Designation: D8503 – 23

Standard Test Method for Determining the Scuffing Temperature Limit of Lubricating Oils Using the SRV Test Machine[1]

This standard is issued under the fixed designation D8503; 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 the determination of a scuffing temperature limit of lubricating oils at prescribed conditions and the retention of friction over temperature load step increases in a roller-on-disk (flat) geometry when subjected to high-frequency, linear oscillation motion. This test method is executed under constant load, frequency and stroke in a SRV test machine. The evolution of coefficient of friction of lubricating oils as function of temperature is recorded and assessed.

1.2 Tribometrical scuffing tests were so far related to load step tests. This test method determines the upper temperature limit for operating a lubricant and can also be used to determine the ability of a non-EP lubricating oil to protect against scuffing with increasing temperature.

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]

A295 Specification for High-Carbon Anti-Friction Bearing Steel

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants

D5706 Test Method for Determining Extreme Pressure Properties of Lubricating Greases Using a High-Frequency, Linear-Oscillation (SRV) Test Machine

D6425 Test Method for Measuring Friction and Wear Properties of Extreme Pressure (EP) Lubricating Oils Using SRV Test Machine

D7755 Practice for Determining the Wear Volume on Standard Test Pieces Used by High-Frequency, Linear-Oscillation (SRV) Test Machine

E45 Test Methods for Determining the Inclusion Content of Steel

G40 Terminology Relating to Wear and Erosion

2.2 *DIN Standards:*[3]

DIN 5402–1 Rolling bearings – Parts of rolling bearings – Part 1: Cylindrical rollers

DIN 51631:1999 Mineral spirits; special boiling point spirits; requirements

DIN 51834 Tribological Test in the Translatory Oscillation Apparatus (Part 4: Determination of friction and wear data for lubricating oils with the cylindrical roller-disk geometry)

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminologies D4175 and G40.

3.1.2 *break-in, n—in tribology*, an initial transition process occurring in newly established wearing contacts, often accompanied by transients in coefficient of friction or wear rate, or both, that are uncharacteristic of the given tribological system's long-term behavior. (*Synonym*: **run-in**, **wear-in**)

3.1.3 *coefficient of friction, μ or f, n—in tribology*, the dimensionless ratio of the friction force (F_f) between two bodies to the normal force (F_n) pressing these bodies together.

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.L0.11 on Tribological Properties of Industrial Fluids and Lubricates.

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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] Available from Deutsches Institut für Normung e.V. (DIN), Am DIN-Platz, Burggrafenstrasse 6, 10787 Berlin, Germany, http://www.din.de.

$$\mu = (F_f / F_n) \quad (1)$$

3.1.4 *extreme pressure (EP) lubricants, n*—formulations whose effects may become observable at different operating conditions, preventing adhesive wear under mixed or boundary lubrication regimes and are characterized by an in crea sed load carrying capacity or increased tribofilm strength.

3.1.5 *Hertzian contact area, n*—the apparent area of contact between two nonconforming solid bodies pressed against each other, as calculated from Hertz‘ equations of elastic deformation.

3.1.6 *Hertzian contact pressure*—the magnitude of the pressure at any specified location in a Hertzian contact area, as calculated from Hertz's equations of elastic deformation.

3.1.6.1 *Discussion*— The Hertzian contact pressure can also be calculated and reported as maximum value P_{max} in the centre of the contact or as $P_{average}$ as average over the total contact area.

3.1.7 *lubricant, n*—any material interposed between two surfaces for the purpose of reducing the friction or wear, or both, between them.

3.1.8 P_{geom}—geometric contact pressure describes the load carrying capacity at test end.

3.1.9 *Ra (C.L.A.), n*—in measuring surface finish, the arithmetic average of the absolute distances of all profile points from the mean line for a given distance.[4]

3.1.10 *Rz (DIN), n*—in measuring surface finish, the average of all *Ry* values (peak to valley heights) in the assessment length.[4]

3.1.11 *wear, n*—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 *seizure, n*—localized fusion of metal between the rubbing surfaces of the test pieces. D5706

3.2.1.1 *Discussion*—In this test method, seizure is indicated by a sharp rise in the coefficient of friction, over steady state, of greater than 0.2 for over 20 s. In severe cases, a stoppage in the motor will occur. Different spontaneous and short manifestations of the friction force curve need not necessarily be indicative of adhesive wear mechanisms. The evolution of the friction signal can be coupled with the stroke as an additional indicators.[5] In such a case and independently from the evolution of the friction signal, the assessment of the signals may be validated as follows: (*1*) Unstable and ragged signal: if $\Delta x < \pm 10$ % of stroke, likely no adhesive wear mechanism. (*2*) Strong fluctuations: if $\Delta x > \pm 10$ % of stroke in combination with homologue friction signals, adhesive mechanisms are likely. (*3*) jump or sharp rise in friction level: if Δcof increases by > ±10 % after sharp peaks either in the fricition and/or stroke signal, adhesive mechanisms are likely, which have damaged the surfaces resulting in higher friction. The reaction layer was pierced resulting in metal-to-metal contact or the ball turned in the holder.

