TECHNICAL REPORT 7147

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Plain bearings — Testing of the tribological behaviour of plastics

Paliers lisses — Essai du comportement tribologique des plastiques

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ISO/TR 7147 was prepared by Technical Committee ISO/TC 123, *Plain bearings*.

The reasons which led to the decision to publish this document in the form of a technical report type 2 are explained in the Introduction.

0 Introduction

As several research institutes are still carrying out tests on the tribological behaviour of plastics for plain bearings and, consequently, results are not yet available, it has been decided, for the time being, to publish work on the test system in the form of a Technical Report.

When the test results from the different institutes are available, the status of this Technical Report will be re-assessed.

1 Scope and field of application

This Technical Report specifies uniform instructions for the testing of tribologically-stressed plain bearing elements manufactured from solid plastics.

The test values will give useful information for practical application only if all parameters of influence are identical.

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The purpose of this Technical Report is to obtain, under specified and exactly defined operating conditions, reproducible measured values for wear and the coefficient of friction as regards plastics/steel or plastics/plastics sliding couples. Consequently, to obtain comparability of these values, exact indications are necessary concerning directly acting influences, such as the form of the specimen, the condition of surface and material or the sliding couple. This Technical Report, therefore, defines the forms that test specimens shall take and specifies uniform manufacturing processes for the test specimens. In order also to eliminate the secondary influences created by the nature of the test system (e.g. conditions of thermal conduction, vibrations, driving vibrations, mounting conditions) the complete test equipment and basic construction and performance requirements have also been standardized.

2 References

ISO 291, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 527, *Plastics — Determination of tensile properties.* [1)]

ISO 4378, *Plain bearings; Terms, definitions and classification* —

Part 1: Design, bearing materials and their properties.

Part 2: Friction and wear.

Part 3: Lubrication.

ISO 6691, *Plain bearings — Thermoplastics — Classification, designation, recommendations.* [2)]

3 Symbols

A_0	nominal contact surface, in square millimetres
f	coefficient of friction
F_n	normal force, in newtons
F_f	friction force, in newtons
k	wear coefficient, in cubic millimetres per newton kilometre
p	nominal specific load, in newtons per square millimetre
r_g	mean radius of sliding way, in millimetres
s	sliding distance, in kilometres
t_d	temperature of the disc, in degrees Celsius
u	sliding velocity, in metres per second
w_l	linear wear of test material, in micrometres
w_v	volumetric wear of test material, in cubic millimetres
$w_{l/s}$	linear wear rate, in micrometres per kilometre
$w_{v/s}$	volumetric wear rate, in cubic millimetres per kilometre

4 Definitions

4.1 dry friction: Condition of friction where two initially degreased and cleaned sliding surfaces are in contact with each other without external lubrication.

4.2 coefficient of friction: Ratio of the friction force between two bodies to the normal force pressing these bodies together, i.e.:

$$f = \frac{F_f}{F_n}$$

4.3 wear rate: The linear or volumetric wear of the test material referred to the sliding distance, i.e.:

$$w_{l/s} = \frac{w_l}{s} \text{ or } w_{v/s} = \frac{w_v}{s}$$

1) At present at the stage of draft. (Revision of ISO/R 527-1966.)

2) At present at the stage of draft.

4.4 wear coefficient: The linear wear rate referred to the nominal specific load or volumetric wear rate referred to the normal force, i.e.:

$$k = \frac{w_{l/s}}{p} \times 10^{-3} = \frac{w_{v/s}}{F_n} \times 10^{-3}$$

5 Form and manufacture of the test specimen

For the testing of plastics in accordance with this Technical Report, the sliding couple shall consist of two test specimens, i.e. a pin and a disc. As to the material, in principle, the possible mating combinations are as given in the table.

Table — Mating combinations

Mating combination	Sliding couple	
	Pin	Disc
I	Plastics	Metal
II	Metal	Plastics
III	Plastics	Plastics

The basic mating combination according to this Technical Report is combination I.

5.1 Pin

The pin shall have a diameter of 3 mm a length of 10 mm (see figure 1).

It can be made by moulding, injection moulding or by cutting an extruded bar to length or by machining it all over. As the structural condition of the plastic pin constitutes an important factor as far as the reproducibility of the test results are concerned, it is necessary to know the following information:

a) the method of manufacture;

b) the condition of the stucture (e.g. skin of injection moulding, degree of crystallinity);

c) the surface hardness;

d) the state of conditioning (e.g. moisture content).

