INTERNATIONAL STANDARD

ISO 11093-8

Second edition
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Paper and board — Testing of cores —

Part 8: Determination of natural frequency and flexural modulus by experimental modal analysis

Papier et carton — Essais des mandrins —

Partie 8: Détermination de la fréquence propre et du module de flexion par analyse modale expérimentale

Reference number
ISO 11093-8:2012(E)

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 11093-8 was prepared by Technical Committee ISO/TC 6, *Paper, board and Pulps*.

This second edition cancels and replaces the first edition (ISO 11093-8:1997), which has been technically revised.

ISO 11093 consists of the following parts, under the general title *Paper and board — Testing of cores*:

— Part 1: Sampling

— Part 2: Conditioning of test samples

— Part 3: Determination of moisture content using the oven drying method

— Part 4: Measurement of dimensions

— Part 5: Determination of characteristics of concentric rotation

— Part 6: Determination of bending strength by the three-point method

— Part 7: Determination of flexural modulus by the three-point method

— Part 8: Determination of natural frequency and flexural modulus by experimental modal analysis

— Part 9: Determination of flat crush resistance

Paper and board — Testing of cores —

Part 8: Determination of natural frequency and flexural modulus by experimental modal analysis

1 Scope

This part of ISO 11093 specifies a method for the determination of the flexural modulus by using experimentally measured natural frequencies in the free-free mode of transverse vibration of cylindrical paper and board cores, which meet the following criteria:

— internal diameter: 50 mm to 350 mm;

— minimum wall thickness: 0,02 × internal diameter or not less than 2,0 mm;

— minimum length of core: 8 × internal diameter.

NOTE For the determination of the flexural modulus by the three-point method, see ISO 11093-7.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 11093-1, *Paper and board — Testing of cores — Part 1: Sampling*

ISO 11093-2, *Paper and board — Testing of cores — Part 2: Conditioning of test samples*

ISO 11093-3, *Paper and board — Testing of cores — Part 3: Determination of moisture content using the oven drying method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
natural frequency
f_1
first frequency which is the lowest natural frequency a structure vibrates in, depending on its material, shape and supporting system, when an impulse is applied to it

3.2
flexural modulus
E
material property which, together with core dimensions, describes the resistance of the core to bending deflection

3.3
rotational speed factor
S_f
core E-modulus divided by its density (E/ρ) which can be used to estimate vibration performance of cores

NOTE 1 Cores with equal dimensions, eccentricity and speed factor deliver at identical chucking conditions an equal resonance frequency

NOTE 2 The higher the speed factor the higher the resonance frequency.

4 Principle

In the experimental modal analysis, the test piece is considered as a "beam" and Timoshenko's beam theory for isotropic materials is applied in evaluating transverse vibration. In this theory the influence of rotary inertia and shear deformations on transverse vibrations are included. During the test, the test piece is suspended so that it is free to vibrate in the transverse direction. The flexural modulus is calculated as described in 8.1.

5 Apparatus

5.1 Test-piece suspension

The basic idea is to measure the first natural frequency in the free-free mode of transverse vibration. To ensure free-free boundary conditions in the lateral direction, the test piece is supported by a wire and hanging with its axis in the vertical direction (see Figure 1). The minimum length of the support wire (1) is about 300 mm. The supporting system consists of two clamps and the wire. An example of attaching the clamps is shown in Figure 2. The mass of the clamps should be less than 0,01 × mass of the test piece. The angle α (see Figure 2) should be more than 45°. The distance of the fixing screw from the edge of the core should be 5 mm to 10 mm.

5.2 The experimental modal analysis system

The first natural frequency is measured with a signal analyser. The test piece is impacted by a hammer in the direction (Z-direction) perpendicular to the plane of the support wires (XY-plane) (see Figure 1). The impulse response is measured by a piezoelectric accelerometer at one end of the test piece mounted with its axis in the Z-direction (see Figure 1). The sensitivity of the accelerometer shall be 8 mV/g to 100 mV/g; the frequency range limit of the accelerometer shall be 0,1 Hz to 10 000 Hz. The measured signal is analysed using a signal analyser and the frequency of the lowest mode of bending vibrations is determined from the frequency response function.

6 Test piece

6.1 Sampling

Samples shall be taken in accordance with ISO 11093-1, but it has to be ensured that the core is not damaged.

6.2 Test-piece size

The minimum length of the test piece shall be 8 times the internal diameter of the core.

NOTE 1 If the test piece is too short, it is not possible to read the response of the frequency analysis.

NOTE 2 The calculated flexural modulus E is more accurate for long test pieces.

