



**International
Standard**

ISO 4385

**Plain bearings — Compression
testing of bearing materials**

Paliers lisses — Essai de compression des matériaux paliers

**Second edition
2024-12**

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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 document 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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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 4385:1981), which has been technically revised.

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

- change of scope;
- restructure of the document;
- implementation of [Clause 2](#);
- revision of [Clause 3](#), Terms and definition;
- implementation of [Clause 4](#);
- revision and of [Clause 4](#) and [5](#), and implementation of [Figures 1, 2, 3, 4, 5](#) and [6](#);
- revision of [Clause 6](#).

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 — Compression testing of bearing materials

1 Scope

This document specifies a method for compression testing of bearing materials. It is applicable for both bulk materials and coatings.

Compression testing within the meaning of this document serves for the determination of the behaviour of bearing materials under uniaxial compression loading which is uniformly distributed over the cross-section. For this purpose, a cylindrical specimen or a setup of two such specimen, with an original cross-section, A_0 , is loaded at constant crosshead speed and the resulting compressive stress and compressive strain are recorded.

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 last edition of the referenced document (including any amendments) applies.

ISO 1101, *Geometrical product specifications (GPS) — Geometrical tolerancing — Tolerances of form, orientation, location and run-out*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometer systems used in uniaxial testing*

ISO 21920-1, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 1: Indication of surface texture*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters*

3 Terms and definitions

No terms and definition are listed in this document.

ISO and IEC maintain terminology 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

For the purposes of this document, the symbols and definitions as listed in [Table 1](#) apply.

Table 1 — Symbols description and units

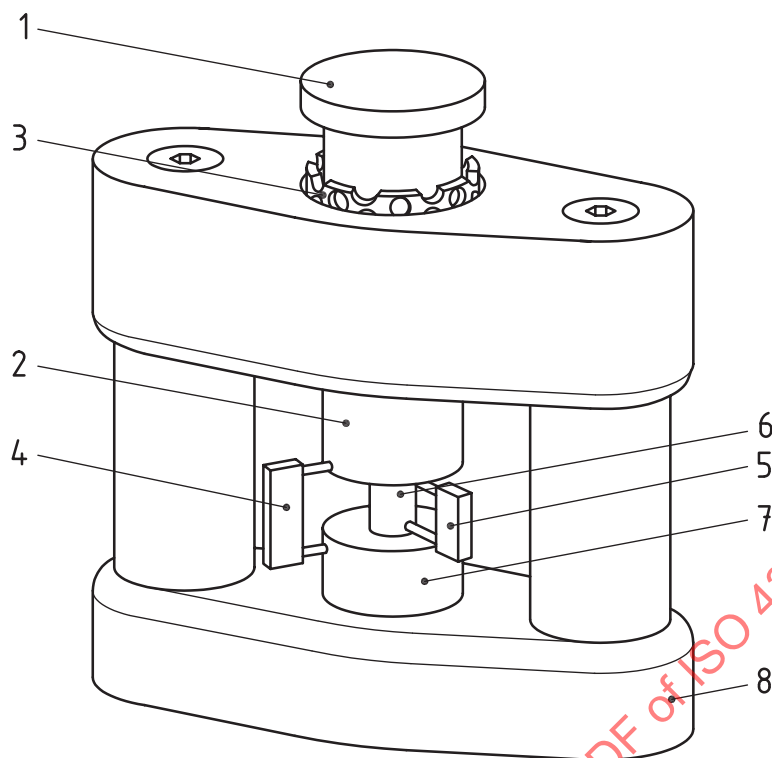
Symbol	Description	Unit
A_0	Original cross-sectional area of a specimen prior to loading. A_0 is calculated using the original diameter as $A_0 = \pi/4 \cdot d_0^2$.	mm ²
A_u	Final cross-sectional area of a specimen after loading. A_u is calculated using the final diameter as $A_u = \pi/4 \cdot d_u^2$.	mm ²
d_0	Original diameter, diameter of a compression specimen prior loading, calculated as the mean of two measurements taken at the specimen centre at right angles to each other. NOTE 1 The original cross-sectional area of the specimen prior to loading, A_0 , is calculated using this diameter ($A_0 = \pi/4 \cdot d_0^2$).	mm
d_u	Final diameter, diameter of a compression specimen after loading, calculated as the mean of two measurements taken at the axial specimen centre at right angles to each other. NOTE 2 The final cross-sectional area of the specimen, A_u , is calculated using this diameter ($A_u = \pi/4 \cdot d_u^2$).	mm
d_s	Compression plate diameter	mm
E_b	Elastic modulus of specimen base material	MPa
e_c	Compressive strain; percentage change in gauge length (L_e or L_0) as given in Formulae (1) and (2): $e_c = \frac{\Delta L_e}{L_e} \cdot 100$ (determined directly at the specimen using an extensometer) (1) or $e_c = \frac{\Delta L_0}{L_0} \cdot 100$ (determined via displacement of the compression dies) (2) NOTE 3 The compressive strain e_c is the sum of elastic and plastic strain.	%
e_{ce}	Elastic compressive strain of the original gauge length section; reversible component of compressive strain	%
$e_{c\text{ eff}}$	Calculated change rate of strain	%
e_{cF}	Compressive strain at fracture, percentage change in gauge length (L_e or L_0) at fracture of the specimen, as given in Formulae (3) and (4): $e_{cB} = \frac{\Delta L_{eF}}{L_e} \cdot 100$ (determined directly at the specimen using an extensometer) (3) or $e_{cF} = \frac{\Delta L_{0F}}{L_0} \cdot 100$ (determined via the displacement of the compression dies) (4)	%
e_{cp}	Plastic compressive strain of the original gauge length section, total compressive strain minus the elastic component at any moment of the test	%
$\dot{e}_c$	Change rate of strain along gauge length L_e or L_0	s ⁻¹
f_m	Sampling frequency	Hz
F_c	Compressive force at any moment of the test	N
h_0	Height of a specimen prior loading	mm
L	Original gauge length on which strain measurements are based	mm
L_e	Base gauge length for the extensometer used for continuously measuring the change in length of the specimen during the test, as measured directly at the specimen.	mm
L_0	Initial length of the specimen prior loading $L_0 = h_0$, for non coated specimen $L_0 = 2 \cdot h_0$, for coated specimen Is only applicable, if the measurement is carried out without a measurement gauge	mm
ΔL	Change in gauge length due to specimen loading	mm
ΔL_e	Change in extensometer gauge length, change in L_e at any moment during the extensometer test, as measured directly at the specimen	mm

