INTERNATIONAL STANDARD

ISO 7148-2

Second edition
2012-10-01

Plain bearings — Testing of the tribological behaviour of bearing materials —

Part 2: Testing of polymer-based bearing materials

Paliers lisses — Essai du comportement tribologique des matériaux antifriction —

Partie 2: Essai des matériaux pour paliers à base de polymère

Reference number
ISO 7148-2:2012(E)

Contents

Page

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 7148-2 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 7148-2:1999), which has been technically revised.

ISO 7148 consists of the following parts, under the general title *Plain bearings — Testing of the tribological behaviour of bearing materials*:

— *Part 1: Testing of bearing metals*

— *Part 2: Testing of polymer-based bearing materials*

Plain bearings — Testing of the tribological behaviour of bearing materials —

Part 2: Testing of polymer-based bearing materials

1 Scope

This part of ISO 7148 specifies tribological tests of polymer-based plain bearing materials under specified working conditions, i.e. load, sliding velocity and temperature, with and without lubrication. From the test results, data are obtained which indicate the relative tribological behaviour of metal-polymer and polymer-polymer rubbing parts.

The purpose of this part of ISO 7148 is to obtain, for polymer material combinations used in plain bearings, reproducible measured values for friction and wear under specified and exactly-defined test conditions without lubrication (dry surfaces) and with lubrication (boundary lubrication).

The test results give useful information for practical application only if all parameters of influence are identical. The more the test conditions deviate from the actual application, the greater the uncertainty of the applicability of the results.

2 Normative references

The following referenced documents are indispensable for the application 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 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics*

ISO 527-3, *Plastics — Determination of tensile properties — Part 3: Test conditions for films and sheets*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 4385, *Plain bearings — Compression testing of metallic bearing materials*

ISO 6691, *Thermoplastic polymers for plain bearings — Classification and designation*

3 Symbols, units and abbreviated terms

See Table 1.

Table 1 — Symbols, units and abbreviated terms

Symbol	Term	Unit
A, B, C, D, E	Test method	-
a	Sliding distance	km
dr	Dry	-
f	Coefficient of friction; ratio between friction force and normal force, i.e.: $f = \frac{F_f}{F_n}$	-
F_f	Friction force	N
F_n	Normal force	N
gr	Grease	
K_w	Coefficient of wear, volumetric wear rate related to the normal force, i.e.: $K_\mathrm{w} = \frac{V_\mathrm{w}}{F_\mathrm{n} \times a} = \frac{w_\mathrm{v}}{F_\mathrm{n}}$	mm^3/(N·km)
l_w	Linear wear as measured by change in distance	mm
M_f	Friction moment	Nm
oi	Oil	-
$\bar{p}$	Specific force per unit area (force/projected contact area)	N/mm^2
$R_\mathrm{d,B}$	Compression strength	N/mm^2
$R_\mathrm{d0,2}$	Compression limit 0,2 %	N/mm^2
so	Solid lubricant	
T	Specimen's temperature near the sliding surface during testing under steady-state conditions	°C
T_amb	Ambient temperature	°C
T_g	Glass transition temperature	°C
T_lim	Maximum permissible temperature	°C
t_Ch	Test duration	h
U	Sliding velocity	m/s
V_W	Material removed by wear as measured by change in volume	mm^3
w_l	Linear wear rate, i.e.; $w_l = \frac{l_w}{a}$	mm/km
w_v	Volumetric wear rate, i.e.: $w_v = \frac{V_w}{a}$	mm^3/km
η	Lubricant viscosity	mPa·s

4 Special features for the tribological testing of polymer-based materials

Polymers have a low thermal conductivity and a low melting temperature, so that heat resulting from contact friction may lead to partial melting and hence feign wear. Due to the high thermal expansion of polymers (up to 10 times higher than that of steel) results obtained can be misleading because the test specimens have expanded under frictional heat. Hence allowance shall be made for the effects of thermal expansion (change of clearance) and thermal conductivity (melting) when assessing the results. Where possible the temperature of both test specimens should be controlled.

Polymers have a glass transition temperature, T_g, which depends on their chemical structure. At this temperature, their physical properties and their tribological behaviour may change.

Injection-moulded polymer surfaces have different properties from machined surfaces. The test specimens shall be tested with the same surface conditions as they have in practical application.

Reinforcements and fillers, i.e. fibres, may lead to very strong anisotropy of the material and influence its wear behaviour depending on fibre orientation. The test specimens should have the same fibre orientation as in practical application.

In order to avoid stick-slip, the test rig shall be very stiff and shall not be susceptible to vibrations.

The tribological behaviour of polymers depends very strongly on the material combination, which part moves and which part remains stationary. The test system shall be similar to practical application.

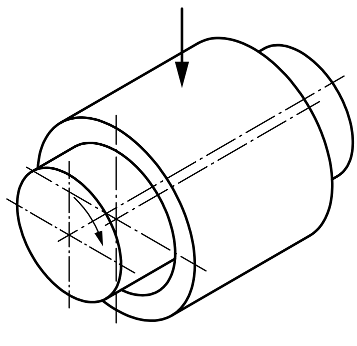
Polymers show wear processes that are different from that of metals. There are not only abrasive processes with powder-like wear debris, but also adhesive processes with the creation of transfer layers which may be smooth or rough. Also ploughing wear and melting or plastic deformation is possible. Therefore, wear cannot be gravimetrically measured in all cases and the wear status shall be judged after the tests (whether the surfaces are fine- or coarse- grained, scored or plucked out, scaled, melted or plastically deformed).

Some polymers may show poor repeatability of the results and require repeated testing (i.e. six or more repetitions).

