INTERNATIONAL

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Standard Test Method for Plastics: Dynamic Mechanical Properties: In Tension[1]

~~ε1 NOTE—Reapproved with an editorial change made to 10.1 in October 2014.~~

1. Scope*

1.1 This test method outlines the use of dynamic mechanical instrumentation for gathering and reporting the viscoelastic properties of thermoplastic and thermosetting resins and composite systems in the form of rectangular specimens molded directly or cut from sheets, plates, or molded shapes. The tensile data generated may be used to identify the thermomechanical properties of a plastic material or composition using a variety of dynamic mechanical instruments.

1.2 This test method is intended to provide a means for determining viscoelastic properties of a wide variety of plastic materials using nonresonant forced-vibration techniques, in accordance with Practice D4065. Plots of the elastic (storage) modulus; loss (viscous) modulus; complex modulus and tan delta as a function of frequency, time, or temperature are indicative of significant transitions in the thermomechanical performance of the polymeric material system.

1.3 This test method is valid for a wide range of frequencies, typically from 0.01 to 100 Hz.

1.4 Apparent discrepancies may arise in results obtained under differing experimental conditions. These apparent differences from results observed in another study can usually be reconciled, without changing the observed data, by reporting in full (as described in this test method) the conditions under which the data were obtained.

1.5 Due to possible instrumentation compliance, the data generated are intended to indicate relative and not necessarily absolute property values.

1.6 Test data obtained by this test method are relevant and appropriate for use in engineering design.

1.7 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This test method is technically equivalent to ISO 6721, Part 4.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D4000 Classification System for Specifying Plastic Materials
D4065 Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures
D4092 Terminology for Plastics: Dynamic Mechanical Properties
IEEE/ASTM SI-10 Practice for Use of the International System of Units (SI) (the Modernized Metric System)

2.2 *ISO Standard:*[3]

ISO 6721, Part 4 Plastics—Determination of Dynamic Mechanical Properties, Part 4: Tensile Vibration—Non-Resonance Method

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.10 on Mechanical Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

***A Summary of Changes section appears at the end of this standard**

3. Terminology

3.1 *Definitions*—For definitions applicable to this test method refer to Terminology D4092.

4. Summary of Test Method

4.1 This test method covers the determination of the viscoelastic properties of a plastic material using dynamic mechanical techniques in tension. A test specimen of rectangular cross section is tested in dynamic tension. The specimen is gripped longitudinally between two clamps. The specimen is placed in mechanical linear tensile displacement at fixed frequencies ~~and at either isothermal conditions or with a linear temperature variation.~~with a linear temperature variation or variable frequencies at isothermal conditions. The elastic moduli or loss moduli, or both, of the polymeric material system are measured in tension.

NOTE 2—The particular method for measurement of the elastic and loss moduli and tan delta depends upon the individual instrument's operating principles.

5. Significance and Use

5.1 This test method provides a simple means of characterizing the thermomechanical behavior of plastic materials using very small amounts of material. The data obtained may be used for quality control, research and development, as well as the establishment of optimum processing conditions.

5.2 Dynamic mechanical testing provides a sensitive method for determining thermomechanical characteristics by measuring the elastic and loss moduli as a function of frequency, temperature, or time. Plots of moduli and tan delta of a material versus these variables can be used to provide graphical representation indicative of functional properties, effectiveness of cure (thermosetting resin system), and damping behavior under specified conditions.

5.3 This test method can be used to assess:

5.3.1 Modulus as a function of temperature,

5.3.2 Modulus as a function of frequency,

5.3.3 The effects of processing treatment, including orientation,

5.3.4 Relative resin behavioral properties, including cure and damping,

5.3.5 The effects of substrate types and orientation (fabrication) on elastic modulus, ~~and~~

5.3.6 The effects of formulation additives which might affect processability or ~~performance.~~performance,

5.3.7 The effects of annealing on modulus and glass transition temperature,

5.3.8 The effect of aspect ratio on the modulus of fiber reinforcements, and

5.3.9 The effect of fillers, additives on modulus and glass transition temperature.

5.4 Before proceeding with this test method, reference should be made to the specification of the material being tested. Any test specimen preparation, conditioning, dimensions, or testing parameters, or combination thereof, covered in the relevant ASTM materials specification shall take precedence over those mentioned in this test method. If there are no relevant ASTM material specifications, then the default conditions apply.

6. Interferences

6.1 Since small test specimen geometries are used, it is essential that the specimens be representative of the polymeric material being tested.

