



Designation: G196 – 08 (Reapproved 2021)

Standard Test Method for Galling Resistance of Material Couples¹

This standard is issued under the fixed designation G196; 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 a laboratory test that ranks the galling resistance of material couples using a quantitative measure. Bare metals, alloys, nonmetallic materials, coatings, and surface modified materials may be evaluated by this test method.

1.2 This test method is not designed for evaluating the galling resistance of material couples sliding under lubricated conditions, because galling usually will not occur under lubricated sliding conditions using this test method.

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

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

G40 Terminology Relating to Wear and Erosion

G98 Test Method for Galling Resistance of Materials

3. Terminology

3.1 Definitions used in this test method are given in Terminology **G40**.

¹ 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.

Current edition approved June 1, 2021. Published June 2021. Originally approved in 2008. Last previous edition approved in 2016 as G196 – 08 (2016). DOI: 10.1520/G0196-08R21.

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.

3.2 Definitions:

3.2.1 *apparent area of contact*—area of contact between two solid surfaces defined by the boundaries of their macroscopic interface.

3.2.2 *galling*—form of surface damage arising between sliding solids, distinguished by macroscopic, usually localized, roughening and creation of protrusions above the original surface; it often includes plastic flow or material transfer, or both.

3.2.3 *triboelement*—one of two or more solid bodies that comprise a sliding, rolling, or abrasive contact, or a body subjected to impingement or cavitation. (Each triboelement contains one or more tribosurfaces.)

3.2.4 *tribosurfaces*—any surface (of a solid body) that is in moving contact with another surface or is subjected to impingement or cavitation.

3.2.5 *tribosystem*—any system that contains one or more triboelements, including all mechanical, chemical, and environmental factors relevant to the tribological behavior. (See also *triboelement*.)

3.3 Definitions of Terms Specific to This Standard:

3.3.1 *galling₅₀*—stress at which the probability of galling occurring on one or both of the test specimens is 50%.

4. Summary of Test Method

4.1 This test method uses available laboratory equipment capable of maintaining a constant, compressive load between two flat specimens, such as hydraulic compression testing machines. One specimen is slowly rotated one complete revolution relative to the other specimen. The surfaces are examined for galling after sliding. The criterion for whether galling occurs is the appearance of the specimens based on unassisted visual examination.

4.2 Appropriate load intervals are chosen to determine the threshold galling stress within an acceptable range.

4.3 The higher the Galling₅₀ value, the more galling resistant is the test couple.

5. Significance and Use

5.1 This test method is designed to rank material couples in their resistance to the failure mode caused by galling and not merely to classify the surface appearance of sliding surfaces.

5.2 This test method has been shown to have higher repeatability than Test Method G98 in determining the galling resistance. Test Method G98 can be used for initial ranking of galling resistance.

5.3 This test method should be considered when damaged (galled) surfaces render components non-serviceable. Experience has shown that galling is most prevalent in sliding systems that are slow moving and operate intermittently. The galling and seizure of threaded components is a classic example that this test method most closely simulates.

5.4 Other galling-prone examples include: sealing surfaces of valves that may leak excessively due to galling and pump wear rings that may function ineffectively due to galling.

5.5 If the equipment continues to operate satisfactorily and loses dimension gradually, then galling is not present, and the wear should be evaluated by a different test method.

5.6 This test method should not be used for quantitative or final design purposes, since many environmental factors influence the galling performance of materials in service. Lubrication, alignment, stiffness, and geometry are only some of the factors that can affect how materials perform. This test method has proven valuable in screening materials for prototypical testing that more closely simulates actual service conditions.

6. Apparatus

6.1 Commonly available laboratory equipment has been used to conduct galling tests. Any apparatus that can apply and maintain a constant compressive load should be acceptable. The use of a displacement controlled machines is generally not acceptable for this test because small variations in displacement of the specimens leads to large changes in the applied load.

6.2 The alignment of the specimens is accomplished via the alignment pin shown in Fig. 1. This pin is readily fabricated by press fit of a tooling ball into a drill rod or similar shaft with an appropriately sized hole machined into the end of the pin. Tooling balls are relatively inexpensive and readily available from industrial suppliers.

6.3 A hardened steel ball with a diameter of 9.53 mm is required for the testing procedure.

7. Test Specimen

7.1 This test method uses two concentric hollow cylindrical specimens with the ends mated. This results in area contact in the shape of an annulus. One specimen is rotated about its axis and the other is held fixed.

