



Designation: D7791 – 17

# Standard Test Method for Uniaxial Fatigue Properties of Plastics<sup>1</sup>

This standard is issued under the fixed designation D7791; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope\*

1.1 This test method covers the determination of dynamic fatigue properties of plastics in uniaxial loading. This method is applicable to rigid and semi-rigid plastics. Uniaxial loading systems with tension and compression capabilities are used to determine these properties. Stress and strain levels are below the proportional limits of the material where the strains and stresses are relatively elastic.

1.2 This test method can be used with two procedures:

1.2.1 *Procedure A*, fatigue testing in tension.

1.2.2 *Procedure B*, fatigue testing in compression, only for rigid plastics.

1.3 Comparative tests can be run in accordance with either procedure, provided that the procedure is found satisfactory for the material being tested.

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

1.5 *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.

1.6 *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*:<sup>2</sup>

[D618 Practice for Conditioning Plastics for Testing](#)

<sup>1</sup> 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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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- [D638 Test Method for Tensile Properties of Plastics](#)
- [D695 Test Method for Compressive Properties of Rigid Plastics](#)
- [D792 Test Methods for Density and Specific Gravity \(Relative Density\) of Plastics by Displacement](#)
- [D883 Terminology Relating to Plastics](#)
- [D1505 Test Method for Density of Plastics by the Density-Gradient Technique](#)
- [D2839 Practice for Use of a Melt Index Strand for Determining Density of Polyethylene](#)
- [D3479/D3479M Test Method for Tension-Tension Fatigue of Polymer Matrix Composite Materials](#)
- [D4883 Test Method for Density of Polyethylene by the Ultrasound Technique \(Withdrawn 2017\)<sup>3</sup>](#)
- [D5947 Test Methods for Physical Dimensions of Solid Plastics Specimens](#)
- [E4 Practices for Force Verification of Testing Machines](#)
- [E83 Practice for Verification and Classification of Extensometer Systems](#)
- [E466 Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials](#)
- [E1942 Guide for Evaluating Data Acquisition Systems Used in Cyclic Fatigue and Fracture Mechanics Testing](#)

## 3. Terminology

3.1 *Definitions*—Definitions of terms applying to this test method appear in Terminology [D883](#).

3.2 *Definitions*:

3.2.1 *compressive proportional limit*—maximum elastic stress or strain exhibited by a material in compression as observed in Test Method [D695](#).

3.2.2 *mean strain*—algebraic average of the maximum and minimum strains in one cycle.

3.2.3 *mean stress*—algebraic average of the maximum and minimum stresses in one cycle.

3.2.4 *R ratio*—ratio of the minimum stress or strain to the maximum stress or strain that the specimen is loaded.

3.2.5 *tensile proportional limit*—maximum elastic stress or strain exhibited by a material in tension as observed in Test Method [D638](#).

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

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

## 4. Summary of Test Method

4.1 *Procedure A*—A specimen of rectangular or circular cross section is gripped by the ends of the specimen, pulled equally in opposite directions, and released back to its original position or load. The specimen is cyclically loaded in tension to a specific stress or strain level at a uniform frequency until the specimen ruptures or yields. From these tests, fatigue strengths can be determined at specified numbers of cycles. At least, four different stress or strain levels are tested to construct a stress versus number of cycles to failure (S-N) curve or a strain versus number of cycles to failure (r-N) to determine the uniaxial endurance limit of the material in tension.

4.2 *Procedure B*—A specimen of rectangular or circular cross section is compressed equally from opposite directions and released back to its original position or load. The specimen is cyclically loaded in compression to a specific stress or strain level at a uniform frequency until the specimen ruptures or yields. From these tests, fatigue strengths can be determined at specified numbers of cycles. At least, four different stress or strain levels are tested to construct a stress versus number of cycles to failure (S-N) curve or a strain versus number of cycles to failure (r-N) to determine the uniaxial endurance limit of the material in compression.

