Designation: ~~D8227 – 18~~ D8227 – 20

Standard Test Method for Determining the Coefficient of Friction of Synchronizer Lubricated by Mechanical Transmission Fluids (MTF) Using a High-Frequency, Linear-Oscillation (SRV) Test Machine[1]

This standard is issued under the fixed designation D8227; 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~~ Scope*

1.1 This test method covers a procedure for determining the coefficient of friction of lubricants (fluids) tribologically interacting with materials used in synchronizers in mechanical transmission (MT) gears under high-frequency linear-oscillation motion using the SRV test machine. A flat areal contact geometry is applied.

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

1.3 *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.*

1.4 *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]

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

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

D5579 Test Method for Evaluating the Thermal Stability of Manual Transmission Lubricants in a Cyclic Durability Test

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

D7421 Test Method for Determining Extreme Pressure Properties of Lubricating Oils Using High-Frequency, Linear-Oscillation (SRV) Test Machine

G40 Terminology Relating to Wear and Erosion

2.2 *Other Standards:*

DIN 51631 Special-boiling-point spirits—Requirements and testing[3]

DIN EN ISO 13565-2 Geometrical Product Specifications (GPS)—Surface texture: Profile method—Surfaces having stratified functional properties—Part 2: Height characterization using linear material ratio curve[3]

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[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.L0.07 on Engineering Sciences of High Performance Fluids and Solids (Formally D02.1100).

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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 Beuth Verlag GmbH (DIN Deutsches Institut für Normung e.V.), Burggrafenstrasse 6, 10787 Berlin, Germany, http://www.en.din.de

***A Summary of Changes section appears at the end of this standard**

DIN EN 17022–3 Heat treatment of ferrous materials; heat treatment methods; case hardening[3]
CEC L-66-99 Evaluation of synchronizer loading parameters and their ability to predict failure[4]
GB/T 3077-2015 Alloy structural steel[5]
YS/T 669-2013 Copper alloy tube of extruded product for synchronizer rings[6]
TL-VW084 (1993) Kupfer-Zink-Legierungen – Werkstoffan forderungen (Copper-Zinc alloys—Material requirements)[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *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, which are uncharacteristic of the given tribological system's long-term behavior. **G40**

3.1.2 *carburization, n*—carburizing is not defined in the ASTM Dictionary of Engineering Science and Technology, but is defined in DIN EN 17022-3 "Heat treatment of ferrous materials; heat treatment methods; case hardening".

3.1.3 *coefficient of friction, μ or f, n—in tribology*, the dimensionless ratio of the friction force (*F*) between two bodies to the normal force (*N*) pressing these bodies together. **G40**

3.1.4 *lubricant, n*—any material interposed between two surfaces that reduces the friction or ~~wear~~ wear, or both, between them. **D4175**

~~3.1.4 *carburization, n*—carburizing is not defined in the ASTM Dictionary of Engineering Science and Technology, but is defined in DIN EN 17022-3 "Heat treatment of ferrous materials; heat treatment methods; case hardening".~~

3.1.5 *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.[8]

3.1.6 *Rpk, n*—reduced peak height according to DIN EN ISO 13565-2; Rpk is the mean height of the peak sticking out above the core profile section.

3.1.7 *Rvk, n*—reduced valley height according to DIN EN ISO 13565-2; Rvk is the mean depth of the valley reaching into the material below the core profile section.

3.1.8 *Rz (DIN), n—in measuring surface finish*, the average of all Ry values (peak to valley heights) in the assessment length.[9]

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *metal specimen, n*—represented by the lower specimen disk in manganese brass alloys, but also friction layers in thermally sprayed molybdenum coatings, sinter iron, paper and carbon fiber tapes are in use.

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

3.2.2.1 *Discussion—*

In this test method, seizure is indicated by a sharp rise in the coefficient of friction, over steady state, of greater than 0.3 for over 20 s. In severe cases, a stoppage in the motor will occur (for example, see Test Methods D5706 and D7421).

