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Lubricants — Determination of tribological quantities for oils and greases — Tribological test in the translatory oscillation apparatus

Lubrifiants — Détermination de quantités tribologiques d'huiles et de graisses — Essais tribologiques dans l'appareil translation-oscillation

Reference number
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Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 28, *Petroleum and related products from synthetic or biological origin*.

Introduction

Liquid lubricants (oils) and consistent lubricants (greases) reduce friction and wear and/or prevent adhesive wear (scuffing, galling). In order to establish the tribological profile of a lubricant adequate tribometric, test methods are required. The test method described in this document can be regarded as an evaluation tool for the determination of the lubricant-related contribution to friction, wear, load carrying capacity and extreme pressure behaviour.

This test method is dedicated to a translatory oscillation apparatus which is fully computer controlled.

This test method harmonizes the following national test methods using the ball-on-disk contact geometry:

a) DIN 51834-2[1] (oil, coefficient of friction and wear);

b) ASTM D6425[2] (oil, coefficient of friction and wear);

ASTM D7421[4] (oil, pass load/O.K. load);

ASTM D5706[6] (grease, pass load/O.K. load);

ASTM D5707[8] (grease, coefficient of friction and wear);

c) SH/T 0721[9] (grease, coefficient of friction and wear);

SH/T 0784[7] (grease, pass load/O.K. load);

NB SH/T 0847[3] (oil, coefficient of friction and wear);

NB/SH/T 0882[5] (oil, pass load/O.K. load).

The harmonization is also related to the use of only one type of cleaning solvent.

Users of this test method should determine whether the results obtained from this method correlate with field performance or other applications.

It is the responsibility of the operator to ensure that all local legislative and statutory requirements are met.

Lubricants — Determination of tribological quantities for oils and greases — Tribological test in the translatory oscillation apparatus

1 Scope

This document describes test methods based on a high-frequency, linear-oscillation test machine to determine tribological quantities like friction, wear, load carrying capacity and extreme pressure behaviour of liquid lubricants (oils) and consistent lubricants (greases) in the ball-on-disk contact geometry.

NOTE This method is technically equivalent to DIN 51834–2/ASTM D6425[1] (NB/SH/T 0847[3]) and ASTM D7421[4] (NB/SH/T 0882[5]) for oils, as well as ASTM D5706[6] (SH/T 0784[7]) and ASTM D5707[8] (SH/T 0721[9]) for greases.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 683-17, *Heat-treated steels, alloy steels and free-cutting steels — Part 17: Ball and roller bearing steels*

IEC 584-1, *Thermocouples — Part 1: Reference tables*

IEC 584-2, *Thermocouples — Part 2: Tolerances*

IEC 751, *Industrial platinum resistance thermometer and platinum temperature sensors*

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

DIN 51631:1999-04, *Mineral spirits — Special boiling point spirits — Requirements*

DIN 51834-3, *Testing of lubricants — Tribological test in the translatory oscillation apparatus — Part 3: Determination of tribological behaviour of materials in cooperation with lubricants*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp/

3.1
wear volume
W_V
irreversible loss of volume to the ball or the disk (flat) at the end of test

Note 1 to entry: The determination of the wear volumes of ball and disk are described in DIN 51834–3 or ASTM D7755 or an equivalent National Standard.

3.2
adhesive failure
particularly severe form of damage to the surface in which *seizure* (3.3) or welding together of surface areas occur

Note 1 to entry: Synonyms frequently used are “galling” (US) or “scoring” (UK). It has different meanings and macroscopic morphologies (see Annex A).

Note 2 to entry: The surface damages are usually material transfer, roughening and plastic flow, or all, as well as localized fusion of metal.

3.3
seizure
localized fusion of metal between the rubbing surfaces of the test pieces

Note 1 to entry: Seizure is usually indicated by a sharp increase in coefficient of friction, over steady-state, of delta >0,2 for over 20 s, or by unusual noise and vibration.

Note 2 to entry: In severe cases, a stoppage in the motor will occur.

Note 3 to entry: Under unlubricated oscillation, ball bearing steel 100Cr6 has coefficients of friction above 0,4.