## 5. Significance and Use

5.1 These fatigue tests are used to determine the effect of processing, surface condition, stress, and so forth, on the fatigue resistance of plastic material subjected to uniaxial stress for relatively large numbers of cycles. The results can also be used as a guide for the selection of plastic materials for service under conditions of repeated flexural stress.

5.2 Properties can vary with specimen depth and test frequency. Test frequency can be 1-25 Hz but it is recommended that a frequency of 5 Hz or less be used.

5.3 Material response in fatigue is not identical for all plastics. If a plastic does not exhibit an elastic region, where strain is reversible, plastic deformation will occur during fatigue testing, causing the amplitude of the programmed load or deformation to change during testing. In this situation, caution shall be taken when using the results for design as they are generally not indicative of the true fatigue properties of the material.

5.4 The results of these fatigue tests are suitable for application in design only when the specimen test conditions realistically simulate service conditions or some methodology of accounting for service conditions is available and clearly defined.

5.5 This procedure accommodates various specimen preparation techniques. Comparison of results obtained from specimens prepared in different manners shall not be considered comparable unless equivalency has been demonstrated.

## 6. Apparatus

6.1 *Testing Machine*—The testing machine shall essentially meet the specifications set forth by Test Method [D638](#) for Procedure A and Test Method [D695](#) for Procedure B except as

described below. The error in the deflection measuring system shall not exceed  $\pm 0.5\%$  of the maximum deflection. The machine shall be able to execute sinusoidal or square/trapezoidal load or deflection programs at the specified test frequency and maintain an error of  $\pm 1\%$  or less of the maximum programmed load or deflection.

6.2 *Recording Equipment*—Calibrated equipment must be used to record the following information during testing at a data acquisition rate and filter in accordance with Guide [E1942](#):

- 6.2.1 Load versus time
- 6.2.2 Change in length versus time
- 6.2.3 Number of cycles

6.3 *Micrometers*—Applicable apparatus in accordance with Test Methods [D5947](#) shall be used to measure the width and thickness or diameter of the test specimen.

6.4 *Extensometers/Compressometer*—A suitable instrument shall be used for determining the distance between two designated points within the gauge length of the test specimen as the specimen is stretched or compressed. This instrument shall be essentially free of inertia at the specified speed of testing. Extensometers shall be classified and their calibration periodically verified in accordance with Practice [E83](#). An extensometer/compressometer with a maximum strain error of 0.0002 mm/mm (in./in.) that automatically and continuously records shall be used. Crosshead stroke of the testing machine can also be used to record deflection as long as it meets the same error requirements listed above.

6.5 *Supporting Jig (Procedure B Only)*—A supporting jig can be used for thin specimens or high compressive loads and shall be in accordance with Test Method [D695](#).

## 7. Sampling, Test Specimens, and Test Units

7.1 Specimens shall be taken from samples that accurately represent the material or design that is being tested.

7.2 The specimens can be cut from sheets, plates, or molded shapes, or can be molded to the desired finished dimensions. The actual dimensions used for calculations shall be measured in accordance with Test Methods [D5947](#).

7.3 *Procedure A*—Specimen dimensions, shape, surface conditions, and limitations shall be in compliance with Test Method [D638](#).

7.4 *Procedure B*—Specimen dimensions, shape, surface conditions, and limitations shall be in compliance with Test Method [D695](#).

7.5 Specimens cut from non-uniform thick molded part sections shall be machined equally and minimally on both sides to create a uniform thickness in the gauge. It must be noted that machining the thickness of plastic can change the mechanical properties and caution shall be taken when applying the results to design.

7.6 It is recommended that density measurements be taken from each sample in the gauge in accordance with Test Methods [D792](#), Test Method [D1505](#), Practice [D2839](#), or Test

Method **D4883** to ensure that the process used to fabricate the specimens creates consistent and uniform material.

## 8. Number of Test Specimens

8.1 At least three test specimens shall be tested at each of the four stress or strain levels (minimum of twelve specimens for each test). For additional sample sizes consult Table 1 of Test Method **D3479/D3479M**.