7.2 A typical geometry of the specimen is shown in Fig. 2.

7.3 The critical dimensions of the specimens are the 12.70 mm outer diameter and the 6.375 mm hole. All other dimensions may be varied to the user's convenience. The hex shape shown on the specimen is not required, however, it does provide a convenient means of gripping the specimens during testing.

7.4 A critical feature of the specimens is the flatness. The contact surface of the specimen shall be flat within 0.005 mm to ensure area contact. Flatness can be measured using a dial indicator.

8. Procedure

8.1 An overall view of the galling test setup is shown in 3.

8.2 *Cleaning*—Immediately prior to testing, clean the test surfaces of the new specimens using a procedure that will remove any scale, oil film, or foreign matter. The following cleaning technique is suggested for metallic specimens:

8.2.1 Clean the specimens in an ultrasonic cleaner using mild ultrasonic cleaning detergent and warm water for 10 min.

8.2.2 Rinse the specimens thoroughly with water.

8.2.3 Repeat this process using fresh solution.

8.2.4 After the final cleaning, dry the specimens with a lint-free wipe.

8.2.5 Remove any spotting with acetone and a lint-free wipe.

8.3 Mount the new specimens in the loading device. Lightly load the specimens. Twist the specimens relative to each other approximately 45° to ensure proper seating of the wear surfaces.

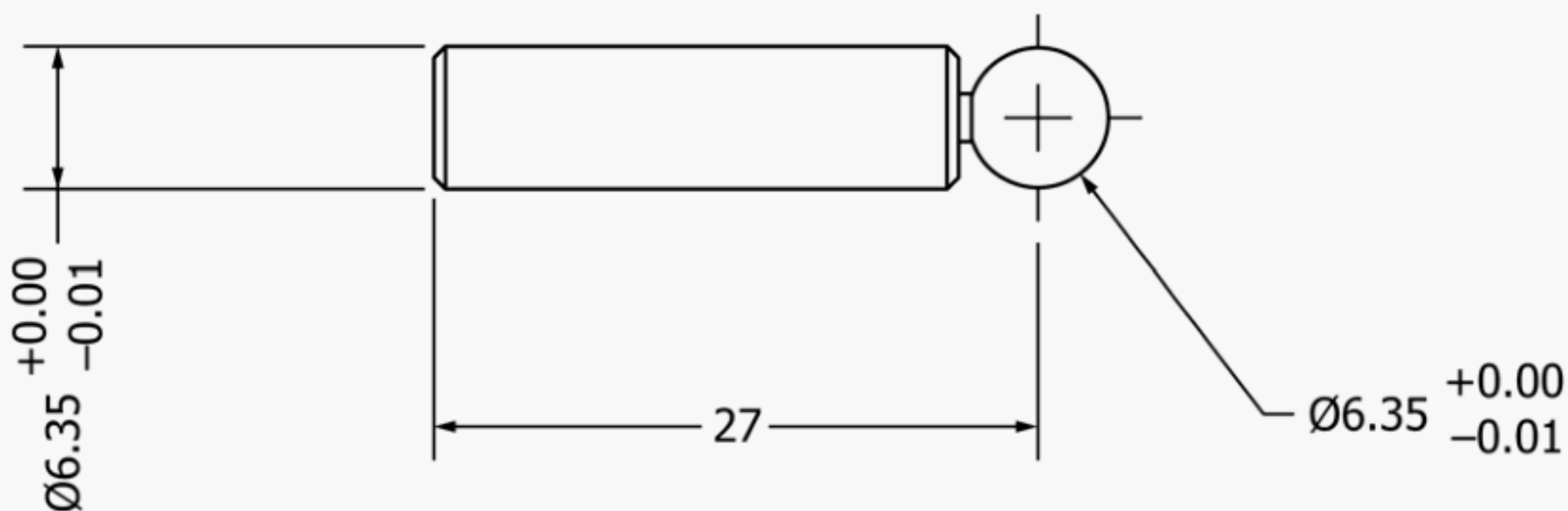


FIG. 1 Geometry of Alignment Pin (all dimensions are in mm)

