INTERNATIONAL STANDARD

ISO 7148-2

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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 polymères

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

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 part of ISO 7148 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard 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.*

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*

Annex A of this part of ISO 7148 is for information only.

Introduction

A first step towards the specification of basic test conditions for friction and wear tests of polymer-based plain bearing materials was made with International Technical Reports ISO/TR 7147, ISO/TR 8285 and ISO/TR 9993. This initial step, lasting several years and which comprised the development of basic test equipment (pin-on-disc device) and its testing in parallel experiments in several institutes, is now concluded. It was subsequently found that in the absence of any other uniform recommendations or standards, a reference for comparative testing was often needed especially in the case of new material development without detailed knowledge of specific applications. At the same time it was found necessary to limit the test variables or to accurately define them in order to obtain in addition, as wide a comparison as possible. It ought be possible to use different test combinations or to test for specific applications (i.e. tests which simulate service conditions). This part of ISO 7148 takes these requirements into account and specifies instructions for the preparation of test specimens, for test principles and test equipment as well as for the selection of test variables, test procedure and analysis.

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 will be the uncertainty of the applicability of the results.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 7148. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 7148 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 527-2, *Plastics — Determination of tensile properties — Part 2: Test conditions for moulding and extrusion plastics.*

ISO 1184, *Plastics — Determination of tensile properties of films.*

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 and units

See Table 1.

Table 1 — Symbols and units

Symbol	Term	Unit
A, B, C, D	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.: $K_w = \frac{V_w}{F_n \times a} = \frac{w_v}{F_n}$	$mm^3/(N \cdot km)$
l_w	Linear wear as measured by change in distance	mm
M_f	Friction moment	Nm
oi	Oil	–
pl	Polymer-based material	–
$\overline{p}$	Specific force per unit area (force/projected contact area)	N/mm^2
$R_{d,B}$	Compression strength	N/mm^2
$R_{d0,2}$	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 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 ten times higher than that of steel) results obtained may 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.

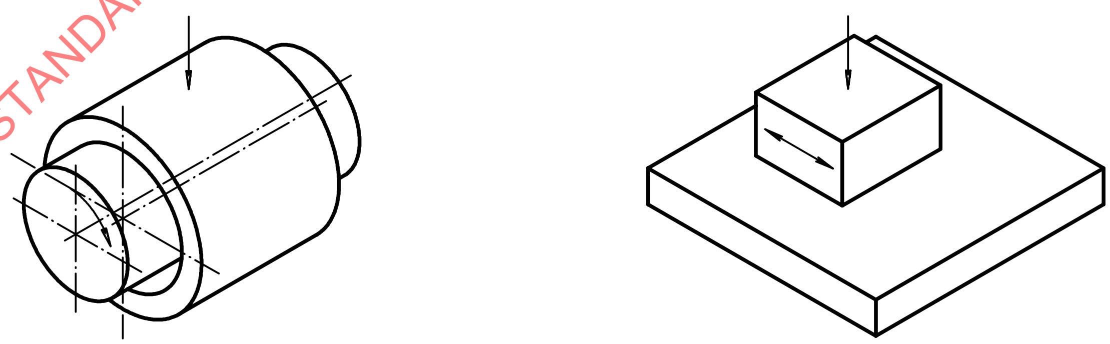
Polymers show wear processes that are different from that of metals. There are not only abrasive processes with powder-like wear debris but also adhesive processes with the creation of transfer layers which may be smooth or rough. Also ploughing wear and melting or plastic deformation is possible. Therefore wear cannot be gravimetrically measured in all cases and the wear status must 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 (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.

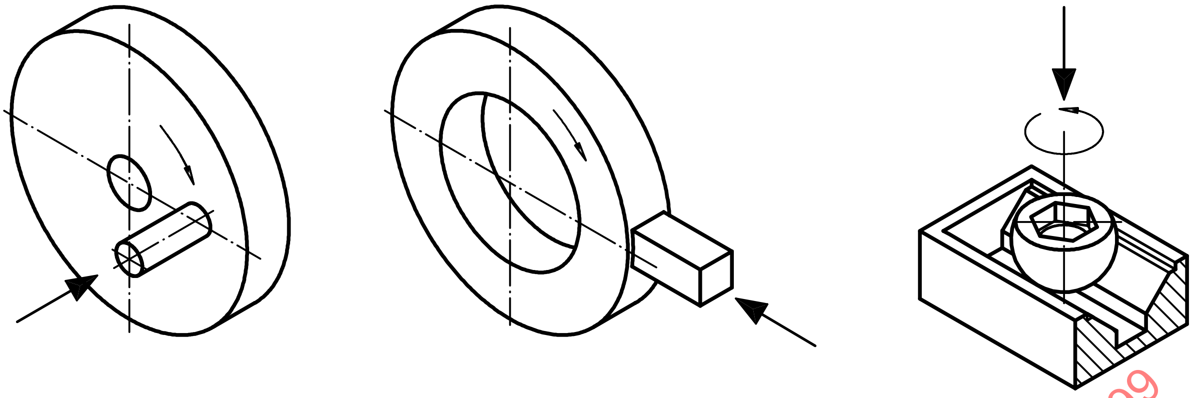
In some thermoplastics, e.g. polyamides, moisture absorption effects a gradual change in linear dimensions and modifies their mechanical properties. Environmental parameters should therefore be controlled in the test array. Moisture absorption prohibits gravimetrical measurement of wear.