3.3 *Abbreviations:*

3.3.1 *SRV®, n*—Schwingung, Reibung, Verschleiss (German); oscillating, friction, wear (English translation).

4. Summary of Test Method

4.1 This test method is performed on a SRV test machine using a test roller oscillated at constant frequency and stroke amplitude and under constant load (F_n), against a test disk that has been wetted with the lubricant specimen, where the temperature is increased stepwise. The movement of the longitudinal roller axis is 90° to the sliding direction (see Fig. 1). The test disk receiving block to which the test disk is attached is stepwise heated to the preset temperature.

NOTE 1—The frequency of oscillation, stroke length, test temperature, test load, test duration, and test roller and disk material can be varied from those specified in this test method. The test roller yields Hertzian line contact geometry.

4.2 The friction force, F_f, is measured by a piezo-electric device mounted in the test disk assembly. Peak values of coefficient of friction, *f*, are determined and recorded as a function of time with the associated with temperature.

5. Significance and Use

5.1 This test method can be used to determine scuffing temperature limit and the evolution of coefficient of friction of lubricating oils with increasing temperatures for use in tribological contacts in which high-speed vibrational or start-stop motions are present for extended periods of time under initial high Hertzian line contact pressures. It has found application as a screening test for engine oils, gear lubricants and turbine oils. The test temperature may reach up to 300 °C. Users of this test method should determine whether results correlate with field performance or other applications. In comparison to the ball-on-disk geometry in accordance with Test Method D6425, the initial contact pressure is better retained over test time in this roller-on-disk geometry.

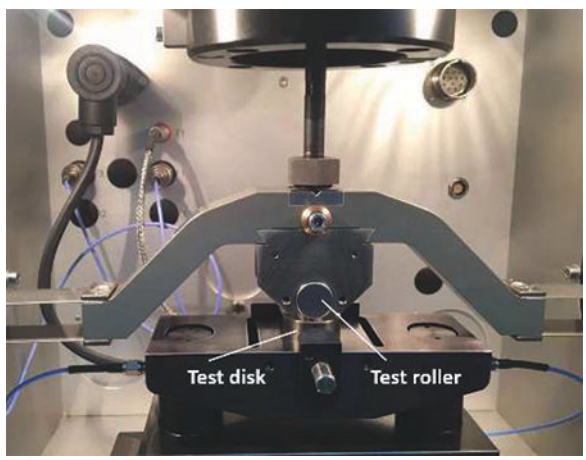


FIG. 1 Test Chamber with Roller and Disk Specimen

[4] Amstutz, Hu, "Surface Texture: The Parameters," Bulletin MI-TP-003-0785, Sheffield Measurement Division, Warner and Swazey, 1985 p. 21.

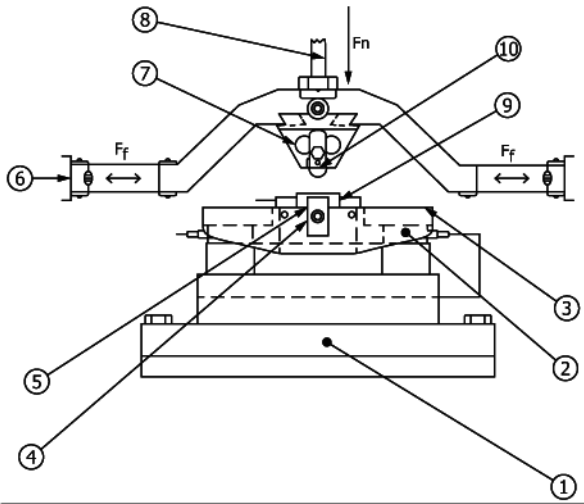
[5] Woydt, M. and G. Patzer, "New methodologies indicating adhesive wear in load step tests on the translatory oscillation tribometer," *LUBRICANTS*2021, Vol. 9, Issue 10, 101, https://doi.org/10.3390/lubricants9100101.