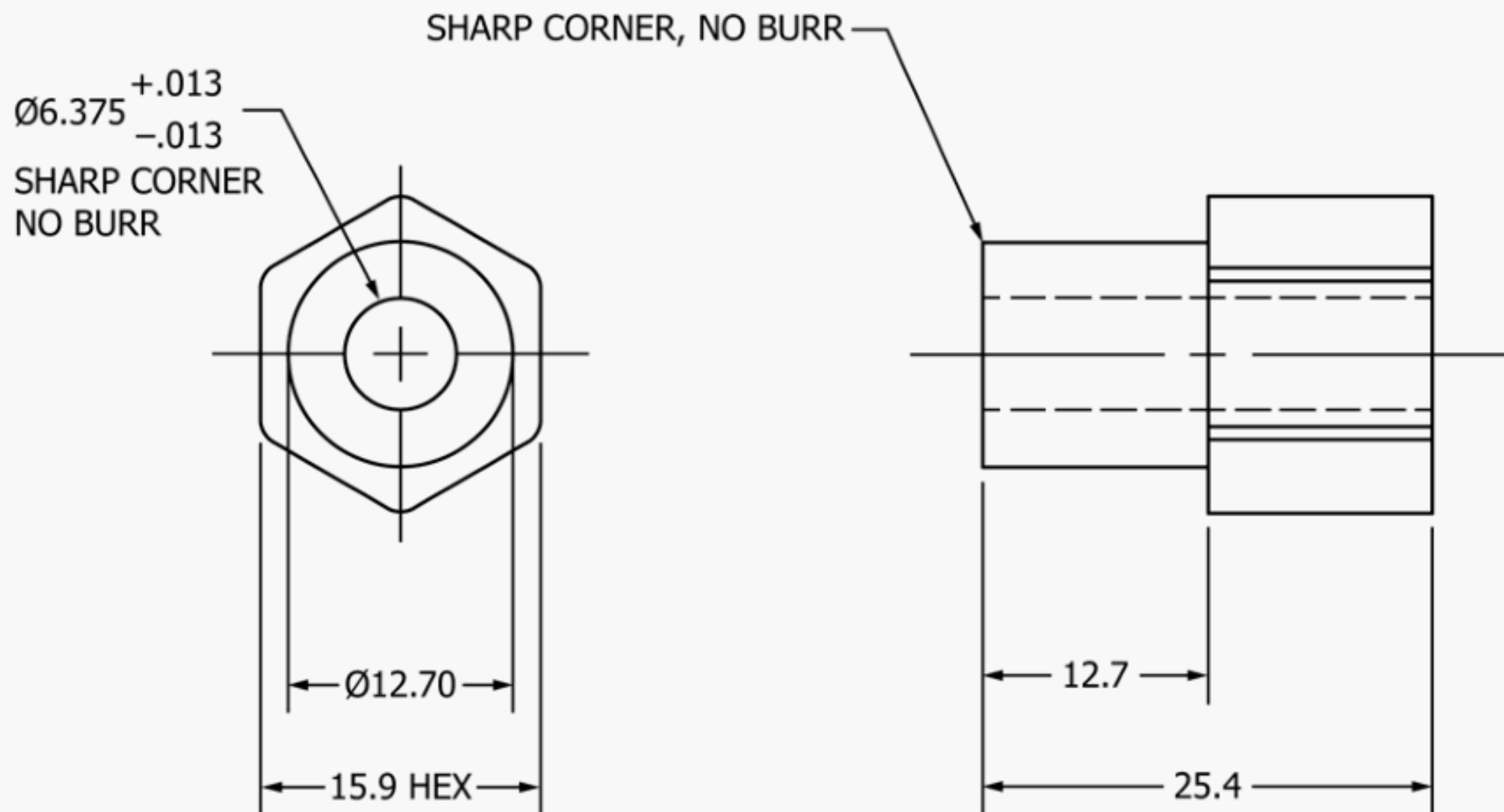


FIG. 2 Geometry of Specimen (all dimensions are in mm)