The more the test conditions deviate from the actual application, the greater will be 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

Figure 2 — Simulation under approximated practical testing conditions and model systems for pre-selection of materials

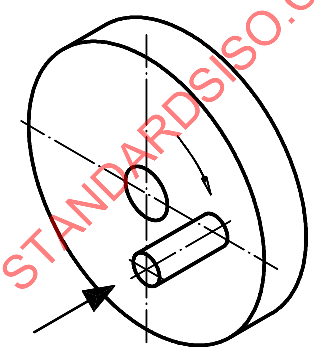
5 Test methods

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 may wipe off lubricant;

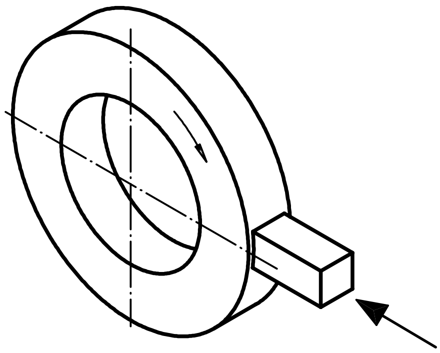
— no injection moulding of the pin with fibre reinforced material;

— 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.

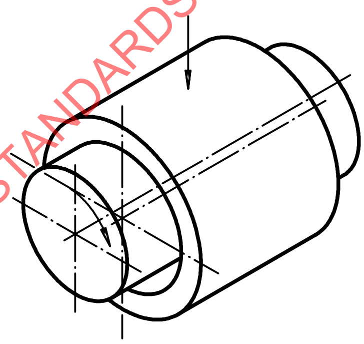
Disadvantages:

- no injection moulding of the block because of problems with shrinkage and fibre orientation;
- edge of the block may 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.

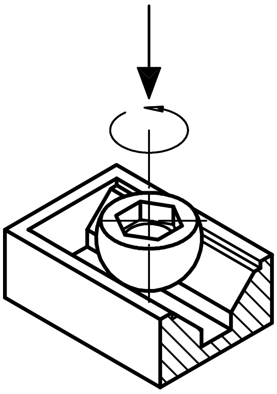
Disadvantages:

- long testing times (accelerated testing may 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 may affect results;

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

Figure 6 — Test method D: sphere-on-prism

6 Test specimens

6.1 Data required

For one series of tests, several specimens of one material must 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 may 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 (see 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 $R_{d0,2}$ (see 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 (see ISO 2818), turned, ground, lapped, polished, milled.

6.2 Polymer-based plain bearing materials (pl)

These can 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 can 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 must 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 would lead to errors in evaluation.

6.4 Dimensions of test specimens

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

6.4.1 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.

6.4.2 Ring

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

6.4.3 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 1184 or ISO 527-2. This allows the correlation of wear and strength tests.