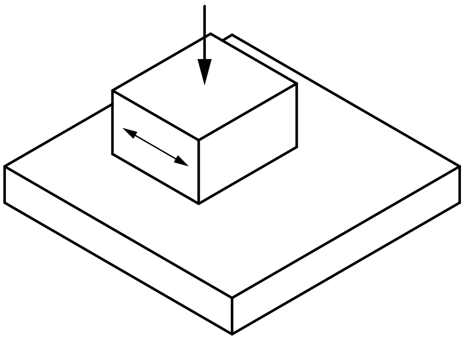
The preparation and preparatory treatment (e.g. conditioning, storage, cleaning) of the test specimens can have a high influence on performance.

In some thermoplastics, e.g. polyamides, moisture absorption effects a gradual change in linear dimensions and modifies their mechanical properties. Environmental parameters should, therefore, be controlled in the test array. Moisture absorption prohibits gravimetrical measurement of wear.

The more the test conditions deviate from the actual application, the greater is the uncertainty of the applicability of the results (see Figures 1 and 2).

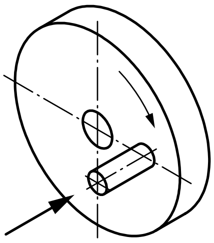


a) Plain bearing-on-shaft

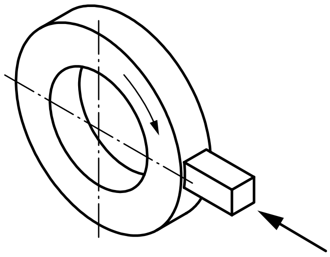


b) Linear guidance system

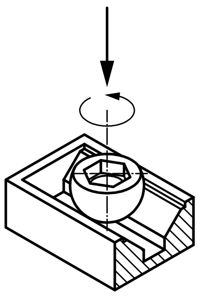
Figure 1 — Simulation of real rubbing contacts



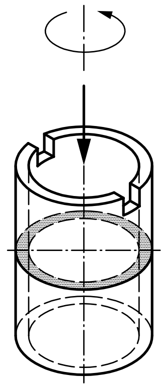
a) Pin-on-disc



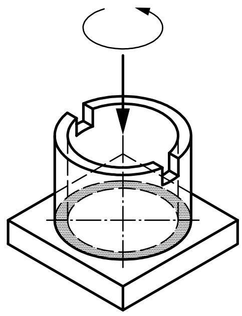
b) Block-on-ring



c) Sphere-on-prism



d) Rotation under thrust load — Sleeve-to-sleeve



e) Rotation under thrust load — Sleeve-to-plate

Figure 2 — Simulation under approximated practical testing conditions and model systems

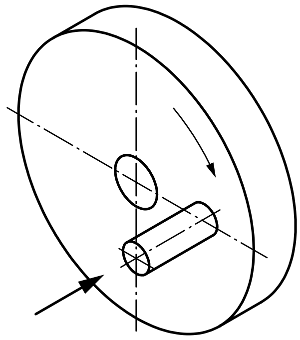
5 Test methods

5.1 General

Different test methods are provided for tests in accordance with this part of ISO 7148 so that the following contact geometries are available. The test methods should correspond to the practical application as closely as possible.

5.2 Test method A — Pin-on-disc

See Figure 3.



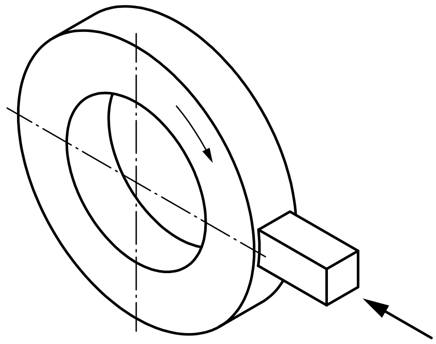
Advantages:
- basic testing of simple test specimens;
- testing of tribological properties;
- no increase of sliding surface area due to wear;
- initial ranking of materials;
- simulation of linear guidance system [see Figure 1b)].

Disadvantages:
- edge of the pin might wipe off lubricant;
- no injection moulding of the pin with fibre reinforced material;
- no injection moulding of the disc because of problems with shrinkage.

Figure 3 — Test method A — Pin-on-disc

5.3 Test method B — Block (or pin)-on-ring

See Figure 4.



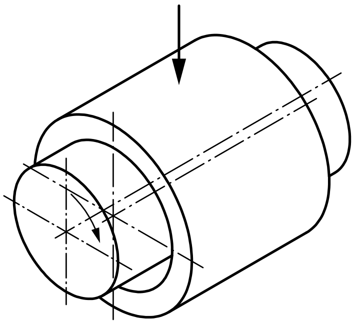
Advantages:
- basic testing of simple test specimens;
- testing of tribological properties;
- no increase of sliding surface area due to wear;
- initial ranking of materials;
- with and without lubrication.

Disadvantages:
- no injection moulding of the block because of problems with shrinkage and fibre orientation;
- edge of the block might wipe off lubricant;
- no injection moulding of the disc because of problems with shrinkage.

Figure 4 — Test method B — Block (or pin)-on-ring

5.4 Test method C — Plain bearing-on-shaft

See Figure 5.



Advantages:

— best simulation of all possible systems;

— testing of original or scaled bearings;

— prediction of practical behaviour;

— with and without lubrication.

Disadvantages:

— long testing time (accelerated testing might cause excessive frictional heating);

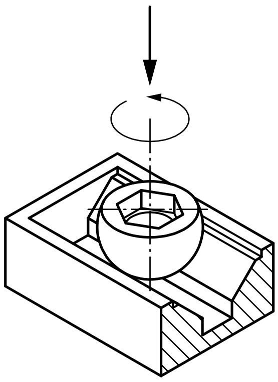
— difficult alignment of the test bearing;

— increasing sliding surface area due to wear under boundary lubrication.

Figure 5 — Test method C — Plain bearing-on-shaft

5.5 Test method D — Sphere-on-prism

See Figure 6.