3.4
pass load
O.K. load
last load during the extreme pressure test where no *adhesive failure* (3.2) or adhesive mechanisms were observed

3.5
load carrying capacity
geometric contact pressure at the end of the test

Note 1 to entry: The load carrying capacity of the tribocouple can be additionally calculated according to the following formula:

$$P_{\text{geom}} = \frac{4 \cdot F_{\text{n}}}{\pi \cdot WSD^2}$$

where

F_{n} is the normal force (synonym: test load);

P_{geom} is the geometric contact pressure;

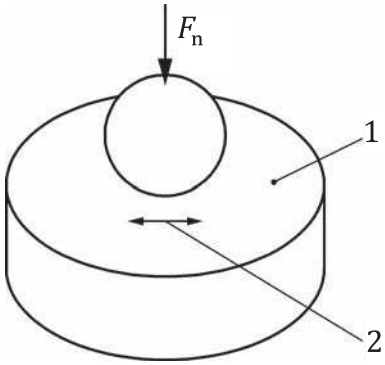
WSD is the mean wear scar diameter of ball.

4 Principle

This test method is performed on a translatory oscillation apparatus using a test ball made in bearing steel mating the top of a flat stationary disk made in bearing oscillating each other, which can be operated under different sets of test parameters (test frequency, stroke length, temperature, load and test time). The general contact situation is shown in Figure 1.

NOTE It has been assumed by the compilers of this test method that anyone using the method will be familiar with the operation manual of the test machine, as well as either be fully trained and familiar with all usual engineering and laboratory practices, or will be under the direct supervision of such a person.

IMPORTANT — Protection against machine noise during testing is recommended.



Key

1 finished test surface

2 Δx, *v*

Figure 1 — Contact situation of the tribosystem

The basic principle of the test system is the exact measurement of the coefficient of friction of a material couple with or without a lubricating interfacial medium. This is done by:

a) pressing the counter upper test specimen onto the base lower test specimen with a defined normal force, F_n;

b) oscillating sliding of the upper specimen on the lower specimen;

c) vibration-compensated measuring of the lateral friction force, F_f, acting on the lower specimen and resulting from the movement of the upper specimen. The coefficient of friction, *f*, is generated from peak-to-peak measurements of each period and calculated according to Formula (1):

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

5 Reagents

5.1 Cleaning solvent, non-chlorinated and non-film forming cleaning fluids of the type of hydrocarbon-based solvents according to DIN 51631:1999, type 2.

NOTE 1 Type 2 in DIN 51631:1999 is termed “special-boiling-point spirits” with distillation characteristics of initial 80 °C and final 110 °C and contains less than 5 % by weight of *n*-hexane and less than 0,2 % by weight of aromatics. The CAS number 64742-49-0[1)] comply with this type of cleaning solvent.

NOTE 2 The synonyms are: naphtha (petroleum), hydrotreated light; Siedegrenzenbenzin (German); petroleum ether or mineral spirits.

1) Seven CAS registration numbers cover this m*ulti-constituent subcategory* composed of predominantly C7 to C9 paraffins with varying compositions of normal paraffins, isoparaffins, and/or cycloparaffins. CAS = Chemical Abstracts Service, http://www.cas.org/.

WARNING — The user of special-boiling-point spirits has to consider the following risk and safety phrases:

— R45: May cause cancer;

— R46: May cause heritable genetic damage;

— R65: Harmful: may cause lung damage, if swallowed;

— S53: Avoid exposure - obtain special instructions before use;

— T: Toxic. The specific toxicity profile for CAS number 678472-49-0 can be downloaded from the OECD website.

6 Apparatus

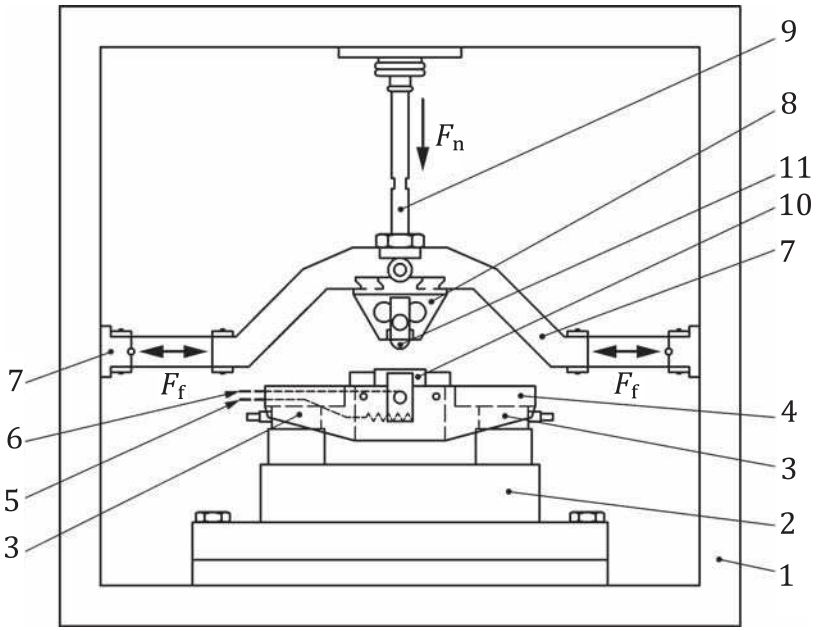
6.1 Translatory oscillation apparatus.

