INTERNATIONAL STANDARD

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Plastics — Film and sheeting — Determination of the coefficients of friction

Plastiques — Film et feuille — Détermination des coefficients de frottement

Reference number
ISO 8295:1995(E)

Foreword

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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.

International Standard ISO 8295 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 11, *Products*.

This second edition cancels and replaces the first edition (ISO 8295:1986), which has been technically revised.

Annex A of this International Standard is for information only.

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Plastics — Film and sheeting — Determination of the coefficients of friction

1 Scope

1.1 This International Standard specifies a method for determining the coefficients of starting and sliding friction of plastic film and sheeting when sliding over itself or other substances. The method is intended to be used for non-sticky plastic film and sheeting (in the following text, referred to simply as "film") of up to approximately 0,5 mm thickness.

1.2 This test method serves primarily for quality control. It does not give a comprehensive assessment of the machinability on packaging or processing machines since other effects, e.g. electrostatic charges, air cushion, local rise of temperature and abrasion are, as a rule, involved.

1.3 The static frictional force increases as a rule, with the time the surfaces are in contact. Therefore, to get comparable results, this time span is specified.

1.4 Slip properties are sometimes generated by additives in the plastic material. The additives have varying degrees of compatibility with the film matrix. They may bloom or exude to the surface and change the slip properties. Since these effects are time-dependent, measurements on such films have to be related to the age of the film.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 friction: The resistance that two surfaces lying in contact with each other build up against sliding. A distinction is made between static friction and dynamic friction.

3.1.1 static friction: Friction which has to be overcome as a "threshold value" at the onset of sliding motion.

3.1.2 dynamic friction: Friction which persists during a sliding motion at a given speed.

3.2 frictional force: The force necessary to overcome friction. A distinction is made between the static frictional force F_S and the dynamic frictional force F_D.

3.3 normal force, F_p: The force acting perpendicular to the surfaces in contact.

3.4 coefficient of friction: The ratio of the frictional force to the normal force, acting perpendicular to the two surfaces in contact.

3.4.1 static coefficient of friction:

$$\mu_S = \frac{F_S}{F_p}$$

3.4.2 dynamic coefficient of friction:

$$\mu_D = \frac{F_D}{F_p}$$

NOTES

1 The coefficient of friction of films usually ranges between 0,2 and 1.

2 Ideally, the coefficient of friction is a characteristic independent of the test equipment and the test conditions. Since films generally do not behave ideally, all test parameters are specified in this International Standard.

4 Principle

The surfaces to be tested are placed together in plane contact and under uniform contact pressure. The force needed to displace the surfaces relative to each other is recorded.

5 Apparatus

5.1 The test device may be constructed in different ways. In general, it consists of a horizontal test table, a sled, and a driving mechanism to produce a relative motion between the sled and the test table, regardless of which is the moving part.

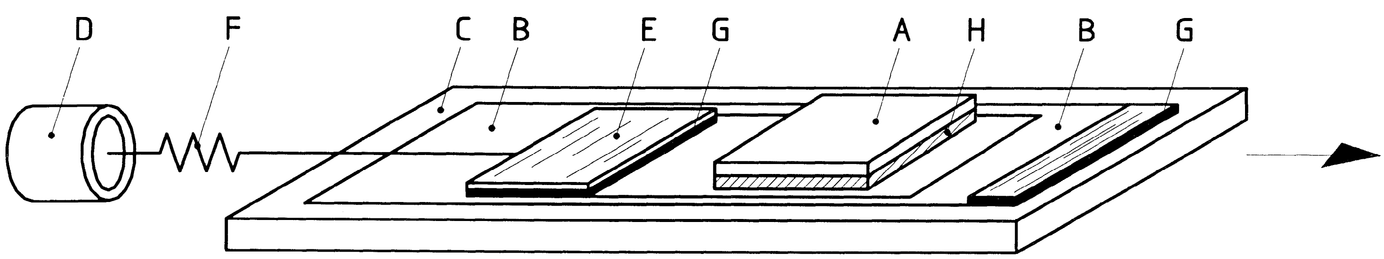
Figure 1 shows an example of apparatus in which the table is moved horizontally. The vertical motion of a tensile tester may also be utilized; in this case, the test table is fixed to the crosshead of the machine and the force is deflected to the horizontal direction by a pulley.

The force is recorded by a chart recorder or an equivalent electrical data-processing unit.

