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Standard Test Method for Measuring the Dynamic Mechanical Properties of Plastics Using Three-Point Bending[1]

This standard is issued under the fixed designation D 5023; 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 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 plastics material or composition using a variety of dynamic mechanical instruments.

1.2 This test method is intended to provide means for determining the modulus as a function of temperature for a wide variety of plastics materials using nonresonant forced-vibration techniques, in accordance with Practice D 4065. 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 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 is 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—There is no similar or equivalent ISO standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 4000 Classification System for Specifying Plastic Materials[3]

D 4065 Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics[3]

D 4092 Terminology Relating to Dynamic Mechanical Measurements on Plastics[3]

3. Terminology

3.1 *Definitions:* For definitions applicable to this test method refer to Terminology D 4092.

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. The test specimen of known geometry is placed in mechanical linear displacement at fixed frequencies at either isothermal conditions or with linear temperature increases. The elastic moduli or loss moduli, or both, of the polymeric material system are measured using three-point bending.

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 plastics materials using very small amounts of 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 test method for determining thermomechanical characteristics by measuring the elastic and loss moduli as a function of

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[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 08.02.

***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 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, and

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

5.4 For many materials, there may be a specification that requires the use of this test method, but with some procedural modifications that take precedence when adhering to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification System D 4000 lists the ASTM materials standards that currently exist.

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 operate in a forced, constant amplitude and 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 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 D 4065).

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

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 support span, resulting in a support-to-span ratio of 16 (tolerance +4 or −2). 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 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618 for those tests where conditioning is required.

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 the center of the support span.

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.

11.6 *Temperature Sweep*:

11.6.1 Temperature increases should be controlled to 1 to 2°C/min for linear increases and 2 to 5°C/min with a minimum of 3-min thermal soak time for step increases. This will allow characterizing the modulus from the glassy region, through the glass-transition region, up to the softening or leathery-rubbery state.

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 D 4065 are used to calculate the following important rheological properties measured in forced, nonresonant dynamic displacement:

12.1.1 Storage (elastic) modulus in bending, E',

12.1.2 Loss (viscous) modulus in bending, E'',

12.1.3 Complex modulus in bending, 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