Designation: D7192 – 10

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

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 Test Method D1004 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 and health 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.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1004 Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting
D1600 Terminology for Abbreviated Terms 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

3. Terminology

3.1 *Definitions*—For definitions see Terminology D883 and for abbreviations, see Terminology D1600.

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, 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 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

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[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.

Current edition approved April 1, 2010. Published May 2010. Originally approved in 2005. Last previous edition approved in 2008 as D7192 - 08a. DOI: 10.1520/D7192-10.

[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 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).

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

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:

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

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 Precision and Bias for this test method are currently under investigation.

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:

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

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 ≥ 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.

A1.2 *Recording Apparatus*—Any recording device that meets the performance requirements of dynamic data acquisition shall be permitted to be used. This includes, but is not limited to, oscilloscopes, data loggers, and computer based data acquisition systems.

A1.2.1 *Performance Requirements*—The recording device used to capture a dynamic signal must have the capability to accurately represent that signal with minimal alteration. The following are system recommendations:

A1.2.1.1 8-bit or larger analog to digital converter,

A1.2.1.2 100 kHz minimum sampling rate,

A1.2.1.3 Minimum 1000 data point storage capacity,

A1.2.1.4 Adjustable test times to optimize data resolution, and

A1.2.1.5 Adjustable signal amplification to optimize load readings.

A1.2.2 For materials with a short t_f (0.1 to 2 ms) or complex loading/failure mechanisms, the sampling rate and number of data points captured should be increased to properly represent the impact event.

APPENDIXES

(Nonmandatory Information)

X1. ADDITIONAL RESULTS AND DATA INTERPRETATION

X1.1 This test method produces a record of load versus displacement for a penetration impact-type test. These recordings may have useful or important characteristics beyond those required in Section 10. These additional parameters shall be permitted to be reported when identified by controlled penetration, photographic, or other means. It must be emphasized that the load-displacement recordings are dependent on specimen geometry, size, thickness and testing speed. The load-displacement recordings may also display signals or artifacts that are the result of physical or electrical contributions from the test device. If the source of these contributions can be verified, they should be disregarded or filtered. Comparisons should only be made between equivalent specimens and test conditions. The following are examples of some characteristics that have been found useful or may affect the interpretation of the test data.

NOTE X1.1—While this test method discusses the interpretation of load-displacement curve data, an impact event is time-based. Therefore, if a "referee" situation arises when data are in question, a load-time curve should be used to determine characteristics of a given impact event.

X1.2 *Inertial Effect*—A loading function encountered when performing an instrumented impact test that may often be recognized as a "bump," a series of "peaks" or an "initial discontinuity" near the beginning of the load-displacement curve (Fig. X1.1). At this point, it is important to list the three main load contributions affecting a load transducer/probe assembly during an impact test: (*1*) Inertial acceleration loads (probe mass and specimen mass), (*2*) Mechanical bending loads (test specimen), and (*3*) Test system "ringing" (test device + transducer/probe + specimen).

X1.2.1 The level of contribution of each of these factors depends upon the portion of the test being studied along with the toughness and stiffness of the test specimen. Generally, when a material has a high toughness and a low to medium stiffness, the inertial effects will occur early in the test and not affect the data required in Section 10. However, some brittle materials, possessing high stiffness and low toughness, will often show inertial effects or system ringing, or both, persisting to the point of first crack. For related information, see X1.9.

NOTE X1.2—Due to the relatively small mass of a typical thin film specimen, it is unlikely that any inertial effects will be observed.

X1.3 *First Crack or Damage*—When there is a sharp loss of load with increasing displacement followed by a noticeable change in the slope of the curve, the loss in load can indicate the first crack or damage in the part (Fig. X1.2). This crack or damage can often be proven by use of controlled penetration or controlled energy input. This is of value where the crack or damage in the part constitutes failure. It is also valuable in composite materials where it signifies first failure of the matrix material.

X1.4 *Relative Stiffness*—Where a distinct linear portion can be identified within the proportional limit, the slope of the initial load-displacement curve is often useful as a relative measure of the elastic response of the specimen (Fig. X1.3). Precautions must be taken to compare only data from specimens of the same thickness and test conditions.