3.3 *Acronyms:*

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

[4] Available from Coordinating European Council (CEC), Services provided by Kellen Europe, Avenue Jules Bordet 142 - 1140, Brussels, Belgium, http://www.cectests.org.
[5] Available from Standardization Administration of China, No. 9 Madian Donglu, Haidian District, Beijing 100088, P.R. China.
[6] Available as a standard of nonferrous industry from Standardization Administration of China, No. 9 Madian Donglu, Haidian District, Beijing 100088, P.R. China.
[7] Available from Volkswagen AG, corporate IP, post stop 1770, D-38346 Wolfsburg, Germany, www.vwgroupsupply.com.
[8] Amstutz, Hu, "Surface Texture: The Parameters," Bulletin MI-TP-003-0785, Sheffield Measurement Division, Warner and Swasey, 1985, p. 21.
[9] Amstutz, Hu, "Surface Texture: The Parameters," Bulletin MI-TP-003-0785, Sheffield Measurement Division, Warner and Swasey, 1985, pp. 29-31.

3.3.2 *UNS, n*—the Unified Numbering System (UNS) is an accepted alloy designation system in North America.

4. Summary of Test Method

4.1 This test method is performed on SRV test machine using ~~a~~an areal flat-on-flat geometry oscillating at 50 Hz against a steel test disk with lubricant (grease) between them. Test load is fixed to 260 N (corresponding to a geometrical contact pressure of 3.1 MPa) using a test temperature of 60 °C and a stroke of 1.0 mm during a test time of 2 h. This test is limited to SRV Models 4 and 5.

NOTE 1—Synchronizer rings operate typically under geometric contact pressures from 2 MPa to 6 MPa.

NOTE 2—Test frequency, stroke length, temperature, and materials and/or coatings used as/on disk and flat material can be varied to simulate field conditions.

NOTE 3—This test runs in the SRV Models 4 and 5 models horizontally and untilted. SRV Models 4 and 5 can be equipped with a maximum test load unit of 2500 N.

5. Significance and Use

5.1 This test method can be used to quickly determine the lubricating ability of fully-formulated lubricants used as mechanical transmission fluids (MTF) to display a frictional behavior against materials used in synchronizers of mechanical gears in automotive vehicles. This test method has found to be complementary to bench tests (for example, Test Method D5579 and CEC L-66-99) by using the present test conditions. This test method is a material and application oriented approach based on inputs from field experiences for characterizing the frictional behavior (coefficient of friction (cof)) using random, discrete, and constant parameter combinations as seen in field experiences. Users of this test method should determine whether results correlate with field performance or other applications prior to commercialization.

6. Apparatus

6.1 *SRV Test Machine,*[10] illustrated in Figs. 1 and 2.

7. Reagents and Materials

7.1 Flat ring disk in carburized 20CrMnTi (similar to ~20MnCr5 and ~SAE 5120) bearing steel in =200.05 mm outer diameter oil quenched from 800 °C ± 10 °C and tempered at 180 °C ± 10 °C during 8 h followed by air cooling to 60 ± 2 HRC. The contact face has an inner cavity with a diameter of 17 mm ± 0.05 mm with a depth of 1.5 mm ± 0.10 mm (see Fig. 3 and Fig. X1.1). The contact face has two straight slits at 180° opposite to each other with a width of 1 mm with a depth of 1.5 mm ± 0.10 mm. Functional surfaces shall be free from scratches and any surface damages. The topography of the disk will be determined by four values:

0.200 µm < Rz (DIN) < 0.350 µm
0.040 µm < Ra (C.L.A.) < 0.060 µm
0.150 µm < R_{pk} < 0.300 µm
0.200 µm < R_{vk} < 0.350 µm

7.2 *Lower Test Disk*—Extruded manganese brass HMn64-8- 5-1.5 according to YS/T 669-2013, homologue to TL-VW084, with HBW2.5/62.5210-260 hardness or 28025 HV0.2, the surfaces of the disk being lapped and polished. α/ß-phase ratio is 50/50. Test disks have an outer diameter of 24 mm ± 0.5 mm diameter with a height of 7.8 mm ± 0.1 mm. (spherodization at 450 °C to 590 °C during 2 h to 6 h in air.) The topography of the disk will be determined by four values:

0.500 µm < Rz (DIN) < 0.700 µm
0.040 µm < Ra (C.L.A.) < 0.060 µm
~~0.250µm~~0.250 µm R_{pk} <~~0.450µm~~<0.450 µm
~~0.300µm~~0.300 µm R_{vk} <~~0.500µm~~<0.500 µm

If other surface roughnesses are applied, they shall be measured and stated in the report. The type of coating and/or thermomechanical treatment shall be reported.

