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PLASTICS

DETERMINATION OF TENSILE PROPERTIES OF FILMS

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BRIEF HISTORY

The ISO Recommendation R 1184, *Plastics – Determination of tensile properties of films*, was drawn up by Technical Committee ISO/TC 61, *Plastics*, the Secretariat of which is held by the American National Standards Institute (ANSI).

Work on this question led to the adoption of Draft ISO Recommendation No. 1667 which was circulated to all the ISO Member Bodies for enquiry in October 1968. It was approved, subject to a few modifications of an editorial nature, by the following Member Bodies :

Australia	Hungary	Romania
Austria	India	South Africa, Rep. of
Belgium	Israel	Spain
Brazil	Japan	Sweden
Canada	Korea, Rep. of	Switzerland
Czechoslovakia	Netherlands	Turkey
France	New Zealand	U.A.R.
Germany	Poland	United Kingdom
Greece	Portugal	U.S.A.

No Member Body opposed the approval of the Draft.

This Draft ISO Recommendation was then submitted by correspondence to the ISO Council, which decided, in February 1970, to accept it as an ISO RECOMMENDATION.

ISO Recommendation | R 1184 | February 1970

PLASTICS

DETERMINATION OF TENSILE PROPERTIES OF FILMS

1. SCOPE

1.1 This ISO Recommendation describes a method for determining the tensile properties of thin sheet less than 1 mm thick or film in the form of standard test pieces tested under defined conditions of pre-treatment, temperature, humidity and rate of separation of grips. The method is not suitable for determining the tensile properties of reinforced films or embossed films.

1.2 Different rates of separation of the grips are specified to suit the different materials to which the method can be applied. It is not possible to make valid comparisons between the results of tensile tests on different materials if the rates of straining are different.

2. DEFINITIONS

2.1 *Tensile stress.* The tensile load per unit area of average original cross-section carried by the test piece at any moment.

2.2 *Percentage elongation.* The increase in the distance between reference lines on the test piece, due to a tensile load, expressed as a percentage of the initial distance between the reference lines.

2.3 *Yield point.* The first point on the load-extension curve at which an increase in extension occurs without an increase in load.

NOTE. – In cases where the yield point is not well defined by the load-extension curve, it is frequently necessary to define an offset yield point. This is done by specifying a point on the load-extension curve where the curve departs from linearity by a specified percentage elongation or extension (see Fig. 1). For this purpose the zero value on the extension axis should be the same as defined in clause 2.4.

2.4 *Elastic modulus* (Young's modulus). The ratio of stress to corresponding strain within the range of the greatest stress that the material is capable of sustaining without any deviation of proportionality of stress to strain.

For the purpose of this test, the origin is defined by extending the initial straight line portion of the load-extension curve so that it intersects the extension axis. This intersection is the origin (see Fig. 3).

NOTE. – It is necessary to define the origin in this way because the start of the load-extension curve is often not well defined when testing film.

2.5 *1 % secant modulus.* The ratio of stress to corresponding strain within the range of the origin and the point on the load-extension curve corresponding to 1 % extension.

The other secant moduli are defined as the ratio of stresses to corresponding strains within the range of the origin and defined points on the load-extension curve.

NOTE. – Secant modulus at other than 1 % should only be used if specified in the relevant material specification.

3. SIGNIFICANCE OF THE TEST

3.1 The tensile properties that can be measured by some or all of the procedures described in this ISO Recommendation include modulus of elasticity, stress and strain at yield point and at break.

Materials of low ductility may not exhibit a well-defined yield point. Stress-strain data at several levels of temperature, humidity and straining rate usually give reasonably reliable indications of the behaviour of materials under tensile stress.

3.2 Tensile tests may provide data for quality control, acceptance or rejection in accordance with the terms of specifications, research and development, engineering design and other purposes. Test results cannot be considered significant for applications in which the rate of application of stress differs considerably from those specified for this method of test. Such applications should be considered in terms such as impact, creep and fatigue.

4. APPARATUS

4.1 *Testing machine,* with grips that can be separated at one or more (as required) of the rates given in section 8.

4.1.1 *Grips,* for holding the test piece, one being attached to a fixed, essentially stationary member of the machine and the other to a movable member. The grips should be self-aligning; that is, they should be attached to the fixed and movable members in such a manner that they will move freely into alignment as soon as a load is applied, so that the long axis of the test piece will coincide with the direction of the applied force through the centreline of the grip assembly. The test piece is held in such a way that slip, relative to the grips, is prevented as far as possible.

NOTE. – One type of grip which has been found satisfactory in use for tensile testing of film is of the design shown in Figure 2.