8.2 In the case of anisotropic materials, a single direction shall be chosen and maintained for all stress or strain levels.

## 9. Calibration and Standardization

9.1 All equipment shall be calibrated in accordance with the manufacturer's specifications and Practice **E4** or Practice **E83**, Class B-2.

9.2 Specimens for each test shall be identically processed and prepared for accurate results.

## 10. Conditioning

10.1 *Conditioning*—Condition the test specimens in accordance with Procedure A of Practice **D618** unless otherwise specified by contract or the relevant ASTM material specification. Condition time is specified as a minimum. Temperature and humidity tolerances shall be in accordance with Practice **D618** unless specified differently by contract or material specification.

10.2 *Test Conditions*—Conduct the tests at the same temperature and humidity used for conditioning with tolerances in accordance with Practice **D618** unless otherwise specified by contract or the relevant ASTM material specification.

## 11. Procedure

### 11.1 Specimen Measurements:

11.1.1 *Procedure A*—Take measurements of all specimens. Measure and record the depth and width, or diameter of the specimen to the nearest 0.025 mm (0.001 in) at several points along its length. The minimum measurement shall be used for calculations. These measurements shall be made in accordance with Test Methods **D5947** and Test Method **D638**.

11.1.2 *Procedure B*—Take measurements of all specimens. Measure and record the depth and width, or diameter of the specimen to the nearest 0.025 mm (0.001 in) at several points along its length. The minimum measurement shall be used for calculations. These measurements shall be made in accordance with Test Methods **D5947** and Test Method **D695**.

### 11.2 Apparatus Setup:

11.2.1 Place the test specimen in the test machine, taking care to align the center line of its axis with the loading axis in accordance with 8.2 of Practice **E466**.

11.2.2 If needed, align the jig support to the load axis (for Procedure B only).

11.2.3 Place the extensometer/compressometer on the specimen.

### 11.3 Test Program Setup:

11.3.1 Program the testing machine to follow a dynamic load (sinusoidal, square, or trapezoidal) or deflection waveform

with the amplitude set to the selected load or deflection level. Unless specified, the default waveform shall be sinusoidal. The selected level shall be below the proportional limit of the material as determined by Test Methods **D638** (Procedure A) or Test Method **D695** (Procedure B). Set the test frequency (maximum 25 Hz).

11.3.2 *Stress Level Selection*—All stress levels shall not exceed the proportional limit of the material. The associated load of a selected stress level can be determined by the following equation:

$$P = \sigma A \quad (1)$$

where:

$P$  = load in N,

$\sigma$  = stress level in MPa, and

$A$  = gauge cross sectional area (mm<sup>2</sup>).

11.3.3 *Strain Level Selection*—All strain levels shall not exceed the proportional limit of the material. The associated extension or compression of a selected strain level can be determined by the following equation:

$$D = rL \quad (2)$$

where:

$D$  = extension or compression in mm,

$r$  = strain (mm/mm), and

$L$  = gauge length in mm.

11.3.4 Set the end of test to 10<sup>7</sup> cycles.

### 11.4 Testing:

11.4.1 The test is recorded continuously using a computerized data retrieval system which records the force and deflection feedback.

11.4.2 Testing continues until the specimen fails by one of the following criteria:

11.4.2.1 Ruptured in the gauge area,

11.4.2.2 Yielded in the gauge area. For load controlled tests, the specimen has yielded if the maximum deflection increases. For strain controlled tests, the specimen has yielded if the maximum load decreases.

11.4.2.3 Reached end of test by completing the number of programmed cycles (about 10<sup>7</sup> cycles).

11.4.2.4 Reached a custom end of test criteria developed by the customer.

11.4.3 Repeat the above steps, using untested specimens, at least three times at each of the four stress or strain levels. For additional sample sizes consult Table 1 of Test Method **D3479/D3479M**.