X1.5 *Proportional Limit*—The proportional limit is the first major deviation from the initial linear portion of the load-displacement curve (Fig. X1.3). It can be used as the point of onset of plastic damage. It is specimen and test condition dependent.

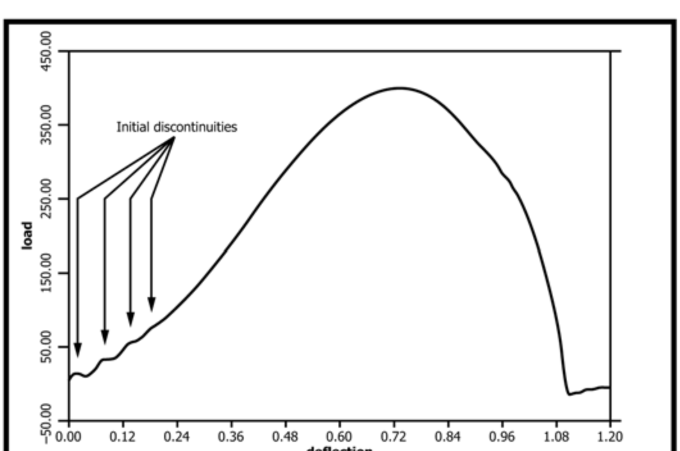

FIG. X1.1 Inertial Effect

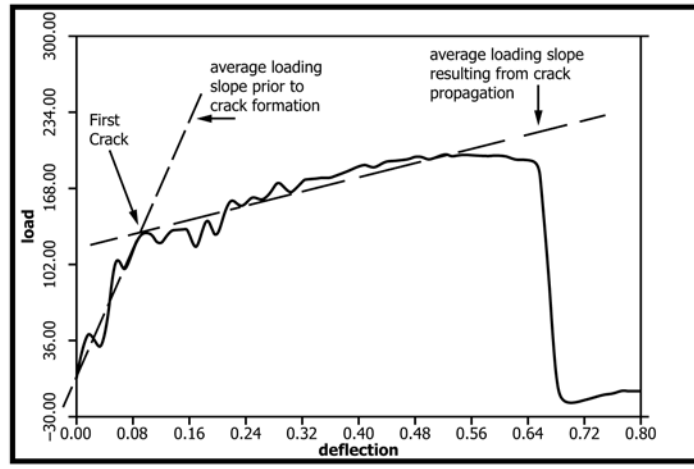

FIG. X1.2 First Crack Determination

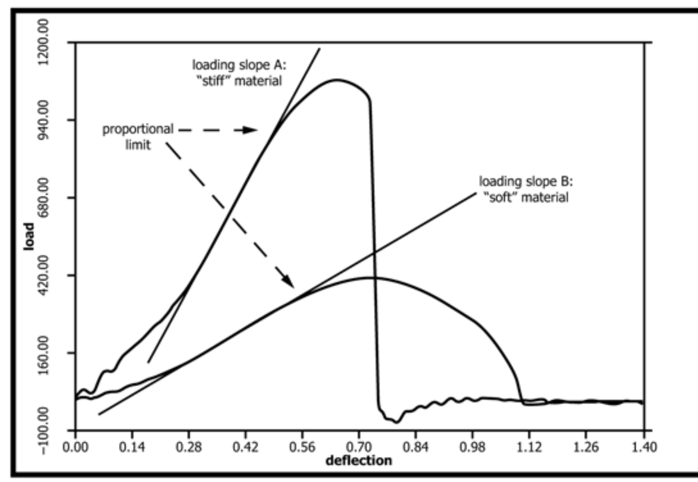

FIG. X1.3 Relative Stiffness Comparison and Proportional Limit

X1.6 *Failure of Layered Film*—The failure of layered structures in the penetration test may be characterized by a variety of changes in the load-displacement curve after first crack or damage. Some of the most common are multiple peaks or multiple slope changes when testing a layered, or filled material (Fig. X1.4). The inclusion of the area under all of the peaks is often important, especially when the total energy absorbed by the part is significant, such as in packaging applications.

NOTE X1.3—Fig. X1.4 represents only one example from a multitude of possibilities that might be encountered while testing layered materials.

