



Designation: G99 – 23

# Standard Test Method for Wear and Friction Testing with a Pin-on-Disk or Ball-on-Disk Apparatus<sup>1</sup>

This standard is issued under the fixed designation G99; 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 a laboratory procedure for determining the wear of materials and friction during sliding using a pin-on-disk apparatus. Materials are tested in pairs under nominally non-abrasive conditions. The principal areas of experimental attention in using this type of apparatus to measure wear are described.

1.2 This test method standard uses a specific set of test parameters (load, sliding speed, materials, etc.) that were then used in an interlaboratory study (ILS), the results of which are given here (Tables 1 and 2). (This satisfies the ASTM form in that “The directions for performing the test should include all of the essential details as to apparatus, test specimen, procedure, and calculations needed to achieve satisfactory precision and bias.”) Any user should report that they “followed the requirements of ASTM G99,” where that is true.

1.3 Now it is often found in practice that users may follow all instructions given here, but choose other test parameters, such as load, speed, materials, environment, etc., and thereby obtain different test results. Such a use of this standard is encouraged as a means to improve wear testing methodology. However, it must be clearly stated in any report that, while the directions and protocol in Test Method G99 were followed (if true), the choices of test parameters were different from Test Method G99 values, and the test results were therefore also different from the Test Method G99 results. This use should be described as having “followed the procedure of ASTM G99.” All test parameters that were used in such case must be stated.

1.4 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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 appro-*

*priate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

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>

E178 Practice for Dealing With Outlying Observations

G40 Terminology Relating to Wear and Erosion

G115 Guide for Measuring and Reporting Friction Coefficients

G117 Guide for Calculating and Reporting Measures of Precision Using Data from Interlaboratory Wear or Erosion Tests (Withdrawn 2016)<sup>3</sup>

2.2 *DIN Standard:*<sup>4</sup>

DIN 50324 Testing of Friction and Wear

## 3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology G40.

## 4. Summary of Test Method

4.1 For the pin-on-disk wear test, two specimens are required. One, a pin with a radiused tip, is positioned perpendicular to the other, usually a flat circular disk. A ball, rigidly held to ensure no rotation about any axis, is often used as the pin specimen. The test machine causes either the disk specimen or the pin specimen to revolve about the disk center. In either

<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.

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

<sup>4</sup> Available from Beuth Verlag GmbH (DIN-- DIN Deutsches Institut für Normung e.V.), Burggrafenstrasse 6, 10787, Berlin, Germany, <http://www.en.din.de>.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.40 on Non-Abrasive Wear.

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**TABLE 1 Characteristics of the Interlaboratory Wear Test Specimens**

NOTE 1—See Note 5 for information.

	Composition (weight%)	Microstructure	Hardness (HV 10)	Roughness <sup>A</sup>	
				$R_z$ (mean) ( $\mu\text{m}$ )	$R_a$ (mean) ( $\mu\text{m}$ )
Steel ball (100 Cr6) (AISI 52 100) <sup>B</sup> Diameter 10 mm	1.35 to 1.65 Cr ← 0.95 to 1.10 C 0.15 to 0.35 Si 0.25 to 0.45 Mn	martensitic with minor carbides and austenite	838 ± 21	0.100	0.010
Steel disc (100 Cr6) (AISI 52 100) <sup>C</sup> Diameter 40 mm	← <0.030 P <0.030 S	martensitic with minor carbides and austenite	852 ± 14	0.952	0.113
Alumina ball, diameter = 10 mm <sup>D</sup>	← 95 % Al <sub>2</sub> O <sub>3</sub> (with additives of TiO <sub>2</sub> , MgO, and ZnO)	equi-granular alpha alumina with very minor secondary phases	1610 ± 101 (HV 0.2)	1.369	0.123
Alumina disc, diameter = 40.6 mm <sup>D</sup>	←		1599 ± 144 (HV 0.2)	0.968	0.041

<sup>A</sup> Measured by stylus profilometry.  $R_z$  is maximum peak-to-valley roughness.  $R_a$  is arithmetic average roughness.

