# INTERNATIONAL STANDARD

# ISO 6721-9

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## Plastics — Determination of dynamic mechanical properties —

## Part 9:
Tensile vibration — Sonic-pulse propagation method

*Plastiques — Détermination des propriétés mécaniques dynamiques —*

*Partie 9: Vibration en traction — Méthode de propagation de signaux acoustiques*

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## 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 6721-9 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

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ISO 6721 consists of the following parts, under the general title *Plastics — Determination of dynamic mechanical properties*:

— *Part 1: General principles*

— *Part 2: Torsion-pendulum method*

— *Part 3: Flexural vibration — Resonance-curve method*

— *Part 4: Tensile vibration — Non-resonance method*

— *Part 5: Flexural vibration — Non-resonance method*

— *Part 6: Shear vibration — Non-resonance method*

— *Part 7: Torsional vibration — Non-resonance method*

— *Part 8: Longitudinal and shear vibration — Wave-propagation method*

— *Part 9: Tensile vibration — Sonic-pulse propagation method*

— *Part 10: Complex shear viscosity using a parallel-plate oscillatory rheometer*



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# Plastics — Determination of dynamic mechanical properties —

## Part 9:
## Tensile vibration — Sonic-pulse propagation method

### 1 Scope

This part of ISO 6721 describes a pulse propagation method for determining the storage component of the complex tensile modulus $E^*$ of polymers at discrete frequencies typically in the range 3 kHz to 10 kHz. The method is suitable for measuring materials with storage moduli in the range 0,01 GPa to 200 GPa and with loss factors below 0,1 at around 10 kHz. With materials having a higher loss, significant errors in velocity measurement are introduced through decay of amplitude.

The method allows measurements to be made on thin films or fine fibres and long specimens, typically tapes of 300 mm x 5 mm x 0,1 mm or fibres of 300 mm x 0,1 mm (diameter).

This method may not be suitable for cellular plastics, composite plastics and multilayer products.

### 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to use the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 1183:1987, Plastics - Methods for determining the density and relative density of non-cellular plastics.

ISO 6721-1:1994, Plastics - Determination of dynamic mechanical properties - Part 1: General principles.



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## 3 Definitions

See ISO 6721-1, Clause 3.

### 3.1 Longitudinal sonic pulse

A single sonic pulse where the deformations coincide with the direction of propagation of the pulse.

## 4 Principle

Measurements are made of the velocity of a single longitudinal sonic wave in a longitudinal thin specimen. The velocity of the longitudinal wave is determined by measuring the transit time of a sonic pulse between two transducers attached to the specimen over a frequency range from 3 kHz to 10 kHz. A sonic pulse is transmitted along the length of the specimen. The velocity is independent on the specimen geometry, if the sonic velocity is measured in a long, thin specimen. The tensile storage modulus is calculated from the product of specimen density and the square of sonic velocity.

## 5 Test device

### 5.1 Apparatus

The requirements for the apparatus shall enable measurement of the velocity of a longitudinal sonic pulse in a specimen.

Figure 1 shows schematically an example for measuring pulse velocity in a test specimen between the transmitting and receiving transducers.

### 5.2 Transducers

Two Piezoelectric transducers having a resonant frequency in the range from about 3 kHz to 10 kHz shall be mounted on the frame so that the direction of the vibration of each transducer accurately coincides with the direction to the position of the other transducer. A mechanical pulse having longitudinal displacement in the test specimen is generated by the transmitting transducer. A pulse propagated through a test specimen is detected by the receiving transducer. One transducer must be movable so that the distance between them can be varied from about 50 mm to 500 mm, and accurately measured to $\pm 0,5$ % of the distance between the transducers.



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### 5.3 Transducer drive unit

This unit shall provide a suitable pulse voltage for the transmitting transducer to produce a sonic pulse.

### 5.4. Pulse arrival time measuring equipment

This instrument shall be capable of measuring the time interval between two pulses, one from transducer drive unit and the other from receiving transducer to an accuracy $\pm 0,5\ \mu s$.

NOTE 1 The time interval will depend upon the distance between the transmitting and receiving transducers and the sonic wave velocity in the material.

### 5.5 Temperature measurement and control equipment

See ISO 6721-1, Subclause 5.5.

## 6 Test specimens

See ISO 6721-1, Clause 6.

