Designation: D7192 – 20

Standard Test Method for High Speed Puncture Properties of Plastic Films Using Load and Displacement Sensors[1]

This standard is issued under the fixed designation D7192; 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 determination of puncture properties of plastic films, over a range of test velocities.

1.1.1 ASTM Terminology Standard D883 has defined film as having a thickness not greater than 0.25 mm. Plastic materials having a thickness above this limit are not to be excluded from use unless shown to be rigid (see 3.2.1). Test Method D3763 is the recommended method for instrumented puncture testing of rigid plastics.

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

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

1.4 *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 does not closely conform to ISO 7765-2. The only similarity between the two tests is that they are both instrumented impact tests. The differences in striker, fixture, specimen geometries and in test velocity can produce significantly different test results.

1.5 *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

D883 Terminology Relating to Plastics

D3763 Test Method for High Speed Puncture Properties of Plastics Using Load and Displacement Sensors

D4000 Classification System for Specifying Plastic Materials

D6988 Guide for Determination of Thickness of Plastic Film Test Specimens

E456 Terminology Relating to Quality and Statistics

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *Definitions*—Terms used in this standard are defined in accordance with Terminology D883, unless otherwise specified. For terms relating to precision and bias and associated issues, the terms used in this standard are defined in accordance with Terminology E456.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *rigid, adj*—any plastic specimen that, when placed on the support component of the open clamp assembly, does not deflect into the center of the unsupported region (under its own weight) by more than 0.05 mm from the horizontal plane of the support component.

3.2.1.1 *Discussion*—This definition is provided as a guideline to allow testing of soft, pliable plastic materials that are thicker than 0.25 mm.

4. Significance and Use

4.1 This test method is designed to provide load versus deformation response of plastic films under essentially multiaxial deformation conditions at impact velocities. This test method further provides a measure of the rate sensitivity of the plastic films to impact.

4.2 Multi-axial impact response, while partly dependent on thickness, does not necessarily have a linear correlation with specimen thickness. Therefore, results should be compared only for specimens of essentially the same thickness, unless specific responses versus thickness formulae have been established for the plastic films being tested.

4.3 For many plastic films, it is possible that a specification exists that requires the use of this test method, but with some procedural modifications that take precedence when adhering

[1] This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.19 on Film, Sheeting, and Molded Products.

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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.

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

to the specification. Therefore, it is advisable to refer to that material specification before using this test method. Table 1 of Classification System D4000 lists the ASTM materials standards that currently exist.

4.4 The values obtained by this test method are highly dependent on the method and conditions of film fabrication as well as the type and grade of resin. Results can vary significantly, depending upon sample quality, uniformity of film gage, die marks, contaminants, and so forth.

5. Apparatus

5.1 The testing machine shall consist of two assemblies, one fixed and the other driven by a suitable method to achieve the required impact velocity (that is, hydraulic, pneumatic, mechanical, or gravity):

5.1.1 *Specimen Clamp Assembly*—This device shall be permitted to be variable with respect to the holding of the specimen material, depending upon specimen characteristics. The unsupported region of the specimen clamp assembly shall have a diameter of 76 ± 3.0 mm. The edges of the unsupported region shall be rounded to a radius of 0.8 ± 0.4 mm. The holding technique employed on the specimen must not interfere with the radius edge of the clamp assembly. Specimens should be held taut but not stretched so as to cause damage to the specimen prior to test.

NOTE 2—The following techniques have been successfully employed for different types of plastic films:

- Parallel rigid plates clamped together with sufficient force (mechanically, pneumatically or hydraulically) to prevent slippage of the specimen in the clamp during impact.
- Rubber-like gaskets or o-rings affixed to the rigid plates to provide cushioning or gripping of the specimen when clamping force is applied.
- Removable assemblies, consisting of two concentric rings (one slightly larger than the other, similar to an embroidery hoop) that, when assembled and clamped between two rigid plates, succeed in pulling the specimen taut over the specified unsupported region prior to testing. All of the above techniques must employ the specified unsupported region and edge radius as noted in 5.1.1.

