TECHNICAL REPORT 4137

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ISO Technical Reports are subject to review within three years of publication, with the aim of achieving the agreements necessary for the publication of an International Standard.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Plastics — Determination of modulus of elasticity by alternating flexure

Plastiques — Détermination du module d'élasticité par flexion alternée

Technical Report 4137 was drawn up by Technical Committee ISO/TC 61, *Plastics*, and approved by the majority of its members. The reasons which led to the publication of this document in the form of a Technical Report are the following :

— there are already in existence well-established standardized methods of test to measure modulus of elasticity using equipment and techniques known and operated by most test laboratories around the world;

— the test proposed (that of alternating flexure using Savart's pendulums) is unique to one country and requires specialized apparatus for which there is only one known manufacturer.

It is therefore believed that the publication of the method as a Technical Report will make it more available and permit ISO/TC 61 to decide on the question of its publication as an International Standard at a later date when the Technical Report is reviewed.

1 SCOPE AND FIELD OF APPLICATION

1.1 This Technical Report describes a method for the determination of the longitudinal modulus of elasticity of plastics by means of Savart's pendulums.

1.2 This method is not considered a dynamic method in the usual sense of the term. It does not lead to the determination of the complex modulus. The period of the oscillations should be of the order of 1 s.

1.3 The method is applicable to products for which the characteristic determined is greater than 1 500 MPa* and from which it is possible to prepare specimens from 1 to 5 mm in thickness, by cutting or moulding.

1.4 The method requires relatively small specimens which may be taken from objects in such a way that heterogeneity or anisotropy may be detected.

1.5 In addition, since the method is non-destructive and the applied strains are small, the determination may be readily repeated on a specimen whose chemical or physical development is to be followed (modification of crystallinity, chemical attack, take-up of moisture, change of cell dimension, etc.).

* 1MPa = 1 N/mm^2

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2 REFERENCES

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

ISO/R 527, *Plastics — Determination of tensile properties.*

3 PRINCIPLE

3.1 The elasticity of the test piece is employed for transmission of energy from one moving pendulum to another, the test piece being used as a support for both pendulums.

3.2 This transmission depends on the static and dynamic characteristics of the pendulums and on the dimensions of the test piece and the modulus of elasticity in tension of the material.

3.3 For the test, a specimen in the form of a rectangular parallelepiped is clamped vertically in a fixed jaw at one end and at the other end to a plate from which two identical pendulums are symmetrically suspended. One pendulum (the driver) being drawn from its equilibrium position and set in motion, successive flexures of the specimen occur, and accumulated energy is transmitted to the other pendulum (the receiver), thus setting it in motion.

3.4 The amplitude of the oscillations of the driving pendulum gradually decreases until it stops. The time between starting up and the first stopping of the driving pendulum is the half-oscillation period, which is a function of the longitudinal (Young's) modulus of elasticity of the specimen in alternating flexure.

4 APPARATUS

4.1 Micrometer, suitable for measuring the dimensions of the test specimens to within 0,01 mm.

4.2 Pendular elasticimeter[1] (see figures in annexes A and B), consisting of the following parts :

a) Rigid frame, fitted with levelling screws (it must be set up on a block of concrete of mass at least 300 kg, which does not transmit vibrations).

b) Fixed support carrying the adjustable upper clamping jaw, fitted with a torque wrench.

c) Plate support.

d) Plate carrying the adjustable lower clamping jaw, fitted with a torque wrench.

e) Two removable and rigid pendulums (of large or small size, see annex B), hung from the plate by stirrups and supported by knife edges, oscillating in the plane of the paper.

f) Intermediary support which, when the apparatus is not in motion, lifts the pendulum stirrups off the knife edges.

g) Releasing lever for the simultaneous starting of the driving pendulum and of the chronometer fixed to the frame.

The distance between the lower and upper jaws shall be 60 ± 0,1 mm.

Both pendulums shall have dynamic characteristics as nearly identical as possible.

The driving pendulum shall have a compensating movable mass for adjustment.