### 6.1 Shape and dimensions

Test specimens in the form of a thin film or fibre are suitable. The dimensions are not critical, however, specimens 200 mm to 500 mm in length, 1 mm to 10 mm in width, and 0,1 mm to 1 mm in thickness or diameter are suitable.

### 6.2 Preparation

See ISO 6721-1, Subclause 6.2.

## 7 Number of specimens

See ISO 6721-1, Clause 7.

## 8 Conditioning



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See ISO 6721-1, Clause 8.

## 9 Procedure

### 9.1 Test atmosphere

See ISO 6721-1, Subclause 9.1.

### 9.2 Mounting the specimen

Place a specimen in the apparatus so that the received pulse has a suitable amplitude to determine its arrival time. Poor contact between the specimen and the transducers makes the pulse energy inadequate for determining the pulse propagation time.

For not rigid specimens, apply a small tension to the specimen to make it tight, but not stretched.

### 9.3 Performing the test

**9.3.1** Position the transducers so that the longitudinal pulse will be transmitted through the specimen. The separation distance between them is determined so that the pulse arrival time shall be at least 100 $\mu$s for good accuracy (See note 2). Measure the separation distance of the transducers, L(m) to an accuracy of $\pm 0,5$ %.

NOTE 2 Since most plastic materials will have a pulse velocity between 1 and $2,5 \times 10^3$ m/s, the minimum separation distance will generally be 0,1 m to 0,25 m.

**9.3.2** Apply a sonic pulse to the specimen, and measure the arrival time $t_A$ (s) to an accuracy of $\pm 0,5$ $\mu$s.

**9.3.3** Repeat the measurements descibed in 9.3.1 and 9.3.2 for the same specimen at least three different separation distances between the transducers. In order to get good accuracy the values of the distance should be selected so as to be distributed uniformly within the whole range of the distance suitable for determining the arrival time (See figure 2).

**9.3.4** Measure the density of the test specimen, $\rho$ (kgm$^{-3}$) at the same temperature that the pulse arrival time is measured to an accuracy of $\pm 0,5$ % using one of the procedures described in ISO 1183.



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## 9.4 Varying the temperature

See ISO 6721-1, Subclause 9.4.

## 10 Expression of the results

### 10.1 Nomenclature

$E'$ (Pa) - tensile storage modulus

$L$ (m) - transducer separation distance

$L_i$ (m) - transducer separation distance for ith measurement

$t_A$ (s) - observed pulse arrival time

$t_{Ai}$ (s) - observed pulse arrival time corresponding to $L_i$

$V_L$ ($ms^{-1}$) - longitudinal wave velocity in the specimen

$\rho$ ($kgm^{-3}$) - specimen density

### 10.2 Calculation of the longitudinal wave velocity

The wave velocity, $V_L$ is given by the slope, $\Delta L/\Delta t_A$ of the plots of $L_i$ vs $t_{Ai}$. The value of the slope shall be obtained from at least three measurements at different distance of the transducer separation, analysing the data with linear regression (See figure 2).

$$V_L = \Delta L/\Delta t_A$$

### 10.3 Calculation of the tensile storage modulus, E'

The tensile storage modulus, E' is calculated using the following equation.

$$E' = \rho V_L^2$$

## 11 Precision

The precision of this test method is not known because inter-laboratory data are not available. When inter-laboratory data are obtained, a preci-



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sion statement will be added with the next revision.

## 12 Test report

The test report shall contain the following informations:

a) reference to this part of ISO 6721;
b) to l) see ISO 6721-1, Subclause 12; and
m) sonic wave frequency used.