Advantages:

— testing of polymer/polymer or polymer/metal combinations;

— with and without lubrication (test specimen contains reservoir for lubricant);

— testing of lubricant's interaction with polymers;

— injection-moulded test specimens available;

— self-adjustment of the alignment of the sliding couple;

— increasing sliding surface area due to wear under boundary lubrication.

Disadvantages:

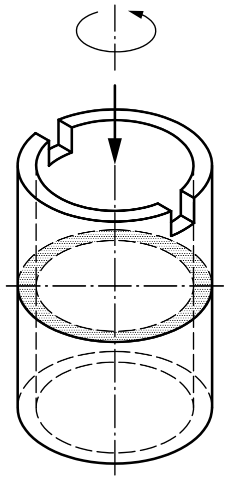
— plastic deformation might affect results;

— increasing sliding surface area due to wear under dry conditions.

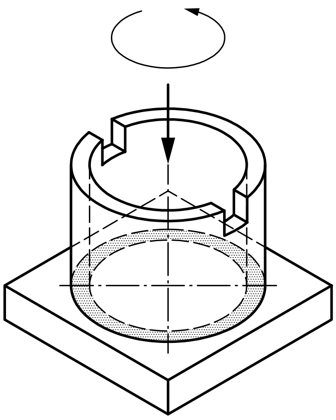
Figure 6 — Test method D — Sphere-on-prism

5.6 Test method E — Rotation under thrust load

See Figure 7.



a) E1 — Sleeve-to-sleeve



b) E2 — Sleeve-to-plate

Figure 7 — Rotation under thrust load

Advantages:

— basic testing of simple specimens;

— injection-moulded test specimens available;

— testing of tribological properties;

— initial ranking of material;

— no increase of sliding surface area due to wear;

— continuous sliding between specimens;

— with and without lubrication.

Disadvantages:

— plastic deformation affects results;

— shrinkage at sliding surface on injection-moulded specimens affects results.

6 Test specimens

6.1 Data required

For one series of tests, several specimens of one material shall be from the same batch, with uniform state after conditioning and uniform finish of the sliding surface. Machined and injection-moulded specimens may create different results because crystallinity can vary with depth from the surface. They should be tested separately.

As the structural condition of the mating materials constitutes an essential factor as far as the repeatability of the test results is concerned, the following information is necessary:

a) material specification and composition, including fillers or details of fibre reinforcement (as specified in ISO 6691);

b) method of manufacture;

c) structure, e.g. density, degree of crystallinity;

d) mechanical material properties, e.g. Shore hardness, 0,2 % compression limit, $R_{d0,2}$ (as specified in ISO 4385), compression strength, $R_{d,B}$;

e) state of conditioning, e.g. moisture content;

f) surface condition and surface roughness, *Ra*, e.g. injection-moulded, machined (as specified in ISO 2818), turned, ground, lapped, polished, milled.

6.2 Polymer-based plain bearing materials (pl)

These may be made by moulding, injection moulding or by cutting bar or tube to length or by machining all over from semi-finished materials or by cutting from injection-moulded or laminated (composite) plates.

If fibre-reinforced polymers are to be tested, the fibres shall lie in the same direction in the test as in the final product, e.g. parallel or perpendicular to the sliding surface.

6.3 Materials of mating component

All metallic and polymer-based materials may be considered as mating materials. The choice should be the same as in practical application. In technical applications, all systems are possible, e.g. gear box of aluminium with injection-moulded gears and shafts of polyoxymethylene (POM). The mating materials shall have the same sliding couple, e.g. rotating POM disc or ball on fixed pin or prism out of aluminium. In this case, the reverse combination POM pin on aluminium disc leads to errors in evaluation.

6.4 Dimensions of test specimens

6.4.1 General

If dimensions other than those described as follows are used, the results might not be comparable due to the effects of transfer films and heat dissipation.

6.4.2 Disc

The disc shall have the following preferred dimensions:

— outside diameter: 110 mm;

— inside diameter: 60 mm;

— radius of the sliding track: (51,5 ± 0,2) mm;

— width: 10 mm.

The basic form of the disc is identical to the ring of deep groove ball thrust bearings on the shaft side.

6.4.3 Ring

The ring shall preferably have an outside diameter of 40 mm and a width corresponding at least to the width of the block.

6.4.4 Pin

The pin shall preferably have a diameter of 3 mm for injection-moulded materials. For fibre-reinforced materials, a larger diameter is preferred.

If a pin with a diameter greater than 7 mm is used, the radius of the sliding track has to be reduced or the disc diameter increased. Means shall be provided for preventing rotation of the pin.

The free length of the pin shall not exceed 2 mm. Due to its dimensions, it is possible to make the 3 mm diameter polymer pin out of a standard tension bar in accordance with ISO 527-3 or ISO 527-2. This allows the correlation of wear and strength tests.