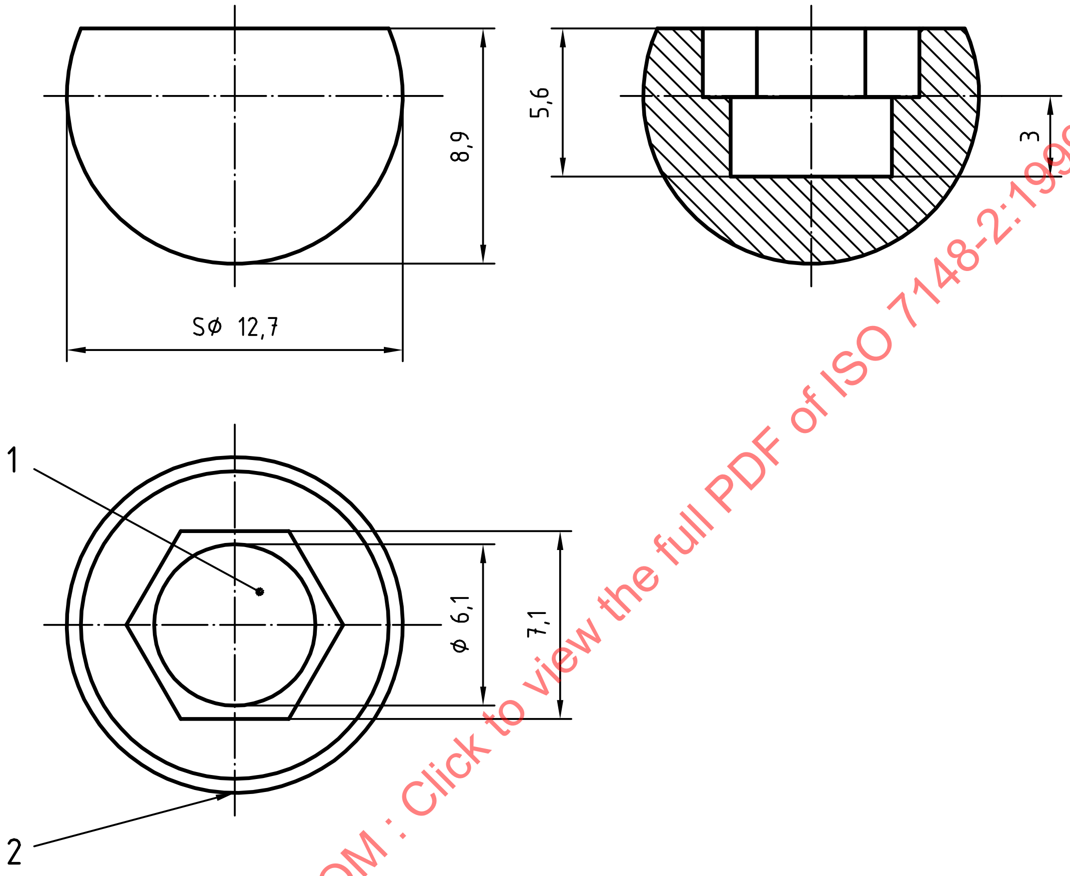
6.4.4 Block

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 can, 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 may be unduly prolonged (see 11.1).

6.4.5 Sphere

The sphere shall preferably have a diameter of 12,7 mm. Thermoplastics may be injection moulded (see Figure 7). 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

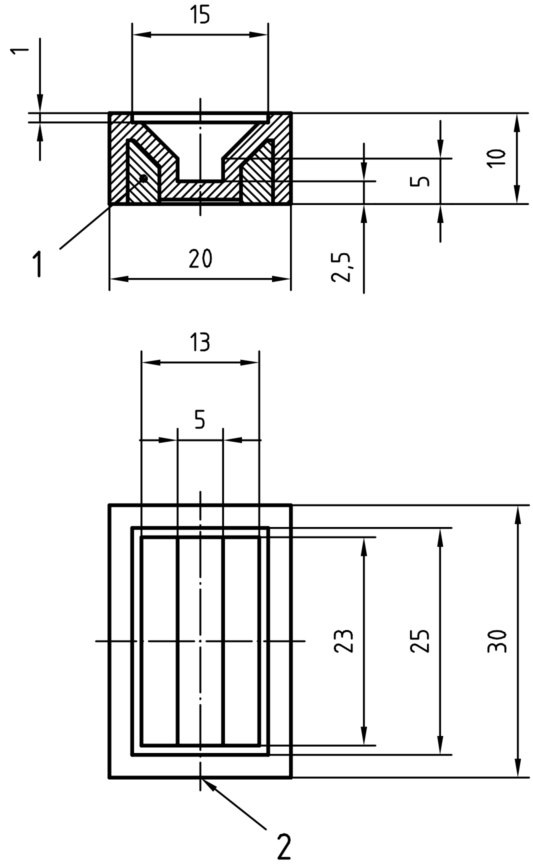
2 Gate position

Figure 7 — Example of an injection moulded sphere

6.4.6 Prism

The prism has a preferred special shape. If injection moulded, the prism specimen shall have a uniform wall thickness (2 mm) and a metallic support (see Figure 8) in order to avoid deformation. Alternatively cut plates may be fitted into a special mount (see Figure 9).