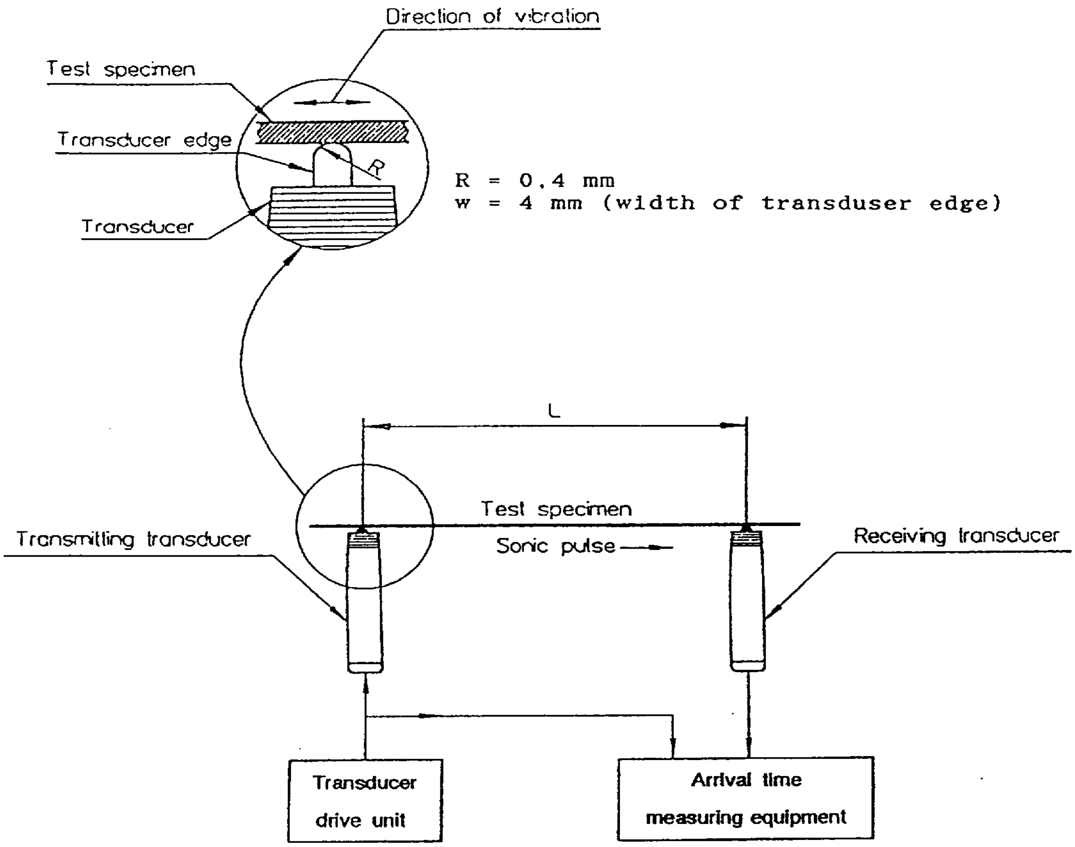


Figure 1 - Schematic diagram of suitable apparatus for measuring pulse velocity between a transmitting and a receiving transducer



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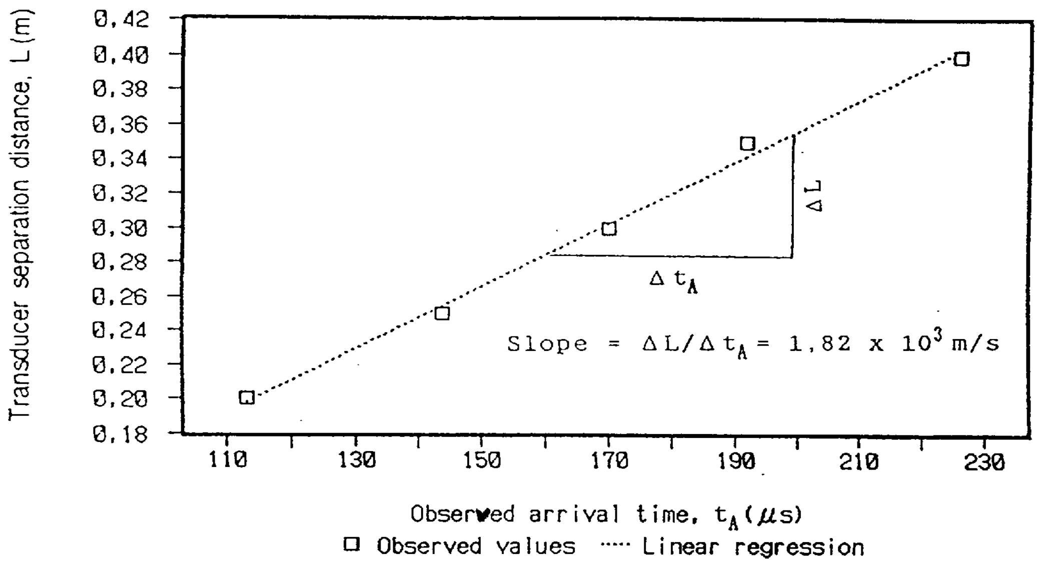


Figure 2 - Linear regression of distance and arrival time



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