Table 1 (continued)

Symbol	Description	Unit
ΔL_{eF}	Change in extensometer gauge length at fracture, total (elastic and plastic) change in length at specimen fracture, as measured directly at the specimen.	mm
ΔL_0	Change in gauge length of the specimen, change in L_0 at any moment during the extensometer test, as measured via the displacement of the compression plates	mm
ΔL_{0F}	Change in gauge length of the specimen at fracture, total (elastic and plastic) change in length at specimen fracture, as measured via the displacement of the compression plates.	mm
m_{de}	Slope of the elastic part of the stress-strain-curve	MPa
R_c	Compressive stress; ratio of compressive force F_c to the original cross-sectional area of the specimen A_0 at any moment of the test, as given in Formula (5): $R_c = \frac{F_c}{A_0} \quad (5)$	MPa
R_{ceH}	Upper compressive yield strength, maximum compressive stress at the end of the elastic range prior to a measured decrease in force NOTE 4 See Figure 4.	MPa
R_{ceL}	Lower compressive yield strength; minimum compressive stress during plastic deformation following a rise of stress in the elastic range, disregarding the initial transient effects NOTE 5 See Figure 4.	MPa
R_{cF}	Compressive strength, compressive stress at the point of fracture of the specimen	MPa
R_{cm}	Compressive stress at a specified maximum strain; ratio of the compressive force F_c and the original cross-sectional area of the specimen A_0 when a specified strain has been reached at the end of testing NOTE 6 The level of the specified maximum strain is expressed by adding a subscript. So, R_{cm10} denotes a compressive stress resulting in a specified compressive strain of 10 %, which is the sum of the elastic and the plastic strain.	MPa
R_{cp}	Compressive stress at a specified relative plastic strain, e.g. $R_{cp0,2}$ for a compressive stress resulting in a plastic strain of 0,2 %	MPa
T	Specimen temperature	K
t_0	Specimen coating thickness prior loading	mm
v_c	Crosshead speed, crosshead displacement per unit time	mm/s
Y	Bulging; maximum relative change in cross-sectional area of an unloaded specimen after the test Maximum percentage change in cross-sectional area of the compression specimen after the test, with the specimen unloaded, as given in Formula (6): $Y = \frac{(A_u - A_0)}{A_0} \cdot 100 \quad (6)$ NOTE 7 In cases where the specimen is broken or unevenly deformed, bulging is not determined.	%

