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Gears — FZG test procedures —

Part 3:
FZG test method A/2,8/50 for relative scuffing load-carrying capacity and wear characteristics of semifluid gear greases

Engrenages — Méthodes d'essai FZG —

Partie 3: Méthode FZG A/2,8/50 pour évaluer la capacité de charge au grippage et les caractéristiques d'usure des graisses d'engrenages semi-fluides

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 of the voluntary nature of standards, 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

This second edition cancels and replaces the first edition (ISO 14635-3:2005), of which it constitutes a minor revision. The changes are as follows:

— ISO 1328-1:1995[1)] has been dated as this document still refers to accuracy grade;

— replacement of ISO 4287 which has been withdrawn and replaced by ISO 21920-2;

— replacement of ISO 4964 which has been withdrawn and similar information can be found in ISO 18265;

— replacement of some bibliography entries which were withdrawn, and changes from dated to undated references;

— Table 1, description "pitch line velocity (v_w)" has been replaced by "circumferential velocity at the pitch line" to harmonize the wording with the ISO 6336-series;

— Table 1, symbol for "specific sliding" has been corrected according to ISO 21771;

— Table 2, grinding: unit for "generating stroke drive" has been corrected;

— Table 3, information on the load coupling has been harmonized with ISO 14635-1;

— Clause 9, the reporting value of the specific weight loss has been corrected.

A list of all parts in the ISO 14635 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

1) Cancelled and replaced by ISO 1328-1:2013.

Introduction

The types of gear failure which can be influenced by the lubricant are scuffing, low-speed wear and the gear fatigue phenomena known as micro- and macropitting. In the gear design process, these types of gear damage are taken into consideration by the use of specific lubricant and service-related characteristic values. In order to provide a reasonable estimate of performance in service, adequate lubricant test procedures are required. The FZG[2)] test procedures described in ISO 14635-1, ISO 14635-2 and ISO 14635-3 can be regarded as tools for the determination of relative scuffing performance of lubricants. Characteristic values can be introduced into the load-carrying capacity calculation of gears. ISO 14635-1 FZG test method, A/8,3/90 for relative scuffing load-carrying capacity of oils, is useful for the majority of applications in industrial and marine gears. ISO 14635-2, FZG step load test A10/16, 6R/120, is related to the relative scuffing load-carrying capacity of high EP oils as used, e.g. for the lubrication of automotive driveline components such as manual transmissions. ISO 14635-3 FZG test method A/2,8/50 describes a test procedure for the determination of the relative scuffing load-carrying capacity and wear characteristics of semi-fluid greases used for enclosed gear drives. Other FZG test procedures for the determination of low-speed wear, micro- and macropitting load capacity of gears are currently being considered for standardization. They can be added later to ISO 14635 as further parts.

It has been assumed by the compilers of this test method that anyone using the method will either be fully trained and familiar with all normal engineering and laboratory practice, or will be under the direct supervision of such a person. It is the responsibility of the operator to ensure that all local legislative and statutory requirements are met.

When the rig is running, there are long-loaded shafts and highly stressed test gears turning at high speed and precaution needs to be taken to protect personnel. It is also necessary to provide protection from noise.

2) FZG = Forschungsstelle für Zahnräder und Getriebebau, Technische Universität München (Gear Research Centre,

Gears — FZG test procedures —

Part 3: FZG test method A/2,8/50 for relative scuffing load-carrying capacity and wear characteristics of semifluid gear greases

1 Scope

This document specifies a test method based on a FZG four-square test machine for determining the relative load-carrying capacity of semi-fluid gear greases defined by the gear surface damage known as scuffing.

This method is useful for evaluating the scuffing load capacity potential of semi-fluid gear greases of NLGI classes 0 to 000, typically used with highly stressed gearing for enclosed gear drives. It can only be applied to greases giving a sufficient lubricant flow in the test gear box of the FZG test machine.

NOTE The test method is technically equivalent to DIN Fachbericht 74.

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 1328-1:1995[3], *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to flanks of gear teeth*

ISO 6743-6, *Lubricants, industrial oils and related products (class L) — Classification — Part 6: Family C (Gears)*

ISO 12925-1, *Lubricants, industrial oils and related products (class L) — Family C (Gears) — Part 1: Specifications for lubricants for enclosed gear systems*

ISO 18265, *Metallic materials — Conversion of hardness values*

ISO 21920-2, *Geometrical product specifications (GPS) — Surface texture: Profile — Part 2: Terms, definitions and surface texture parameters*

ASTM D 235, *Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)*

3 Terms and definitions

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

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

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

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

3) Cancelled and replaced by ISO 1328-1:2013.