5.2 The test device shall comply with the following conditions.

5.2.1 The surface of the test table shall be flat and smooth, and made of a non-ferromagnetic metal.

5.2.2 The normal force shall be generated by a sled with a square-shaped contact base of 40 cm^2 (edge length 63 mm). To ensure uniform pressure distribution, the base of the sled shall be covered with an elastic material, for example felt. The structure of this covering material shall be fine enough to avoid embossing thin films. The total mass of the sled shall be 200 g ± 2 g (exerting a normal force of 1,96 N ± 0,02 N).



Key

A Sled
B Test specimens
C Moving table
D Load cell
E Reinforcement plate
F Spring
G Double-faced adhesive tape
H Felt

Figure 1 — Example of moving-table apparatus for determination of coefficients of friction

5.2.3 The motion that induces the friction process shall be free of vibrations and shall normally have a speed of 100 mm/min ± 10 mm/min.

In the case of specialist films or where difficulties are encountered, a speed of 500 mm/min ± 10 mm/min may be used. This shall be reported in clause 11, item f).

5.2.4 The force-measuring system, including the recording instrument, shall not exceed an error of ± 2 %. Its transition time $t_{99\ \%}$ shall not exceed 0,5 s. The pulling direction shall be in straight alignment with the frictional plane.

If the force-measuring system of a tensile tester is used, the transition time $t_{99\ \%}$ shall be particularly checked, as the indicating systems of these machines are often rather inert.

5.2.5 For the measurement of the static friction, the friction drag of the force-measuring system shall be adjusted to 2 N/cm ± 1 N/cm. This may be accomplished by using a suitable spring. For the measurement of the dynamic friction in the case of slipstick behaviour, this spring shall be replaced by a rigid connection.

NOTE 3 The inertia of the mass of the sled induces an additional force at the start of the sled movement; thus the coefficient of friction differs from its true value by an amount Δ given by

$$\Delta = \frac{v}{g}\sqrt{\frac{D}{m}}$$

where

- v is the speed of the sled relative to the table (= 100 mm/min);
- m is the mass of the sled (= 200 g);
- g is the acceleration due to gravity (= 9 810 mm/s^2);
- D is the friction drag (2 N/cm = 2 × 10^5 g/s^2).

Under these conditions, the overshoot of the coefficient of friction is 0,005. In the worst case, this means that, at a low coefficient of friction of 0,2, the overshoot equals an error of 2,5 %.

6 Test specimens

For each measurement, two test specimens measuring about 80 mm × 200 mm are needed. At least three such pairs of test specimens taken from points uniformly distributed over the width of the sample, or the circumference in the case of tubular film, shall be tested.

Unless otherwise specified, the long axis, and thus the test direction, shall be parallel to the machine direction of the film.

When different frictional properties are expected for the two surfaces, front (1) and back (2), the two surfaces shall be identified and tested 1/1, 2/2 and/or 1/2 as agreed between the interested parties.

Extreme care shall be taken in handling the samples and specimens. The test surfaces shall be kept free of dust, fingerprints or any foreign matter that might change the surface characteristics.

NOTES

4 Testing of three pairs of test specimens represents a minimum for estimating the statistical tolerance interval. Depending on the intended precision and the homogeneity of the material under test, the number of specimens tested may have to be increased. ISO 2602:1980, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*, gives guidance in this respect.

5 To avoid contamination of the surfaces, several test specimens may be cut simultaneously and separated immediately before testing.

7 Conditioning

Unless otherwise specified, specimens shall be conditioned for at least 16 h in standard atmosphere 23/50 as defined in ISO 291 prior to testing.

8 Procedure

The following directions refer to an apparatus designed in accordance with figure 1. If another equivalent apparatus is used, the appropriate procedure shall be followed. The testing shall be carried out in the same atmosphere as used for conditioning.

8.1 Measurement of film against film

8.1.1 Fix the right-hand end of the first test specimen on the test table with double-faced adhesive tape (or by a suitable clamp) so that the length axis of the test specimen coincides with that of the table. Reinforce the left-hand end of the second test specimen by attaching a small plate to it with double-faced adhesive tape. The mass of this plate shall not exceed 5 g. Connect this plate via a spring (see 5.2.5) to the load cell. Lay the second test specimen on the first and place the sled on top, gently and without shock, in the middle of the second test specimen (for films producing high blocking or other than frictional forces, the contact area, i.e. the size of the upper test specimen, shall be reduced as closely as possible to the area of the sled). Before starting the test, the apparatus shall be free of stress. After 15 s, start the motion of the test table and start up the recording instrument. The first force peak is caused by static friction.