5 Test equipment

The test shall be carried out using a class 1 compression testing machine as specified in ISO 7500-1 and a compression test fixture, e.g. as shown in Figure 1. The compression plates shall be ground so as to be flat and even with a surface roughness of $R_z \leq 1,6 \mu\text{m}$ in accordance with ISO 21920-1 and ISO 21920-2. Their contact faces shall have a greater hardness than the specimen material in order to avoid their plastic deformation.

**Key**

- 1 thrust plate (with spherical cup between plate and upper compression plate)
- 2 upper compression plate (with contact face hardened and polished)
- 3 guide bearing
- 4 extensometer (attached to the compression plates)
- 5 extensometer (attached to specimen)
- 6 specimen
- 7 lower compression plate (with contact face hardened and polished)
- 8 base plate

Figure 1 — Example of a compression test fixture

The compression plates shall be aligned so that their longitudinal axis coincides with the loading axis of the testing machine. For rigid compression plates, parallelism of the two contact faces shall be checked and corrected prior testing. Any deviation of parallelism shall not exceed 0,02 mm or 0,000 5 mm per mm of specimen diameter, whichever is greater. The requirement for parallelism of the contact faces shall be deemed adequate only if the specimens do not show signs of bending or buckling during the test.

For the determination of the strain limit up to plastic strains of less than or equal to 2 %, the extensometer shall, in the relevant range, be at least of class 1 as specified in ISO 9513. For plastic strains greater than 2 %, the extensometer in the relevant range may be of class 2 as specified in ISO 9513. Length may be measured with the extensometer either

- a) attached to the specimen, or
- b) attached to the compression plates.

In case a), gauge length L_e shall be determined using the extensometer and should be at least equal to 50 % of the specimen height h_0 .

In case b), gauge length shall be equal to the specimen height h_0 , and the extensometer should be fixed as close as possible to the contact faces of the compression plates in order to minimize the effects of elastic deformation of the compression plates.

In cases where the test is performed at any other temperature than room temperature, a heating or cooling device is to be installed at least around the specimen and the pressure plates. Throughout the duration of the test, temperature of specimen and pressure plates T is to be kept constant to within 1 K and specimen temperature is to be measured throughout the testing process to an accuracy of 1 K.

6 Specimen shape and preparation

Cylindrical specimens are to be used. For coated specimen, the compressive stress at a plastic strain of 0,2 % of the base material shall be at least 120 % of the compressive stress at a plastic strain of 0,2 % of the coating.

Unless otherwise agreed upon, specimen shall be completely machined with parallel end faces and surface roughness $R_z \leq 1,6 \mu\text{m}$ according to ISO 21920-1 and ISO 21920-2. Their lateral surfaces shall have a roughness of $R_z \leq 3,2 \mu\text{m}$ according to ISO 21920-1 and ISO 21920-2. The deviation of the end faces from cylindricity and angularity relative to the specimen axis as described in ISO 1101 shall not exceed 0,02 mm or 0,000 5 mm per mm of specimen diameter, whichever is greater. For bulk specimen, the ratio between the height h_0 and the diameter d_0 of a specimen shall be as given in [Formula \(7\)](#):

$$1 \leq \frac{h_0}{d_0} \leq 2 \quad (7)$$

For coated specimen, the ratio between the height h_0 and the diameter d_0 of a specimen shall be as given in [Formula \(8\)](#):

$$0,5 \leq \frac{h_0}{d_0} \leq 1 \quad (8)$$

After specimen manufacturing, diameter and height of each specimen shall be measured to an accuracy of 0,2 %. The original diameter d_0 shall be calculated as the mean of two orthogonal measurements made at right angles to each other, the original height h_0 may be determined using a single measurement. For coated specimen, the measurement is to be taken at the contact face, otherwise at the axial centre of the specimen.

7 Test procedure

After assembly of the specimen in the testing machine, the point of zero force shall be set with the loading train open. After the force was set to zero, no changes shall be made to the force-measuring system until the end of the test.

