Designation: G223 – 23

Standard Test Method for Measuring Friction and Adhesive Wear Properties of Lubricated and Nonlubricated Materials Using the Twist Compression Test (TCT)[1]

This standard is issued under the fixed designation G223; 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 laboratory procedures for determining the coefficient of friction (COF) and resistance of materials to adhesion under flat sliding using the twist compression test (TCT). This test method ranks material couples, surface treatments, coatings, and lubricant combinations by COF and their resistance to adhesion.

1.2 The time until adhesion for the materials under the test conditions are reported and used to quantify the tribocouple's adhesion resistance and susceptibility to galling or scuffing. Systems of higher adhesion resistance will give longer time until failure.

1.3 The coefficient of friction values averaged between the test reaching full test pressure and the time of the onset of adhesion or the end of tests run for a predetermined time period are recorded. Systems are ranked by their average coefficients of friction before adhesion occurs.

1.4 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard except psi and pounds in Table 1.

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 appropriate 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:*[2]

G40 Terminology Relating to Wear and Erosion

3. Terminology

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

3.1.1 *adhesive wear, n*—wear caused by localized bonding between contacting solid surfaces leading to material transfer between the two surfaces or loss from either surface.

3.1.2 *apparent area of contact, n—in tribology,* the area of contact between two solid surfaces defined by the boundaries of their macroscopic interface.

3.1.3 *galling, n*—form of surface damage arising between sliding solids distinguished by macroscopic, usually localized, roughening and the creation of protrusions above the original surface; it is characterized by plastic flow and may involve material transfer.

3.1.4 *nominal contact pressure, FL^{-2}, n—in tribology,* an average contact pressure between two conforming bodies calculated by dividing the contact force by the apparent area of contact.

3.1.5 *plowing, n—in tribology,* the formation of grooves by plastic deformation of the softer of two surfaces in relative motion.

3.1.6 *scoring, n—in tribology,* a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding.

3.1.7 *scratching, n—in tribology,* the mechanical removal or displacement or both of material from a surface by the action of abrasive particles or protuberances sliding across the surfaces.

3.1.8 *scuffing, n*—form of adhesive wear occurring in inadequately lubricated tribosystems that is characterized by macroscopically observable localized changes in surface texture.

[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.

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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.

3.1.9 *sliding wear, n—in tribology,* wear caused by the relative motion in the tangential plane of contact between two solid bodies.

3.1.10 *stick-slip, n—in tribology,* a cyclic fluctuation in the magnitudes of friction force and relative velocity between two elements in sliding contact, usually associated with a relaxation oscillation dependent on elasticity in the tribosystem and a decrease of the coefficient of friction (COF) with onset of sliding or increase in sliding velocity.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *coefficient of friction in twist compression testing, CFT, n—in twist compression testing (TCT),* the transmitted torsional force at a specific radius of gyration divided by the applied normal force:

$$\mathrm{CFT(dimensionless)} = F_{\mathrm{torq,\ Rg=\_}}/F_{\mathrm{n}} \quad (1)$$

where:

$F_{\mathrm{torq,\ Rg=\_}}$ = transmitted torsional force at radius and
R_{g} and F_{n} = normal force.

3.2.2 *radius of gyration, n—in TCT using an annular contact between a flat specimen and a cylindrical specimen of inner radius, R_i, and outer radius, R_o* , the radius of gyration, *Rg*, is defined as:

$$R_g = \frac{1}{2}\sqrt{R_i^2 + R_o^2} \quad (2)$$

This may be approximated by the mean radius defined as:

$$R_{mean} = \frac{(R_o - R_i)}{2} \quad (3)$$

3.2.3 *seizure, n*—localized fusion of metal between the rubbing surfaces of the test pieces that is characterized by a rapid rise in the CFT versus time curve.

4. Summary of Test Method

4.1 The TCT is used to determine the coefficient of friction in twist compression testing, CFT, and adhesion resistance of nonlubricated and lubricated material couples in conformal normal area contacts under continuous unidirectional sliding conditions. While it is most often used to evaluate material couples, surface treatments, coatings, and lubricants for metalworking processes, the TCT has application in other conformal sliding contacts.

4.2 This test method uses laboratory equipment capable of maintaining a constant, compressive load in a cylindrical flat-on-flat geometry and a mechanism that will produce the necessary relative motion between a rotating ring and the fixed flat specimen. The transmitted torsional force is measured between the rotating ring and a flat specimen. The coefficient of friction determined using TCT is referred to as the coefficient of friction in twist compression testing (CFT). The coefficient of friction in twist compression testing is the ratio of the torsional force transmitted from the rotating specimen to the fixed specimen to the applied normal force. The resulting contact area is an annulus with approximately the same macro dimensions as the cylinder end (see Fig. 1). As surface films are removed or, in the case of lubricated tests, the lubricant is depleted, the adhesive nature of the contact surfaces is revealed

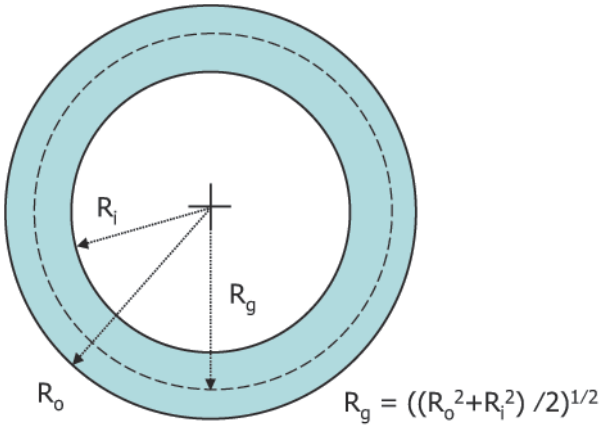

FIG. 1 Radius of Gyration of an Annulus

in both the magnitude of the CFT and in the duration of CFT versus time graph features.

4.3 The test often ends with the seizure (or cold welding) of the surfaces. This seizure is often characterized by a rapid rise in torque and the CFT versus time curve. Either the annular cylinder or the flat surface may be visually examined to confirm the occurrence of adhesive wear (Fig. 2).

5. Significance and Use

5.1 This test method is designed to rank material couples, surface treatments, and lubricants by CFT and in their resistance to adhesive wear. Since adhesive wear is a complex phenomenon and stochastic in nature, it is essential to evaluate surfaces to confirm the presence of adhesion.

5.2 This test method should be considered when evaluating the impact of changes in a process or application that is prone to adhesive wear, including any combination of scoring, galling, and plowing. These modes of failure commonly occur under sliding contact, at high contact stress, and, when applicable, at lubricant starvation.

5.3 The TCT is often used to evaluate the ability of material couples, surface treatments, coatings, and lubricants to prevent or reduce adhesive wear in metalworking operations including

FIG. 2 TCT Specimens after Testing