The characteristics of the apparatus *A*, *B* and *C*, determined by the method given in annex C, shall be such that the duration of the test is at least 60 s, but not more than 120 s.

The chronometer shall permit readings to 0,1 s.

It is advantageous to use a suitable spot-follower in order to record the driving pendulum oscillations. This complementary apparatus allows operator error to be eliminated in estimating the time at which the pendulum stops. It is thus possible to make good determinations with test times of less than 60 s.

The torque wrench shall be adjusted so that the jaws exert on the specimens, after tightening, a locking pressure of 10 MPa.

The apparatus shall be so designed that when the specimen is clamped in the jaws, its axis coincides with the axis of symmetry of the apparatus, whatever the thickness of the specimen.

1) Pendular elasticimeter of the "Le Rolland-Sorin" type is suitable.

5 TEST SPECIMENS

5.1 Dimensions

To permit correct measurements, specimens shall be sufficiently even. The width shall be constant to the nearest 0,02 mm, from one end of the specimen to the other. Uniformity of thickness is also necessary.[1)]

The dimensions of the standard specimen are as follows :

- length l : 100 ± 2 mm
- width b : 10 ± 0,2 mm
- thickness h : 4 ± 0,1 mm

In cases where, for various reasons, it is not possible or desirable to use the thicknesses indicated above, specimens of thickness between 1 and 6 mm may be used.

5.2 Sampling

The method of sampling and machining of the specimens, as well as their number, shall be as indicated in the relevant International Standard or agreed between seller and purchaser. Unless otherwise specified, two specimens shall be used. The wide faces should not be machined. If it is impossible to follow this prescription, the test report shall indicate the number of faces machined.

5.3 Conditioning

The specimens shall be conditioned for at least 24 h in an atmosphere[2)] having the following characteristics :

- temperature : 23 ± 2 °C
- relative humidity : (50 ± 5) %

6 PROCEDURE

6.1 Carry out the test in an atmosphere[2)] having the following characteristics :

- temperature : 23 ± 2 °C[3)]
- relative humidity : (50 ± 5) %

6.2 Measure the dimensions of the specimens to the nearest 0,01 m with the micrometer (4.1). Measure the thickness of each specimen at three points taken respectively in the middle and at 25 mm from each end. Use the arithmetic mean value, h, rounded to the nearest 0,01 mm, of these three measurements in the calculations.

6.3 Ensure that the upper surface of the apparatus is level, using the levelling screws.

6.4 Fix the ends of the specimen in the two clamping jaws with the torque wrench.

With the chronometer at zero, set the starting device.

Adjust the pendulum stirrups to ensure contact with the knife edges.

Release the driving pendulum and the chronometer, simultaneously.

6.5 If the amplitude of oscillation of the driving pendulum does not become null, begin the test again after having modified the oscillation period by raising or lowering the compensating weight. This weight shall be lowered if the two pendulums are moving out of phase when the oscillation of the driving pendulum passes its minimum value. On the contrary, the weight shall be raised if at this instant the pendulums are in phase.

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1) Since the uniformity of thickness cannot be adequately controlled by instruments whose precision is no better than 0,01 mm, it shall be checked by repeating the test after turning the specimen end for end. The second result shall not differ from the first by more than 1 %.

2) According to ISO 291.

3) Other temperatures may be used, by agreement between seller and purchaser, if the requirements of 1.3 are met.

6.6 Note the time (t_1) from the start to the first stopping of the driving pendulum, to the nearest 0,2 s.

6.7 Repeat the test with the specimen reversed in position and note the corresponding time (t_2), to the nearest 0,2 s.

7 EXPRESSION OF RESULTS

7.1 The longitudinal (Young's) modulus of elasticity, E, is given, in megapascals, by the formula

$$E = \frac{1}{b\,h^3}\left(A\,t + \frac{B}{t} + C\right)$$

where

b is the width of the specimen, in millimetres;

h is the thickness of the specimen, in millimetres (see 6.2);

t is the time interval between the release and stopping of the driving pendulum, in seconds;

A, B and C are the characteristics of the apparatus[1], expressed in appropriate units.

