Designation: G190 – 15

Standard Guide for Developing and Selecting Wear Tests[1]

This standard is issued under the fixed designation G190; 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 guide covers general information for the development and selection of a wear test for an intended application.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D2266 Test Method for Wear Preventive Characteristics of Lubricating Grease (Four-Ball Method)
D2670 Test Method for Measuring Wear Properties of Fluid Lubricants (Falex Pin and Vee Block Method)
D2714 Test Method for Calibration and Operation of the Falex Block-on-Ring Friction and Wear Testing Machine
D3702 Test Method for Wear Rate and Coefficient of Friction of Materials in Self-Lubricated Rubbing Contact Using a Thrust Washer Testing Machine
D3704 Test Method for Wear Preventive Properties of Lubricating Greases Using the (Falex) Block on Ring Test Machine in Oscillating Motion
D4170 Test Method for Fretting Wear Protection by Lubricating Greases
D4172 Test Method for Wear Preventive Characteristics of Lubricating Fluid (Four-Ball Method)
F732 Test Method for Wear Testing of Polymeric Materials Used in Total Joint Prostheses
G32 Test Method for Cavitation Erosion Using Vibratory Apparatus
G40 Terminology Relating to Wear and Erosion
G56 Test Method for Abrasiveness of Ink-Impregnated Fabric Printer Ribbons and Other Web Materials
G65 Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus
G73 Test Method for Liquid Impingement Erosion Using Rotating Apparatus
G75 Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)
G76 Test Method for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets
G77 Test Method for Ranking Resistance of Materials to Sliding Wear Using Block-on-Ring Wear Test
G81 Test Method for Jaw Crusher Gouging Abrasion Test
G83 Test Method for Wear Testing with a Crossed-Cylinder Apparatus (Withdrawn 2005)[3]
G98 Test Method for Galling Resistance of Materials
G99 Test Method for Wear Testing with a Pin-on-Disk Apparatus
G105 Test Method for Conducting Wet Sand/Rubber Wheel Abrasion Tests
G117 Guide for Calculating and Reporting Measures of Precision Using Data from Interlaboratory Wear or Erosion Tests
G118 Guide for Recommended Format of Wear Test Data Suitable for Databases
G119 Guide for Determining Synergism Between Wear and Corrosion
G132 Test Method for Pin Abrasion Testing
G133 Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear
G134 Test Method for Erosion of Solid Materials by Cavitating Liquid Jet
G137 Test Method for Ranking Resistance of Plastic Materials to Sliding Wear Using a Block-On-Ring Configuration
G163 Guide for Digital Data Acquisition in Wear and Friction Measurements
G171 Test Method for Scratch Hardness of Materials Using a Diamond Stylus
G174 Test Method for Measuring Abrasion Resistance of Materials by Abrasive Loop Contact
G176 Test Method for Ranking Resistance of Plastics to Sliding Wear Using Block-on-Ring Wear Test—Cumulative Wear Method
G181 Test Method for Conducting Friction Tests of Piston Ring and Cylinder Liner Materials Under Lubricated Conditions

---

[1] This guide is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.20 on Data Acquisition in Tribosystems.

Current edition approved May 1, 2015. Published May 2015. Originally approved in 2006. Last previous edition approved in 2006 as G190 – 06 which was withdrawn January 2015 and reinstated in May 2015. DOI: 10.1520/G0190-15.

[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology G40 for terms used in this guide.

3.1.2 *wear*—damage to a solid surface, generally involving progressive loss of material, due to relative motion between that surface and a contacting substance or substances.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *wear test*—any test for the determination of wear characteristics of materials.

4. Summary of Guide

4.1 This guide describes the generic elements that need to be considered in the selection and development of a wear test for it to be relevant to an application. General recommendations and considerations regarding these elements and their significance in the process of selecting and developing a wear test are provided. Variability to be expected with a well-controlled test is discussed as well as the correlation with an application.

4.2 This guide describes a general methodology for the implementation of a wear test. This methodology comprises the elements of simulation, acceleration, apparatus design, specimen preparation, test protocol, measurement, and documentation of results.

5. Significance and Use

5.1 The guidance and methodology provided by this guide is applicable for any wear situation and is not limited to material or lubrication. This guide is intended to provide general information and guidance regarding the selection and development of a wear test and does not provide specifics about any one wear test or intended application. In general the variability and correlation that is obtained with any wear test is determined by the degree to which the various elements of the wear test methodology described in this guide are followed.