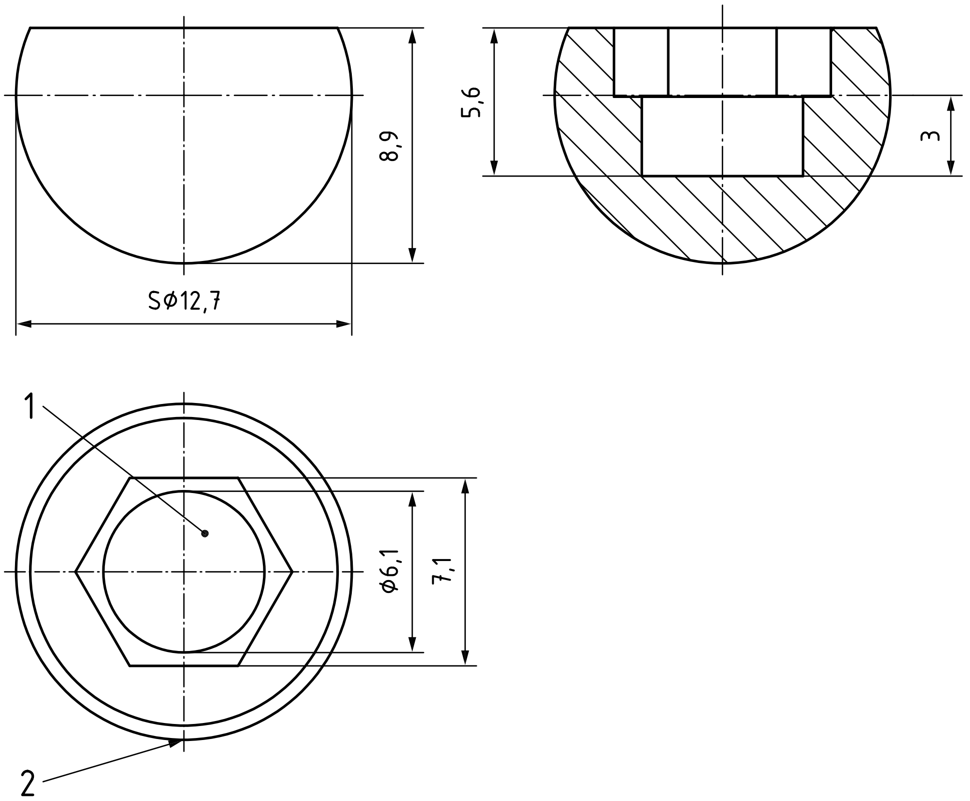
6.4.5 Block

The preferred basic dimensions of the block should be 10 mm × 10 mm × 20 mm. If a suitably large component is not available, the block may, as an exception, be used with a length of 10 mm. The roughness of the block depends on the machining conditions, e.g. milling or turning. The radius of the rubbing surface of the block should be a minimum of 1,001 times the radius of the ring. If the maximum radius exceeds 1,003 times the radius of the ring (line contact), the running-in period can be unduly prolonged (see 11.1).

6.4.6 Sphere

The sphere shall preferably have a diameter of 12,7 mm. Thermoplastics may be injection-moulded (see Figure 8). Spheres made out of metals are commercially available (balls for ball bearings or valves).

Dimensions in millimetres



Key

1 six-flat mount with cylindrical hole

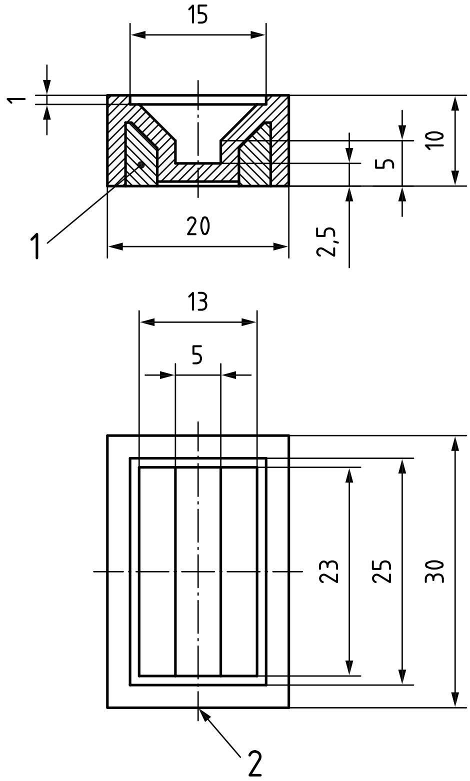
2 gate position

Figure 8 — Example of an injection-moulded sphere

6.4.7 Prism

The prism has a preferred special shape. If injection-moulded, the prism specimen shall have a uniform wall thickness (2 mm) and metallic support (see Figure 9) in order to avoid deformation. Alternatively, cut plates may be fitted into a special mount (see Figure 10).

Dimensions in millimetres

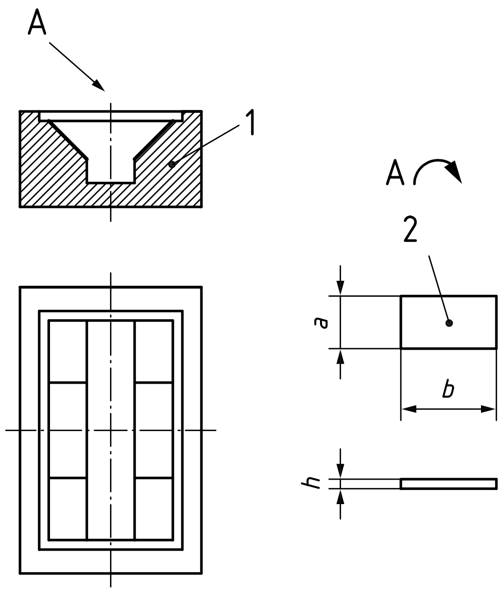


Key

1 metal stiffening

2 gate position

Figure 9 — Example of an injection-moulded prism



Key

1 metal holder

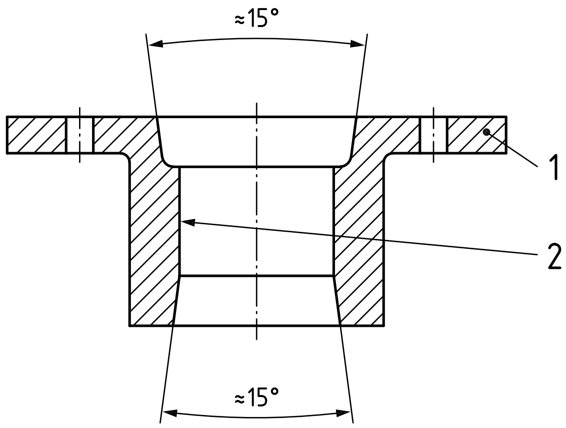
2 machined plate

Figure 10 — Example of machined plates, inserted in a metallic holder

6.4.8 Plain bearing

The plain bearing bush may be made by machining or by injection moulding. Depending on the test equipment used, it is possible to use plain bearings with different inside diameters, the preferred inside diameters being 20 mm, 5 mm or 1 mm, the latter being used for special applications, the width/diameter ratio being 0,75 or 1.