Dimensions in millimetres

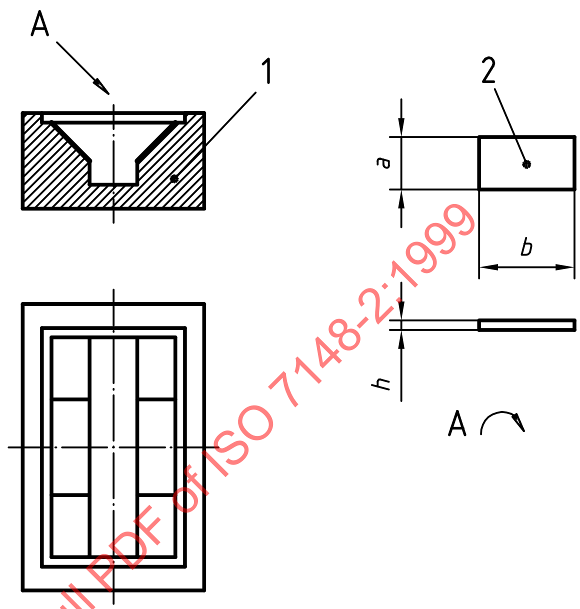


Key

1 Metal stiffening

2 Gate position

Figure 8 — Example of an injection moulded prism



Key

1 Metallic holder

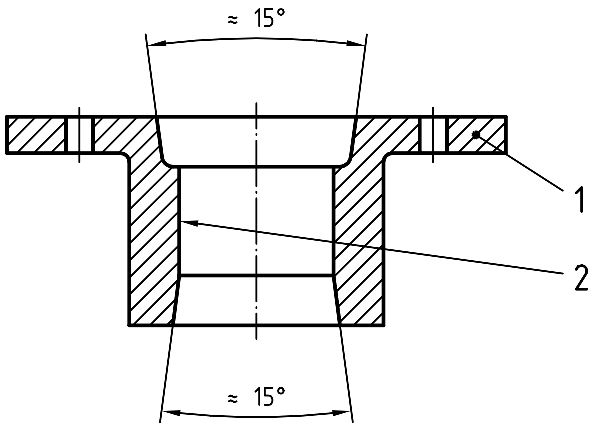
2 Machined plate

Figure 9 — Example of machined plates, inserted in a metallic holder

6.4.7 Plain bearing

The plain bearing bush can 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 10). The sliding surface area shall lie within the cylindrical part of the plain bearing.



Key

1 Flange

2 Sliding surface

Figure 10 — Example of an injection moulded plain bearing with step and chamfer in the bore

6.4.8 Shaft

The shaft piece used for the test shall be made with a circular run-out tolerance of 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 will depend on the wall thickness, temperature of operation and material properties. The (cold) diametral clearance may vary from 0,003 to 0,01 times the shaft diameter, being kept as small as possible consistent with avoiding seizure.

6.5 Preparation of 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 may result from remainders of the cutting solutions and other substances that may possibly have been used in the manufacture of the test specimens.

After cleaning procedure has been completed, the test specimens shall not be touched on the sliding surfaces, which will 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 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, e.g. 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. The last-mentioned variant above (testing of an original component) allows the use of original components as test specimens, e.g. 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 6.4.3 and discs in accordance with 6.4.1.

The spindle holding the disc shall be mounted in precision rolling bearings with no clearance. The electric drive must 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 or 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 almost stable temperature measured at this point is approximately proportional to the frictional heating and can 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 6.4.4 and rings in accordance with 6.4.2. 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 can 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 can be applied, e.g., by means of springs. The wear measurement is made 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.

8 Lubrication

8.1 General

Plain bearings made of polymers can 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 must be compatible with the lubricant. Ageing and solubility characteristics must be taken into account. Furthermore high surface pressures may 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 may 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 must 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 (so)

Solid lubricant 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 (pl) 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 - pl - A - dr - F4 - U3

EXAMPLE 2

The testing of the tribological behaviour of polymer-based material (pl) 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 - pl - D - oi - F5 - U1

NOTE For abbreviations, 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 must be noted in the test report.

NOTE For some polymers, e.g. polyamides, tighter control of the environmental conditions may 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 specimens of metal or 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 must be fully described in the test report.

10.3 Test variables

The following parameters can 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.

10.3.1 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 may 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) $R_{d0,2}$	$0{,}6 \times \frac{(T_{lim} - T_{amb})}{f \times \overline{p} \times Q}$
NOTE $Q = (T_{lim} - T_{amb})/(f \times \overline{p} \times U)$ 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.

10.3.2 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 forces per unit area, $\bar{p}$ N/mm^2
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 will not be 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 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, and hence wear may not occur after running-in of the bearing.

NOTE 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.