3.1
scuffing
particularly severe form of gear tooth surface damage in which seizure or welding together of areas of tooth surface occurs, owing to insufficient or breakdown of lubricant film between the contacting tooth flanks of mating gears, typically caused by a combination of high temperature, high pressure and other factors

Note 1 to entry: Scuffing is most likely when surface velocities are high. It can also occur at relatively low sliding velocities when tooth surface pressures are high enough either generally or, because of uneven surface geometry and loading, in discrete areas.

Note 2 to entry: Care should be taken that scuffing does not occur and is polished away before ending the running time at the higher load stages.

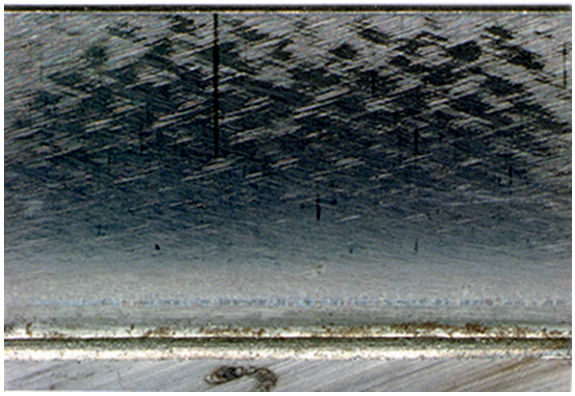
3.2
wear
continuous removal of material occurring when two surfaces roll and slide against one another

3.3
scuffing load-carrying capacity
⟨of a lubricant⟩ maximum load which can be sustained under a defined set of conditions

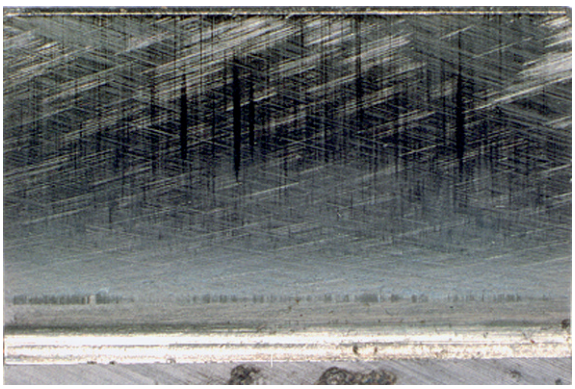
3.4
FZG test condition A/2,8/50
test condition where A is the particular tooth form of the test gears, according to Table 1, 2,8 is the speed at the pitch circle in metres per second (m/s), and 50 is the initial lubricant temperature in degrees Celsius, from load stage 4 onward in the lubricant sump

3.5
failure load stage
load stage reached when the summed total width of scuffing damage on the active flank area of the 16 pinion teeth exceeds one gear tooth width, i.e. 20 mm

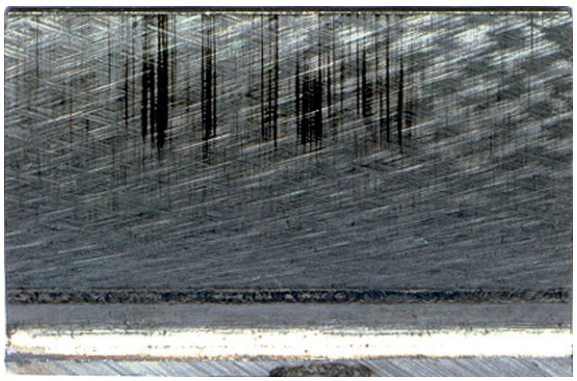
Note 1 to entry: For examples of failure, see Figure 1. Examples of tooth flank changes due to continuous wear are given in Figure 2. Continuous wear is not a failure criterion for the test.