5.1.2 *Plunger Assembly,* consisting of a 12.70 ± 0.13-mm diameter rod with a hemispherical end of the same diameter positioned perpendicular to, and centered on, the clamp hole. Plunger assembly shall be of sufficient length so as to allow for complete puncture of the test specimen. Plunger assembly material shall be stainless steel, steel or aluminum. Surface finish of the plunger assembly shall be 16 µin. (0.4 µm).

5.1.3 *Other Geometries*—The dimensions given in 5.1.1 and 5.1.2 shall be the standard geometry. If other plunger or hole sizes are used they shall be highlighted in the report. Correlations have not been established between different plunger geometries, materials, and finishes.

5.1.4 *Load Sensing System*—A load cell of sufficiently high natural resonance frequency, as described in A1.1, used together with a calibrating network for adjusting load sensitivity.

5.1.5 *Plunger Displacement Measurement System*—A means of monitoring the displacement of the moving assembly during the loading and complete penetration of the specimen. This can be accomplished through the use of a suitable transducer or potentiometer attached directly to the system. Photographic or optical systems can also be utilized for measuring displacement.

5.1.5.1 Alternatively, displacement shall be permitted to be calculated as a function of velocity and total available energy at initial impact, along with increments of load versus time, using a microprocessor.

5.1.5.2 Some machines use an accelerometer, whose output is used to calculate both load and displacement.

5.1.6 *Display and Recording Instrumentation*—Use any suitable means to display and record the data developed from the load and displacement-sensing systems, provided its response characteristics are capable of presenting the data sensed, with minimal distortion. The recording apparatus shall record load and displacement simultaneously. For further information, see A1.2.

5.1.6.1 The most rudimentary apparatus is a cathode-ray oscilloscope with a camera. This approach also requires a planimeter or other suitable device, capable of measuring the area under the recorded load-versus-displacement trace of the event with an accuracy of ±5 %.

5.1.6.2 More sophisticated systems are commercially available. Most of them include computerized data reduction and automatic printouts of results.

5.2 *Measuring Instrument,* accurate to 0.0025 mm in the film thickness range defined in 1.1.1 (see Guide D6988).

6. Test Specimen

6.1 Specimens must be large enough to be adequately gripped in the clamp. In general, the minimum lateral dimension should be at least 13 mm greater than the diameter of the hole in the clamp or any clamping gaskets or o-rings incorporated into the clamping mechanism (see 5.1.1 and 9.9).

6.2 Specimens shall be cut from plastic films produced by any suitable process.

6.3 The specimens shall be free of pinholes, wrinkles, folds or other obvious imperfection, unless such imperfections constitute variables under study.

7. Conditioning

7.1 *Conditioning*—Condition the test specimens in a room or enclosed space maintained at 23 ± 2°C and 50 ± 10 % relative humidity, in accordance with Procedure A of Practice D618 unless otherwise specified.

7.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of 23 ± 2°C and 50 ± 10 % relative humidity unless otherwise specified. In cases of disagreement, the tolerances shall be ±1°C and ±5 % relative humidity.

7.2.1 By changing the conditioning and test temperature in a controlled manner for a given test velocity, the temperature at which transition from ductile to brittle failure occurs can be determined for most plastic films.

8. Speed of Testing

8.1 For recommended testing speeds, see 9.4.

9. Procedure

9.1 Test a minimum of five specimens at each specified speed.

9.2 Measure and record the thickness of each specimen to the nearest 0.0025 mm at the center of the specimen.

9.3 Clamp the specimen between the plates of the specimen holder, taking care to center the specimen for uniform gripping.