11.5 *Retests*—The test must be repeated if the specimen fails outside the gauge area or if frequency or amplitude is not maintained throughout the test.

## 12. Plotting and Interpretation of Results

### 12.1 Plotting Results:

12.1.1 *S-N Curve*—Plot the maximum stress level versus the logarithm of the number of cycles to failure ( $N_f$ ). Plot all test data and define the S-N curve by creating a best-fit curve.

Indicate on the curve specimens that did not fail by an arrow directed away from the plotted point in the direction of increasing cycles.

12.1.2 *r-N Curve*—Plot the maximum strain level versus the logarithm of the number of cycles to failure ( $N_f$ ). Plot all test data and define the *r-N* curve by creating a best-fit curve. Indicate on the curve specimens that did not fail by an arrow directed away from the plotted point in the direction of increasing cycles.

12.1.3 As the number of specimens tested at the given stress or strain levels increases, use probability plots and other statistical analysis to create mean *S/r-N* curves.

12.2 *Interpretation of Results*—If the *S-N* or *r-N* curve becomes horizontally asymptotic to a constant stress or strain, this stress or strain value is interpreted as the endurance limit of the test material. If an asymptote to a constant stress or strain is not observed on the curve, additional stress or strain levels shall be tested until the number of cycles reached is greater than the number of cycles that the material will be expected to withstand in its life. The amplitude, stress or strain, at this number of cycles shall be interpreted as the endurance or fatigue limit of this material. If tests are deliberately terminated by the user before the specimens fail, the constant stress or strain value determined from the resulting *S-N* or *r-N* curve shall be reported as the Estimated Endurance Limit.

### 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 fabrication process,

13.1.2 Direction of cutting and loading specimens, including machining or other alterations that results in asymmetrical specimen preparation,

13.1.3 Type of test specimen and dimensions,

13.1.4 Conditioning procedure,

13.1.5 Procedure used,

13.1.6 Depth and width, or diameter of specimen,

13.1.7 Gauge length of specimen,

13.1.8 Waveform used,

13.1.9 Test frequency,

**TABLE 1 Number of Cycles to Failure Repeatability Data for One Laboratory and One Unfilled UHMW-PE Materials**

Materials	Average	$S_r$	$r$
UHMW-PE	11 488	1132	3204

13.1.10 Strain ( $r_N$ ) or stress ( $S_N$ ) level, R value, and mean strain or stress level,

13.1.11 Number of stress or strain levels tested,

13.1.12 Number of test specimens,

13.1.13 Classification of extensometers/compressometers used,

13.1.14 Number of cycles to failure ( $N_f$ ) for each specimen,

13.1.15 *S-N* Curve,

13.1.16 *r-N* Curve,

13.1.17 Uniaxial Endurance Limit or Fatigue Limit,

13.1.18 Mode of failure, and

13.1.19 Date of test.

### 14. Precision and Bias

14.1 The precision of this test method is under investigation by a task group of Section D20.10.24. If anyone wishes to participate in this work, contact the Chairman of Section D20.10.24, at ASTM Headquarters. The repeatability standard deviation has been determined and is listed in [Table 1](#). Repeatability conditions during the two week duration were the following:

14.1.1 Procedure A, Tension,

14.1.2 Specimen thickness, 0.25 in.,

14.1.3 Type III specimen shape,

14.1.4 Test frequency, 3 Hz,

14.1.5 Stress level, 10.3 MPa,

14.1.6 R value, 0.001,

14.1.7 Mean stress, 5.2 MPa,

14.1.8 Sinusoidal waveform, and

14.1.9 Failure mode, yield.

14.2 *Bias*—No statement can be made about the bias of this test method, as there is no standard reference material or reference test method available.

### 15. Keywords

15.1 compression; fatigue properties; plastics; *S-N* Curve; tension; uniaxial

## SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D7791 - 12) that may impact the use of this standard. (May 1, 2017)

(1) Added 11.4.2.4.

(2) Revised the title of Table 1.

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