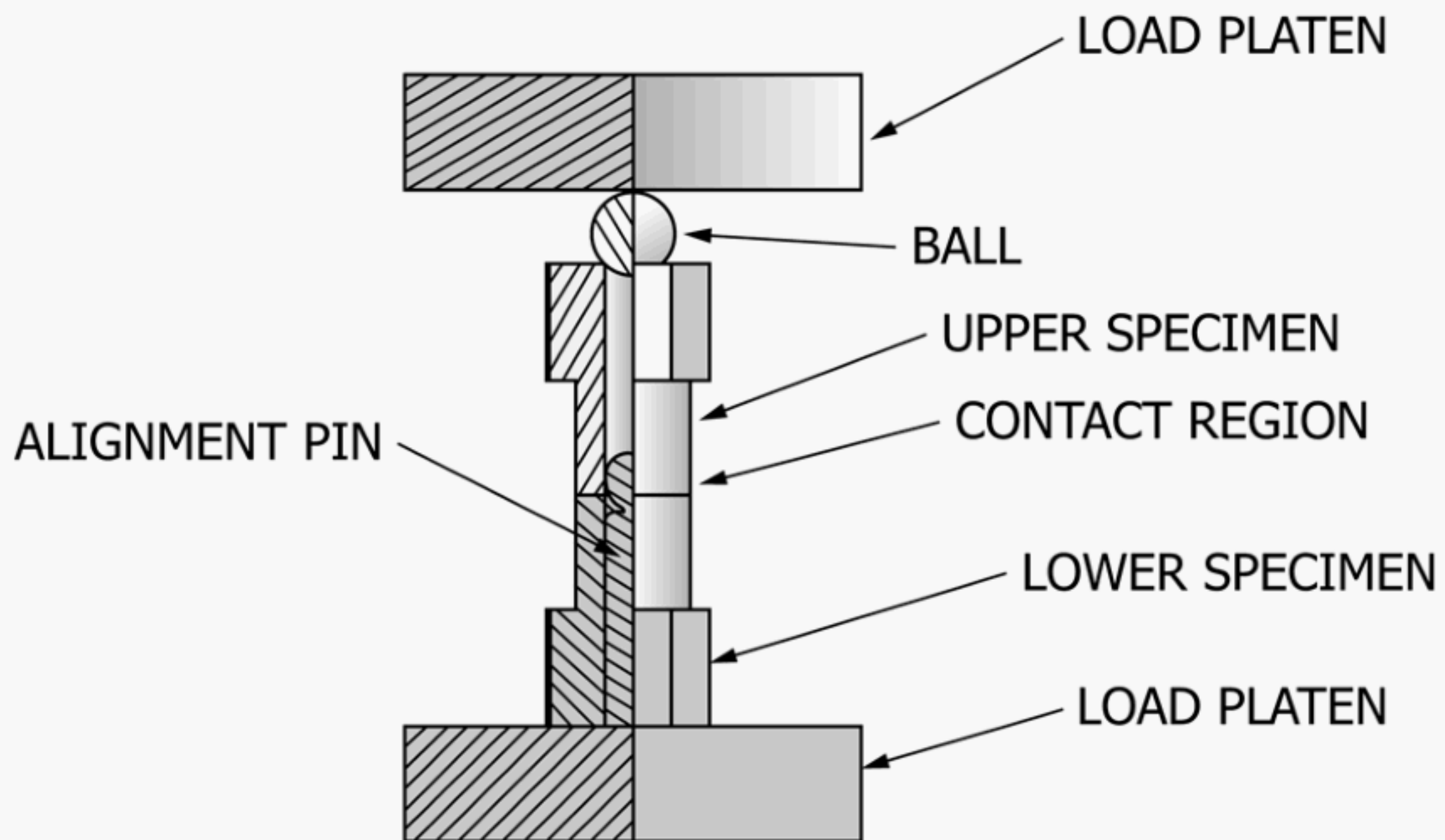


FIG. 3 Schematic Diagram of Galling Test Setup

8.4 Apply the selected load and rotate one specimen one revolution using an open-end wrench or other tool in order to grip the specimens. A mechanized system may also be used to rotate one specimen relative to the other. This may allow torque measurement during testing which may provide useful data on incipient scoring.

8.5 Sliding time should be approximately 10 s. Stopping for re-gripping of the turning tool is permitted, but re-gripping should be minimized. The elapsed time to re-grip is not counted in the 10 s test time.

8.6 Release the load.

8.7 Examine both specimens for galling. A photograph of typical galled specimens is shown in Fig. 4. If the specimens appear smooth and undamaged (burnishing does not constitute damage) to the unaided eye then galling is said to not have occurred. If any galling is present, regardless of the magnitude, then galling is said to be present. In this method, there are no degrees of galling. Galling is said to either exist on the test specimens or not. If the surfaces exhibit scratch marks, this is not galling. A wavy surface is not considered galled. At least



FIG. 4 Photograph of Typical Specimens after Testing

one of the contacting surfaces shall exhibit torn metal for galling to have occurred.