The faces of the compression plates in contact with specimen shall be slightly greased with a lubricant, e.g. molybdenum disulphide (MoS_2), before each test. For coated specimen, two specimens shall be placed with the coated surfaces facing each other as indicated in [Figure 2](#), with the contact surface slightly greased.

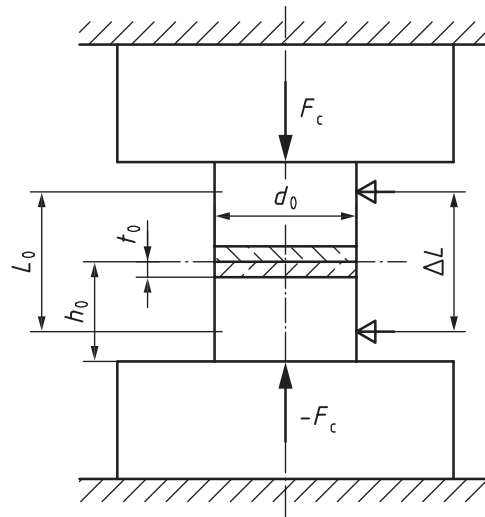
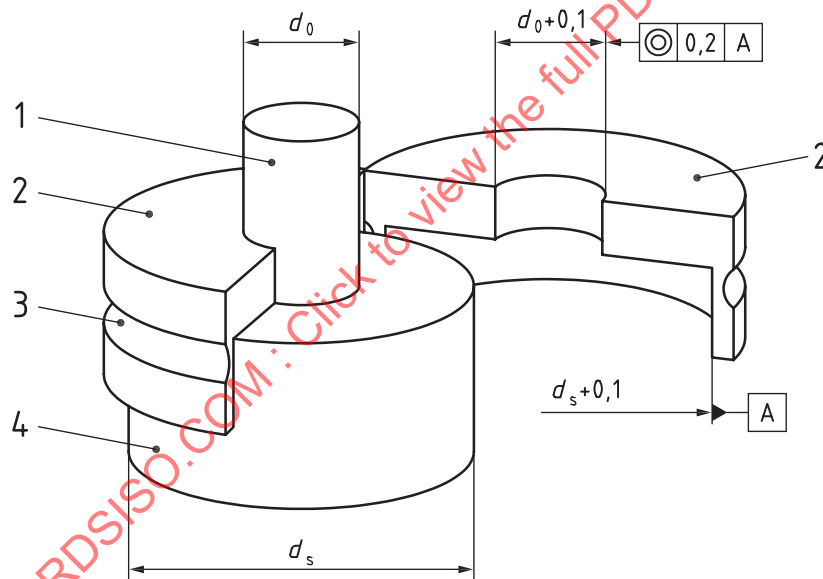


Figure 2 — Test setup for coated specimen

The specimen shall be centred using a suitable fixture so that the distance between the specimen axis and the vertical axis of the compression plate does not exceed 0,2 mm. Please see [Figure 3](#) for an example of a centring fixture.

**Key**

- 1 specimen
- 2 semi-circular shell
- 3 groove for tension spring
- 4 lower compression plate

Figure 3 — Example of a centering fixture

After initial placement, the specimen should be held in place through application of a compressive stress of 1 MPa. In this condition, the centring fixture shall be removed and the extensometer fixed to either the sample or the pressure plates. The compression offset due to the preload is to be taken into account in the evaluation.

The change rate of strain shall be $\dot{\epsilon}_c = 0,005 \text{ s}^{-1}$, with a relative tolerance of $\pm 20 \%$.

For bulk specimen crosshead speed shall be $v_c = h_0 \cdot \dot{e}_c$

For coated specimen crosshead speed shall be $v_c = t_0 \cdot 2 \cdot \dot{e}_c$

The compression test shall be continued until specimen fracture or until a specified maximum compressive strain e_c is reached. During loading, time, crosshead displacement, change in length ΔL and compressive force F_c shall be recorded continuously, with a sampling frequency f_m at least equal to the value obtained in [Formula \(9\)](#):

$$f_m = \dot{e}_c \cdot m_{de} / R_{ceH} \cdot 100 \quad (9)$$

NOTE The factor 100 is chosen as to ensure sampling frequency to be significantly higher than the characteristic frequency of the test procedure.