6. Elements of Method

6.1 Wear behavior is a complex phenomenon, involving two or more bodies, one or more materials, and dependent on a wide range of factors, such as motion, loading, and environment. A material can wear by different mechanisms in different situations and different materials can wear by different mechanisms in the same wear situation. Wear of one surface or body can also be influenced by the wear of the other contacting body. As a result, wear behavior, or simply wear, is best viewed as a system property not a material property. The group of elements that affect wear behavior is referred to as a tribosystem.

6.2 Because of this complex nature of wear, the primary element involved in the selection of a wear test for an application is the simulation of the tribosystem of the application in the wear test. Another element of the methodology for selecting a wear test is acceleration of wear results, which is related to the consideration of simulation. Apparatus design, specimen preparation, test protocol, and measurement are additional elements of this methodology. In addition to their relationships with the need for simulation, these further elements are important in obtaining acceptable repeatability of test results.

6.3 Documentation of the result of a wear test is also an element of this methodology, and this is important for assessment and interpretation of the data obtained, as well as for the reporting of such data.

6.4 *Simulation:*

6.4.1 Simulation ensures that the behavior experienced in the test is the same as in the application. Given the complexity of wear and the current incomplete understanding of wear and its phenomena, test development is subject to trial and error and is dependent on the capability of the developer. Ideally, the test would exactly duplicate a wear situation. However, this generally is neither practical nor possible. Some differences will have to be accepted. While this is the case, any difference between the test and the intended application should be evaluated carefully to obtain relevant and useful wear data for the application.

6.4.2 The literature, prior data, and results of auxiliary or preliminary tests are useful in assessing the possible effects of differences.

6.4.3 The engineer concerned with reliability and life generally requires precise simulation. However, the material developer interested in a convenient test to rank the wear resistance of materials usually requires only that the test simulates the general area of application.

6.4.4 Contact conditions, primarily, the motion, contact stress, wear agent, lubrication, and environment, generally need to be representative of the application for adequate simulation.

6.4.5 Wear test simulation does not require that an application be replicated to provide valid data, provided the essential elements of a wear situation are replicated. For example, a sliding wear test is used to evaluate the wear resistance of material used for print elements in mechanical printers. In this application, the apparent key element is impact. Print element wear, however, is caused by sliding abrasive action that occurs during impact, which is simulated in a sliding test (see Test Method G56). As another example, the configuration of the dry-sand rubber wheel test (see Test Method G65), useful in ranking material wear situations involving dry abrasion, is not typical of some situations to which the test is applied. In the test, a rotating rubber wheel presses and rubs sand across the face of a specimen. A typical use of this test is to select materials for farm tools operating in sandy soils, where dry abrasion often dominates the wear situation.

6.4.6 *Wear Scar Morphology and Debris*—Although general knowledge and experience can aid in assessing the differences between test and application, correlations in wear behavior between test and application should also be studied. The most helpful correlation in developing a test is comparison of the worn surface and wear debris produced in the test to those produced in the application. The morphology of the scar, the presence or absence of oxidized or other surface layers, changes in the microstructure of the material, and wear debris size, shape, and composition can be compared. If major features of the wear scar and debris are different, valid simulation is unlikely. Wear mechanisms frequently result in characteristic wear particles. Consequently, comparing wear debris can be very useful.

6.4.7 *Test Geometry:*

6.4.7.1 Selection of test geometry is another factor that must be considered when simulating wear conditions. For example, laboratory sliding contact wear tests employ three general types of contact—point contacts (such as a sphere on a plane) for example, Test Methods G83 and G133, line contacts (such as a cylinder on a flat), for example, Test Method G77, and conforming contacts (such as a flat on a flat), for example, Test Methods D3702 and G75. In addition to simulation aspects, each of these geometries has advantages and disadvantages. Point-contact geometry eliminates alignment problems and allows wear to be studied from the start of the test. However, stress levels change as wear progresses, requiring more complex data analysis and comparison techniques. Furthermore, in the presence of a lubricant, point, line, and conforming contacts will differ greatly with respect to viscosity and anti-wear additives.

6.4.7.2 Because of the differences in stress behavior, a point or line contact is more sensitive to stress-dependent wear mechanisms than a conforming contact. For example, a point or line contact results in a different relationship between wear and sliding distance when the wear is a function of stress, compared with when it is not, because the stress level changes as wear progresses. A conforming contact with constant stress does not show this response. Stress dependency of the line contact lies between the point and conforming contact. The differences in these geometries must be recognized to obtain the required simulation.

6.4.7.3 Conforming-contact tests generally allow the parts to "wear-in" to establish uniform and stable contact geometry before taking data. As a result, it is difficult to identify wear-in phenomena, because there is no continuous observation of wear behavior. Consequently, it is difficult to differentiate surface modifications from simple alignment improvements. In addition, for applications in which allowed wear is small, the wear-in period of these tests may be the most relevant portion of the test. However, conforming contact provides constant load and stress conditions once the parts are worn-in.

