 0{,}281 \times 1{,}380 + 0{,}046 \times 1{,}380^2$$

$$A_1 = 1{,}253$$

$$B_1 = b_{1,0} + b_{1,1} \cdot E_2^* + b_{1,2} \cdot E_2^{*2}$$

$$B_1 = -0{,}441 - 0{,}090 \times 1{,}380 + 0{,}032 \times 1{,}380^2$$

$$B_1 = -0{,}504$$

A.2.6 Calculation of dimensionless stress

Running surface:

$$\sigma_2^* = A_2 + B_2 \cdot s^*$$

$$\sigma_2^* = 0{,}529 + 0{,}347 \times 0{,}060$$