The tribological test system is shown in Figure 2 and includes a test chamber in which an upper and a lower specimen are installed in their respective holders. An electromagnetic linear drive with integrated stroke sensor generates the oscillating movement performed by the upper specimen on the lower specimen. The normal force, F_n, is applied to the specimen pairing by a servomotor and a load rod. To carry out tests below ambient temperature, the block can be provided with an integrated cooling coil. Environmental conditions, like relative humidity, may be measured optionally.

The holder of the lower specimen is equipped with a thermostatically monitored electric resistance heater and a resistance thermometer conforming to IEC 751 for temperatures up to 350 °C or an electric temperature sensor conforming to IEC 584-1 and IEC 584-2 for temperatures up to 1 000 °C.

Operation of the test system is monitored by several electronic control units (for drive, load, temperature, frequency, stroke) and a specific software.

The friction force, F_f, is measured continuously by a piezo-electric device contained in the test block and recorded throughout the test. Wear can be measured during the test by means of a sensor as total linear wear length of the tribosystem. After the test, wear quantities can be determined by an external measuring device (see 9.5).



Key

1	test chamber	9	drive rods of the load unit
2	receiving block	10	disk
3	piezo force measurement elements	11	test ball
4	lower specimen holder	F_n	normal force (test load)
5	electrical resistance heating	F_f	friction force
6	resistance thermometer		
7	oscillation drive rods		
8	upper specimen holder		

Figure 2 — Scheme of a translatory oscillation apparatus

NOTE A suitable apparatus is the SRV®[2)] test machine.

6.2 Torque wrench, adjustable between 0,01 Nm and 5 Nm.

6.3 Measuring microscope, or similar length measuring device, with a scale range of 2 mm or above, and scale intervals of 0,005 mm or less and sufficient magnification to allow for ease of measurement.

7 Test pieces

7.1 General

The tribosystem consists of a ball mated to the top side of the surface of a flat disk (see Figure 1). At the start of the test, a point contact is formed. The contact zone is wetted by the lubricant.

2) This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results. SRV is an abbreviation from the German attributes „Schwingung, Reibung, Verschleiß“ and translates into English as “oscillating, friction, wear” or into French « oscillation, frottement, usure ».

The initial contact pressure $P_{0,mean}$ using the Hertzian equations calculates to the following:

a) for oil; F_n = 300 N: $P_{0,mean}$ = 2,092 MPa;

b) for greases; F_n = 200 N: $P_{0,mean}$ = 1,828 MPa.

NOTE Assuming "no wear" during an extreme pressure test and reaching the maximum load of F_n = 2 000 N, $P_{0,mean}$ calculates to 3,938 MPa.

7.2 Test ball

The test balls have a diameter of 10 mm, grade 10. The balls are made of 100Cr6 (1.3505, corresponds to SAE E 52100 or UNS G52986). The hardness is (60 ± 2) HRC and the surfaces are finished to Ra of 0,025 µm ± 0,005 µm (Ra formerly corresponded to C.L.A. = centre line average).

7.3 Disk

The flat test disk has an outer diameter of 24 mm ± 0,5 mm with a height of 7,8 mm ± 0,1 mm. The alloy is made of 100Cr6 (1.3505, corresponds to SAE E 52100 or UNS G52986) and is vacuum arc remelted (VAR). The inclusion rating is an inclusion sum value K1 ≤ 10 according to ISO 683-17. The heat treatment is spherodized and annealed to obtain globular carbides, the micro-hardness range between 710 HV to 820 HV 0,2 (62 HRC ± 1 HRC). The test surface of the disk being first grinded followed by lapping and are free of lapping raw materials.

The lapping process ensures aperiodic surface finishing. The test surface topography of the disk is characterized by four values: 0,500 µm < R_Z < 0,650 µm, 0,035 µm < R_a < 0,050 µm, 0,020 µm < R_{PK} < 0,035 µm and 0,050 µm < R_{VK} < 0,075 µm.

