# 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: $w_v = \frac{V_w}{a}$ | $mm^3/km$ |
| $\eta$ | 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.

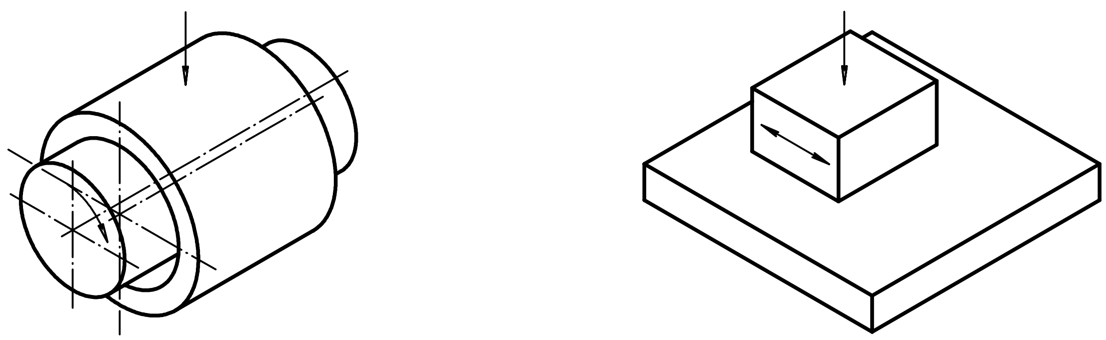
Polymers show wear processes that are different from that of metals. There are not only abrasive processes with powder-like wear debris but also adhesive processes with the creation of transfer layers which may be smooth or rough. Also ploughing wear and melting or plastic deformation is possible. Therefore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

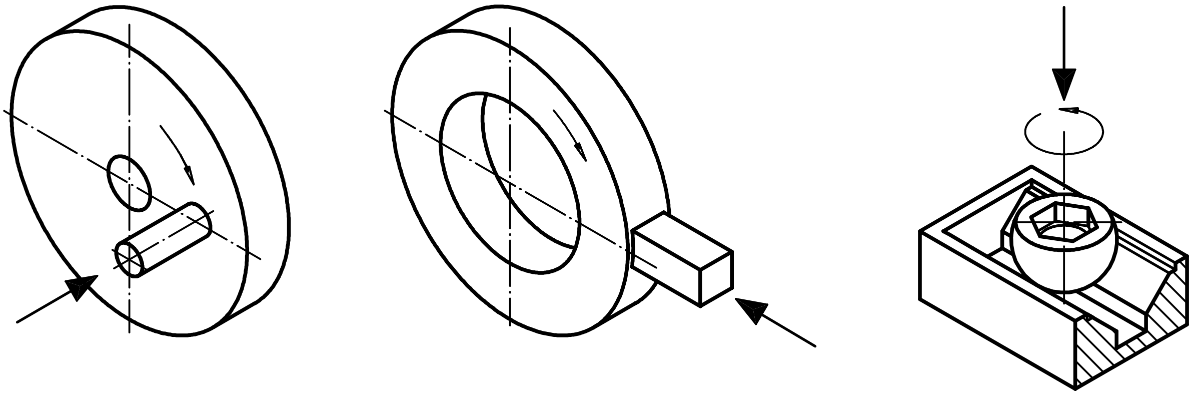
The more the test conditions deviate from the actual application, the greater will be the uncertainty of the applicability of the results (see Figures 1 and 2).



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

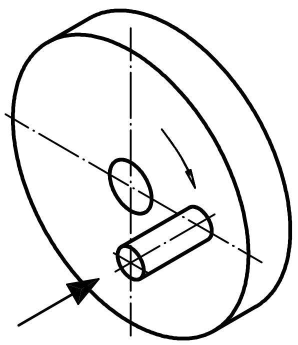
Different test methods are provided for tests in accordance with this part of ISO 7148 so that the following contact geometries are available. The test methods should correspond to the practical application as closely as possible.



### 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;

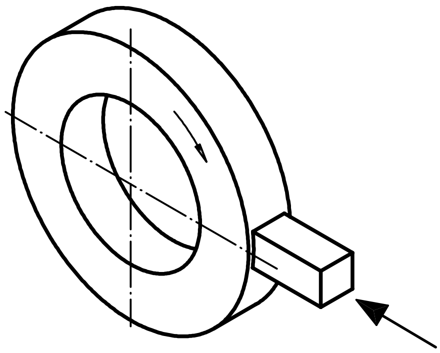
— no injection moulding of the pin with fibre reinforced material;

— 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:**

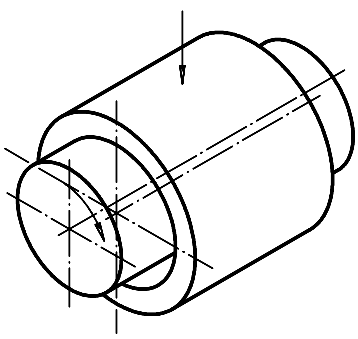
- no injection moulding of the block because of problems with shrinkage and fibre orientation;
- edge of the block may wipe off lubricant;
- no injection moulding of the disc because of problems with shrinkage



**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.

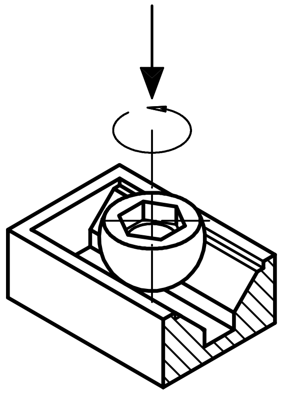
**Disadvantages:**

- 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).