8.1.2 After the first peak, oscillations in the force may sometimes occur. In this case, the oscillating part of the graph cannot be used to determine the dynamic coefficient of friction. The dynamic coefficient shall be determined by a separate measurement in which slipstick behaviour is eliminated by replacing the spring with a rigid connection.

This type of determination cannot be used to determine the static coefficient of friction because of the inertia error (see note 3 in 5.2.5).

NOTE 6 The load cell may also be attached directly to the sled. In this case, the second test specimen is fastened to the front edge of the sled with double-faced adhesive tape. However, this procedure is not advisable for stiff films since the bending moment may cause an unequal pressure distribution.

8.2 Measurement of film in contact with metal or another material

If the frictional behaviour of a film in contact with a metal surface or the surface of another material is to be determined, the lower test specimen (see figure 1) shall be replaced by a specimen of the material in question. Otherwise, the same procedure shall be used.

The coefficients of friction determined in this way are dependent on the type of material as well as on its surface finish.

If subsequent measurements are made on the same test specimen of a material, it should be noted that abrasion may have occurred, which will change the surface properties. Also, the possibility of transfer of slip or antislip agent shall be considered.

9 Expression of results

9.1 Static coefficient of friction

The force increases linearly to a maximum which represents the static frictional force F_S. Measurements made at a high friction drag (i.e. without a spring) permit the dynamic coefficient of friction to be calculated, but not the static coefficient of friction (see 8.1.2).

The static coefficient of friction μ_S is given by the equation

$$\mu_S = \frac{F_S}{F_p}$$

where

F_S is the static frictional force, expressed in newtons;

F_p is the normal force exerted by the mass of the sled, expressed in newtons (= 1,96 N).

9.2 Dynamic coefficient of friction

The frictional force acting during the sliding motion often differs from the constant value which would exist in an ideal situation due to secondary effects related to increasing path length.

The dynamic frictional force F_D is the average force over the first 6 cm of movement after the start of relative movement between the surfaces in contact, neglecting the static force peak F_S. The dynamic coefficient of friction μ_D is calculated from the dynamic frictional force using the equation

$$\mu_D = \frac{F_D}{F_p}$$

where

F_D is the dynamic frictional force, expressed in newtons;

F_p is the normal force exerted by the mass of the sled, expressed in newtons (= 1,96 N).

10 Precision

The dispersion of the coefficients of friction of several plastics has been investigated in a preliminary interlaboratory trial intended, first and foremost, to assess an alternative test speed, and also to provide preliminary precision data (see annex A). When further repeatability and reproducibility data are obtained, they will be added at the following revision.

11 Test report

The test report shall include the following particulars:

a) a reference to this International Standard;

b) all information necessary for identification of the plastic film sample, and, if known, the approximate age of the film;

c) which of the two surfaces was tested;

d) the individual and average values and, if required, the standard deviation and the number of tests for

1) the static coefficient of friction,

2) the dynamic coefficient of friction;

e) if measurements were made with the film in contact with other materials, an exact description of these surfaces;

f) any deviations from this International Standard.

Annex A
(informative)

Preliminary precision data

A preliminary inter-laboratory trial was carried out in 1993 to verify whether a test speed of 500 mm/min can be used instead of 100 mm/min for plastics having a high coefficient of friction which may cause insufficient precision of the results. The trial was conducted not only to assess the alternative test speed, but also to acquire preliminary precision data. The precision data obtained show that a test speed of 100 mm/min is suitable for all the materials tested in the trial.

The trial was organized and the results analysed in accordance with ISO 5725-1, ISO 5725-2 and ISO 5725-3 [1)] and involved four laboratories (in China, France, Japan and the UK) and four samples of which both the internal and external surfaces were tested. Although the number of participating laboratories did not satisfy the requirements of ISO 5725, tables A.1 and A.2 have been prepared from selected data as useful examples, pending a full-scale precision trial to be conducted before the next revision. The data are arranged in order of magnitude and classified by coefficient of dynamic and coefficient of static friction. To make it easier to compare the standard deviations between the levels, with no regard to the absolute values, the coefficients of variation have been calculated and included in parentheses in tables A.1 and A.2.

$$\text{coefficient of variation (\%)} = \frac{\text{standard deviation}}{\text{average coefficient of friction}} \times 100$$

No outliers were detected by Grubb's test.