X1.7 *Ductile or Elastomeric Failure*—There are several means of defining the point of failure of ductile- or elastomeric types of materials. The operator must define the criteria used if reporting this point. The failure may be obvious if the load drops to zero with little or no increase in displacement. A percent drop in load from the peak is one type of criteria used. If the probe is a one-piece design from the load transducer to the impact point, the portion of the load-displacement recording that follows penetration represents the friction effect of the probe sliding through the puncture and has no utility for describing the impact fracture.

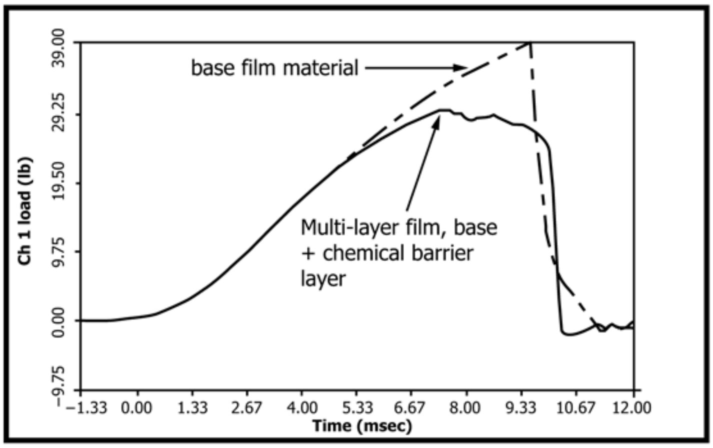

FIG. X1.4 Single Versus Multi-layer Film Data

X1.8 *Failure Mode*—Information can be submitted on the type of failure of the specimen, by visual inspection, using the following terms:

X1.8.1 *Ductile Failure*—One where the specimen deformed plastically before fracturing. The specimen is in one piece after the penetration and the deformed material exhibits plastic flow.

X1.8.2 *Brittle Failure*—One where the specimen test area is broken into two or more pieces, with sharp edges and shows almost no plastic flow.

NOTE X1.4—The ductile-to-brittle failure modes are a continuum and may be hard to separate. Each contains features of both and should be specific to the material under consideration.

X1.9 *Multiple Zero Slope Points*—Despite "noise" on the load-displacement recording, the recording may exhibit two or more points of zero slope. These may be indicative of cracks, tears, or failure of individual film layers. If they are significant to the application of the test data, they should be described and reported. See Fig. X1.4. Care must be taken to ensure that the zero slope points are not caused by inertial effects. See section X1.4.

X1.9.1 *Investigating Noise or Multiple Peaks on the Load-Displacement Curve*—Care should be exercised that the peak or peaks reported are real and not artifacts of the impact test or inertial effects. This is especially true when brittle failures are encountered. The impact can produce inertial effects along with excitation of the natural frequencies of the transducer/probe/test device/specimen combination and since the "ringing" is added to the test data, significant errors can occur. If the multiple peaks of the unfiltered or unsmoothed test curve are approaching the natural frequency of the force measuring system, the validity of the data should be investigated.

X1.9.2 *Validity Determination*—Observe the multiple peaks on the load-displacement curve just after the probe has penetrated the specimen. If the peaks continue and are similar in frequency to the peaks on the data curve, the peaks are probably ringing noise. Another method involves performing additional tests at decreasing impact velocities. If, at slower velocities, the general curve shape and amplitude remain constant but the multiple peaks decrease in amplitude, the peaks are probably artifacts of the test.

X1.9.3 *Natural Frequency Determination*—It is recommended that each laboratory know the approximate natural frequency of its load transducer/probe assembly. The determination can be made by "ringing the system" much like the ringing of a tuning fork. With the transducer/probe assembly attached to the tester, a steel mallet or other hard tool is used to impact the probe in the same direction as the test impact, thereby exciting the natural frequency of the transducer/probe assembly. A recording system such as an analog or digital memory oscilloscope or computer data acquisition can be used to record the "ringing" of the load signal versus time following the impact. From this data, the approximate natural frequency can be characterized. Care should be taken not to overload and damage the transducer.

X1.10 For further information, consult the literature.[4,3]

[4] Analysis and Control of Inertial Effects During Instrumented Impact Testing, *ASTM STP 563*, ASTM, pp. 50-55.