6.5 *Test Acceleration*—Acceleration in a test is desirable, since unaccelerated tests frequently are more costly and time consuming. However, acceleration may threaten simulation by significantly altering or introducing different phenomena. Wear mechanisms generally have threshold acceleration values for transition from mild to severe wear behavior. In addition, acceleration of such parameters as load or speed can emphasize one wear mechanism over another, thus causing different wear behavior. Nevertheless, most wear tests incorporate some element of acceleration—continuous operation, measurement of smaller quantities of wear, or higher loads, speeds, and temperatures. All acceleration aspects associated with a test need to be evaluated in terms of their possible effect on simulation and should focus on potential changes in wear mechanism.

6.6 *Apparatus Considerations, Specimen Preparation and Test Protocol:*

6.6.1 Apparatus design, specimen preparation, and test protocol are important elements for precision and repeatability. Lack of attention to these areas cause unacceptable scatter in wear tests. However, when properly addressed, scatter can generally be reduced to acceptable levels for most engineering application.

6.6.2 In general, the test apparatus should be designed with enough ruggedness and precision to provide repeatable and stable wear conditions.

6.6.3 To reduce scatter in wear testing, a test should be built around uniform, consistent, and readily obtainable reference material. Periodic standard tests should monitor the condition of the test rig, skill of the operator, and such factors as the influence of ambient environment, for example, room temperature and humidity, effects. Examples of the use of a reference material in wear testing can be found in Test Methods D2714, G56, and G75.

6.6.4 Generally, close simulation or replication exists in tests that show good correlation to practice, and tight controls are evident in tests that provide good repeatability and low scatter. The ASTM wear test methods provide examples of the detail and care that are necessary to obtain good repeatability and minimum scatter (see Test Methods D2266, D2670, D3704, D4170, D4172, F732, G32, G73, G76, G81, G98, G99, G105, G119, G132, G134, G137, G163, G171, G174, G176, and G181). The precision of the apparatus, specimen preparation, conditions of the counterface and the abrasive (when appropriate) and details of wear measurement and reporting are discussed in each procedure.

6.6.5 Specimen preparation and the details of test control vary with the test and materials involved. For metals, surface roughness, geometry of the specimens, microstructure, homogeneity, hardness, and presence of surface layers usually must be controlled. Similar controls are also necessary for the counterface and the wear-producing mediums. For example, in a test using sand as an abrasive, the purity, particle shape and size, and moisture content of the sand must be controlled (see Test Method G65). In wear tests involving fluids (for example, as an erosive medium or lubricant), the properties of these fluids must be controlled.

6.6.6 Parameters such as load, speed, rigidity of apparatus construction (see Related Material for references regarding the effect of stiffness (rigidity) and vibration on wear), ambient environment, location and alignment, and supply of abrasive or fluid require adequate control. In test development, investigation is necessary to assess the degree of control required and to establish repeatability.

6.6.7 Because of the complexity of wear behavior and the possibility of large variation in test result, multiple tests should be done. A minimum of three replicate measurements is recommended for most situations. However, a larger number of replicates (as many as six) may be needed, particularly if there is large scatter in test results or a need to develop a statistical characterization.

6.7 *Measurement:*

6.7.1 Common wear measures are mass or weight loss, volume loss or displacement, scar width or depth or other geometrical measures, and indirect measures, such as the time required to wear through a coating or the load required to cause severe wear or a change in surface reflectance. The selection of parameter to measure wear is often based on convenience, the nature of the wear specimens, significance to an application, and available techniques. (See Guides G117 and G118 for guidelines regarding reporting and analysis of wear data.)

6.7.2 For large amounts of wear, weight-loss measurement is suitable, because it is simple and scales usually are available. However, weight-loss measurement has two major limitations. First, wear is related primarily to volume of material removed or displaced. If the tested materials differ in density, weight loss does not provide a true ranking. Second, this measure does not account for wear by material displacement; a specimen may gain weight by transfer. Therefore, weight-loss measurement is valid only when material densities are the same and when material displacement and transfer do not occur.

6.7.3 Volume loss or displacement, although directly attributable to wear, frequently is difficult to measure. Except for simple wear scar geometries, determination of volume loss is complex and time consuming. A linear dimension, such as the depth or width of the scar, often is measured, because it is related to volume through the test geometry. However, the applicability of this type of measurement is limited to each specific test geometry and test.

6.7.4 Wear measurement by indirect techniques is viable in some cases. For example, when comparing the wear resistance of very thin coatings, the time required to wear through may be the only convenient way of measuring performance. However, indirect techniques generally are limited in scope and applicability and do not easily provide or establish fundamental wear parameters.