The diameter, bearing clearance, wall thickness and type of bearing used (bush or half bearing) shall be indicated in the test report. Smaller plain bearings should have a flange in order to allow to fix them in the mount (see Figure 11). The sliding surface area shall lie within the cylindrical part of the plain bearing.



Key

1 flange

2 sliding surface

Figure 11 — Example of an injection-moulded plain bearing with step and chamfer in the bore

6.4.9 Shaft

The shaft piece used for the test shall be made with a circular run-out tolerance 1 µm maximum and a circularity of not more than 5 µm. Irrespective of the test equipment used, it shall be ensured that the test specimens (test bush and shaft) mounted in the test equipment have a maximum angular deviation of 0,05° prior to the test and in the absence of a normal force. The diameter of the shaft (i.e. the bearing clearance) shall be sufficient to allow for thermal expansion of the bush (risk of bore closure leading to seizure) and depends on the wall thickness, temperature of operation and material properties. The (cold) diametral clearance may vary from 0,003 times to 0,01 times the shaft diameter, being kept as small as possible consistent with avoiding seizure.

6.4.10 Sleeve

The sleeve may be made by machining or injection moulding. The preferred basic dimensions of the sleeve are shown in Figure 12.

Dimensions in millimetres

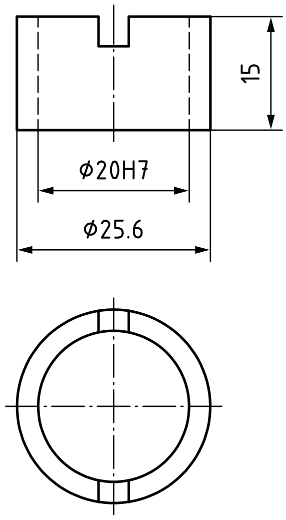
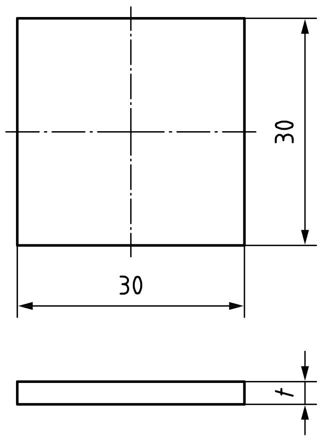


Figure 12 — Dimensions of sleeve

6.4.11 Plate

The plate may be made by machining or injection moulding. The preferred basic dimensions of the sleeve are shown in Figure 13.

Dimensions in millimetres



t = 2 to 5

Figure 13 — Dimensions of plate

6.5 Preparation of the test specimens

The preparation applies to bearing materials and mating materials.

Immediately prior to the test, a cleaning procedure shall be carried out in order to avoid influences on the sliding behaviour which can result from remainders of the cutting solutions and other substances that could possibly have been used in the manufacture of the test specimens.

After the cleaning procedure has been completed, the test specimens shall not be touched on the sliding surfaces, which are to be in contact with each other, neither by hand nor with any tool.

The following cleaning procedures shall be carried out.

— Brush loose particles from the test specimens. Then immerse the test specimens in three separate baths of a high-quality solvent (with a maximum impurity volume of 5 × 10^{-4} %) which is suitable for the type of material to be tested. Suitable solvents are, for example, 2-propanol, ethanol, acetone, fluorocarbons, some water solutions or cyclohexane. In all cases, the compatibility of plastic material and solvent shall be ensured. Data pertaining to the cleaning procedure and the solvent selected shall be included in the test report.

— The test specimens shall be dried in an oven at a maximum temperature of 60°C.

— Test specimens of polymers which are affected by humidity, e.g. polyamides, shall be pre-conditioned prior to the test at standard atmosphere (23°C and 50 % air humidity) for a period of 24 h.

— This cleaning method cannot be carried out in all cases, for example for thermoplastic amorphous materials that show incompatibilities with the solvents, or polymers with incorporated lubricants or porous fibres. They shall be machined dry (no cutting fluid) or injection-moulded without mould release agent. The sliding surfaces shall not be touched by hand.

7 Test methods and test equipment

7.1 General

In order to give manufacturers or users of polymer-based materials for plain bearings the opportunity to simulate different practical applications, different test methods are standardized.

This part of ISO 7148 lays down test methods according to the following categories:

— basic testing of simple test specimens;

— approximated practical testing of simple test specimens;

— testing of an original component or a scaled-down unit.

This means that this part of ISO 7148 proposes only tests with basic or simulation tests for selection. Variant c) above (testing of an original component) allows the use of original components as test specimens, for example plain bearings made of thermoplastic materials in real size.

7.2 Test method A — Pin-on-disc

This test shall be carried out with pins in accordance with 6.4.4 and discs in accordance with 6.4.2.

The spindle holding the disc shall be mounted in precision rolling bearings with no clearance. The electric drive shall be such that a continuously adjustable speed setting is possible. Alternatively, it shall be possible to obtain an arc-shaped translatory motion by adopting an oscillating operation. The specimen holder, which shall have appropriate flexural strength, shall be equipped with a guide with no clearance and little friction. The loading system shall allow the force to be held constant, increased continuously or use of step-by-step loading.

The measured variables are the coefficient of friction, the rate of wear and a reference temperature for the temperature of the specimens. It is preferred that a thermocouple be fitted in the pin. The position of measurement of temperature should be specified in the test report. The coefficient of friction is obtained from the determination of the friction force. Wear is measured at the pin by determining the linear volume of material removed by wear (continuous of intermittent measurement). At the end of the test, the wear shall be confirmed by dimensional measurements of disc and pin in order to detect transfer film or wear of the disc.

