



Designation: D 4440 – 01

Standard Test Method for Plastics: Dynamic Mechanical Properties Melt Rheology¹

This standard is issued under the fixed designation D 4440; 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 approval. 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 use in gathering and reporting the rheological properties of thermoplastic resins. It may be used as a test method for determining the complex viscosity and significant viscoelastic characteristics of such materials as a function of frequency, strain amplitude, temperature, and time. Such properties may be influenced by fillers and other additives.

1.2 It incorporates a laboratory test method for determining the relevant rheological properties of a polymer melt subjected to various oscillatory deformations on an instrument of the type commonly referred to as mechanical or dynamic spectrometer.

1.3 This test method is intended to provide means of determining the rheological properties of molten polymers, such as thermoplastics and thermoplastic elastomers over a range of temperatures by nonresonant forced-vibration techniques. Plots of modulus, viscosity, and tan delta as a function of dynamic oscillation (frequency), strain amplitude, temperature, and time are indicative of the viscoelastic properties of a molten polymer.

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

1.5 This test method is intended for homogenous and heterogenous molten polymeric systems and composite formulations containing chemical additives, including fillers, reinforcements, stabilizers, plasticizers, flame retardants, impact modifiers, processing aids, and other important chemical additives often incorporated into a polymeric system for specific functional properties, and which could affect the processability and functional performance. These polymeric material systems have molten viscosities less than 10^6 Pa·s (10^7 poise).

1.6 Apparent discrepancies may arise in results obtained under differing experimental conditions. Without changing the observed data, reporting in full (as described in this test method) the conditions under which the data were obtained will enable apparent differences observed in another study to be reconciled.

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

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

1.9 *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 10.

2. Referenced Documents

2.1 ASTM Standards:²

D 4000 Classification System for Specifying Plastic Materials

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

D 4092 Terminology Relating to Dynamic Mechanical Measurements on Plastics

2.2 ISO Standard:³

ISO 6721, Part 10 Plastics— Determination of Dynamic Mechanical Properties, Part 10, Complex Shear Viscosity Using a Parallel-Plate Oscillatory Rheometer

3. Terminology

3.1 *Definitions:* Definitions are in accordance with Terminology D 4092.

4. Summary of Test Method

4.1 A known amount of thermoplastic resin (molten powder or pellet, or solid preform disk) is placed in mechanical oscillation at a fixed or varying frequency at isothermal conditions or over a linear temperature increase or a time-temperature relation simulating a processing condition. Storage (elastic) G' or loss (viscous) moduli, G'' , or both, or the corresponding dynamic viscosity functions $n' = g''/w$ and $n'' = g'/w$, of the polymeric material specimen are measured in shear as a function of frequency, strain, temperature, or time.

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.

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

5. Significance and Use

5.1 This test method provides a simple means of characterizing the important rheological properties and viscosity of thermoplastic resins using very small amounts of material (approximately 25 to 50 mm in diameter by 1 to 3 mm in thickness ... approximately 3 to 5 g). Data 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 molten polymer properties by measuring the elastic and loss moduli as a function of frequency, strain, temperature, or time. Plots of viscosity, storage, and loss moduli, and tan delta as a function of the aforementioned process parameters provide graphical representation indicative of molecular weight, molecular weight distribution, effects of chain branching, and melt-processability for specified conditions.

5.3 Values obtained in this test method can be used to assess the following:

5.3.1 Complex viscosity of the polymer melt as a function of dynamic oscillation,

5.3.2 Processing viscosity, minimum as well as changes in viscosity as a function of experimental parameters,

5.3.3 Effects of processing treatment,

5.3.4 Relative resin behavioral properties, including viscosity and damping, and

5.3.5 Effects of formulation additives that 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 quantities of resin are used, it is essential that the specimens be homogeneous and representative.

6.2 Toxic or corrosive effluents, or both, may be released when heating the resin specimen to its molten state and could be harmful to personnel or to the instrumentation.

6.3 Entrapped air/gas may affect the results obtained using powder or pellet samples.

7. Apparatus

7.1 The function of the apparatus is to hold a molten polymer of known volume and dimensions so that the material acts as the elastic and dissipative element in a mechanically driven oscillatory system, as outlined in Practice D 4065. These instruments operate in one or more of the following modes for measuring rheological behavior in dynamic oscillatory shear: (1) forced constant amplitude, fixed frequency, (2) forced constant amplitude, varying frequency, and (3) forced varying amplitude, fixed frequency.

7.2 The apparatus shall consist of the following:

7.2.1 *Test Fixtures*—A choice of either polished cone and plate, having a known cone angle, or parallel plates having

either smooth, polished, or serrated surface. Variations of this tooling, such as bottom plates with concentric overflow rims, can be used as necessary.

7.2.2 *Oscillatory Deformation (Strain)*—A device for applying a continuous oscillatory deformation (strain) to the specimen.

7.2.3 *Detectors*—A device or devices for determining dependent and independent experimental parameters, such as force (stress or strain), frequency, and temperature. Temperature should be measurable with a precision of $\pm 1^\circ\text{C}$, frequency to $\pm 1\%$, and force to $\pm 1\%$.

7.2.4 *Temperature Controller and Oven*—A device for controlling the specimen temperature, either by heating (in steps or ramps), cooling (in steps or ramps), or maintaining a constant specimen environment, or a combination thereof. Fig. 1 illustrates several time-temperature profiles. A temperature programmer should be sufficiently stable to permit measurement of sample temperature to 1°C .

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

8. Test Specimens

8.1 The molten polymer composition should be both homogeneous and representative.

8.2 Due to various geometries that might be used for dynamic mechanical characterization of molten polymeric systems, size is not fixed by this test method; however, sample geometry (diameter and thickness) should be reported for any series of comparisons.

8.3 Serrated tooling might be used for materials exhibiting interfacial slippage due to high modulus.

9. Calibration

9.1 Calibrate the instrument using procedures recommended by the manufacturer.

10. Procedure

10.1 Lower the upper test fixture so that it is touching the bottom fixture with approximately the same normal force as will be experienced during testing. Zero the gap indicator dial.

10.2 If a dynamic temperature sweep (linear heating rate or ramp temperature scan) were required for the specimen, then

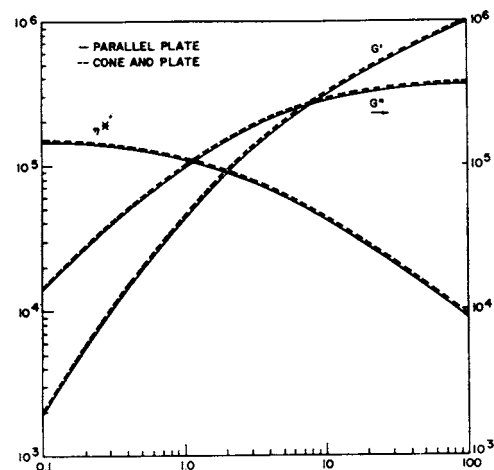


FIG. 1 Rheological Properties of a Polymer Melt