6.7.5 In wear tests used to rank materials, the wear data are often used directly. However, the wear measurement may also be used to establish parameters that rank material performance and used to project behavior in an application. Examples of this are the wear coefficient often used for sliding wear, K (volume lost/load·sliding distance), and the zero-wear factor, γ_r, used in a stress models for sliding and impact wear, which are used to determine the relationship between wear and parameters, such as load and usage. These latter uses often involve multiple wear measurements as a function of usage, for example, sliding distance, rather than a single, end-value measurement, typical of the former use.

6.7.6 Material wear behavior can be compared by determining a wear curve, wear as a function of test duration, or by measuring wear at a single point, that is, at the end of a test. Because wear behavior frequently is nonlinear and transitions in wear behavior with test duration are possible, a wear curve provides more information and allows evaluation of more complex behavior than single-point measurement. With nonlinear behavior it is possible to obtain different rankings of materials with tests of different durations. Therefore, the potential for nonlinear and transitional behavior should be considered when a wear test is developed. When a single-point measurement is used, it is generally necessary to select a test duration that ensures stable wear behavior to provide valid and consistent data.

6.7.7 In engineering applications for which material life and reliability are concerns, the wear curve provides more complete information about material behavior and aids in data extrapolation. However, single-point measurement frequently is selected when quick evaluation and simple ranking of materials are desired.

6.8 *Precision:*

6.8.1 The precision of a wear test result, in terms of within-lab repeatability, depends on several factors, including the design and fabrication of the apparatus, materials, nature of the wear, test implementation, and measurement technique. As a guideline, existing standardized wear tests show coefficients of variation in wear measurement ranging from 5 to 50 % or larger.

6.8.2 A method for determining the precision of a wear test is described in Guide G117.

6.9 *Documentation:*

6.9.1 Wear is a system response. When reporting wear data, supply a description of the wearing system that includes:

6.9.1.1 Apparatus,

6.9.1.2 Geometry of contact,

6.9.1.3 Type of motion,

6.9.1.4 Load,

6.9.1.5 Speed,

6.9.1.6 Description of materials,

6.9.1.7 Surface and material preparations,

6.9.1.8 Roughness,

6.9.1.9 Environmental condition,

6.9.1.10 Condition of wearing mediums,

6.9.1.11 Description of lubricant and lubrication used,

6.9.1.12 Description of wear-in period, if appropriate, and

6.9.1.13 Unusual observation, for example, evidence of transfer.

6.9.2 The report should describe the material tested, general nature of the test, conditions of the counter face, testing environment, and any other significant features. For example, in metal/metal wear, transfer film formation should be recorded and reported. Frequently, such observations lead to a greater understanding of the wear situation and material response and to improved test development.

6.9.3 Additional information concerning the reporting of wear test data can be found in Guides G117 and G118.

7. Correlation to Application

7.1 While the selection of a wear test involves the element of simulation, the existence of correlation between a wear test and an application is not necessarily ensured, since the simulation is typically not exact. Consequently, correlation between a test and an application, while expected, should not be presumed. Correlation needs to be demonstrated by comparison of results.

8. Keywords

8.1 erosion; erosion test; tribology; wear; wear test

RELATED MATERIAL

ASTM STP 615, *Selection and Use of Wear Tests for Metals*, ASTM International, 1977.

ASTM STP 701, *Wear Tests for Plastics: Selection and Use*, ASTM International, 1980.

ASTM STP 769, *Selection and Use of Wear Tests for Coatings*, ASTM International, 1982.

ASTM STP 1010, *Selection and Use of Wear Tests for Ceramics*, ASTM International, 1988.

ASTM STP 1199, *Tribology: Wear Test Selection for Design and Application*, ASTM International, 1993.

ASTM STP 1247, *Effects of Mechanical Stiffness and Vibration on Wear*, ASTM International, 1995.

Aronov, V., D'Souza, A. F., Kalpakjan, S., Shareef, I., "Experimental Investigation of the Effect of System Rigidity on Wear and Friction-induced Vibrations," *Journal of Lubrication Technology*, Vol 105, 1983, pp. 206-211.

Aronov, V., D'Souza, A. F., Kalpakjan, S., Shareef, I., "Interactions Among Friction, Wear, and System Stiffness—Part II: Effect of Normal Load on System Stiffness," *Journal of Lubrication Technology*, Vol 106, 1984, pp. 54-58.

Aronov, V., D'Souza, A. F., Kalpakjan, S., Shareef, I., "Interactions Among Friction, Wear, and System Stiffness—Part II: Vibrations Induced by Dry Friction," *Journal of Lubrication Technology*, Vol 106, 1984, pp. 59-64.