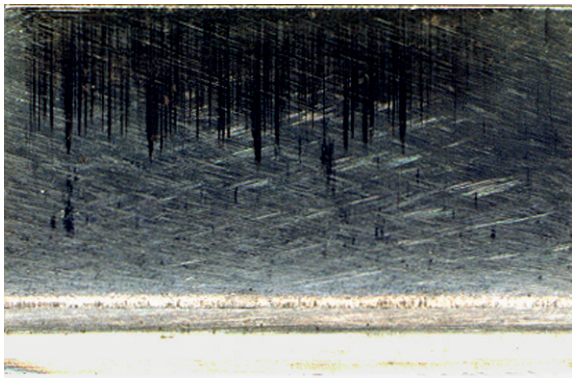
a) Marks, no failure



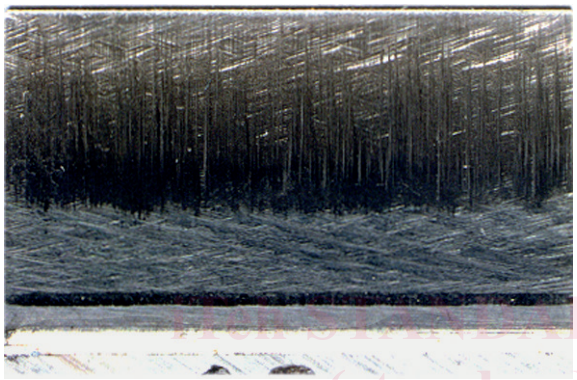
b) Marks, no failure



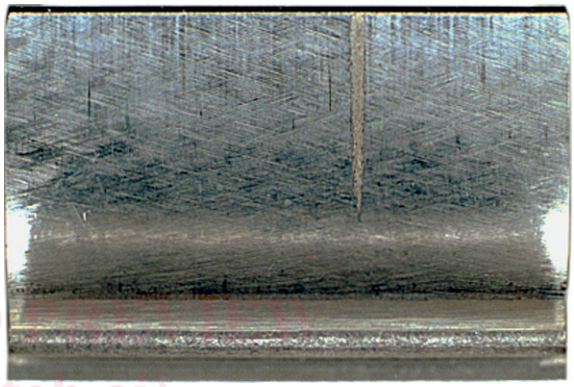
c) Approx. 5 mm failure marks



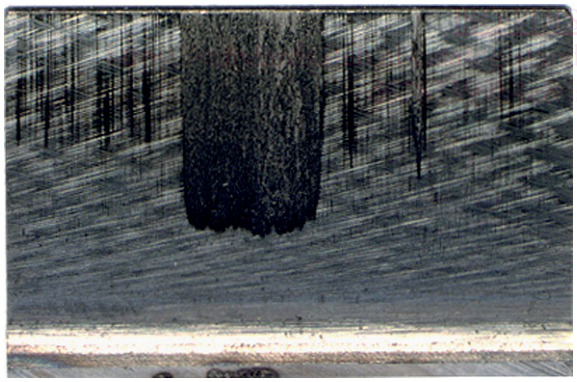
d) Approx. 15 mm failure marks



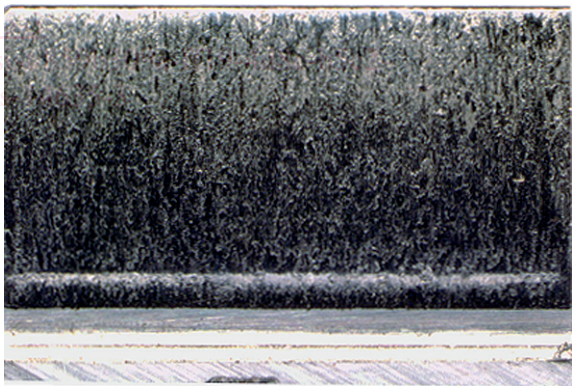
e) 20 mm failure marks



f) Approx. 2 mm failure marks



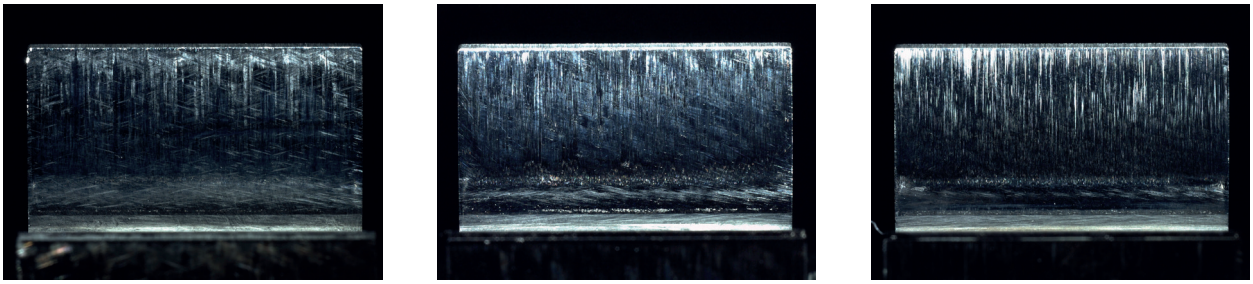
g) Approx. 6 mm failure marks



h) 20 mm failure marks

NOTE This figure describes the typical pinion tooth flank changes occurring in FZG scuffing type tests. Changes in the original surface condition (criss-cross grinding) can be described by their physical appearance. One and the same type of flank damage can be described in different places in the world by using different terminology (e.g. “scuffing”, “scoring” and “severe wear”). In order to avoid misinterpretation of the pinion tooth flank changes occurring during the test, typical examples of non-failure and failure are given.

