Designation: D7027 – 20

Standard Test Method for Evaluation of Scratch Resistance of Polymeric Coatings and Plastics Using an Instrumented Scratch Machine[1]

This standard is issued under the fixed designation D7027; 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 describes a laboratory procedure using an instrumented scratch machine to produce and quantify surface damage under controlled conditions. This test method is able to characterize the scratch resistance of polymers by measuring many significant material parameters. The scratch-inducing and data acquisition process is automated to avoid user-influenced effects that may affect the results.

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

1.3 *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 standard is equivalent to ISO 19252.

1.4 *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]

A276/A276M Specification for Stainless Steel Bars and Shapes
D618 Practice for Conditioning Plastics for Testing
D638 Test Method for Tensile Properties of Plastics
D883 Terminology Relating to Plastics
D1894 Test Method for Static and Kinetic Coefficients of Friction of Plastic Film and Sheeting
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
E456 Terminology Relating to Quality and Statistics
G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus
G171 Test Method for Scratch Hardness of Materials Using a Diamond Stylus

3. Terminology

3.1 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:*

3.2.1 *ASV Software, n—Automatic Scratch Visualization*, a computer program which automates the identification of the point of failure in a rising load scratch tests using contrast as the failure criteria.

3.2.1.1 *Discussion*—The ASV software determines failure if a continuous change in contrast between the scratch groove and the undamaged material surface reaches +3 %, -3 %, or ±3 %. The continuity criterion is defined as a region of length equal to 2 diameters of the scratch stylus with 90 % or more of the region exceeding the contrast criterion. The lowest load point on the scratch from which there is a continuous contrasting region is considered the point of failure. This program is useful for visual analysis of the test and may be used for other applications, such as pass-fail criterion for scratch visibility. An example of the application of ASV is shown in Fig. 1.

3.2.2 *critical normal load, n*—the normal load at which failure (see 3.2.4) of the material within the scratch groove first occurs.

3.2.3 *normal load, n*—a load applied onto the scratch stylus that is imposed in a vertically downward direction, perpendicular to the surface of the specimen.

3.2.3.1 *Discussion*—The normal load is also referred to as the "Z-direction load."

3.2.4 *point of failure, n*—the point along a rising-load scratch path at which the damage to the surface is first considered to be unacceptable.

[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.

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

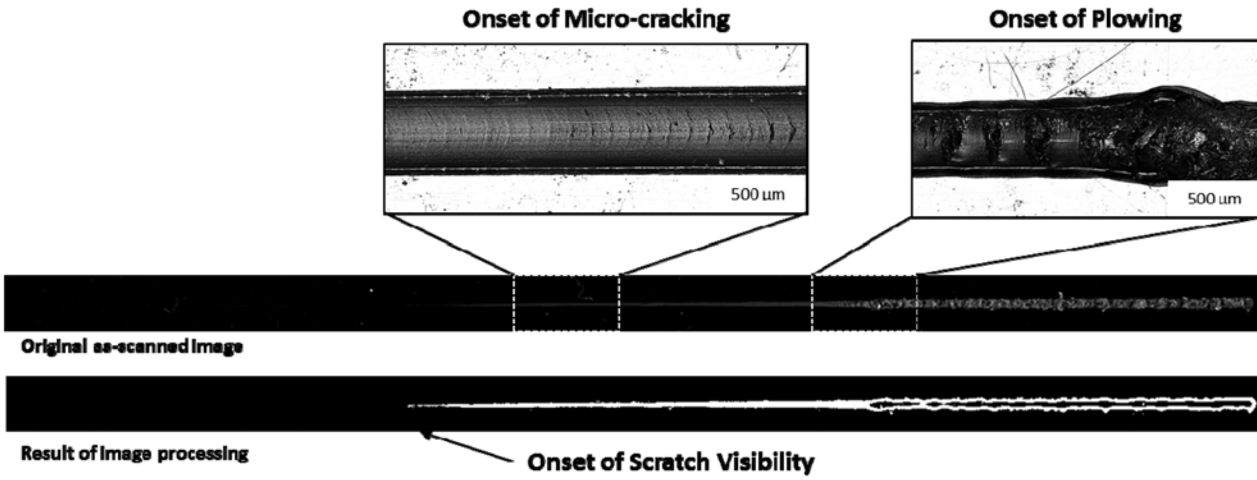

FIG. 1 Images of Polystyrene-Acrylonitrile (SAN) Subjected to Test Mode A Under a Progressive Load of 1-90 N Showing Examples of Points of Failure