A temperature-measurement probe, touching the reverse side of the disc corresponding to the radius of the sliding track of the pin, shall be provided to measure the bulk temperature of the disc. The almoststable temperature measured at this point is approximately proportional to the frictional heating and may be used as a way of monitoring the temperature behaviour.

For tests requiring constant temperature of the sliding surface, the temperature of the disc should be controlled.

7.3 Test method B — Block-on-ring

This test of the block-on-ring principle shall be carried out on preformed (conformal) blocks in accordance with 6.4.5 and rings in accordance with 6.4.3. A thermally isolated ring having a maximum radial run out of 25 µm shall be mounted on a driving shaft with continuously adjustable speed setting. The block shall be placed in a self-adjustable holder, which may be continuously or step-wise loaded. This test system is equipped with measuring instruments for continuous measurement of the friction coefficient, linear wear of the block and the temperature of the ring.

The ring temperature is given as the average value of two measured values read by means of two thermocouples located at both sides of the block in the direction of sliding. A constant specific test temperature is essential for the repeatability of the measurement results; thus, in simple test equipment without thermostatic control it is only possible to carry out comparative tests. Tests to establish proof of material properties (test certificate) shall be carried out with thermally regulated rings or a thermally regulated test shaft with heating or cooling liquid flowing through it.

7.4 Test method C — Plain bearing-on-shaft

7.4.1 General

The plain bearing-on-shaft test is based on the combination of a plain bearing bush (or two half bearings) and a shaft.

7.4.2 Test method C 1

In the test equipment, solid plain bearing bushes are used together with a steel shaft. The force may be applied, e.g., by means of springs. The wear measurement is carried out by means of gauges or a measuring microscope. For high loads and speeds and large diameters (e.g. 20 mm), it may be necessary to thermostatically control the temperature of both test specimens.

7.4.3 Test method C 2

In the test equipment, a plain bearing bush is used, inserted in a pendulum device. It is supported by a cantilevered shaft. The pendulum device applies the force to the test bearing by means of weights and enables, due to its lateral deflection, the friction force to be measured.

7.4.4 Test method C 3

By means of a collet chuck, a shaft piece, which can be easily replaced, is clamped into a spindle with maximum running accuracy (radial run out tolerance 2 µm), which is mounted in precision rolling bearings. The test bearing supported in a holder shall be placed on the cantilevered end of the shaft.

7.5 Test method D — Sphere-on-prism

The test equipment shall allow continuous or step-by-step adjustment of the speed of the sphere by means of a variable speed drive. The balance device induces the force of the system by means of weights or a continuously adjustable load setting system. A control unit shall ensure that both test specimens are held at constant temperature and that environmental parameters, i.e. air humidity or gases, are controlled in the test array.

The measured variables are the friction force dependent on sliding speed, force and temperature and the total wear depth of sphere and prism. The wear is measured by a dial gauge or by continuously determining the wear by means of an electronic displacement transducer. The volumetric wear rate and the coefficient of wear may be calculated from these data.

7.6 Test method E — Rotation under thrust load

7.6.1 General

The rotation test under thrust load is based on the combination of a sleeve and plate, sleeve-to sleeve or sleeve-to-plate.

7.6.2 Test method E 1

This test shall be carried out with the sleeve made of bearing material and the sleeve made from the material of the mating surface component in accordance with 6.4.10.

The spindle holding the specimen shall have enough rigidity to withstand under applied load and to rotate smoothly without unevenness and/nor vibration. The run-out of spindle shall be 0,005 mm or less.

The centre of rotational axis of specimen holder for bearing material and the centre of fixed specimen holder for mating surface shall be in line. The specimen holder, which has appropriate strength, shall be equipped with a guide with no clearance and key to avoid slip between specimen and the holder. The loading system shall allow the force to be held constant, increased continuously or use step-by-step loading.

The measured variables are the coefficient of friction, the rate of wear and the reference temperature of the fixed specimen. The position of measuring instrument for temperature should be specified in the test report. The coefficient of friction is obtained from determination of the rotational torque. The wear is measured at specimens by determining the volume of material removed by wear. The dimensional measurement is also applicable to determine the wear.

7.6.3 Test method E 2

This test shall be carried out with the sleeve made from the material of the mating surface component in accordance with 6.4.10 and the plate made of bearing material in accordance with 6.4.11.

The spindle holding the specimen shall have enough rigidity to withstand under applied load and to rotate smoothly without unevenness and/nor vibration. The run-out of spindle shall be 0,005 mm or less.

The centre of rotational axis of specimen (sleeve) holder and centre of fixed plate holder shall be in line. The specimen (sleeve) holder, which has appropriate strength, shall be equipped with a guide with no clearance and a key to avoid slip between specimen and the holder. The loading system shall allow the force to be held constant, increased continuously or use step-by-step loading.

The measured variables are the coefficient of friction, the rate of wear and the reference temperature of the fixed specimen. The position of measuring instrument for temperature should be specified in the test report. The coefficient of friction is obtained from determination of the rotational torque. The wear is measured at specimens by determining the volume of material removed by wear. The dimensional measurement, such as thickness change, is also applicable to determine the wear.

8 Lubrication

8.1 General

Plain bearings made of polymers may run dry, i.e. without any lubricant, but they may also be lubricated with oil, grease and some other fluids (assuming chemical compatibility).

Lubricated plain bearings can withstand higher tribological duty. The endurance depends on the condition of lubrication (boundary lubrication or hydrodynamic). Furthermore, it is possible to apply solid lubricants to the sliding surfaces on assembly, for example, polytetrafluorethylene (PTFE), graphite and molybdenum disulphide.