NOTE Only one of the flat surfaces is the test surface.

The surface topographies of the disk are determined using the following parameters:

— traversing length l_t: 5,6 mm;

— total measuring length l_m: 4,0 mm for R_Z and 1,25 mm for R_a;

— tip radius of the stylus: 2,0 µm;

— angle of the tip: 90°;

— cut-off: 0,8 mm.

8 Preparation of apparatus

8.1 Installing the specimen holders and test specimen in the test chamber

Check the disk and the ball for any visible damage or corrosion and clean them with the cleaning solvent (see 6.1) for approximately 5 min in an ultrasonic bath by respecting the relevant safety procedures.

Using tweezers or gloves, place the previously cleaned test ball (ball diameter 10 mm) (11) into the cleaned upper specimen holder (8) and tighten it slightly (approximately 0,1 Nm, using a 7 mm torque wrench).

Install the disk (disk diameter 24 mm, disk height 7,8 mm ± 0,1 mm) (10) into the lower specimen holder (4). Tighten the screw on the holder only lightly (approximately 0,1 Nm using a 7 mm torque wrench). For oil tests, apply approximately 0,3 ml of lubricating oil using a graduated pipette, or for grease tests, apply approximately 1 mm in height of grease onto the lower test specimen (10) using a grease caliper.

Place the ball holder (8) with the upper test specimen (11) in the intended fastening slots and tighten the specimen holder to the drive rods (approximately 2 Nm).

According to the input in the controlling software, a preload is applied. This can be either F_n = 50 N ± 1 N or F_n = 100 N ± 2 N, depending on the test mode.

The tightening screws of the ball with a diameter of 10 mm and the disk with a diameter of 24 mm and a height of 7,8 mm ± 0,1 mm need to be loosened when the preload is applied and immediately tightened again using a torque wrench to 2,0 Nm to 2,5 Nm.

8.2 Test conditions

Table 1 compiles the test modes applicable for oils and greases.

Table 1 — Summary of test parameters

Test mode	Coefficient of friction and anti-wear of oils	Extreme pressure of oils	Coefficient of friction and anti-wear of greases	Extreme pressure of greases
	1	2	3	4
Test temperature [°C]	+50 °C, +80 °C or +120 °C	+50 °C, +80 °C or +120 °C	+50 °C or +80 °C	+50 °C or +80 °C
Stroke Δx [mm]	1,0	2,0	1,0	1,5
Frequency of oscillation [Hz]	50	50	50	50
Load during running-in [N]	50	100[a]	50	100[a]
Running-in time [s]	30	900[a]	30	900[a]
Normal force [N]	300 N constant	First load: 100 N, then increase by 100 N every 2 min	200 N constant	First load: 100 N, then increase by 100 N every 2 min
Test time after running-in [min]	120 (total 120,5)	<40	120 (total 120,5)	<40

[a] Load previously 50 N for 30 s.

IMPORTANT — By using F_n = 200 N, the initial Hertzian wear scar diameter of the ball (10 mm) calculates to 0,374 mm and by using F_n = 300 N, the initial Hertzian wear scar diameter of the ball (10 mm) calculates to 0,428 mm. When using one of the mentioned normal forces (test loads), the wear scar diameter of the balls must be greater than or equal to the calculated Hertzian contact diameter.

9 Test procedure

9.1 General

The oil or the grease can be subjected to tribological conditions for determining either the extreme pressure behaviour or for determining friction and wear (see Table 1). Extreme pressure tests as well as friction and wear tests require different test parameters and consequently tests using new samples. Carry out at least duplicated tests.

Before starting the test, heat the lower test specimen to the desired temperature for 5 min ± 1 min with the electrical resistance heating (5).

Start the test run after the time for preheating the specimen is over.

NOTE Experience shows that approximately 5 min after the beginning of the preheating period, the test specimen reach the pre-set test temperature of 50 °C, 80 °C or 120 °C.

9.2 Friction and wear

Friction and wear properties of a grease or an oil are determined by using the test parameters shown in Table 1.

IMPORTANT — It is highly recommended to ensure by an extreme pressure test, that the oil or grease to be tested has a sufficient load carrying capacity for the friction and wear testing at 300 N (oil) or 200 N (grease). A sufficient load carrying capacity of the oil or grease is indicated by a pass load/O.K. load of >200 N above the test load.

9.3 Extreme pressure test

Extreme pressure properties of a grease or an oil are determined by using the test parameters shown in Table 1. The test duration depends from the selected test mode and/or the properties of the lubricant (see Table 1) and do not exceed 40 min.