3.2.4.1 *Discussion*—The point of failure for a given study shall be defined in a quantifiable manner. For aesthetic studies the recommended criteria is a contrast of ±3 % between the scratch groove and the undamaged material surface. For different studies other criteria for failure may be used. For example, failure may occur when the scratch width or depth exceeds a predetermined value. Onset of micro-cracking, crazing, fish-scale formation, plowing can also be used as failure criteria. For a coated specimen the point of failure might be defined as the point at which the coating is penetrated, revealing the underlying substrate. An image of styrene acrylonitrile (SAN) subjected to Test Mode A (4.1.1) under a linearly increasing normal load range of 1-90 N is shown in Fig. 1 to illustrate several possible points of failure that can occur during the scratch process.

3.2.5 *scratch coefficient of friction, n*—the ratio of the tangential force (3.2.10) to the normal load (3.2.3).

3.2.5.1 *Discussion*—This coefficient is a measure of the resistance of a material to scratching motion. For tests conducted under constant load, two distinct quantities may be characterized, the static and kinetic coefficients. The static coefficient is related to the tangential force measured prior to the movement of the scratch stylus while the kinetic coefficient is related to the constant tangential force measured in sustaining this movement. This quantity is not equivalent to the *coefficient of friction*, which is obtained in accordance with Test Method D1894 and is similar to the *stylus drag coefficient* as defined in Test Method G171.

3.2.6 *scratch depth, n*—the vertical distance to be measured from the trough of the scratch groove to the undisturbed specimen surface (D1) or to the peaks of the scratch path (D2). Refer to Fig. 2.

3.2.7 *scratch resistance, n*—ability to withstand damage that is accompanied by the gross deformation typically associated with sliding indentation of asperities that may involve compressing, plowing, and shearing of material.

3.2.7.1 *Discussion*—Quantification of scratch resistance can be accomplished through the measurement of critical normal load scratch depth (3.2.6), scratch width (3.2.8) and other geometric or visual characteristics of the scratch.

3.2.8 *scratch width, n*—the horizontal distance between the two peaks on both sides of the scratch groove (W1). Refer to Fig. 2.

3.2.9 *scratching, v*—process involving surface deformation (displacement or mechanical removal, or both, of material) caused by the action of one of more asperities, or protuberances, or both, sliding across the surface.

3.2.10 *tangential force, n*—the force present at the interface between the scratch tip and the specimen, acting opposite to the direction of motion of the scratch tip.

3.2.10.1 *Discussion*—The tangential force acts parallel to the scratch direction and is composed of two components: the kinetic friction acting on the scratch tip, plus the reaction force generated during deformation of the surface. The magnitude of the component forces can vary. At small scratch depths the tangential force is kinetic friction. As scratch depth increases, the forces due to elastic and plastic deformation increase. Tangential force is also referred to as the "X-direction force" measured by the scratch instrument.

3.2.11 *whitening, n*—a phenomenon occurring as a result of light scattering by surface deformation resulting from the scratch process that causes the scratch path to be brighter, or "whiter," than the undisturbed background surface.

3.2.11.1 *Discussion*—A key deformation mechanism that contributes to whitening is the increase in surface roughness due to micro-cracking. Whitening is measurable as a contrast change between the scratch groove and the undamaged material surface.

4. Summary of Test Method

4.1 This test method utilizes an automated scratch machine to administer controlled scratch tests on polymeric specimens. Two basic test modes (Test Modes A and B) are presented.

4.1.1 *Test Mode A*—A scratch is applied onto the specimen surface under an increasing normal load from 2 to 50 N (±0.5

