Designation: D5023 – 15

Standard Test Method for Plastics: Dynamic Mechanical Properties: In Flexure (Three-Point Bending) [1]

This standard is issued under the fixed designation D5023; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method outlines the use of dynamic mechanical instrumentation for determining and reporting the visco-elastic properties of thermoplastic and thermosetting resins and composite systems in the form of rectangular bars molded directly or cut from sheets, plates, or molded shapes. The data generated, using three-point bending techniques, may be used to identify the thermomechanical properties of a plastic material or compositions using a variety of dynamic mechanical instruments.

1.2 This test method is intended to provide means for determining the viscoelastic properties of a wide variety of plastics 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 polymeric material systems.

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 the 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 equivalent to ISO 6721, Part 5.

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

2.2 *ISO Standard:*[3]

ISO 6721, Part 5 Plastics—Determination of Dynamic Mechanical Properties Part 5: Flexural Vibration—Non-Resonance Method

3. Terminology

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

4. Summary of Test Method

4.1 A specimen of rectangular cross section is tested in flexure as a beam. The bar rests on two supports and is loaded by means of a loading nose midway between the supports. Using three-point bending, the test specimen is placed in mechanical linear displacement at fixed frequencies with linear temperature variation or variable frequencies at isothermal conditions. The elastic moduli or loss moduli, or both, of the polymeric material system are measured.

NOTE 2—The particular method for measurement of the elastic and loss

---

[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.

Current edition approved July 1, 2015. Published July 2015. Originally approved in 1989. Last previous edition approved in 2007 as D5023 - 07. DOI: 10.1520/D5023-15.

[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**

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 compositions 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 means 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 a 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,

5.3.4 Relative resin behavioral properties, including cure and damping.

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

5.3.6 The effects of formulation additives which might affect processability or 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, refer 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 mode at a fixed frequency.

7.2 The apparatus shall consist of the following:

7.2.1 *Loading Nose and Supports*—The loading nose and supports shall have cylindrical surfaces having a sufficient radius to avoid excessive indentation or failure due to stress concentration directly under the loading nose.

7.2.2 *Linear Deformation (strain)*—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).

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

7.2.4 *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. Typically, the support span shall be 16 (tolerance +4 or −2) times the depth of the beam. Specimens shall be long enough to allow overhanging on each end of at least 10 % of the support span, but in no case less than 6.4 mm (0.25 in.) on each end. Overhang shall be sufficient to prevent the specimen from slipping through the supports. A typical rectangular test beam is 64 by 13 by 3 mm (2.5 by 0.5 by 0.125 in.) tested flatwise on a 50 mm (2 in.) support span, resulting in a span to depth ratio of 16. Rectangular test specimens of other dimensions can be used but should be clearly identified in the report section.

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°C (73.4 ± 3.6°F) and 50 ± 10 % relative humidity for not less 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, such as temperature or time sweep. Measure the width and depth of the specimen to the nearest 0.03 mm (0.001 in.) at its center.

11.2 Center the specimen on the supports, with the long axis of the specimen perpendicular to the loading nose and supports.

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

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

11.5 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.

11.6 *Temperature Sweep:*

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

11.6.2 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 where:

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

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 Direction of cutting and loading specimen, including pre-load 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 Depth and width of specimen,

13.1.8 Support span length,

13.1.9 Support span-to-depth ratio,

13.1.10 Radius of supports and loading nose,

13.1.11 Frequency of dynamic displacement,

13.1.12 Amplitude of displacement,

13.1.13 Thermal gradient; heating gradient, if appropriate,

13.1.14 Number of specimens tested,

13.1.15 Table of data and results, including moduli and tan delta as a function temperature, frequency, strain, or time (as appropriate), and

13.1.16 A plot of the modulus (moduli) and tan delta as a function of temperature (see Fig. 1), frequency, strain, or time (as appropriate).

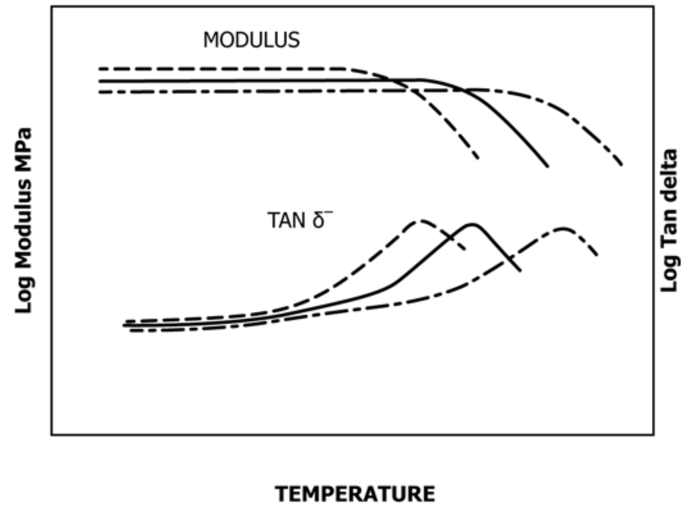

FIG. 1 Dynamic Mechanical Properties in Three-Point Bending (at Different Frequencies)

14. Precision and Bias

14.1 The repeatability standard deviation has been determined for the materials shown in Table 1. A single laboratory evaluated four thermoplastic neat resins and composites and the values shown were obtained with the same test method in the same laboratory by the same operator using the same equipment in the shortest practical period of time using test specimens taken at random from a single quantity of homogeneous material.

TABLE 1 DMA Three-Point Bending, Elastic Modulus, E' (E^{10} Pa) or (E^{11} dynes/cm^2) at Selected Temperatures

Material	Temperature, °C				
	40	60	80	100	120
Polycarbonate:					
Mean	2.302	2.319	2.187	2.079	1.818
Standard deviation	0.044	0.078	0.073	0.042	0.005
Polypropylene:					
Mean	1.242	0.5744	0.2893	0.1835	. . .
Standard deviation	0.255	0.0553	0.0151	0.0117	. . .
ABS:					
Mean	2.294	2.232	1.461	. . .	. . .
Standard deviation	0.011	0.004	0.052	. . .	. . .
Glass Reinforced Polycarbonate:					
Mean	4.014	3.970	3.883	3.687	3.582
Standard deviation	0.130	0.087	0.118	0.064	0.134

15. Keywords

15.1 dynamic mechanical rheological properties; elastic; flexural viscoelastic behavior; linear displacement; loss; storage modulus; tan delta

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D5023 - 07) that may impact the use of this standard. (July 1, 2015)

(1) Revised 4.1, 10.1, 12.1, and 13.1.13.
(2) Added 5.3.7, 5.3.8, and 5.3.9.
(3) Revised title of Table 1.