When testing materials with no marked compressive yield point, $R_{cp0,2}$ shall be used instead of R_{ceH} in [Formula \(9\)](#).

8 Test evaluation

8.1 General

Compression testing in accordance with this document enables determination of the below described parameters. All force-related values are treated as absolute values, without sign.

8.2 Determination of the upper compressive yield stress

The upper compressive yield stress, R_{ceH} , is the maximum stress at the end of the elastic range, prior to the first measured decrease in force. It is calculated as the ratio of the force effective at said time and the original specimen cross-section A_0 . R_{ceH} can be read directly from the compressive stress-strain diagram, see [Figure 4](#). It can only be determined if the tested material has a distinctive compressive yield stress.

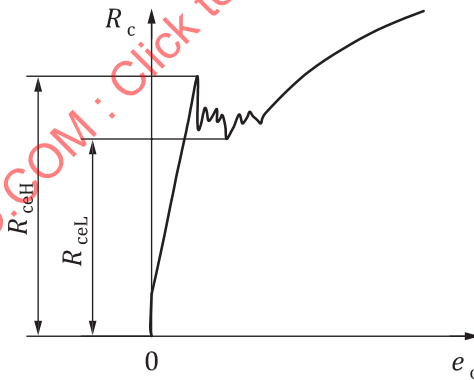


Figure 4 — Example of a compressive stress-strain diagram with upper and lower yield point

8.3 Determination of the lower compressive yield stress

The lower compressive yield point, R_{ceL} , is the minimum stress during plastic deformation following a rise of stress in the elastic range, without taking into account initial transient effects. It is calculated as the ratio of the minimum force effective in this range and the original specimen cross-section A_0 . R_{ceL} can be read directly from the compressive stress-strain diagram, see [Figure 4](#).

8.4 Determination of compressive strain limits

8.4.1 Determination of strain for coated specimen

For coated specimen, coating strain is determined using [Formula \(10\)](#):

$$e_{c\text{eff}} = \frac{L_0}{2 \cdot t_0} \cdot \left[\frac{e_c}{100} - \frac{F_c}{A_0 \cdot E_b} \cdot \left(1 - \frac{2 \cdot t_0}{L_0} \right) \right] \cdot 100 \quad (10)$$

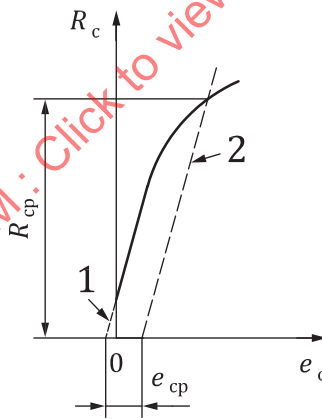
All stress-strain diagrams shall be corrected accordingly before evaluation.

8.4.2 Determination of compressive strain limits for existing linear part of the stress strain curve

The compressive strain limit R_{cp} is the stress at a specified plastic strain which is added to the subscript, e.g. $R_{cp0,2}$ for the compressive strain limit at a plastic strain of 0,2 %. It is derived from the compressive stress-strain diagram through the following procedure:

- A first line shall be drawn through the linear part of the compressive stress-strain diagram and the intersection with the strain axis shall be determined (item 1 in [Figure 5](#)).
- A second line shall be drawn which is parallel to the first linear in a distance of the specified plastic strain from the intersection of the first line with the strain axis. The intersection of the second line with the compressive-stress-strain diagram shall be determined. This is the accounting for the preload (item 2 in [Figure 5](#)).
- The compressive strain limit for the specified plastic strain is the stress at the intersection of the second line with the compressive stress-strain diagram.

This procedure is indicated in [Figure 5](#).



Key

- 1 linear part of compressive strain curve and intersection with the strain axis
- 2 parallel line to 1, with a distance of e_{cp}

Figure 5 — Determination of compressive strain limit R_{cp} at a specified plastic strain e_{cp} , with preload (example)

8.4.3 Determination of compressive strain limits for non-existing linear part of the stress strain curve

If it is not possible to determine a linear part of the stress-strain curve, a hysteresis loop may be used for this purpose. In this case, the compressive strain limit is derived through the following procedure:

- During the measurement, once the specified compressive strain limit is exceeded by 5 %, the compressive stress shall be reduced to a value of 10 % of the stress obtained at the specified strain limit.