7. Apparatus

7.1 The function of the apparatus is to hold a rectangular test specimen of a polymeric material system so that the material acts as the elastic and dissipative element in a mechanically driven linear displacement system. Dynamic mechanical instruments described in this test method generally operate in a forced, constant amplitude, at a fixed frequency.

7.2 The apparatus shall consist of the following:

7.2.1 *Fixed Member*—A fixed or essentially stationary member carrying one grip.

7.2.2 *Movable Member*—A movable member carrying a second grip.

7.2.3 *Grips*—Grips for holding the test specimen between the fixed member and the movable member. The grips shall be mechanically aligned, that is, they shall be attached to the fixed and movable member, respectively, in such a manner that they will move freely into alignment as soon as any load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

7.2.3.1 The test specimen shall be held in such a way that slippage relative to the grips is prevented as much as possible.

7.2.4 *Linear Deformation (Strain) Device*—A device for applying a continuous linear deformation (strain) to the specimen. In the force-displacement device the deformation (strain) is applied and then released (see Table 1 of Practice D4065).

7.2.5 *Detectors*—A device or devices for determining dependent and independent experimental parameters, such as force (stress), deformation (strain), frequency, and temperature. Temperature should be measurable with a precision of ±1°C, frequency to ±1 %, strain to ±1 %, and force to ±1 %.

7.2.6 *Temperature Controller and Oven*—A device for controlling the temperature, either by heating (in steps or ramps), cooling (in steps or ramps) or maintaining a constant specimen environment, or a combination thereof. A temperature controller should be sufficiently stable to permit measurement of environmental chamber temperature to within 1°C.

7.3 *Nitrogen,* or other inert gas supply, for purging purposes, if appropriate.

8. Test Specimens

8.1 The test specimens may be cut from sheets, plates, or molded shapes, or may be molded to the desired finished dimensions. Any rectangular specimen (representative of the material being tested and within the fixturing capabilities of the test equipment) may be used as long as it is clearly described in the test report.

9. Calibration

9.1 Calibrate the instrument using procedures recommended by the manufacturer.

10. Conditioning

10.1 Condition the test specimens at 23.0 ± 2.0°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not fewer than 40 h prior to test in accordance with Procedure A of Practice D618 unless otherwise specified by contract or relevant ASTM material specification.

11. Procedure

11.1 Use an untested specimen for each measurement. Measure the width and thickness of the specimen to the nearest 0.03 mm (0.001 in.) at the center of the specimen.

11.2 Clamp the test specimen between the movable and stationary members; use shim stock, if necessary, to minimize slippage within the clamp.

11.3 Pre-load the test specimen so that there is a positive force. Monitor the normal force to ensure adequate pre-loading.

11.4 Measure to the nearest 0.03 mm (0.001 in.) the jaw separation between the movable and stationary members.

11.5 Select the desired frequency (or frequencies) for dynamic linear displacement.

11.6 Select the linear-displacement amplitude within the linear elastic region of the material being tested. If the linear elastic region is not known, perform a strain sweep at ambient temperature to determine an appropriate amplitude.

11.7 *Temperature Sweep:*

11.7.1 Temperature increases should be controlled to 1 to 2°C for linear increases and 2 to 5°C/min with a minimum of 1-min thermal-soak time for step increases.

11.7.2 The tan delta peak shall coincide with the dramatic change in modulus through the glass transition region.

12. Calculation

12.1 The equations listed in Practice D4065 are used to calculate the following important rheological properties measured in forced, nonresonant dynamic ~~displacement:~~displacement where:

E' = storage (elastic) modulus in bending,
E'' = loss (viscous) modulus in bending,
E^* = complex modulus in bending, and
$Tan\delta$ = tan delta.

~~12.1.1 Storage (elastic) modulus in tension, *E′*,~~
~~12.1.2 Loss (viscous) modulus in tension, *E″*,~~
~~12.1.3 Complex modulus in tension, *E**, and~~
~~12.1.4 Tan delta, *d**.~~

13. Report

13.1 Report the following information:

13.1.1 Complete identification of the material tested, including type, source, manufacturer's code, number, form, principal dimensions and previous processing, or thermal history, or both, if available,

13.1.2 Description and direction of cutting and loading specimen, including preload force,

13.1.3 Conditioning procedure,

13.1.4 Description of the instrument used for the test,

13.1.5 Description of the calibration procedure,

13.1.6 Identification of the sample atmosphere by gas composition, purity, and rate used, if appropriate,

13.1.7 Width and thickness of specimen,