Figure 1 — FZG A-type gear tooth face changes (flank damages)



a) Light wear **b) Medium wear** **c) Severe wear**

Figure 2 — FZG A-type gear tooth flank changes due to continuous wear

4 Brief description of method

4.1 General

A set of test gears as defined in Clause 5, Tables 1 and 2, weighed to the nearest 0,001 g before the test, is run with the test lubricant at constant speed for a fixed number of revolutions in dip lubrication mode. Loading of the gear teeth is increased in the steps outlined in Table 3. Beginning with load stage 5, the initial lubricant temperature is controlled between (50 ± 3) °C. During the test run of each load stage, the lubricant temperature is allowed to rise freely. After load stage 4, the weight loss of the gear set is determined to the nearest 0,001 g and the pinion tooth flanks are inspected for surface damage. For each subsequent load stage, the pinion tooth flanks are inspected for surface damage at the end of each load stage and any changes in appearance are noted. A test is considered complete when either the failure criterion has been met or when load stage 12 is run without meeting the failure criterion. If load stage 12 is reached without meeting the failure criterion, the gear set weight loss is determined to the nearest 0,001 g.

4.2 Precision

Values of repeatability, *r*, and reproducibility, *R*, as defined in ISO 5725-2, are not valid for this test procedure. However, experience suggests that similar methods (see ISO 14635-1) are expected to be representative.

Values for ISO 14635-1 are indicated below.

r = 1 load stage

R = 2 load stages

NOTE The above precision results apply to the range of failure load stages 5 to 12.

5 Test materials

5.1 Test gears

A pair of type “A” gears with a specification according to Table 1 and Table 2 shall be used for testing. Each pair of test gears may be used twice for testing, using both tooth flanks as load-carrying flanks.

5.2 Cleaning fluid

Petroleum spirits conforming to ASTM D 235 shall be used.

Table 1 — Details of FZG test gears type A

Dimension		Symbol	Numerical value	Unit
Shaft centre distance		a	91,5	mm
Effective tooth width		b	20	mm
Working pitch diameter	pinion	d_{w1}	73,2	mm
	wheel	d_{w2}	109,8	mm
Tip diameter	pinion	d_{a1}	88,77	mm
	wheel	d_{a2}	112,5	mm
Module		m	4,5	mm
Number of teeth	pinion	z_1	16	
	wheel	z_2	24	
Profile-shift coefficient	pinion	x_1	0,853 2	
	wheel	x_2	- 0,50	
Pressure angle		α	20	°
Working pressure angle		α_w	22,5	°
Circumferential velocity at the pitch line		v_w	2,8	m/s
Addendum engagement	pinion	e_{a1}	14,7	mm
	wheel	e_{a2}	3,3	mm
Sliding speed at tooth tip	pinion	v_{ga1}	1,85	m/s
	wheel	v_{ga2}	0,42	m/s
Specific sliding at tooth tip	pinion	ζ_{E1}	1,86	
	wheel	ζ_{A2}	0,34	
Specific sliding at tooth root	pinion	ζ_{A1}	- 0,52	
	wheel	ζ_{E2}	- 5,96	
Hertzian contact pressure		p_c	$14{,}7 \cdot \sqrt{F_{nt}}$ [a]	N/mm²

[a] F_{nt} = normal tooth load in N (see Table 3).

Table 2 — Manufacturing details of FZG test gears type A

Material	Case-hardening steel with restricted hardenability to 2/3 of the lower scatter band. Material composition: C = 0,13 % to 0,20 % — Mo = max. 0,12 % Si = max. 0,40 % — Ni = max. 0,30 % Mn = 1,00 % to 1,30 % — Al = 0,02 % to 0,05 % P = max. 0,025 % — B = 0,001 % to 0,003 % S = 0,020 % to 0,035 % — Cu = max. 0,30 % Cr = 0,80 % to 1,30 %
Heat treatment	The test gears are carburized and case hardened. The case depth at a hardness of 550 HV10 shall be 0,6 mm to 0,9 mm. The surface hardness after tempering: 60 HRC to 62 HRC, core strength in tooth root centre: 1 000 N/mm² to 1 250 N/mm² (determined in accordance with ISO 18265 based on Brinell hardness). Retained austenite should be nominally 20 %.
Gear accuracy grade	Q5 according to ISO 1328-1:1995