These details may be omitted if one of the following methods is used for the manufacture of the pin:

a) by machining the pin out of a standard tension bar in accordance with ISO 527 [see figure 2a)];

b) by taking the pin out of an existing sliding element [see figure 2b)];

c) by manufacturing the pin out of semi-finished materials from which the sliding elements are made [see figure 2c)].

For the treatment of the machined pin, the maximum surface roughness shall be in accordance with the requirements of of figure 1.

5.2 Disc

Discs in accordance with this Technical Report are defined as steel rings with the dimensions as given in figure 3. The basic form of these discs is identical to the raceways of deep groove ball thrust bearings. The surface which is intended to be the sliding surface shall be made in accordance with figure 3.

Rolling bearing steel 100 C6 shall be used as material. If other materials are used the following details shall be given:

a) material specification, composition and condition of structure;

b) surface condition (manufacturing process, roughness, hardness).

Dimensions in millimetres

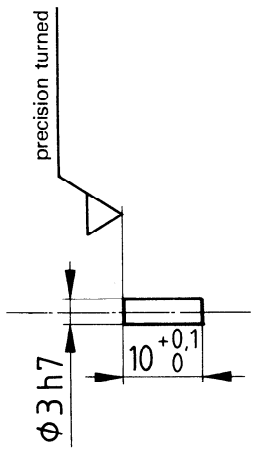
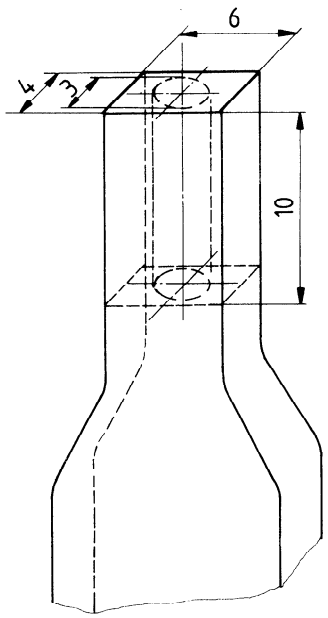


Figure 1 — Test specimen — Pin

Dimensions in millimetres



a) from a standard tension bar

Dimensions in millimetres

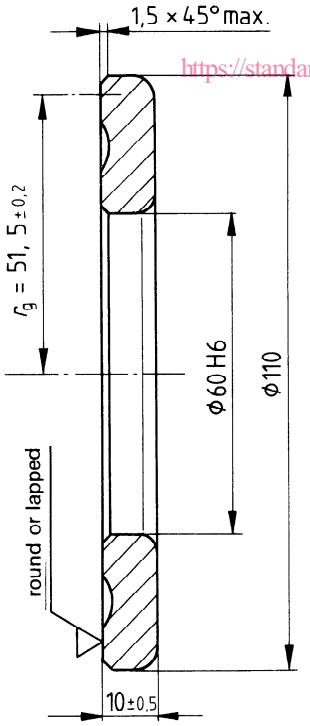
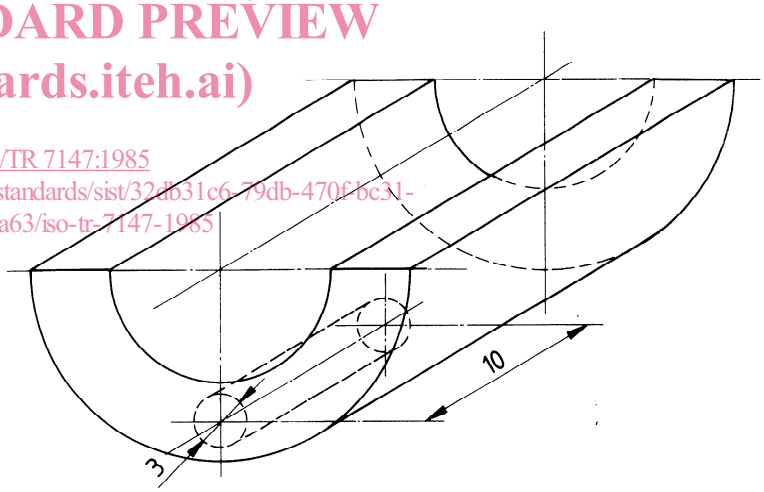
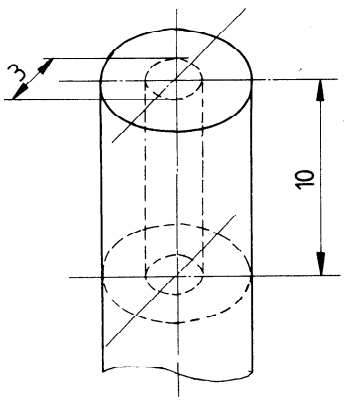


Figure 3 — Test specimen — Disc



b) from an existing sliding element



c) from semi-finished material

Figure 2 — Machining of the pin

6 Preparation of the test specimen

Immediately prior to the test the cleaning procedure outlined in 6.1 and 6.2 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 be used in the manufacture of the specimen.