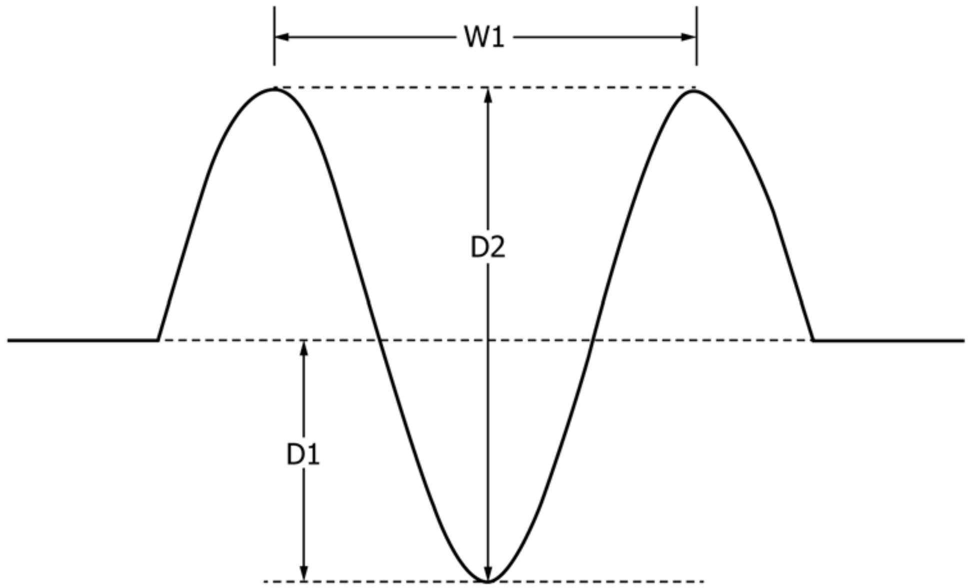

FIG. 2 Cross Section of Scratch Path Showing Scratch Width Measurement (W1) and Depth Measurements (D1 and D2)

N) over a distance of 0.1 m (±0.0001 m) at a constant scratch rate of 0.1 m/s (±0.0005 m/s). This test mode is intended to determine the critical normal load for failure for a material system. A test is considered valid when the point of failure occurs in the second or third quartile of the test length. For materials that do not exhibit failure in this range, the load range shall be changed to ensure that the point of failure occurs in the middle of the scratch path.

4.1.2 *Test Mode B*—A scratch is applied onto the specimen surface under a constant normal load of 30 N (±0.1 N) over a distance of 0.1 m (±0.0001 m) at a constant scratch rate of 0.1 m/s (±0.0005 m/s). This test mode is intended to evaluate the load-dependant homogeneous response of the material and establish the scratch coefficient of friction. The constant load value may be increased if 30 N is insufficient to generate damage on the specimen.

4.2 The scratched surface can be inspected visually or by using evaluation tools to study the surface damage. For Test Mode A, the critical normal load is determined by the point of failure criteria established for that experiment. Measurement of the scratch width, or depth, or both, may also be taken to aid the quantification of scratch resistance. ASV Software may be used to automate the measurement of the point of failure with regard to scratch visibility.

4.3 Scratch coefficient of friction as defined in 3.2.5 can be computed for material characterization using the tangential force and normal load data recorded during tests.

5. Significance and Use

5.1 Scratch tests are performed on specimens:

(1) to evaluate the scratch resistance of a particular material,

(2) to rank the relative scratch resistance of different materials, or

(3) to determine the scratch coefficient of friction of materials.

5.2 Since polymers exhibit mechanical properties that are strongly dependent on temperature, the test standard prescribed herein is designed to yield reproducible results when users perform tests under the similar testing environment and on specimens of the same material and surface texture that are subjected to the same conditioning procedures.

5.3 Certain polymers are self-healing (recoverable) when subjected to scratches and other physical deformations because of their viscoelastic and relaxation properties. It is important to note the difference between the instantaneous (if readily measurable) and residual scratch damage and compare results appropriately to ensure reproducibility. It is recommended that 24 hours be allowed for viscoelastic recovery when considering residual scratch depth.

5.4 "Whitening" of the scratched surface is a key damage mechanism that has prompted much concern in automotive and other applications where surface aesthetics is important. This type of damage is undesirable because it is evident to the human eye. The critical normal load at which this phenomenon appears serves as a benchmark in ranking material performance, especially from an aesthetic point of view.

6. Apparatus

6.1 *General Description*—The instrumented scratch machine[3] described here has been developed at Texas A&M University under the auspices of the Scratch Behavior of Polymeric Materials Consortium. A schematic of the scratch machine is shown in Fig. 3. The instrument consists of a sample stage, clamping devices, a load generator, and a horizontal motion servo system. Optional systems such as a

[3] The sole source of supply of the apparatus known to the committee at this time is Surface Machine Systems, LLC, http://www.surfacemachines.com. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee[1], which you may attend.