If the values of E_1 and E_2 from the same specimen differ by more than 1 %, reject the data and commence a new series of measurements or, if necessary, take a new specimen.

8 TEST REPORT

The test report shall include the following particulars :

a) complete identification of the materials tested;

b) the dimensions of the specimens;

c) the thicknesss of the specimens, if it is different from standard;

d) the place from which specimens have been cut in the object under examination, and the orientation of the specimens;

e) the number of specimens tested;

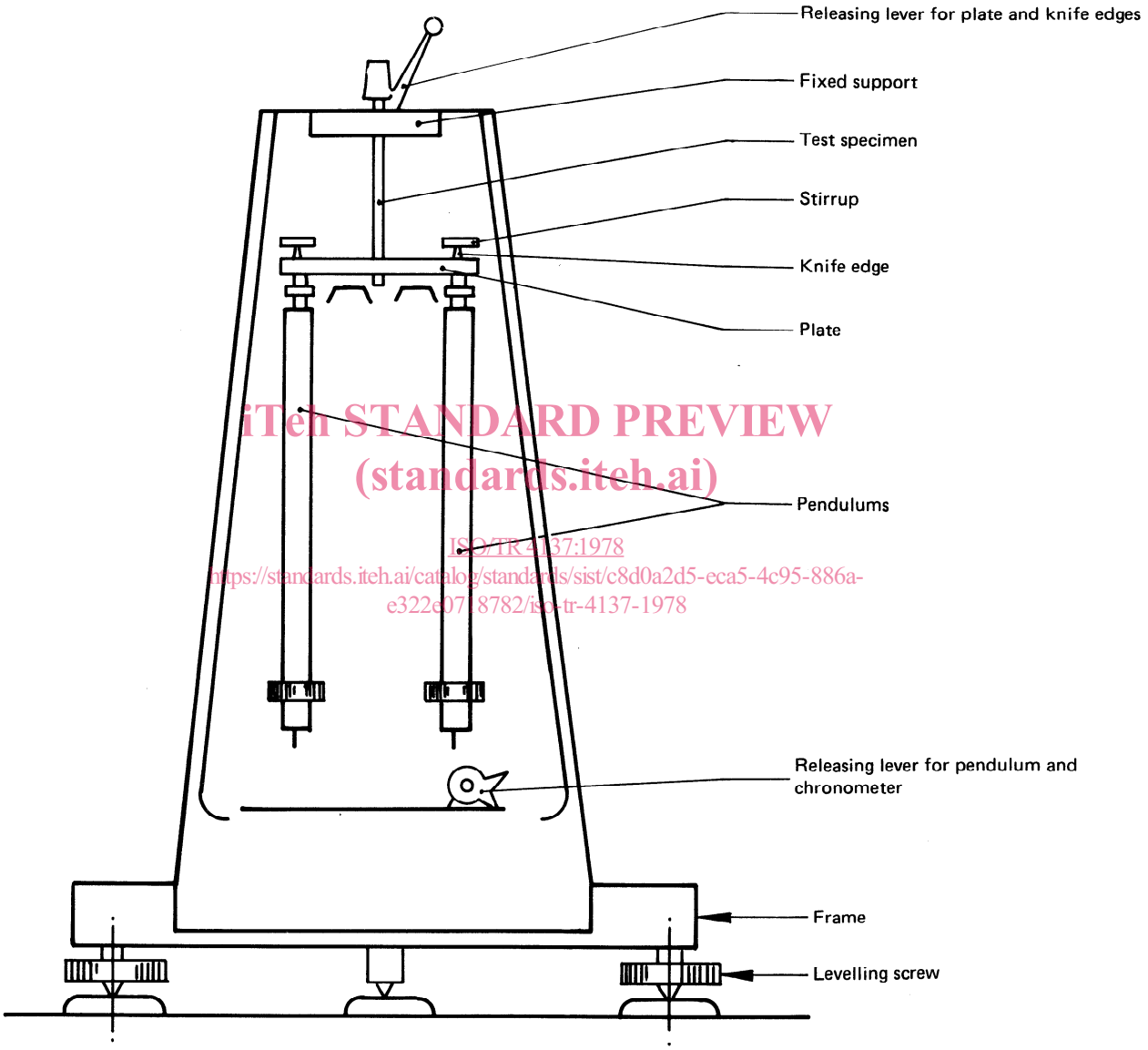
f) the characteristics A, B and C of the apparatus;

g) the average and extreme values of the longitudinal modulus of elasticity.