8.8 A minimum of 12 replicates shall be tested at each load level.

8.9 A minimum of four load levels shall be tested in order to perform the data analysis. At least two load levels shall be above the load where 50 % of the specimens would gall. At least two load levels shall be below the load where 50 % of the specimens would gall.

8.10 At least two data points shall lie within the galling frequency range of 0.2 to 0.8, or one data point within the galling frequency range of 0.35 to 0.65.

8.11 A data point at the origin, (0,0) should be included in the data set.

9. Presentation of Data and Calculations

9.1 The data collected using this test method are to be plotted on a galling frequency versus applied stress diagram. A sample diagram depicting the results of three types of materials is shown in Fig. 5. The applied stress on the x-axis is found by dividing the applied force by the apparent area of contact, that is, the cross-sectional area of the specimen. For the given specimen geometry, this area is 14.96 mm². The galling frequency shown on the y-axis quantifies the percentage of specimens that experienced galling at each applied load. For example, if 8 of the 12 specimens tested at a given load experienced galling, then the galling frequency for the associated stress would be 8/12 or 0.667.

9.2 Each of the load levels tested will result as a single data point on the galling frequency versus stress diagram.

9.3 A best fit curve can be fitted to the data once all of the data points have been plotted on the diagram. This can be accomplished by fitting a two parameter sigmoid equation to the data. The two parameter sigmoid has the following form:

$$f = \frac{1}{1 + e^{-\left(\frac{\sigma - G_{50}}{b}\right)}} \quad (1)$$

where:

- f = galling frequency,
- σ = applied stress,
- G_{50} = Galling₅₀ value, and
- b = related to the steepness of the curve.

Parameters G_{50} and b shall be fitted to the galling frequency versus applied stress data. The best fit curve can also be drawn with a French curve or similar drawing instrument in lieu of mathematically fitting the data to the sigmoid equation.

9.4 The Galling₅₀ value, the stress at which 50 % of the specimens are expected to gall, can be determined using either the parameters of the curve fit or the graphical results.

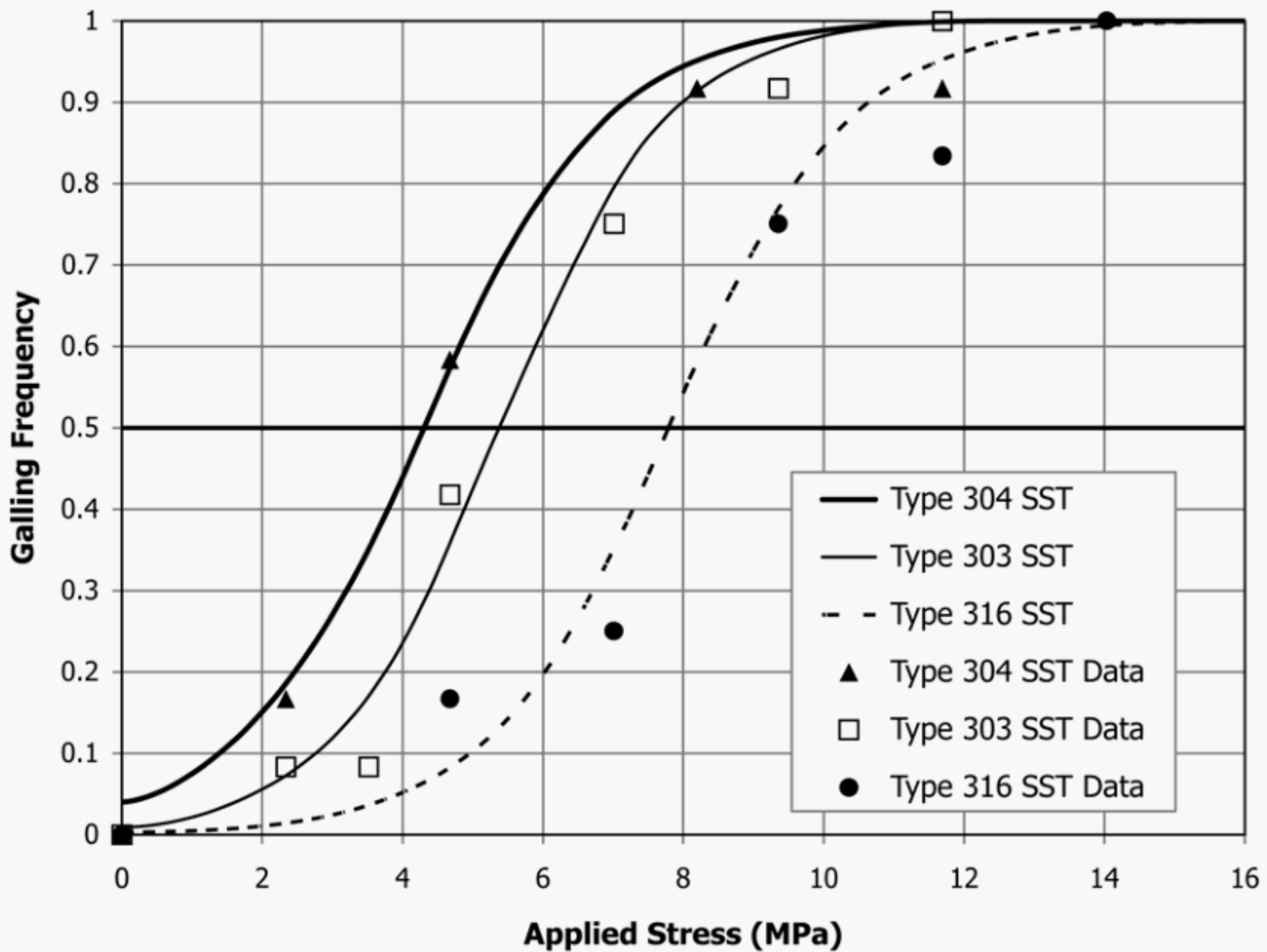
9.4.1 The Galling₅₀ value is parameter G_{50} in Eq 1.