6.1 Pin

Brush loose particles from the pin. Then immerse the pin in three separate baths of a high quality solvent (with a maximum impurity content of 5 ppm) which is suitable for the type of plastic material to be tested, using an ultrasonic cleaner. Instead of the "three-bath" process, cleaning may be carried out using Soxhlet extraction apparatus.

Prior to the test, pre-condition the pin at standard atmosphere 23/50, defined in ISO 291, for a period of 24 h.

After the cleaning procedure has been completed, the test specimen shall not be touched on the sliding surfaces, which are in contact with each other, neither with the hand nor with any tool. Data pertaining to the cleaning procedure and solvents selected shall be included in the test report.

6.2 Disc

For the disc the same procedure as given in 6.1 shall be used. Suitable solvents are, for example, trifluorotrichloroethane, cyclohexane or ethanol. The disc shall be dried in an oven at a maximum temperature of 60 °C without pressurized or hot air being used.

7 Test equipment

The example of the test system shown in the annex is based on the pin/disc or pin/ring system. As the performance requirements concerning the bearing and guide system of the test machine are specified, it is ensured that a high degree of reproducibility is maintained.

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. Furthermore, it shall be possible to obtain a translatory arc-shaped motion by setting 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 load shall be applied continuously via an attenuator.

The following measurable variables are obtained:

a) the coefficient of friction;

b) the time factor of wear;

c) a reference temperature for the temperature of the sliding surface.

The coefficient of friction is obtained from the determination of the moment of reaction of the disc caused by the friction force of the pin.

The wear is measured at the pin by determining the linear volume of material removed by wear (continually or intermittent).

A thermometer probe touching the reverse side of the disc, corresponding to the radius of the sliding way of the pin, shall be provided to control the temperature of the sliding surface.

The almost stable temperature measured at this point is approximately proportional to the temperature of the sliding surface and can be taken as a control of the temperature behaviour.

For tests requiring constant temperature of the sliding surface, the disc shall be heated using a temperature control device.

8 Test procedure

8.1 Environmental conditions

Ambient conditions for the test shall normally be 23 ± 5 °C and 40 to 60 % relative humidity. Deviations from these conditions shall be noted in the test report.

NOTE — For polyamides, tighter control of the environmental conditions is required, i.e. 23 ± 2 °C and (50 ± 5) %.

In order to ensure the reproducibility of the measurement results, all test programmes shall be carried out at a standard atmosphere which shall be specified according to requirements.

8.2 Mounting of the specimen

Mount the cleaned disc in the test machine; the axial run-out measured with appropriate measuring equipment (e.g. precision indicator) shall not exceed 10µm.

Mount the cleaned pin in the specimen holder by means of a clamping device in such a way that the free length of the specimen does not exceed 1,5 mm. However, it is not allowed to fix the specimen by bonding or other jointing methods.

8.3 Running-in

In order to ensure that the areas of contact lie plane and parallel and to ensure conformity of the roughness profile of the sliding partners, the test system shall be run in prior to the test proper.

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

The running-in period shall be terminated when

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

b) the wear rate is constant.

It is recommended in critical cases to test both criteria.

Under normal conditions and proper test preparation, a running-in period of 1 to 2 h is sufficient for most plastics.

8.4 Test programmes

In special cases (e.g. for plastics which are extremely sensitive to temperature), the test programmes shall be carried out with steel discs subject to temperature control. If the value of $F_n \times u$ is high, it is necessary, on account of the self-heating, either to make provision for a higher temperature level for the disc or to cool the disc.

Three test programmes for testing tribological behaviour (specified in 8.4.1 to 8.4.3) are proposed in this Technical Report.

8.4.1 Test programme A — Using a single load and a single sliding velocity (see figure 4)

This programme shall be preferably applied for approval testing.

After the running-in period, the duration of the test run shall be determined by measuring a minimum wear volume corresponding to 20 times the value of the measurement uncertainty.

8.4.2 Test programme B — Using three combinations of load and a sliding velocity, each with the same value of $F_n \times u$.

The aim of this programme is to determine the influence of load and sliding velocity on the coefficients of friction and of wear.

Testing in accordance with this programme is carried out in the same way as outlined for programme A, however there are three test runs with different loads and sliding velocities in accordance with the illustration in figure 5.