1) The method for the determination or verification of these characteristics is given in annex C.

ANNEX A

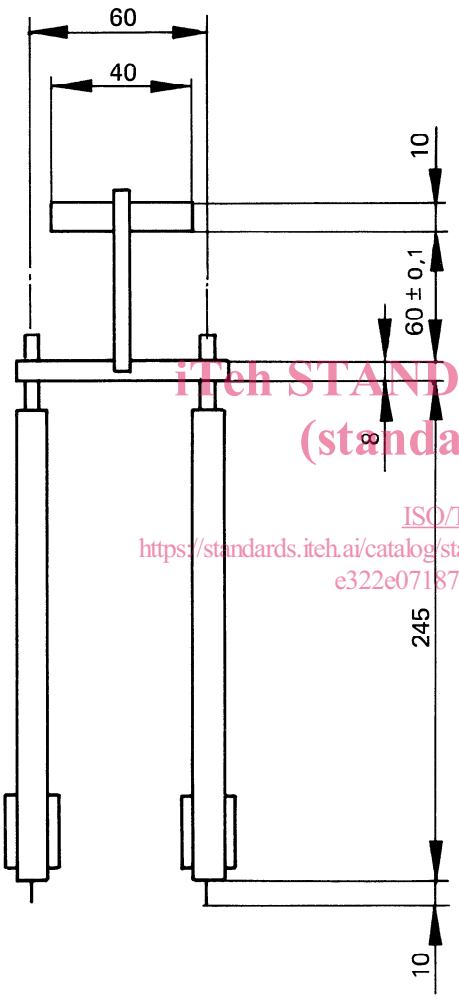
DIAGRAM OF PENDULUM ELASTICIMETER



ANNEX B

CHARACTERISTICS OF A TYPICAL PENDULUM ELASTICIMETER

Dimensions in millimetres



Large pendulums

length : 245 mm
diameter : 39 mm
mass : 2 kg

Small pendulums

length : 245 mm
diameter : 13,5 mm
mass : 400 g

Spacing of the pendulums : 60 mm

Maximum amplitude of oscillations : 4°

ANNEX C

DETERMINATION OR VERIFICATION OF THE CHARACTERISTICS OF THE PENDULUM ELASTICIMETER

The characteristics A, B and C of the apparatus are determined by applying to three different metallic standards the procedure of clause 6 and the formula of clause 7.

The following materials[1)] are recommended for the preparation of the metallic standards :

- pure iron;
- electrolytic copper;
- aluminium 99,99 %.

The longitudinal modulus of elasticity in tension, E, of the standards must be known with a precision better than 5 per thousand.[2)]

According to the size of the pendulums used, the dimensions of the metallic standards are as shown in the following table.

Standard	Length l mm	Width b mm	Thickness h mm
Large cross-section	100 ± 2	10 ± 0,1	2 ± 0,02
Small cross-section	100 ± 2	10 ± 0,1	0,8 ± 0,02

NOTE – It is possible to determine the three characteristics A, B and C by applying to the two coupled pendulums the formula derived from the theories of elasticity. However, the measurements of dimensions and mass, the determination of the centre of gravity and of the oscillation time of the synchronous pendulum seem more delicate than the determination of the characteristics by use of the standards proposed here; the results of the two methods are in good agreement.

1) As an example, the following metals have been used for the preparation of the metallic standards :

Metal	Density ρ	Longitudinal modulus of elasticity in tension E
	t/m^3	GPa
Steel	7,7	196
Copper	8,93	118
Aluminium	2,69	72,6

2) To achieve this, use ISO/R 527.

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