Polymers shall be compatible with the lubricant. Ageing and solubility characteristics shall be taken into account. Furthermore, high-surface pressures can induce stress cracks within the rubbing contact and create oil pools or blisters under the unloaded part of the surface (especially with amorphous thermoplastics). Powder-like wear debris can thicken the oil or grease.

8.2 Dry (dr)

No lubrication of the test specimens.

8.3 Grease (gr)

Lubrication with initial grease only. Grease is smeared by means of a small spatula at a controlled volume on the mating surface prior to the start of the test.

8.4 Oil (oi)

A controlled volume of oil is fed, on assembly, to the fixed test specimen (in adequate proportion to the volume in the practical application). The oil shall be chosen so as to be retained in the sliding area (depending on the surface tension and the wettability of oils in polymer combinations, some oils may creep from the sliding area).

8.5 Solid lubricant (so)

Solid lubricant is applied to one or both surfaces before the test by burnishing, lacquer spraying or suitable means.

9 Designation

EXAMPLE 1 The testing of the tribological behaviour of polymer-based materials according to test method pin-on-disc (A), dry (dr), specific test force 3 N/mm^2 (F4) and sliding velocity 0,1 m/s (U3) is designated as follows:

Test ISO 7148-2 -A - dr - F4 - U3

EXAMPLE 2 The testing of the tribological behaviour of polymer-based material according to test method sphere-on-prism (D), lubricated with oil (oi), specific force per unit area 10 N/mm^2 (F5) and sliding velocity 0,01 m/s (U1) is designated as follows:

Test ISO 7148-2 -D - oi - F5 - U1

NOTE For abbreviatied terms, see also Tables 3 and 4.

10 Test conditions

10.1 Environmental conditions

Ambient conditions for the tests should normally be T_{amb} = (23 ± 5) °C and 40 % to 60 % relative humidity. Deviations from these conditions shall be noted in the test report.

NOTE For some polymers, e.g. polyamides, tighter control of the environmental conditions can be required, i.e. T_{amb} = (23 ± 2) °C and relative air humidity (50 ± 5) %.

In order to ensure the repeatability of the measurement results, all test programmes shall be carried out in air at standard atmosphere and at a given (controlled) specimen temperature which shall be specified according to the requirements.

10.2 Mounting of the test specimens

Mount the cleaned mating surface material in the test equipment and measure radial and axial run-out, and also the misalignment, if applicable, with appropriate measuring instruments (e.g. precision indicator). Mount the cleaned test specimen of polymer-based material in the specimen holder. Normally, it is not allowed to fix the test specimen by bonding or other jointing methods. If, however, this is necessary due to the small size of available test piece, the fastening procedure shall be fully described in the test report.

10.3 Test variables

The following parameters may generally be chosen as test variables:

— mean sliding velocity;

— test force or specific force per unit area;

— temperature of the test specimens.

The sliding motion may be continuous rotation, rotary oscillation or axial reciprocation. For specific applications, these test variables shall be agreed upon by the contracting parties (e.g. manufacturer of plain bearing materials and user). For general test purposes, the following test regimes are recommended.

The test conditions should be based upon the technical properties of the polymer-bearing materials, i.e. the 0,2 % compression limit, $R_{d0,2}$, and a maximum permissible temperature, T_{lim}. The test parameters have to be chosen in such a manner, that no mechanical or thermal destruction of the polymers can occur. Three test stages each should be defined for the specific force per unit area, $\overline{p}$, and the sliding velocity, U (see Table 2).

Table 2 — Test stages

Test stage	Specific force per unit area, $\overline{p}$ N/mm^2	Sliding velocity, U m/s
1	(0,003 up to 0,01) $R_{d0,2}$	$0{,}2\times\frac{(T_{lim}-T_{amb})}{f\times\overline{p}\times Q}$
2	(0,01 up to 0,05) $R_{d0,2}$	$0{,}4\times\frac{(T_{lim}-T_{amb})}{f\times\overline{p}\times Q}$
3	(0,05 up to 0,1) $R_{d0,2}$	$0{,}6\times\frac{(T_{lim}-T_{amb})}{f\times\overline{p}\times Q}$
$Q=(T_{lim}-T_{amb})/(f\times\overline{p}\times U)$ is the thermal constant of the test equipment, to be determined from preliminary measurements, actual bearing temperature, T, resulting from given test parameters, $\overline{p}$, and estimated, U, at a certain ambient temperature, T_{amb}.		

Thus, there are in all nine combinations of test variables $\overline{p}$ and U available, which make it possible after the analysis of the test to indicate the characteristic surface of the wear behaviour. Depending on the field of application, these combinations of test variables may be set individually, by the line, in columns or as single parameters. In the case of heated test specimens, it is also possible to specify the specimen temperature so that the above-mentioned combinations of variables are related to one or more specific temperature values.

Different polymer materials may be compared at the same specific forces per unit area, speeds and temperatures, irrespective of their limiting properties.

Table 3 — Test conditions — Specific forces per unit area

Variant	Specific force per unit area, $\overline{p}$ N/mm²
F 1	0,1
F 2	0,3
F 3	1
F 4	3
F 5	10
F 6	30

Table 4 — Test conditions — Sliding velocities

Variant	Sliding velocity, *U* m/s
U 1	0,01
U 2	0,03
U 3	0,1
U 4	0,3
U 5	1
U 6	3

All testing variants of specific test force per unit area and sliding velocity may be combined, although combinations of high specific test force per unit area and high sliding velocity are not suitable for dry running.

Tests at other combinations of specific test force per unit area and sliding velocity, or certain temperatures may be agreed upon between the supplier and customer. Lubricated tests shall be carried out under conditions for simulating the specific force per unit area and sliding velocity of the practical application. It should be noted that hydrodynamic lubrication (lubricant separating the sliding surfaces) may be established even at low velocities depending on viscosity and specific test force per unit area; hence, wear may not occur after running-in of the bearing.