<sup>B</sup> Standard ball-bearing balls (SKF).

<sup>C</sup> Standard spacers for thrust bearings (INA).

<sup>D</sup> Manufactured by Compagnie Industrielle des Ceramiques Electroniques, France.

**TABLE 2 Results of the Interlaboratory Tests<sup>A</sup>**

NOTE 1—See Footnote A for test conditions.

NOTE 2—Numbers in parentheses refer to all data received in the tests. In accordance with Practice E178, outlier data values were identified in some cases and discarded, resulting in the numbers without parentheses. The differences are seen to be small.

NOTE 3—Values preceded by ± are one standard deviation.

NOTE 4—Data were provided by 28 laboratories.

NOTE 5—Calculated quantities (for example, wear volume) are given as mean values only.

NOTE 6—Values labeled “NM” were found to be smaller than the reproducible limit of measurement.

NOTE 7—A similar compilation of test data is given in DIN 50324.

Results (ball) (disk)	Specimen Pairs			
	Steel-steel	Alumina-steel	Steel-alumina	Alumina-alumina
Ball wear scar diameter (mm)	2.11 ± 0.27 (2.11 ± 0.27)	NM	2.08 ± 0.35 (2.03 ± 0.41)	0.3 ± 0.06 (0.3 ± 0.06)
Ball wear volume (10 <sup>-3</sup> mm <sup>3</sup> )	198 (198)	...	186 (169)	0.08 (0.08)
Number of values	102 (102)	...	60 (64)	56 (59)
Disk wear scar width (mm)	NM	0.64 ± 0.12 (0.64 ± 0.12)	NM	NM
Disk wear volume (10 <sup>-3</sup> mm <sup>3</sup> )	...	480 (480)	...	...
Number of values	...	60 (60)	...	...
Friction coefficient	0.60 ± 0.11	0.76 ± 0.14	0.60 ± 0.12	0.41 ± 0.08
Number of values	109	75	64	76

<sup>A</sup> Test conditions:  $F = 10\text{ N}$ ;  $v = 0.1\text{ ms}^{-1}$ ;  $T = 23^\circ\text{C}$ ; relative humidity range 12 to 78 %; laboratory air; sliding distance 1000 m; wear track (nominal) diameter = 32 mm; materials: steel = AISI 52 100; and alumina =  $\alpha$ -Al<sub>2</sub>O<sub>3</sub>.

case, the sliding path is a circle on the disk surface. The plane of the disk may be oriented either horizontally or vertically.

NOTE 1—Wear results may differ for different orientations.

4.1.1 The pin specimen is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. Other loading methods have been used, such as hydraulic or pneumatic.

NOTE 2—Wear results may differ for different loading methods.

4.2 Wear results are reported as volume loss in cubic millimetres for the pin and the disk separately. When two

different materials are tested, it is recommended that each material be tested in both the pin and disk positions.

4.3 The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after the test, or by weighing both specimens before and after the test. If linear measures of wear are used, the length change or shape change of the pin, and the depth or shape change of the disk wear track (in millimetres) are determined by any suitable metrological technique, such as contact profilometry. Linear measures of wear are converted to wear volume (in cubic millimetres) by using appropriate geometric relations. Linear

TABLE 3 Test Parameters Used for Interlaboratory Tests

Normal Force (N)	10
Sliding Speed (m/s)	0.1
Sliding Distance (m)	1000
Pin-end Diameter, spherical (mm)	10
Environment	air
Temperature, nominal (°C)	23
Humidity, (%RH)	12–78
Track Diameter (mm)	25–35

measures of wear are used frequently in practice since mass loss is often too small to measure precisely. If loss of mass is measured, the mass loss value is converted to volume loss (in cubic millimetres) using an appropriate value for the specimen density.

4.4 Wear results are usually obtained by conducting a test for a selected sliding distance and for selected values of load and speed. One set of test conditions that was used in an interlaboratory measurement series is given in Tables 1-3. Other test conditions may be selected depending on the purpose of the test. In such cases, the user should report their results as “following the procedure of ASTM G99.”