Table A.1 — Precision of dynamic coefficient of friction

Plastics (Nominal thickness in µm), surface/surface	Average coefficient ($n = 5$)	Reproducibility-within-laboratory standard deviation, s_{Rw} (Coefficient of variation)	Reproducibility standard deviation, s_R (Coefficient of variation)
PP (60), I/I	0,210	0,014 5 (6,9 %)	0,048 5 (23,1 %)
PVC (200), I/I	0,432	0,072 5 (16,8 %)	0,037 6 (8,7 %)
PE-LL (30), I/E	0,443	0,044 2 (10,0 %)	0,069 8 (15,8 %)
PC (100), I/I	0,618	0,044 2 (7,2 %)	0,127 5 (20,6 %)
Average		0,064 3 (14,83 %)	0,070 9 (17,05 %)

I/I friction between internal surface and internal surface;

I/E friction between internal surface and external surface.

1) ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

ISO 5725-2:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.*

ISO 5725-3:1994 *Accuracy (trueness and precision) of measurement methods and results — Part 3: Intermediate measures of the precision of a standard measurement method.*

Table A.2 — Precision of static coefficient of friction

Plastics (Nominal thickness in μm), surface/surface	Average coefficient ($n = 5$)	Reproducibility-within-laboratory standard deviation, s_{Rw} (Coefficient of variation)	Reproducibility standard deviation, s_R (Coefficient of variation)
PP (60), I/I	0,277	0,035 0 (12,6 %)	0,077 1 (27,8 %)
PVC (200), I/I	0,857	0,136 8 (16,0 %)	0,100 0 (11,7 %)
PE-LL (30), I/E	0,765	0,173 3 (22,7 %)	0,207 5 (27,1 %)
PC (100), I/I	0,612	0,042 5 (6,9 %)	0,037 2 (6,1 %)
Average		0,096 9 (14,55 %)	0,105 5 (18,18 %)

I/I friction between internal surface and internal surface;

I/E friction between internal surface and external surface.

The dynamic and static data were obtained simultaneously in the same test run.

The inter-laboratory trial was carried out not only to obtain precision data but also to improve the test method. The data obtained and many of the observations made during the test were of considerable interest. They will be considered at the next revision with the aim of improving the method. The following comments are particularly worth noting:

(i) Condition of sample

The average reproducibility-within-laboratory standard deviations s_{Rw} given in the tables are nearly the same as the reproducibility standard deviations s_R, and in some instances s_R is less than s_{Rw}. These data are unusual because s_{Rw} is usually approximately one-third of s_R. The data suggest either that the measurements can fluctuate greatly due to the various factors encountered, or that the specimens tested were not identical.

The samples were distributed from a single source and were identical but, judging from the reports of the state of the samples received and tested by some laboratories, it is doubtful that the specimens used in each laboratory were strictly identical. Some samples were reported to have had surfaces which were not flat, or even creased. These samples should not, of course, have been used for testing.

The condition of the sample should therefore be described in much more detail in the test report.

(ii) Static electricity

It was reported that, in some specimens, static charge was observed during testing, which made it difficult to handle the specimens properly. The effect of static charge should be investigated, but it is suggested in any case that the static charge should be eliminated before testing.

(iii) Measurement of frictional force

The recorded plots of the static frictional force varied from lab to lab. Some were rather flat while some showed curves which rose as the test proceeded. It is possible that the operators have interpreted these plots differently, thus giving values which vary more widely than expected.

The system of measuring, recording and calculating the average frictional force should therefore be investigated in detail in order to reduce the variation in the data.

(iv) Sled material and weight of sled

These two factors affect the actual contact area between the surfaces of specimens. Stiff films tend to have a smaller contact area, and hence the pressure is less uniform, when the sled is not heavy enough. This aspect may well be worth studying. This International Standard requires that the sled be covered with an elastic material. The sled and the elastic material used should be defined as specifically as possible in order to keep the pressure uniform and obtain more reproducible results.

(v) The spring

The spring, intended to control the initial speed of the sled to give even acceleration, could not be used in the case of high-friction film such as PE-LLD, because no spring was available which met the requirements of the standard. The sled was therefore connected directly to the load cell, and the value obtained depended on the apparatus used, different apparatus giving a different initial acceleration. The values of the dynamic coefficient of friction obtained are only relative values.

NOTES

7 Reproducibility is the precision under conditions in which the test results are obtained using the same method and identical test material but in different laboratories with different operators using different equipment, and are expressed in terms of the reproducibility standard deviation.

8 Reproducibility-within-laboratory is the precision under conditions in which the test results are obtained in the same laboratory using the same method and identical test material, but the operator, the equipment and/or the time of measurement may be different.

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ICS 83.140

Descriptors: plastics, films, sheets, tests, friction tests, determination, friction factor, test equipment.

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