9.4 Set the test speed to the desired value. The testing speed (movable-member velocity at the instant before contact with the specimen) shall be as follows:

9.4.1 For single-speed tests, use a velocity of 200 m/min.

9.4.1.1 Other speeds are permissible, provided they are clearly stated in the report.

9.4.2 To measure the dependence of puncture properties on impact velocity, use a broad range of test speeds. Some suggested speeds are 2.5, 25, 125, 200, and 250 m/min.

9.5 Set the available energy so that the velocity slowdown is no more than 20 % from the beginning of the test to the point of peak load. If the velocity should decrease by more than 20 %, discard the results and make additional tests on new specimens with more available energy.

NOTE 3—It is observed that when the available energy is at least three times the absorbed energy at the peak load velocity slow-down is less than 20 %.

9.6 Make the necessary adjustments to data collection apparatus as required by the manufacturer's instructions or consult literature such as STP 936[3] for further information regarding setting up data acquisition systems.

9.7 Conduct the test, following the manufacturer's instructions, for the specific equipment used.

9.8 Remove the specimen and inspect the gripped portion for striations or other evidence of slippage. If there is evidence of slippage, modify the clamping conditions or increase the specimen size and repeat test procedures.

9.9 Check plunger assembly for any film debris or residue before performing subsequent tests.

10. Calculation

10.1 Using the load-versus-displacement trace and appropriate scaling factors, calculate the following:

10.1.1 Peak load, in Newtons.

10.1.2 Deflection, in millimetres, to the point where peak load first occurred.

10.1.3 From the area within the trace, calculate:

10.1.3.1 Energy, in Joules, to the point where peak load first occurred.

10.1.3.2 Total energy absorbed. The point for determining this has not been standardized. Therefore, the point used for each test must be stated in the report.

10.1.4 Load, deflection, energy, or combination thereof, at any other specific point of interest (see Appendix X1).

10.2 For each series of tests, calculate the arithmetic mean for each of the above, to three significant figures.

10.3 Calculate the estimated standard deviations as follows:

$$S = \left(\frac{\sum X^2 - n\,\bar{X}^2}{n-1} \right) 1/2 \qquad (1)$$

where:

S = estimated standard deviation,
X = value of a single determination,
n = number of determinations, and
$\bar{X}$ = arithmetic mean of the set of determinations.

11. Report

11.1 Report the following information:

11.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form and previous history,

11.1.2 Specimen size and thickness,

11.1.3 Method of preparing test specimens (extrusion molding, blow molding, and so forth),

11.1.4 Geometry of clamp and plunger, if different from 5.1.1 and 5.1.2,

11.1.5 Source and types of equipment,

11.1.6 Speed of testing (see 9.4),

11.1.7 The point on the curve at which total energy was calculated (see 10.1.3.2),

11.1.8 Average value and standard deviation for each of the properties listed in 10.1,

11.1.9 Whether or not any slippage of the specimens was detected (see Note 3),

11.1.10 If the effect of testing speeds was studied (see 9.4.2),

11.1.11 Type of plunger material used for the test, and

11.1.12 Test specimen conditioning, if different from 7.1.

NOTE 4—When slippage or cutting of the test specimen occurs at or near the edge of the support clamp, the result shall be considered invalid due to the error in calculated energy absorption caused by the slipping or cutting of the specimen during the impact test. Alternate clamping techniques, adhering to the requirements of 5.1.1, must be used to prevent any slippage or cutting of the test specimen.

12. Precision and Bias

12.1 The precision of this test method is based on an interlaboratory study of this standard conducted in 2019. A single laboratory tested three different materials. Every "test result" represents an individual measurement. Four replicate test results from a single operator were reported by the single laboratory. Except for the number of participating laboratories, Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. D20-1275.[4]

12.1.1 **Warning—**The data in Tables 1-4 shall not be rigorously applied to acceptance or rejection of material, as those data are specific to the interlaboratory study and are not necessarily representative of other lots, conditions, materials, or laboratories. Users of this test method shall apply the principles outlined in Practice E691 to generate data specific to their laboratory and materials, or between specific laboratories.