9.4.2 The Galling₅₀ value is determined graphically by finding the applied stress that corresponds to a point on the curve where the galling frequency is 0.50. This galling frequency is shown with a bold line on Fig. 5.

10. Report

10.1 The following data should be included in the test report:

- 10.1.1 Material composition of specimens,
- 10.1.2 Hardness of specimens,
- 10.1.3 Flatness of specimens
- 10.1.4 Thermal history of specimens,
- 10.1.5 Surface roughness, R_a , of contact surfaces prior to testing,
- 10.1.6 Cleaning process used,
- 10.1.7 Surface treatment history such as passivation, etc.,
- 10.1.8 The Galling₅₀ value,
- 10.1.9 Number of replicates performed at each load,
- 10.1.10 Magnitude of loading,
- 10.1.11 Test system used, type, size, and
- 10.1.12 Temperature, humidity, atmosphere.



NOTE 1—Specimens used in this sample test had a flatness of 0.002 mm, no heat treatment or surface treatment, and a surface roughness of 80 μm . The specimens were cleaned using the process described in this test method. Twelve replicates were run at each load. The testing was performed in a servo-hydraulic universal testing machine. The hardness of the Type 303, 304, and 316 stainless steel specimens was 98, 107, and 102 Rockwell B, respectively.

FIG. 5 Graphical Results of Three Different Materials

11. Precision and Bias

11.1 Absolute magnitudes of galling resistance of material couples are not available because of the wide range variables in any given tribosystem that influence galling resistance.

11.2 No rigorous statement can be made regarding bias since there is no independent measure of galling resistance of a given tribosystem.

11.3 The wear measurement conditions established by this test method are designed to facilitate obtaining precise and reproducible data.

11.4 The repeatability of the results using this test method improve with the number of replicates used to generate each data point and with the number of data points used to create the galling frequency versus applied stress graph. Table 1 indicates the repeatability standard deviation and the coefficient of variation for various numbers of replicates and data points.

TABLE 1 Repeatability^A

Number of Replicates per Data Point	Number of Data Points in Data Set	Level of Applied Stress, MPa	Repeatability Standard Deviation, σ , MPa	Coefficient of Variation, CV, %
12	4	2.0, 4.0, 6.0, 8.0	0.46	9.2
12	5	2.0, 4.0, 5.0, 6.0, 8.0	0.38	7.6
20	4	2.0, 4.0, 6.0, 8.0	0.38	7.6
20	5	2.0, 4.0, 5.0, 6.0, 8.0	0.33	6.6

^A The data in the table above is for a material couple with following parameters for the sigmoid function shown in Eq 1: $b = 1.2$, and $G_{50} = 5.0$.

11.5 The reproducibility standard deviation and coefficient of variation will be determined upon completion of an inter-laboratory testing program and will be available on or before June 2011.

12. Keywords

12.1 adhesive wear; galling; galling resistance; macroscopic surface damage; seized components; sliding metallic surfaces

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