For wear tests, the parameters of sliding velocity and specific load should be chosen in such a way that a boundary lubrication status is reached, especially when lubricants are tested (influence of viscosity, etc.). All wear tests should be carried out under the same conditions in order to better compare and evaluate the results of different materials.

Preferred test parameters for test method sphere-on-prism are given in Table 5. These are standard test conditions.

Table 5 — Test parameters for test method sphere-on-prism

Test	Parameters	Values	Variables
Wear	Normal force F_n	30 N	1 N to 50 N
	Sliding velocity U	0,028 m/s	0,01 m/s to 0,1 m/s
	Test duration t_{Ch}	100 h	10 h to 500 h
	Lubricants (oi/gr)	0,2 g	0,1 g to 0,5 g
Friction	Normal force F_n	1 N, 3 N, 6 N	0,5 n to 50 N
	Sliding velocity U	0 to 0,2 m/s	0 to 0,5 m/s
	Ambient temperature T_{amb}	25°C	-35°C to +150°C
	Lubricants (oi/gr)	0,2 g	0,1 g to 0,5 g

11 Test procedure

11.1 Running-in

The test system shall be run in prior to the commencement of the test proper.

The running-in period depends on the material, surface condition and alignment of the test specimens.

The running-in period shall be terminated when any of the following criteria are attained:

a) the coefficient of friction is constant within a small scatter range;

b) the wear rate is constant within a small scatter range (if this is not achieved, a graph shall be prepared showing the linear or volumetric wear plotted against sliding distance);

c) the temperature of the test specimens is constant within a small scatter range.

In critical cases, two or all three criteria shall be given. The wear measured shall be at least 10 times the measurement uncertainty. A running-in period of 0,5 h to 3 h is sufficient for most polymer-based bearing materials.

11.2 Carrying out the tests

For general application tests, the test variables according to 10.3 shall be chosen. In principle, it is possible to use a single combination of variables, the combination of a complete force range or all nine different combinations of the test variables. Each test shall be carried out a minimum of three times. For tests with different combinations of variables, new bearing material specimens shall be used each time.

12 Analysis

12.1 General

The following information shall be included in the test report:

a) designation of the test in accordance with Clause 9;

b) description of the mating parts according to material, geometry, the method of finishing (see 6.1), and surface roughness *Ra*;

c) details of the cleaning procedure and solvents and surface treatment;

d) description of the test equipment;

e) environmental conditions;

f) lubrication conditions;

g) force, sliding velocity, temperature data and test procedure for the test programme.

12.2 Test results

The following individual results shall be evaluated:

a) coefficient of friction, *f*, in steady-state condition (dependent on sliding speed, force and temperature) after running-in;

b) linear wear rate, w_l, in millimetres per kilometre (mm/km), in steady-state condition, if it is reached (alternatively, provide a graph dependent on time or sliding distance);

c) volumetric wear rate, w_v, in cubic millimetres per kilometre (mm^3/km), in steady-state condition, if it is reached (alternatively, provide a graph dependent on time or sliding distance);

d) coefficient of wear, k_w, in cubic millimetres per Newton kilimetre [mm^3/(N·km)] in steady-state condition, if it is reached (alternatively, provide a graph dependent on time or sliding distance);

e) surface condition of the mating parts prior to and at the end of the test, description of the wear status of both test specimens (layers, cracks, etc.) and the wear debris (fine- or coarse-grained, etc.);

f) cases of interaction between lubricants and polymers due to tribochemical reactions;

g) location, date and operator.

Annex A
(informative)

Test report

Unless otherwise agreed, the test report shall include the following information:

Table A.1 — Test report

Test ISO 7148-2 – …	Symbol	Unit	Test specimen	Mating specimen
Specimens:				
Type/name				
Chemical composition				
Method of production				
Kind of treatment				
Mechanical properties:				
Hardness			HB, HV, HRC	
Dimensions[a]			mm	
Surface roughness	*Ra*		µm	
Lubricant:				
Type/name				
Chemical composition				
Viscosity at ….. °C		η	mPa·s	
Environmental conditions:				
Atmosphere				
Relative humidity				
Ambient temperature		T_{amb}	°C	
Test conditions:				
Test method				
Normal force		F_n	N	
Sliding velocity		U	m/s	
Test duration		t_{Ch}	h	
Sliding distance		a	km	
Test results:				
Coefficient of friction under steady-state conditions		f	-	
Specimen's temperature[b]		T	°C	
Linear wear rate		w_l	mm/km	
Volumetric wear rate		w_v	mm^3/km	
Coefficient of wear		K_w	mm^3/(N·km)	
Surface condition				
Wear debris				

Table A.1 *(continued)*

Test ISO 7148-2 – ...	**Symbol**	**Unit**	**Test specimen**	**Mating specimen**
Location:	Date:		Operator:	

[a] This is including radial clearance for plain bearing tests (see 5.4).

[b] In some cases, it may be necessary to report the temperature created during the sliding motion (caused by frictional heat).

In such cases, the temperature should be measured nearest to the sliding surface and provided in the test report.

Bibliography

[1] ISO 175, *Plastics — Methods of test for the determination of effects of immersion in liquid chemicals*

[2] ISO 4378-1, *Plain bearings — Terms, definitions, classification and symbols — Part 1: Design, bearing materials and their properties*

[3] ISO 4378-2, *Plain bearings — Terms, definitions, classification and symbols — Part 2: Friction and wear*

[4] ISO 4378-3, *Plain bearings — Terms, definitions, classification and symbols — Part 3: Lubrication*

[5] ISO 7148-1, *Plain bearings — Testing of the tribological behaviour of bearing materials — Part 1: Testing of bearing metals*

ICS 21.100.10

Price based on 25 pages

--`,`,,,,,```,````,`,,`,`````-`-`,,`,,`,`,,`---