Designation: D5418 – 15

Standard Test Method for Plastics: Dynamic Mechanical Properties: In Flexure (Dual Cantilever Beam)[1]

This standard is issued under the fixed designation D5418; 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 viscoelastic 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 elastic modulus data generated may be used to identify the thermomechanical properties of a plastics material or composition.

1.2 This test method is intended to provide a means for determining the viscoelastic properties of a wide variety of plastics using nonresonant, forced-vibration techniques as outlined in Practice D4065. In particular, this method identifies the procedures used to measure properties using what is known as a dual-cantilever beam flexure arrangement. Plots of the elastic (storage) modulus, loss (viscous) modulus, and 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 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 Test data obtained by this test method are relevant and appropriate for use in engineering design.

1.6 The values stated in SI units are to be regarded as standard.

1.7 *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—There is no known ISO equivalent to this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing

D4065 Practice for Plastics: Dynamic Mechanical Properties: Determination and Report of Procedures

D4092 Terminology for Plastics: Dynamic Mechanical Properties

D5279 Test Method for Plastics: Dynamic Mechanical Properties: In Torsion

3. Terminology

3.1 For definitions applicable to this practice see Terminology Standard D4092.

4. Summary of Test Method

4.1 This test method covers the determination of the elastic modulus of plastics using dynamic mechanical techniques. A bar of rectangular cross section is tested as a beam in dynamic linear displacement or bending. The dual-cantilever beam specimen is gripped between two clamps. The specimen of known geometry is placed in mechanical linear displacement, with the displacement strain or deformation applied at the center of the dual-cantilever beam. The forced-strain displacement is at either a fixed frequency or variable frequencies, and at either isothermal conditions or with a linear temperature variation. The elastic or loss modulus, or both, of the polymeric material system are measured in flexure.[3]

5. Significance and Use

5.1 This test method provides a simple means of characterizing the thermomechanical behavior of plastic compositions using a very small amount of material. Since small test

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

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

specimen geometries are used, it is essential that the specimens be representative of the material being tested. The data obtained can be used for quality control and/or research and development purposes. For some classes of materials, such as thermosets, it can also be used to establish 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 graphic representation indicative of functional properties, effectiveness of cure (thermosetting-resin systems), and damping behavior under specified conditions.

5.3 This test method can be used to assess the following:

5.3.1 The modulus as a function of temperature or aging, or both,

5.3.2 The modulus as a function of frequency,

5.3.3 The effects of processing treatment, including orientation, induced stress, and degradation of physical and chemical structure,

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,

5.3.6 The effects of formulation additives that 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 material 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. Apparatus

6.1 The function of the apparatus is to hold a rectangular cross-sectional bar so that the material acts as the elastic and dissipative element in a mechanically driven linear displacement system. Dynamic mechanical instruments described in this standard generally operate in a forced, constant amplitude mode at either a fixed frequency or variable frequencies.

6.2 The apparatus consists of the following:

6.2.1 *Fixed Grips*—A fixed or essentially stationary fixture consisting of two grips to secure the rectangular specimen horizontally in a dual cantilever configuration.

6.2.2 *Movable Grip*—A movable grip applying the linear displacement at the center of the rectangular beam.

6.2.3 *Grip Alignments*—The grips shall be mechanically aligned or centered, that is, they shall be attached in such a manner that they will move into alignment as soon as any load is applied.

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

6.2.4 *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).

6.2.5 *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, strain, and force to ±1 %.

6.2.6 *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.

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

7. Test Specimens

7.1 The 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) is permitted as long as it is clearly stated in the test report.

8. Calibration

8.1 Calibrate the instrument according to procedures recommended by the manufacturer.

9. Conditioning

9.1 *Conditioning*—Condition the test specimens at 23.0 ± 2.0°C 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.

10. Procedure

10.1 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.

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

10.3 Pre-load the test specimen so that there is a positive force. The positive pre-load should be sufficient to maintain a positive deflection during testing unless the test mode allows a zero-displacement measurement.

10.4 Measure the length of the specimen between the stationary end grips to the nearest 0.03 mm (0.001 in.).

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

10.6 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.

10.7 *Temperature Sweep:*

10.7.1 Temperature variations shall be controlled to 1 to 2°C/min for linear increases or to 2 to 5°C/min with a minimum of 1-min thermal-soak time for step increases.

10.8 The tan delta peak will coincide with a significant decrease in the *E*' (elastic or storage) modulus, with increasing temperature, through the glass-transition region. Another indication of the glass-transition is a maximum value of the *E*" (loss or viscous) modulus.

11. Calculation

11.1 The equations listed in Practice D4065 are used to calculate the 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.

12. Report

12.1 Report the following information:

12.1.1 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,

12.1.2 Description and direction of cutting and loading specimen, including pre-load force,

12.1.3 Conditioning procedure,

12.1.4 Description of the instrument used for the test,

12.1.5 Description of the calibration procedure,

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

12.1.7 Width and thickness of specimen,

12.1.8 Grip separation distance of the beam,

12.1.9 Frequency of dynamic displacement,

12.1.10 Amplitude of displacement,

12.1.11 Thermal gradient; heating rate, if appropriate,

12.1.12 Number of specimens tested,

12.1.13 Table of data and results, including moduli and tan delta as a function of temperature or of time as appropriate, and

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

13. Precision and Bias

13.1 The repeatability standard deviation has been determined for the following materials. A single laboratory evaluated a polyurethane sample and the values in Table 1 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. This laboratory tested the same polyurethane material used for the precision and bias statement in Test Method D5279 and obtained the results in Table 1.

TABLE 1 Dual Cantilever Beam, Elastic Modulus, E' (E^9 Pa) or (E^{10} dynes/cm^2) at Selected Temperatures

	–40°C	0°C
Mean	1.162	0.04953
Standard deviation	0.004	0.00373

14. Keywords

14.1 dual cantilever; dynamic mechanical rheological properties; linear displacement; modulus storage; viscous; loss modulus; complex; tan delta; viscoelastic behavior

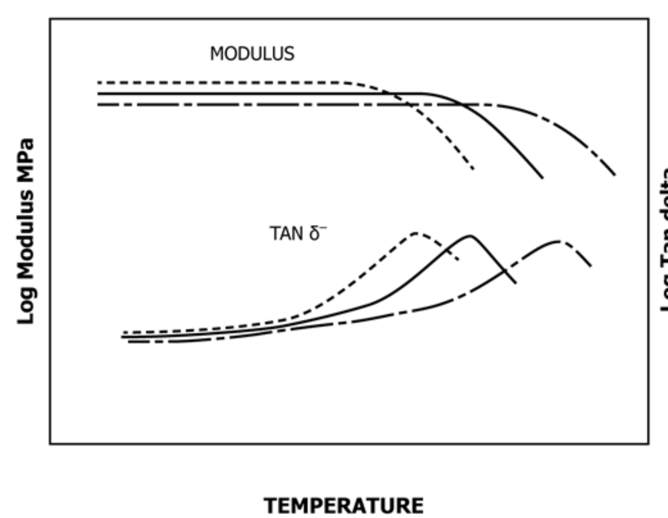

FIG. 1 Dynamic Mechanical Modulus in Bending as a Function of Temperature at Different Frequencies

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D5418 - 07) that may impact the use of this standard. (July 1, 2015)

(1) Added 5.3.7, 5.3.8, and 5.3.9.
(2) Revised 9.1, 11.1, and 12.1.11.
(3) Revised the title of Table 1.