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

FIG. 1 SRV Model 5 Test Machine

NOTE 4—The steel 20CrMnTi has its origin in the Russian 18KHGT steel (GHOST 18ХГТ), homologue to DIN 20MnCr5G (1.7147). GHOST= GOST are the national standards of the Russian Federation and CIS countries.

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

NOTE 5—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. Chinese reference: ~~XK13-201-00181(substitute~~ XK13-201-00181 (substitute for GB/T15894- 2008).

8. Preparation of Apparatus

8.1 When using SRV Models 4 and 5, clean and install the specimens as specified under 9.1 to 9.7. 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 6—Depending on the software version, names and availability of the parameters can vary.

8.2.1 Start conditions (thermostatic stabilization):

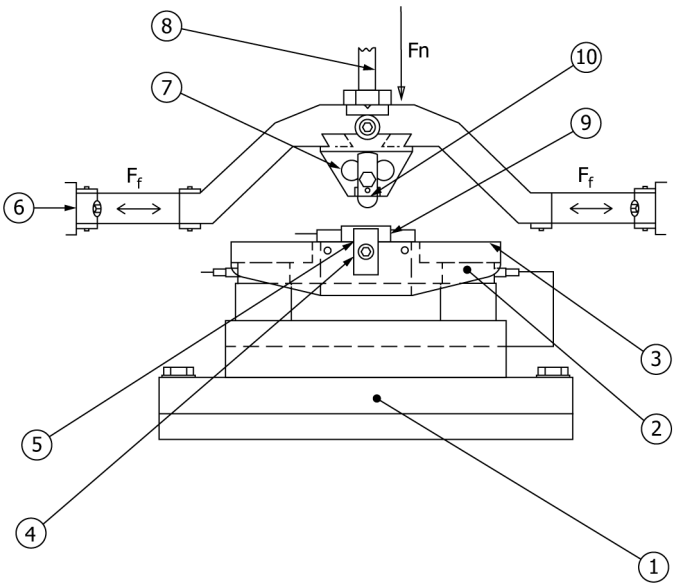

FIG. 2 Test Chamber Elements of SRV Models 4 and 5

1 base of the receiving block
2 piezo force measurement elements
3 supporting surface (head plate) of the receiving block
4 lower specimen holder
5 position of the electrical resistance heating and resistance thermometer
6 oscillation drive rods
7 upper specimen holder
8 drive rods of the load unit
9 test disk
10 test ball
F_n normal force (test load)
F_f friction force

FIG. 3 Contact Surface of Upper Specimen with Slits

Temperature: for example, 60 °C ± 1 °C
Test load: 50 N ± 1 N for 30 s
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 or a coefficient of friction, f (cut-off value for one-off increase of level): 0.35.

8.2.3 Test parameters:
Frequency: 50 Hz
Stroke: 1.00 mm
Temperature: e.g. +60 °C (+80 °C, +100 °C or +120 °C)
Test load: running-in under 50 N for 30 s, then constant load of 260 N using the standard load step function having a load ramp rate of 15 N⁄s ± 1 N⁄s.

8.2.4 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 7—For SRV 5 models, it is recommended to do one sampling per period (that is, 20 ms) for coefficient of friction and stroke.

9. Procedure

9.1 Using solvent resistant gloves, clean the test pieces and disk holder by wiping the surfaces with laboratory tissue soaked with cleaning solvent (single boiling point spirit type 2-A according to DIN 51631). (**Warning—**This mixture is flammable and health hazard.) Repeat wiping until no dark residue appears on the tissue. Immerse the ball and disk in a beaker of the cleaning solvent under ultrasonic vibration (if available) for 10 min. Dry the disk holder. Dry the test pieces with a clean tissue, ensuring that no streaking occurs on the surface.

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

9.3 Carefully place the lower test disk on the test area platform. Tighten the lower test disk by means of the three screws at the side of the adapter.

9.4 Apply 0.4 mL of lubricating oil with a syringe in the center of the lower disk.

9.5 Place the upper test disk in the adapter with the level side facing the adapter and the test surface downwards (Fig. 4). Align the upper test disk as shown in Fig. 5 and make sure, that the slit is perpendicular oriented to the sliding direction and tighten it with knurled screws.