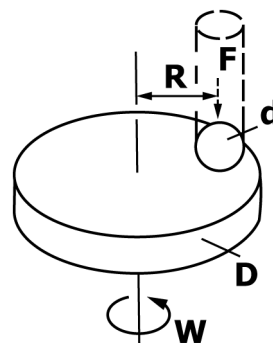
4.5 Wear results may in some cases be reported as plots of wear volume versus sliding distance using different specimens for different distances. Such plots may display non-linear relationships between wear volume and distance over certain portions of the total sliding distance, and linear relationships over other portions. Causes for such differing relationships include initial “break-in” processes, transitions between regions of different dominant wear mechanisms, and so forth. The extent of such non-linear periods depends on the details of the test system, materials, and test conditions.

4.6 It is not recommended that continuous wear depth data obtained from in-situ direct measurement (for example, position-sensing gages, ultrasound) be used because of the complicated effects of wear debris and transfer films present in the contact gap, and interferences from thermal expansion or contraction.

4.7 If required, friction force should be recorded during a test. A tension-compression load cell or similar force-sensing device may be used to measure the friction forces generated during sliding. Calibration of the friction force is required. Modern data acquisition systems capable of sampling frequencies in excess (at least two orders of magnitude is suggested, that is, at least two measurements per revolution) of the rotating frequency of the test being conducted are preferred. The method of sensing and recording friction force during the test shall be described in the testing report. Refer to Guide G115 for further guidance.

## 5. Significance and Use

5.1 The amount of wear in any system will, in general, depend upon the number of system factors such as the applied load, machine characteristics, sliding speed, sliding distance, the environment, and the material properties. The value of any wear test method lies in predicting the relative ranking of material combinations. Since the pin-on-disk test method does not attempt to duplicate all the conditions that may be



NOTE 1— $F$  is the normal force on the pin,  $d$  is the pin or ball diameter,  $D$  is the disk diameter,  $R$  is the wear track radius, and  $w$  is the rotation velocity of the disk.

FIG. 1 Schematic of Pin-on-Disk Wear Test System

experienced in service (for example, lubrication, load, pressure, contact geometry, removal of wear debris, and presence of corrosive environment), there is no insurance that the test will predict the wear rate of a given material under conditions differing from those in the test.

5.2 The use of this test method will fall in one of two categories: (1) the test(s) will follow all particulars of the standard, and the results will have been compared to the ILS data (Table 2), or (2) the test(s) will have followed the procedures/methodology of Test Method G99 but applied to other materials or using other parameters such as load, speed, materials, etc., or both. In this latter case, the results cannot be compared to the ILS data (Table 2). Further, it must be clearly stated what choices of test parameters/materials were chosen.

## 6. Apparatus

6.1 *General Description*—Fig. 1 shows a schematic drawing of a typical pin-on-disk wear test system.<sup>5</sup> One type of typical system consists of a driven spindle and chuck for holding the revolving disk, a lever-arm device to hold the pin, and attachments to allow the pin specimen to be forced against the revolving disk specimen with a controlled load. Another type of system loads a pin revolving about the disk center against a stationary disk. In any case the wear track on the disk is a circle, involving multiple wear passes on the same track. The system may have a friction force measuring system, for example, a load cell, that allows the coefficient of friction to be determined.

6.2 *Motor Drive*—A variable speed motor, capable of maintaining constant speed ( $\pm 1\%$  of rated full load motor speed) under load is required. The motor should be mounted in such a manner that its vibration does not affect the test. Rotating speeds are typically in the range 1 r/min to 2000 r/min.

6.3 *Revolution Counter*—The machine shall be equipped with a hardware- or software-based revolution counter or its equivalent that will record the number of disk revolutions, and

<sup>5</sup> Three commercially-built pin-on-disk machines were either involved in the interlaboratory testing for this standard or submitted test data that compared adequately to the interlaboratory test data. Further information on these machines can be found in Research Report RR:G02-1008.