6. Apparatus

6.1 *SRV Test Machine*[6], illustrated in Figs. 2 and 3 consists of an linear oscillation drive, a test chamber (see Fig. 3 and Fig. 1), and a loading device with a servomotor and a load cell. The machine is operated by a control device for the oscillating drive, a timer, a load control, a frequency control, a stroke control, a data amplifier to determine the friction coefficient, and a switch and a controller for the heating. An oscilloscope may be used for monitoring of quantities. Friction coefficients, stroke and sample temperature are recorded in relation to time by data acquisition in a computer.

6.1.1 The roller is mounted in the holder so that the longitudinal axis of the roller is 90° to the sliding direction. This test is limited to SRV IV&V models, because SRVIII and older models do not execute a movement of the roller exactly parallel to the disk surface.

6.1.2 On the firmly mounted receiving block (*1*) in the test chamber (see Fig. 2 and Fig. 3), there is a piezoelectric device (*2*) to measure the friction force, F_f, and the friction coefficient, *f*, the holder for the test disk (*3*) with a thermostat-controlled electrical resistance heating element (*4*); a resistance thermometer (*5*); the oscillation drive rods (*6*); an exchangeable holder for the test roller (*7*); and the load rods of the loading device (*8*).



1	Base of the receiving block	7	Upper specimen holder
2	Piezo force measurement elements	8	Drive rods of the load unit
3	Supporting surface (head plate) of the test disk receiving block	9	Test disk
4	Lower specimen holder	10	Test roller
5	Position of the electrical resistance heating and resistance thermometer	F_n	Normal force (test load)
6	Oscillation drive rods	F_f	Friction force

FIG. 3 Test Chamber Elements of SRV Models IV and V

[6] The sole source of supply known to the committee at this time is Optimol Instruments Prüftechnik GmbH, Flößergasse 3, D-81369 Munich, Germany. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee[1], which you may attend.

FIG. 2 SRV Test Machine (Model 5)

6.1.3 The design of the receiving block for the test disk should be such that it has integrated cooling coils, or that cooling coils are wound around it, so that the receiving block must be capable of maintaining test temperatures down to 233 K. The test disk (*9*) and the test roller (*10*) are inserted into their respective holders (*3*, *4*) (see Fig. 2 and Fig. 3).

6.1.4 Disks are generally used as the lower test piece.

6.2 *Microscope,* equipped with a filar eyepiece graduated in 0.005 mm divisions or equipped with a micrometre stage readable to 0.005 mm. Magnification should be sufficient to allow for ease of measurement.

6.3 *Syringe,* suitable for applying 120 µL of the lubricating oil under test.

6.4 *Tweezers,* straight, round, about 200 mm long, with non-marring tips.

6.5 *Torque Wrench,* initial torque 0.5 Nm to 5 Nm.

6.6 *Ultrasonic Cleaner.*

7. Reagents and Materials

7.1 *Test Roller*[7], in AISI 52100 Steel Vickers microhardness of 660 HV0.2 to 730 HV0.2 (Rockwell hardness number of 60 HRC ± 2 HRC), 0.025 µm ± 0.005 µm Ra (C.L.A.) polished surface finish, is a cylinder Ø 15 mm × 22 mm with chamfered ends, so that the contact length l_1 at the beginning of the test is 21 mm. The shape and geometry of the roller is in accordance with DIN 5402, part 1.

[7] ASM Handbook, *Friction, Lubrication, and Wear Technology*, Vol 18, October 1992.

7.2 *Test Disk,* Lamellar grey cast iron with a high carbon content having a perlitic matrix. Shape of graphite IA4-5. Carbon content between 3.65 % by weight to 3.85 % by weight carbon. Carbon equivalent: 4.15 < C + Si/4.3 < 4.30 (elemental concentrations in percent by weight). Vickers micro-hardness of 170 HV10 to 220 HV10 (Brinell hardness is between 160 HBW to 210 HBW 5/250). The topography of the disk will be determined by two quantities: 0.500 µm < Rz < 0.650 µm; 0.035 µm < Ra (C.L.A.) < 0.050 µm; 24 mm ± 0.5 mm diameter by 7.85 mm ± 0.1 mm in height. Other grey cast iron cast alloys used for cylinder liners as well as coatings can be selected as well. The finishing and topography may be oriented onto the real topography of the cylinder liner and differ.

7.3 *Cleaning Solvent,* single boiling point spirit type 2-A according to DIN 51631-1999 (published in English). (**Warning—**Flammable. Health hazard.)

NOTE 2—In the case of unavailability, please refer to Specification D235 regarding Type I, Class C (with less than 2 % by volume of aromatics), mineral spirits.