4.1.2 *Load indicator.* A suitable load-indicating mechanism capable of showing the total tensile load carried by the test piece when held by the grips. This mechanism should be essentially free from inertia lag at the specified rate of testing and should indicate the load with an accuracy of at least 1 % of the indicated value.

NOTE. – To obtain maximum accuracy, the displacement of the grip attached to the stationary member should be at a minimum. Tensile testing machines fitted with electronic force-measuring devices can be regarded as being sufficiently free of inertia for the speeds of testing given in clause 8.2 but this does not necessarily apply to the electronic recorders normally used with these devices, which sometimes have a response time for full scale travel of up to 1 second.

Experience has shown that the error caused by the inertia of these recording systems can be neglected if the rise time (T_W) of the load is not shorter than the response time (T_E) for full scale travel of the recorder, i.e. :

$$T_W \geqslant T_E$$

For a full scale response, the relationship with the testing speed is :

$$V_M^{100} = \frac{l_o E_p}{T_W} \leqslant \frac{l_o E_p}{T_E}$$

where

V_M^{100} is the testing speed;

l_o is the grip (or gauge mark) separation;

E_p is the percentage elongation corresponding to the maximum force.

If only a fraction δ of full scale travel is involved, the permissible maximum testing speed is increased to V_M^{δ} which is given approximately by the relationship :

$$V_M^{\delta} \approx \frac{1}{\delta} V_M^{100}$$

This should be taken into account when using testing machines fitted with these devices.

4.2 *Extension indicator* (when required). A suitable instrument for determining the distance between the two reference lines located within the middle part of the test piece at any time during the test. It is desirable, but not essential, that this instrument automatically records this distance (or any change in it) as a function of the load on the test piece, or of the time elapsed from the beginning of the test, or both. If only distance as a function of elapsed time is recorded, load-time data should also be taken. The instrument should be essentially free of inertia lag at the specified speed of testing and should be capable of measuring the distance between the reference lines with an accuracy of ± 0.1 mm.

4.3 *Micrometers.* Means for measuring the width and thickness of the test pieces.

For measuring the thickness, dial gauges fitted with flat circular feet that will apply a pressure of 0.1 to 0.3 kgf/cm^2 to the test piece should be used; these should allow readings with the following accuracies :

0.0005 mm for film up to 0.01 mm thick;
0.001 mm for film 0.01 to 0.05 mm thick;
0.002 mm for film 0.05 to 0.1 mm thick;
0.005 mm for film greater than 0.1 mm thick.

For measuring the width, use a travelling microscope having an accuracy of at least 1 %.

5. TEST PIECES

5.1 For the measurement of stress and strain at yield point and at break, the test piece should be cut from the material under test in the form of a strip 10 to 25 mm wide and not less than 150 mm long. The thickness of the test piece is the thickness of the material under test.

Reference lines, if used, should be at least 50 mm apart and should be marked on the middle part of the test piece using ink or some other medium that will not affect the material being tested. Reference lines must not be scratched, punched or impressed upon the test piece.

5.2 For the measurement of modulus of elasticity, the test piece should be cut from the material under test in the form of a strip 10 to 25 mm wide. The thickness of the test piece is the thickness of the material under test.

5.2.1 When the extension is measured by the grip separation, the test piece should be of sufficient length so that an initial grip separation of at least 250 mm is used.

5.2.2 When the extension is measured by a gauge or extension indicator, the test piece should be as described in clause 5.1. When an extension indicator is used, the test piece should not carry the weight of the instrument.

5.3 The test pieces described in clauses 5.1 and 5.2 should be cut or machined so that the edges are smooth and free of notches; examination with a low-power magnifier is recommended to check freedom from notches. Razor blades, suitable paper cutters, drawing cutters or other devices capable of cutting the test pieces to the proper width and producing straight, clean parallel edges with no visible imperfections should be used. Striking dies are not recommended because of poor and inconsistent test piece edges which are produced by these dies.

6. CONDITIONING

The test pieces should be conditioned and tested in accordance with ISO Recommendation R 291, *Plastics – Standard atmospheres for conditioning and testing,* unless otherwise stated in the specification for the material.

7. NUMBER OF TEST PIECES

7.1 Use at least five test pieces for each sample.

7.2 The properties of certain types of film materials may vary with direction in the plane of the film. In such cases, take five test pieces in each of the two directions at right angles to one another and in the plane of the film which are ideally intended to furnish the maximum and minimum test values. These two directions can usually be inferred from some visible feature of the film or from a knowledge of the method of manufacture of the film.

7.3 Test pieces which break in the grips or break at some obvious flaw should be discarded and replaced by further test pieces.