9.4 Calibration and inspection

The oscillation machine shall be checked regularly, at least once a year. A reference test run shall be carried out at least once a month or after each inspection using a known reference lubricant in order to ensure that the translatory oscillation apparatus is operating correctly and with the accuracy specified in the precision statements. Instructions on how to carry out maintenance are stated in the manual from the supplier of the translatory oscillation apparatus.

The stroke is controlled after each test. The length of the wear track on the disk is determined. The calculated stroke is the length of the wear track minus the average wear scar diameter of the ball and should be within ±10 % of the stroke presetted for the selected test mode (see Table 1).

9.5 Determining the tribological quantities

9.5.1 General

Wear quantities are determined after completion of the test at which no seizure occurred.

9.5.2 Wear scar diameter of ball

Remove and clean the ball and measure the wear scar diameters to an accuracy of 0,01 mm using a measuring microscope or a comparable length measuring device. Calculate the mean wear scar diameter MWSD in mm from the wear scar diameters d_1 and d_2 in the directions parallel and perpendicular to the sliding direction.

9.5.3 Wear volume of ball

The wear volume in cubic millimetres of the cleaned ball is determined and calculated according to ASTM D7755 or DIN 51834-3.

9.5.4 Wear volume of disk

The wear volume in cubic millimetres of the cleaned disk is determined and calculated according to ASTM D7755 or DIN 51834-3.

9.5.5 Optional

Although not specifically part of the procedure, it is recommended to determine the wear volume and wear rate of ball and disk occurred during the “friction and wear tests” according to DIN 51834-3, or ASTM D7755, by performing a profilometric stylus trace across the wear track on the test disk. The load carrying capacity is an additional and recommended tribological quantity to rank oils and greases.

As the test equipment models are fully computer-controlled, the data acquisition system displays the evolution of the coefficients of friction during “friction and wear testing” and “extreme pressure testing”. It is recommended to archive these test protocols for future requests and bench markings.

10 Expression of results

10.1 General

If seizure occurs during friction and wear testing, the test shall be terminated and only the test duration is reported.

If the coefficients of friction during “friction and wear testing” and “extreme pressure testing” are available, it is recommended to archive these test protocols for future requests and bench markings.

10.2 Friction and wear testing

Report the coefficient of friction at the start (friction value taken within one minute of test running) and at the end of the test, the average wear scar diameter of the test ball, in mm, and the calculated wear volumes of ball and disk.

10.3 Extreme pressure testing

Report the pass load/O.K. load in Newton.

11 Precision

11.1 General

The precision given in 11.2 and 11.3 was determined by statistical examination of interlaboratory test results in accordance with ISO 4259.

NOTE The annual round robin results were discussed during the annual DIN 51834 working group meetings and are disclosed in their minutes as well as were discussed during the sub-committee meetings at ASTM and were filed as research reports at the ASTM Headquarter. The data pools used for the present precision statements are from 2006 to 2013 and are limited to the cleaning solvent described in Clause 5.

11.2 Repeatability, *r*

The difference between two test results, obtained by the same operator with the same apparatus under constant operating conditions on identical test material would in the long run, in the normal and correct operation of the test method, exceed the value given in Table 2 in only one case in 20.

11.3 Reproducibility, *R*

The difference between two single and independent results, obtained by different operators working in different laboratories on identical test material, would in the long run, in the normal and correct operation of the test method, exceed the value given in Table 3 only in one case in 20.

Table 2 — Repeatability data

Test mode		Coefficient of friction, f (range 0,07 to 0,13)	Wear scar diameter ball [mm] (range 0,42 to 0,60)	Pass load or O.K. load [N] (range 700 to 1 800)
Coefficient of friction and anti-wear of oils	50 °C	0,010	0,028 7 + 0,047 8·X	—
	80 °C	0,012	0,07	—
	120 °C	0,012	0,06	—
Extreme pressure of oils	50 °C	—	—	772,252 – 0,196 6·X
	80 °C	—	—	65,391 + 0,201·X
	120 °C	—	—	–122,898 + 0,373 7·X
Coefficient of friction and anti-wear of greases	50 °C	0,010 8 – 0,013 4·X	0,031 2 + 0,032 2·X	—
	80 °C	–0,001 3 + 0,107 1·X	0,007 + 0,073 4·X	—
Extreme pressure of greases	50 °C	—	—	201,341 + 0,118 3·X
	80 °C	—	—	–181,655 + 0,703 8·X
Where X is the average of the two results being compared.				