8. Preparation of Apparatus

8.1 Clean and install the specimens as specified under 9.1. Turn on the test machine and the PC and allow to warm up for 15 min prior to running tests.

8.2 Create a set point profile in the SRV control software with the following parameters.

NOTE 3—Depending on the software version, names and availability of the parameters can vary.

8.2.1 Start conditions (thermostatic stabilization):

Temperature: 40 °C ± 1 K
Test load: 40 N ± 1 N
Start delay: 600 s (is displayed by all versions of the SRV software)

8.2.2 Cut-off criteria for friction, if occurs:

Coefficient of friction, *f* (cut-off value for permanent increase of level):	0.3 during *t* > 20 s
Coefficient of friction, *f* (cut-off value for one-off increase of level):	0.35

8.3 Test parameters:

Frequency:	50 Hz
Stroke:	2.000 mm
Pre-load	50 N for 30 s
Test load:	running-in under 100 N for 30 s, then increase to a constant load of 500 N

Dynamic temperature profile: start at 40 °C, then steps of 10 K with a duration of seven minutes each until 120 °C have been reached, continuing in steps of 10 K with a duration of ten minutes each until 180 °C have been reached, continuing in steps of 10 K with a duration of twelve minutes each until 240 °C have been reached and continuing in steps of 10 K with a duration of fifteen minutes each until 300 °C has been reached, or failure occurred. (**Warning—**The test temperature can exceed the flash temperature of the oil tested as stated in its technical data sheet or materials safety data sheet. In consequences, safety measured shall be in place, even the oil sample volume is considered to be small.)

NOTE 4—The initial Hertzian contact stresses for the roller-disk geometry calculate for F_N = 500 N to P_{0mean} of 268 MPa and P_{0max} of 341 MPa. The initial contact width calculates to 178 µm. A final test temperature of 150 °C may be sufficient for some oils, like, for example, hydraulic oils. For jet turbine oils or engine oils it may the useful to exceed 200 °C.

8.4 Sample rates for result-relevant measurement channels:

Coefficient of friction, *f*:	≤32 ms
Stroke:	≤2 s
Test load:	≤2 s
Frequency:	≤2 s
Temperature:	≤2 s

NOTE 5—For SRV V models, it is recommended to do one sampling per period (that is 20 ms) for coefficient of friction and stroke.

9. Procedure

9.1 *Installation of the Test Pieces and Lubricating Oil Specimen in the Test Chamber:*

9.1.1 Using solvent resistant gloves, clean the test roller and disk by wiping the surfaces with laboratory tissue soaked with cleaning solvent as stated in 7.3 or Note 2. (**Warning—**This mixture is flammable and a health hazard.) Repeat wiping until no dark residue appears on the tissue. Immerse the roller and disk in a beaker of the cleaning solvent under ultrasonic vibration (if available) for 10 min. Dry the roller holder. Dry the test roller and disk with a clean tissue, ensuring that no streaking occurs on the surface.

9.1.2 Ensure that the test load unit is in the release position (refer to your operating manual for details).

9.1.3 Place 100 µL of the lubricating oil to be tested on the cleaned disk where the contact with the roller will occur. Then install the disk (place on the block). Tighten the fastening screw until resistance just begins.

NOTE 6—The syringe filled with 120 µL shall be free of bubbles. The oil sample injection on the test disk should be as straight as possible along the contact direction and contact area of the test disk.

9.1.3.1 The test roller should be installed in the holder and shall not be tilted. The holder of the test disk must be adjustable to ensure that the wear scar is in the center of the disk.

9.1.3.2 Cleaning of test parts: the same as the existing SRV method, no other special requirements.

9.1.3.3 Each sample should be repeated once, and the test parts of the first test should be reused when repeated. The test disk should be turned over and cleaned with petroleum ether. The test roller should be positioned without wear scar contacting the plate. After cleaning the test parts test contact surface can not be touched with bare hands. In the second test, try to use the position opposite the abrasion mark on the test roller. If the installation is a little tight, you can use fine sandpaper to gently hit the abrasion scar.

9.1.3.4 **Warning—**After test, be sure to disassemble the fixture and test parts in room temperature. If temperature is too high the holder and equipment may be damaged.

9.1.4 Place the cleaned roller, using the tweezers, in the disassembled, cleaned, and dried roller holder. Tighten the fastening screw until resistance just begins.

9.1.5 Install the roller holder and test roller in the test chamber.

9.2 *Preparing Test:*

9.2.1 Open the Assistant for starting a test in the SRV control software. Select the created set-point profile and, if