9.6 Tighten both specimen clamps until resistance to tightening just begins. Load unit to 100 N and tighten the specimen clamps to a torque of 2.5 N·m. Reduce the load to 50 N for running-in.

9.7 In the SRV basic software, enter the following test parameters:
Frequency = 50 Hz
Stroke = 1.0 mm
Temperature = 60 °C
Load 50 N for 30 s of running-in, then increase load to ~~260 N~~ 260 N using the standard load step function
Test duration = 120 min.

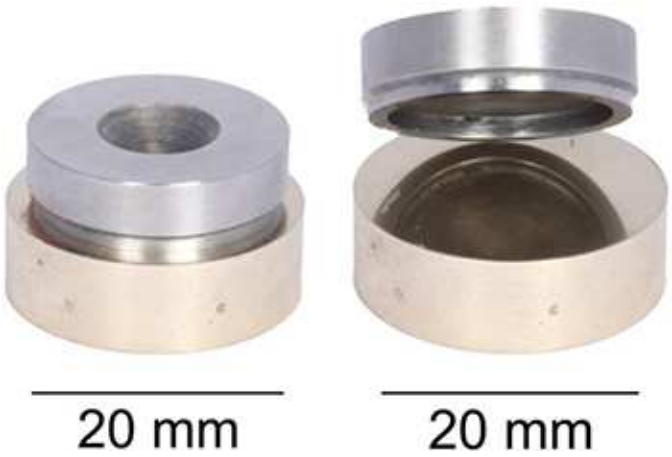

FIG. 4 Test Geometry and Contact Position (right) of the Upper Steel Disk Specimen and Lower Brass Disk Specimen

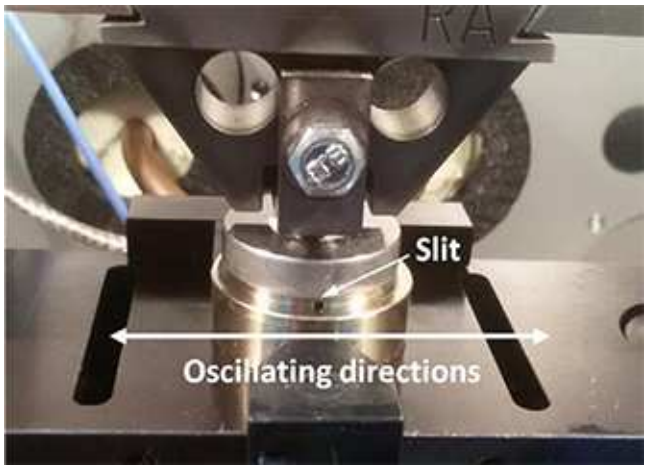

FIG. 5 Scheme for Alignment of Upper Specimen Toward Sliding Direction

10. Report

10.1 During testing, friction coefficient f determined from test load F_n and friction load F_f is recorded continuously as well as actual testing temperature. The evolution of the coefficient of friction over test time must be stored on data records.

10.2 Report the following information all parameters used to evaluate the lubricant:

10.2.1 Temperature, °C,

10.2.2 Stroke, mm,

10.2.3 Frequency, Hz,

10.2.4 Relative humidity,

10.2.5 Brand name, lab/development code of fluid/oil, type of base oil, denomination of additive package, kinematic viscosities at 40 °C and 100 °C,

10.2.6 Brass type test disk material (or other alloy with or without coating),

10.2.7 Carburized test disk material (or other alloy with heat treatment with or without thermochemical treatment).

10.3 Clean steel disk specimens after testing in an ultrasound cleaning bath.

10.4 Report the coefficient of friction at test end as a floating average over 30 s and state in the test report the coefficients of friction at test begin and after each 15 min.

11. Precision and Bias

11.1 The precision statements were established using test disks in the same alloys, carburized 20CrMnTi and manganese brass HMn64-8-5-1.5 according to YS/T 669-2013, homologue to TL-VW084, as used in synchronizers of mechanical shifting gears. In 2017,[11] nine co-operators (using eight SRV 4 and one SRV 5 model) tested twelve commercially available mechanical transmission fluids at +60 °C, of which 3 samples passed and 2 samples failed to pass bench tests as per Test Method D5579 and CEC L-66-99 as well as seven were not bench tested. The precision statements are expressed variable as function of the measured coefficient of friction.

[11] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1894. Contact ASTM Customer Service at service@astm.org.