8.4.3 Test programme C — With increased sliding velocity and increased load (see figure 6).

The aim of this programme is to test the tribological behaviour of the sliding couple over a wide service range [up to ($F_n \times u$) max.]. The test programme is identical to the procedure outlined for programme A for each load and each sliding velocity.

The value of $F_n \times u$ shall be selected according to figures 6 and 7 respectively.

Test programme C consists of a sufficient number of separate tests carried out in accordance with programme A.

9 Test report

9.1 General

The following general information shall be included in the test report:

a) the test conditions (temperature, climate, data for the test programme);

b) details about the pin, in accordance with 5.1;

c) any additional specification for the disc, in accordance with 5.2;

d) details of the cleaning procedure and solvents, in accordance with clause 6.

9.2 Test results

The following test results shall be included in the test report;

a) the coefficient of friction, f, in steady-state condition;

b) the linear wear rate of pin, $w_{l/s}$, in micrometres per kilometre, in steady-state condition;

c) the volumetric wear rate of the pin, $w_{v/s}$, in cubic millimetres per kilometre, in steady-state condition;

d) the wear coefficient of the pin, k, in cubic millimetres per newton kilometre, in steady-state condition;

e) the initial surface roughness values for the pin and the disc (R_a or R_z, in micrometres).

In general, there is no measurable wear on the metal disc. The data concerning the wear on the test disc may be omitted in this case, however, visible sliding tracks as well as plastic residues on the sliding way shall be noted separately.

For tests with mating combinations II and III (see the table), the presentation of results shall be modified accordingly.