Table 3 — Reproducibility data

Test mode		Coefficient of friction, f (range 0,07 to 0,13)	Wear scar diameter ball [mm] (range 0,42 to 0,60)	Pass load or O.K. load [N] (range 700 to 1 800)
Coefficient of friction and anti-wear of oils	50 °C	0,030	–0,026 6 + 0,313 4·X	—
	80 °C	0,049 – 0,266 3·X	<0,23	—
	120 °C	0,036 4 – 0,144 1·X	<0,23	—
Extreme pressure of oils	50 °C	—	—	740,961 + 0,080 3·X
	80 °C	—	—	–114,793 + 0,583 7·X
	120 °C	—	—	–72,551 + 0,541 7·X
Coefficient of friction and anti-wear of greases	50 °C	0,027 1 – 0,051 8·X	–0,057 1 + 0,334 4·X	—
	80 °C	0,010 1 + 0,098 9·X	0,055 8 + 0,077 4·X	—
Extreme pressure of greases	50 °C	—	—	503,454 + 0,204·X
	80 °C	—	—	52,207 + 0,721 7·X
Where X is the average of the two results being compared.				

12 Test report

The test report shall include at least the following information:

a) a reference to this document, i.e. ISO 19291;

b) the test method (friction and wear or extreme pressure testing);

c) the test result (see Clause 10);

d) any deviation, by agreement or otherwise, from the procedure specified;

e) the date of the test.

See Annex B for an example of the test report.

Annex A
(informative)

Translations of terms

The *Glossary of terms and definitions in the field of friction, wear and lubrication (Tribology)*[3] discloses translations and different meanings, which are compiled in the Table A.1.

Table A.1 — Translation of specific technical terms

English term	French term	German term	Chinese term	Japanese term	Persian term
Galling	arrachement par grippage	Starkes Fressen	□□	□□□□□	□□□□□□□□
Scoring	éraillage (aussi griffures)	Furchung (auch Riefenbildung)	□□	□□□□□□	□□□□□□□□□
Scuffing	grippage naissant	Örtliches Fressen	□□	□□□□□□□	□□□□□□□
Seizure	grippage	Festfressen	□□	□□□	□□□□□□
Aanti-seizure property	propriété an-ti-grippage	Fressverhindernde Eigenschaft	□□□	□□□□□	□□□□□ □□ □□□□□□

3) Organisation for Economic Co-operation and Development (OECD), 2, rue André Pascal, F-75775 Paris Cedex 16; www.oecd.org/libraryandarchives.

Annex B
(informative)

Compilation of test results for filing

Table B.1 gives an example that may be copied by the user of this document.

By means of friction signal analysis the coefficient of friction may be calculated based on the integral of the hysteresis of the friction force vs. stroke and each hysteresis fully recorded in a computer.

Table B.1 — Test report example

ISO 19291 — Test report																
T (in °C) =							**Fluid tested (oil/grease):**									
F_n (in N) =							**Denomination:**									
v (in Hz) =							**Base oil:**					**Thickener type:**				
Δx (in mm) =							**Additive package:**					**Performance grade:**				
							Viscosity grade or NLGI class:									
Test mode	f_{min}	f_{max}	f_{15}	f_{30}	f_{60}	f_{90}	f_{120}/f_{end}	**Ball**			**Disk**			P_{geom}	O.K. load/ pass load	
								d_1 mm	d_2 mm	W_v mm³	d_2 mm	W_q mm²	W_v mm³	MPa	N	
Friction and wear															—	
															—	
Extreme pressure	—	—	—	—	—	—	optional			—	—	—	—	—		
	—	—	—	—	—	—	optional			—	—	—	—	—		

Bibliography

[1] DIN 51834-2[4], *Testing of lubricants — Tribological test in the translatory oscillation apparatus — Part 2: Determination of friction and wear data for lubricating oils*

[2] ASTM D6425, *Standard Test Method for Measuring Friction and Wear Properties of Extreme Pressure (EP) Lubricating Oils Using SRV Test Machine*

[3] NB/SH/T 0847, *Standard test method for measuring friction and wear properties of extreme pressure (EP)lubricating oils using SRV test machine*

[4] ASTM D7421, *Standard Test Method for Determining Extreme Pressure Properties of Lubricating Oils Using A High-Frequency, Linear-Oscillation (SRV) Test Machine*

[5] NB/SH/T 0882, *The SRV tester method for determination of the lubricating oil extreme pressure performance*

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