[3] *Instrumented Impact Testing of Plastics and Composite Materials, ASTM STP 936*, ASTM, 1986.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D20-1275. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Peak Load (Newtons)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Repeatability Limit
	n	$\bar{x}$	S_r	r
LLDPE	1	15.358	0.255	0.714
HDPE	1	7.248	0.231	0.646
LDPE	1	32.723	0.916	2.565

[A]The average of the laboratory's calculated average.

TABLE 2 Energy to Peak Load (Joules)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Repeatability Limit
	n	$\bar{x}$	S_r	r
LLDPE	1	0.113	0.002	0.007
HDPE	1	0.014	0.001	0.003
LDPE	1	0.240	0.014	0.038

[A]The average of the laboratory's calculated average.

TABLE 3 Total Energy (Joules)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Repeatability Limit
	n	$\bar{x}$	S_r	r
LLDPE	1	0.188	0.004	0.011
HDPE	1	0.019	0.001	0.002
LDPE	1	0.307	0.008	0.021

[A]The average of the laboratory's calculated average.

TABLE 4 Deflection (Millimeters)

Material	Number of Laboratories	Average[A]	Repeatability Standard Deviation	Repeatability Limit
	n	$\bar{x}$	S_r	r
LLDPE	1	29.708	0.824	2.308
HDPE	1	13.343	0.010	0.027
LDPE	1	19.288	0.212	0.593

[A]The average of the laboratory's calculated average.

12.1.2 Repeatability limits are listed in Tables 1-4.

12.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

12.3 The precision statement was determined through statistical examination of 48 results, from one laboratory, on three materials.

13. Keywords

13.1 falling weight; impact testing; plastic thin film; puncture properties

ANNEX

(Mandatory Information)

A1. MINIMUM INSTRUMENTATION REQUIREMENTS

A1.1 *Force Measurement*—Any transducer that meets the performance requirements for dynamic force measurement shall be permitted to be used. This includes, but is not limited to, strain gage force transducers, piezo-electric force transducers and accelerometers.

A1.1.1 *Performance Requirements*—The natural frequency (f_{dev}) of the transducer plus striker shall be sufficient to avoid distortion of the force-time or acceleration-time data. The time failure (t_f), in seconds, of a given test specimen regulates the minimum natural frequency for a transducer/striker assembly by the following relationship:

$$t_f = 3/f_{dev} \quad \text{(A1.1)}$$

Since time to failure is generally greater than 0.5 ms for plastics, a transducer assembly with a natural frequency greater than 6 kHz is recommended ($0.0005 \geq 3/6000$). In addition, the transducer must have the durability to survive repeated impact tests without change in output from its initially calibrated state.

NOTE A1.1—Failure has been shown to be difficult to universally define. One application might define failure as the point on a load versus time curve where the load returns to zero. Another might define failure as a sharp drop in load, followed by a change in load slope, indicating formation of a crack.

A1.1.2 *Natural Frequency*—The mass of the striker assembly between transducer and specimen is directly related to the natural frequency (f_{dev}) of that transducer and can influence the force or acceleration data. Appendix X1, (X1.9.3) describes a method for approximating f_{dev} for any given transducer assembly.

A1.1.3 *Transducer Location*—The transducer should be located as close as possible to the impact point of the transducer/striker assembly to minimize the mass effect as described in A1.1.2. For testing involving extremely tough materials, it shall be permitted to locate the transducer further from the impact point to prevent damage. Generally, this class of materials will produce a high loading impact event with a long t_f. Under these conditions, a transducer/striker assembly with a f_{dev} lower than 6 kHz will not adversely affect the test data. This is due to the damping effect of the test specimen itself as well as the large magnitude of the loading event in comparison to the initial oscillation produced by the transducer assembly.