Designation: D5279 – 21

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

This standard is issued under the fixed designation D5279; 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 covers 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 torsional 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 means for determining the torsional modulus of plastics as a function of temperature using nonresonant forced-vibration techniques, as outlined in Practice D4065. Plots of the elastic (storage), loss (viscous), and complex moduli 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 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—This test method is equivalent to ISO 6721, Part 7.

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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

3. Terminology

3.1 For definitions applicable to this test method, refer to Terminology D4092.

4. Summary of Test Method[3]

4.1 This test method covers the determination of the shear modulus of plastics using dynamic mechanical techniques. A test specimen of rectangular cross section is tested in dynamic torsion. The specimen is gripped longitudinally between two clamps. The specimen of known geometry is placed in mechanical torsional displacement at either a fixed frequency, or variable frequencies at either isothermal conditions, or with a linear temperature increase. The elastic or loss modulus, or both, of the polymeric material system are measured in torsion.

5. Significance and Use

5.1 This test method provides a simple means of characterizing the thermomechanical behavior of plastics material. The data obtained may be used for quality control, research and development, and 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

[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, 2021. Published August 2021. Originally approved in 1992. Last previous edition approved in 2013 as D5279 - 13. DOI: 10.1520/D5279-21.

[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**

frequency, temperature, or time. Plots of moduli and tan delta of a material versus temperature provide graphical representations indicative of physical and mechanical 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 The modulus as a function of temperature,
5.3.2 The 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 that might affect processability or performance.

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 materials 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 material being tested.

7. Apparatus

7.1 The function of the apparatus is to hold a rectangular test specimen so that the material acts as the elastic and dissipative element in a mechanically driven torsional system. Dynamic mechanical instruments operate at a forced, constant amplitude, and either at a fixed frequency, or variable frequencies.

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 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 minimized.
7.2.4 *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.)
7.2.5 *Detectors*—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 %, 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), 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.

8. Test Specimens

8.1 Any rectangular specimen, representative of the material being tested and within the fixturing capabilities of the specific test instrument employed, shall be used so long as an accurate description of the specimen is clearly stated in the test report.

NOTE 2—The test specimens may be cut from sheets, plates, or molded shapes, or may be molded to the desired finished dimensions.

9. Calibration

9.1 Calibrate the instrument using procedures recommended by the manufacturer.

10. Conditioning

10.1 *Conditioning*—Condition the test specimens at 23.0 ± 2.0°C and 50 ± 5 % relative humidity for not less than 40 h prior to testing in accordance with Procedure A of Practice D618, unless otherwise specified by the contract or relevant 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 at the center of the specimen and enter those dimensions into the test program using the instrument's software.

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

11.3 Preload the test specimen so that a positive normal force is maintained during the test. Monitor the normal force during testing to ensure adequate preloading.

11.4 Measure the jaw separation between the movable and stationary members to the nearest 0.03 mm and enter that dimension into the test program using the instrument's software.

NOTE 3—Tests may be conducted in several modes depending on the desired characterization requirements and the properties of interest. Generally those modes include a strain sweep during which the temperature and frequency are maintained at constant values; a frequency sweep during which the temperature and strain are maintained at constant values; a temperature sweep during which the strain and frequency are maintained at constant values or a frequency-temperature sweep during which the strain is maintained at a constant value and properties are measured across a range of frequencies at step increments of temperature.

11.5 Based on the type of test being conducted:

11.5.1 Select the frequency (or range of frequency) for dynamic-torsional displacement as desired.

11.5.2 Select the torsional-displacement amplitude (or range of amplitude) as desired, making sure it is within the material's linear elastic region.

NOTE 4—An independent strain sweep test may need to be run to establish this property.

11.5.3 Select the temperature (or range of temperature), dwell time and either ramp rate or step increments to be used if temperature is to be varied.

11.5.3.1 Temperature increases should be controlled to 1 to 2°C/min for linear increases or 2 to 5°C/min (with a minimum of 1-min thermal-soak time for step increases). These soak times should be set to assure thermal equilibrium of the test material. Appropriate soak times are generally related to the mass of the test specimen and to the ramp rate or step increment being used.

11.6 Conduct the desired test recording the appropriate data.

12. Calculations

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

where:

G' = storage (elastic) modulus in torsion,
G'' = loss (viscous) modulus in torsion,
G^* = complex modulus in torsion, and
d^* = 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 history as 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,

13.1.7 Width and thickness of specimen,

13.1.8 Jaw separation distance,

13.1.9 Frequency of dynamic displacement,

13.1.10 Amplitude of displacement,

13.1.11 Thermal gradient; heating rate,

13.1.12 Number of specimens tested,

13.1.13 Table of data including moduli, tan delta, frequency, strain, and temperature as appropriate, and

13.1.14 A plot of the modulus (moduli) and tan delta as appropriate. (See Fig. 1.)

14. Precision and Bias

14.1 The repeatability standard deviation has been determined for the following materials. Laboratory A 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. Laboratory B tested the same material and obtained the results shown in Table 1.

15. Keywords

15.1 dynamic mechanical rheological properties; elastic; loss; storage; tan delta; torsional shear modulus; viscoelastic behavior; viscous

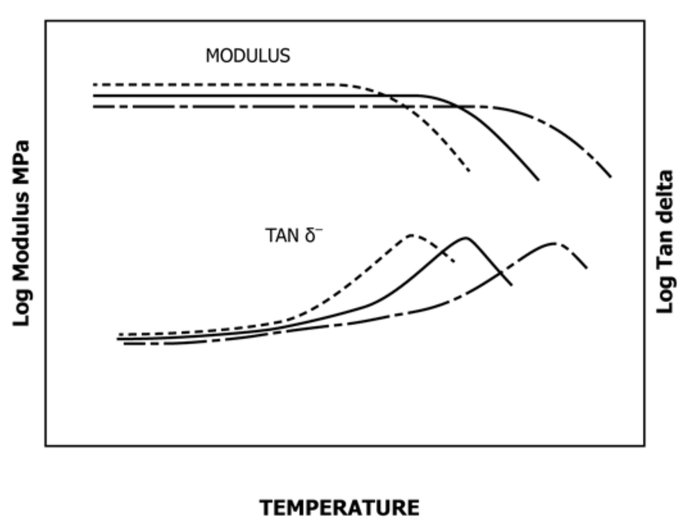

FIG. 1 Dynamic Mechanical Modulus in Torsion as a Function of Temperature