Regarding the dimensions of the test piece, the following tolerances are specified:

— length of the core L: ±1 mm;

— outer diameter of the core D: ±0,1 mm;

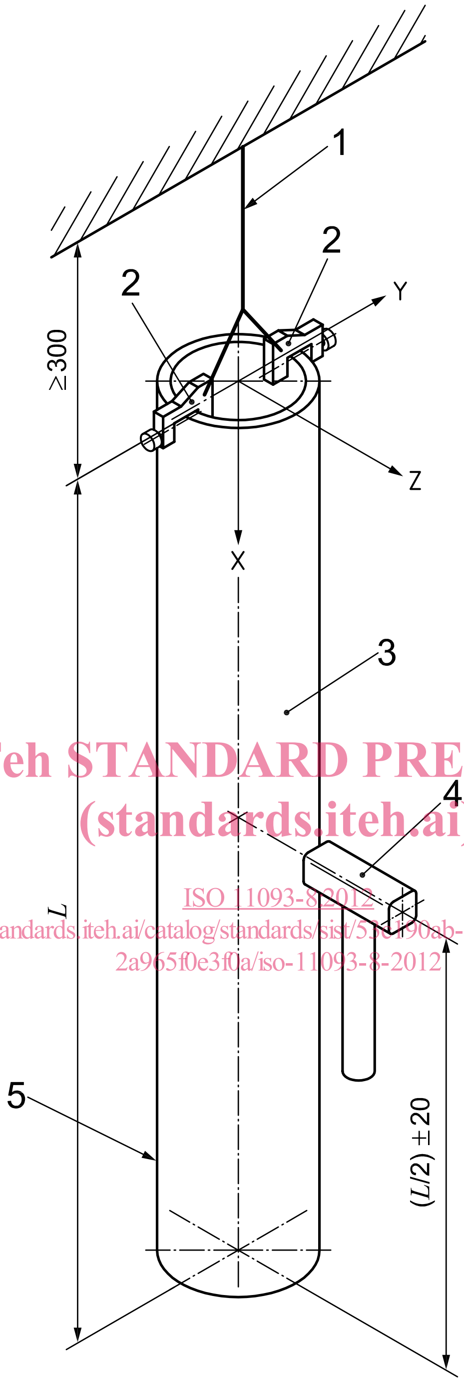
— internal diameter of the core d: ±0,1 mm.

6.3 Conditioning

The test piece shall be conditioned in accordance with ISO 11093-2. The moisture content of the test piece shall be measured in accordance with ISO 11093-3.

In practice, the test piece shall be conditioned and dried such that the moisture content shall be equal to that specified for the lot.

Dimensions in millimetres

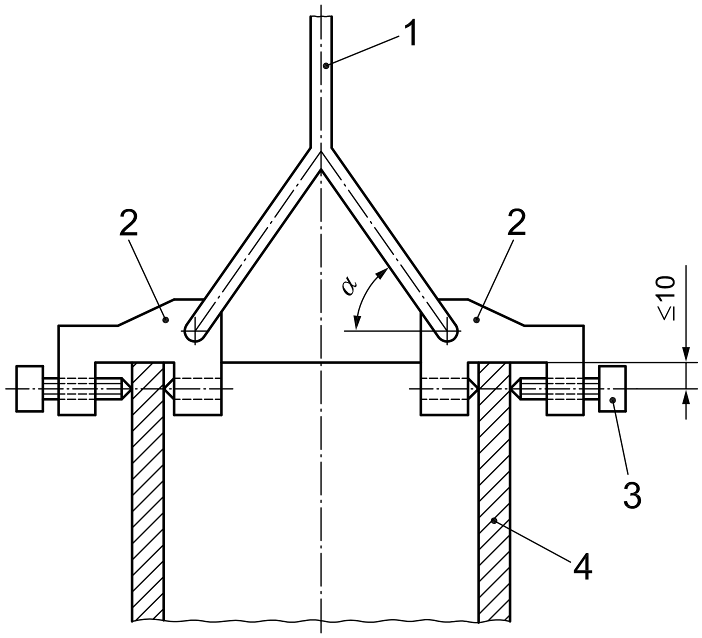


Key

1 Support wire
2 Clamps
3 Test piece
4 Hammer
5 Accelerometer

Figure 1 — Schematic drawing of the test

Dimensions in millimetres



Key

1 Support wire

2 Clamps

3 Test bolt

Figure 2 — Schematic drawing of the test-piece supension

7 Procedure

Carry out the test under the same atmospheric conditions as those used to condition the test piece.

Impact the test piece in the Z-direction in the middle of the length of the test piece by means of a hammer as shown in Figure 1. After the impact, the first natural frequency in bending shall be read from the frequency response of the analysis. The obtained value f_1 is used in Formula (1) to calculate the flexural modulus of each tested test piece.

8 Calculation

8.1 Calculation of the flexural modulus

The flexural modulus E, in megapascals, is calculated by using Formula (1):

$$E = 7{,}88 \times 10^{-8} \times \frac{f_1^2 \cdot m_L \cdot L^4 \cdot Q}{L} \quad (1)$$

where

f_1 is the natural frequency of the first order, expressed in hertz;

m_L is the length-related mass, expressed in kilograms per metre;

L is the length of the core, in millimetres;

Q is the dimensionless coefficient.