X2. ALGORITHMS FOR INTERPRETATION OF HIGH SPEED TEST DATA

X2.1 This appendix covers algorithms for the interpretation of load-displacement or load-time curves acquired by computer data acquisition systems for transducers in high-speed material testing. In such systems, the curves are represented digitally as numeric arrays of load-displacement of load-time.

X2.1.1 The following information is limited to algorithms for the interpretation of data. It does not cover issues pertaining to the resolution, accuracy, or frequency of data acquisition.

X2.1.2 This appendix defines a set of algorithms to be used for calculating standard material properties of polymers, elastomers and related materials. It does not cover any visual interpretation or non-standard calculations not required in Section 10.

X2.2 *Symbols:*

X2.2.1 m = mass of falling weight including all attachments; that is, load cell, mounting hardware, and strikers,

X2.2.2 g = acceleration of gravity, $g = v$ for horizontal testing equipment,

X2.2.3 v = velocity of the falling weight,

X2.2.4 a = acceleration of the falling weight,

X2.2.5 F = force measured by the load cell,

X2.2.6 r = resultant force applied to specimen,

X2.2.7 t = time,

X2.2.8 E = energy, and

X2.2.9 d = displacement.

X2.3 *Load Cell*—Displacement calculated using load measurements shall be permitted to be achieved using the following method:

$$mg - P(t) = ma(t) \quad (X2.1)$$

where:

$a(t)$ = $g - \frac{1}{m} P(t)$

$V(t)$ = $_i\int^t a(t)dt$

$x(t)$ = $_i\int^t V(t)dt$

where:

i = the point when the specimen is engaged.

NOTE X2.1—This procedure has only been proven for free-fall, drop-weight impact test machines. Mechanically driven systems require monitoring of the crosshead acceleration and have not been experimentally verified.

X2.4 *Velocity* —The three most commonly used methods for measuring velocity are: direct measurement, calculation from deflection-measuring device, and calculation from load-cell output and the determination of output initial velocity.

X2.4.1 *Direct Measurement*—Direct measurement gives a continuous output and requires no calculations.

X2.4.2 *Calculated from Displacement-Measuring Device*—Velocity from this type of measurement is simply:

$$V(t) = \frac{dx^2}{dt} \quad (X2.2)$$

X2.4.3 *Calculation from Load-Cell Output and the Determination of Initial Velocity*—To calculate the initial velocity for drop-weight systems it is common to use a light-beam detector in which a flag passes through. The flag has a known dimension and using equations of motion the velocity can be determined at some point prior to the testing event:

$$V_i = V_0 + gt \quad (X2.3)$$

where:

V_0 = measured velocity of falling weight,
V_i = velocity at the point when the specimen is engaged, and
t = the time elapsed between V_0 and V_i.

The following equations are used to determine the velocity versus time:

$$a(t) = g - \frac{P(t)}{m} \quad (X2.4)$$

$$V(t) = V_i + {}_i\int^t a(t)dt$$

where:

i = the point the specimen is engaged.

X2.5 *Energy*—Energy shall be computed by either the integration of the load-displacement curve or an energy balance.

X2.5.1 *Integration of the Load-Displacement Curve*—In systems that utilize a direct-measurement system for displacement the following is a simple method:

$$E(x) = {}_i\int^{14} Fdx \quad (X2.5)$$

NOTE X2.2—Systems that calculate displacement through multiple calculations can induce large errors using this method.

X2.5.2 *Energy Balance*—For a drop-weight machine the energy at any time can be calculated with the following equation:

$$E(t) = \frac{1}{2} m(v_i^2 - v(t)^2) + mg(\times(t)) \quad (X2.6)$$

NOTE X2.3—The operator of the test should view each curve to ensure that the algorithm has picked the correct value for the peak load.

NOTE X2.4—The algorithm for peak load must have the capabilities for the operator to select a point for peak load other than the value chosen by the algorithm.

NOTE X2.5—For referee purposes, all integration will be done using the trapezoid method.

SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue (D7192 - 08a) that may impact the use of this standard. (April 1, 2010)

(1) Revised Section 7.