8. SPEED OF TESTING

8.1 The speed of testing is the rate of separation of the grips of the testing machine during the test.

8.2 The speed of testing should preferably be chosen from among those listed below, but in any case should be determined by the specification for the material being tested or by agreement between the parties concerned :

Speed A	1 mm/min ± 50 %
Speed B	5 mm/min ± 20 %
Speed C	10 mm/min ± 10 %
Speed D	25 mm/min ± 10 %
Speed E	50 mm/min ± 10 %
Speed F	100 mm/min ± 10 %
Speed G	500 mm/min ± 10 %

If the modulus of elasticity is being measured, the speed of testing should be selected so that the strain rate is as near as possible to 1 % of the initial distance between the grips or the gauge marks per minute.

Modulus determination should be made with separate test pieces from those used to determine tensile stress and percentage elongation whenever the speeds of testing are not the same.

NOTE. – When the specification for the material is unknown, the lower speeds are generally used for rigid and semi-rigid materials, and the higher speeds for non-rigid materials.

9. PROCEDURE

9.1 Measure the width and thickness of the test piece to the required accuracy (see clause 4.3) at several points along its length. The thickness of very thin film (film less than 0.005 mm thick) may be determined by a gravimetric method (see Appendix).

9.2 Place the test piece in the grips of the testing machine, taking care to align the long axis of the test piece and the grips with an imaginary line joining the points of attachment of the grips to the machine. Tighten the grips evenly and firmly to the degree necessary to prevent the test piece from slipping during the test, but not to a point where the test piece would be damaged. Clamp the test piece so that the distance between the grips of the testing machine is 100 mm and the reference lines on the test piece are centrally disposed between the grips. When the extension is to be measured by grip separation, clamp the test piece in the grips with an initial separation of 250 mm.

9.3 If modulus of elasticity is being determined, proceed as follows :

9.3.1 If appropriate, attach the extension indicator.

9.3.2 Set the speed of testing to the required value (see clause 8.2) and start the machine.

9.3.3 Record the load and corresponding deformation at appropriate and approximately even intervals of strain in the region of elastic behaviour.

9.4 If stress and strain at yield point and at break are being determined, proceed as follows :

9.4.1 If appropriate, attach the extension indicator.

9.4.2 Set the speed of testing to the required value (see clause 8.2).

9.4.3 Record the load-extension curve during the test up to the point of rupture of the test piece.

10. CALCULATION AND EXPRESSION OF RESULTS

10.1 Tensile stress at break and/or at yield point or at maximum load

Divide the load at yield point or at break or at maximum load, as appropriate, by the original minimum cross-sectional area of the test piece.

Express the result in kilonewtons per square metre (or in kilogrammes-force per square centimetre)* to two significant figures.

10.2 Percentage elongation at yield point or at break

Divide the extension at yield point or at break, as appropriate, by the original distance between the reference lines and multiply by 100.

Express the result to two significant figures.

10.3 Modulus of elasticity

10.3.1 Calculate the elastic modulus from the initial linear portion of the load-extension curve (see Fig. 3), by dividing the difference in stress corresponding to a section of the straight line by the corresponding difference in strain. For this purpose the difference in stress is the difference in load divided by the original cross-sectional area of the test piece and the difference in strain is the difference in extension divided by the original distance between the fixed points used for the measurement of extension under load.

Express the result in kilonewtons per square metre (or in kilogrammes-force per square centimetre)* to three significant figures.

10.3.2 Calculate the 1 % secant modulus as follows :

Extend the initial straight line portion of the load-extension curve to intersect the extension axis (see Fig. 3). This intersection point is the origin of the curve as defined in clause 2.4. At a point corresponding to 1 % extension from this origin, determine the load from the load-extension curve. Calculate the nominal stress at 1 % by dividing the load by the original cross-sectional area of the test piece. Divide the nominal stress at 1 % by the corresponding strain (which in this case is 0.01) to give the 1 % secant modulus.

Express the result in kilonewtons per square metre (or in kilogrammes-force per square centimetre)* to three significant figures.

10.4 For each group of five results, calculate the arithmetic mean of the five values obtained, to two significant figures (except for modulus of elasticity, for which the mean should be calculated to three significant figures) and report this as the "average value" for the particular property in question.

10.5 If the standard deviation (estimated) is required, it should be calculated as follows and reported to two significant figures :

$$s = \sqrt{\frac{\Sigma x^2 - n\bar{x}^2}{n - 1}}$$

where

s is the estimated standard deviation;

x is the value of a single observation;

$\bar{x}$ is the arithmetic mean of a set of observations;

n is the number of observations.

* 1 kgf/cm^2 = 98 kN/m^2 approximately.