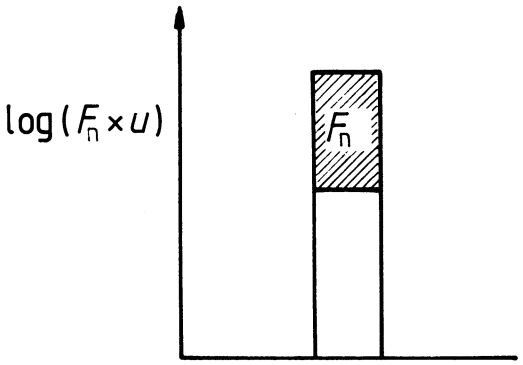


Figure 4 — Test programme A

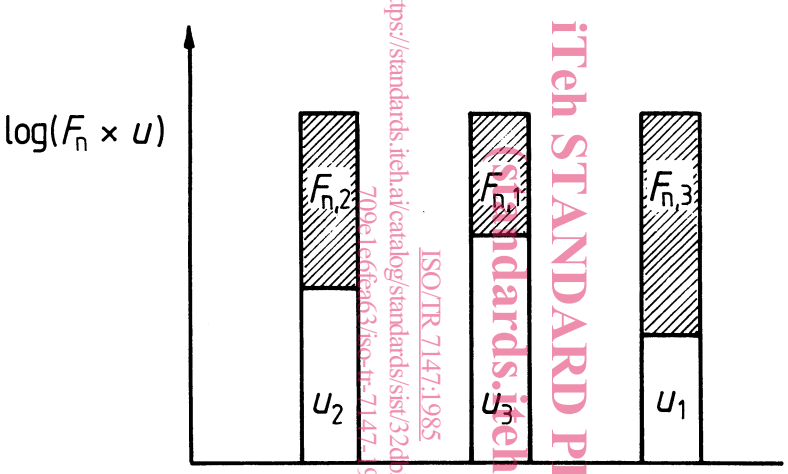


Figure 5 — Test programme B

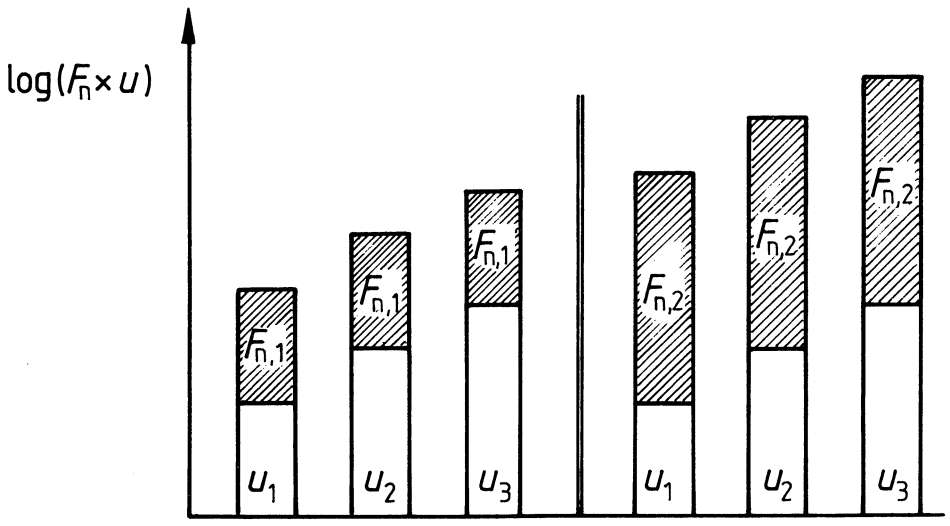


Figure 6 — Test programme C

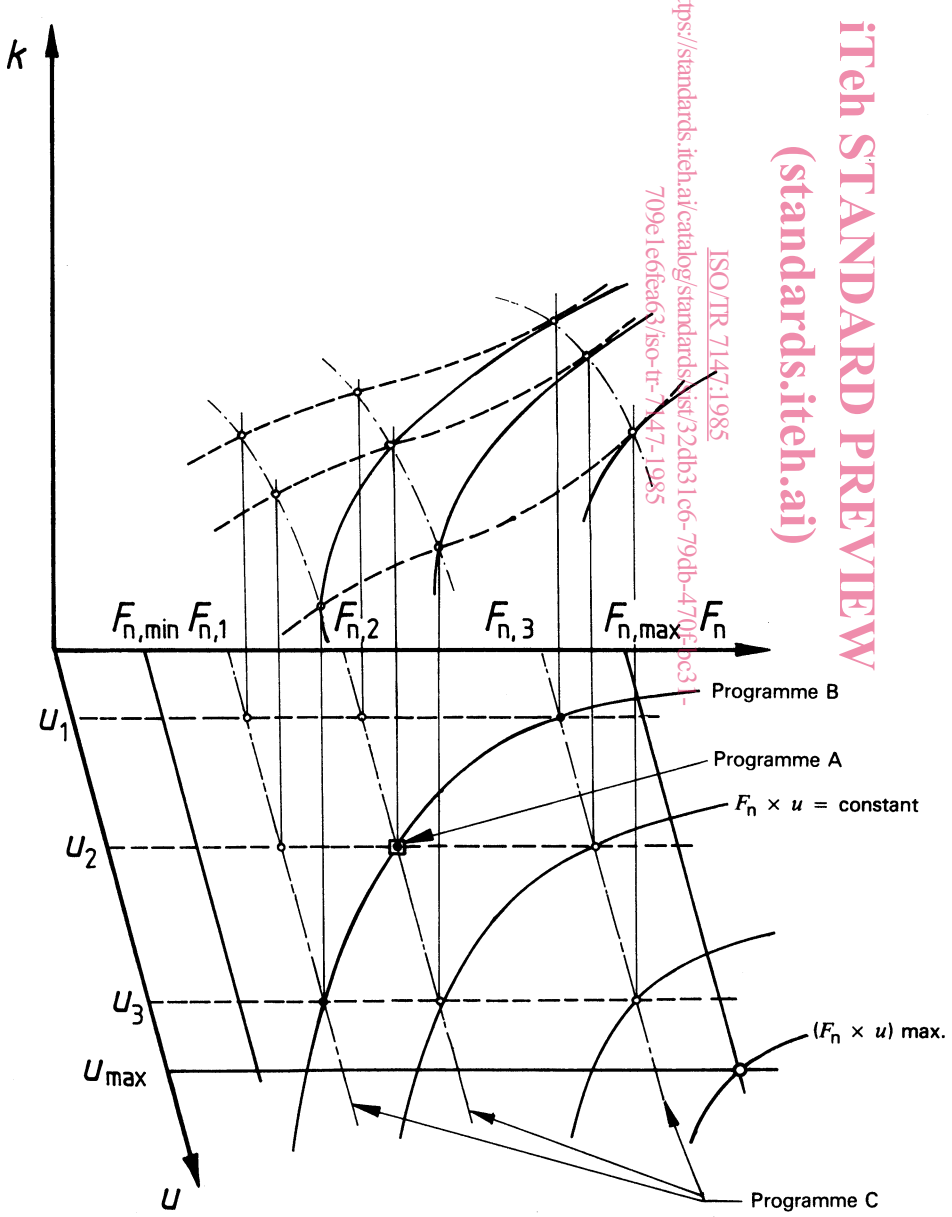


Figure 7 — Schematic representation of the characteristic surface of the wear behaviour of a sliding couple