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Gears — FZG test procedures —

Part 1:
FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils

Engrenages — Méthodes d'essai FZG —

Partie 1: Méthode FZG A/8,3/90 pour évaluer la capacité de charge au grippage des huiles

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 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 14635-1:2000), of which it constitutes a minor revision. The changes are as follows:

— ISO 1328-1:1995[1)] has been dated as this document uses accuracy grade which is numerically different than tolerance class in ISO 1328-1:2013;

— replacement of ISO 4287 which has been withdrawn and replaced by ISO 21920-2;

— replacement of ISO 4964 which has been withdrawn and similar information can be found in ISO 18265;

— replacement of some bibliography entries which were withdrawn, and changes from dated to undated references;

— subclause 5.2, wording harmonized with the ISO 14635 series;

— Table 1, description "pitch line circumferential speed (v_w)" has been replaced by "circumferential velocity at the pitch line" to harmonize the wording with the ISO 6336 series;

— Table 4, insertion of lines "Direction of rotation" and "Test lubrication volume" to conform to the information in the ISO 14635 series.

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 failures which can be influenced by the lubricant in use are scuffing, low-speed wear and the gear-surface fatigue phenomena known as micro- and macropitting. In the gear design process, these gear damages are taken into consideration by the use of specific lubricant and service-related characteristic values. For an accurate, field-related selection of these values, adequate lubricant test procedures are required. The FZG[2)] test procedures described in this document, ISO 14635-2 and ISO 14635-3 can be regarded as tools for the determination of the lubricant-related characteristic values to be introduced into the load-carrying capacity calculation of gears.

FZG test method A/8,3/90 for the relative scuffing load-carrying capacity of oils described in this document is typical for the majority of applications in industrial and marine gears. ISO 14635-2 is related to the relative scuffing load-carrying capacity of oils of very high extreme pressure (EP) properties, as used for the lubrication of automotive driveline components. Other FZG test procedures for the determination of low-speed wear, micro- and macropitting load-carrying capacity of gears are intended to be added to the ISO 14635 series as further parts.

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

Gears — FZG test procedures —

Part 1:
FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils

1 Scope

This document specifies a test method based on a FZG four-square test machine to determine the relative load-carrying capacity of lubricating oils defined by the gear-surface damage known as scuffing. High surface temperatures due to high surface pressures and sliding velocities can initiate the breakdown of the lubricant films. This test method can be used to assess such lubricant breakdown under defined conditions of temperature, high sliding velocity and stepwise increased load.

NOTE This method is technically equivalent to ASTM D 5182-19 and CEC L-07-A-95.

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 : Definitions and allowable values of deviations relevant to flanks of gear teeth*

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/

3.1
scuffing load-carrying capacity
(of a lubricant) maximum load which can be sustained under a defined set of conditions

Note 1 to entry: For examples of failure see Figure 1.

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

Note 2 to entry: Scuffing is a particularly severe form of damage to the gear-tooth surface in which seizure or welding together of areas of tooth surface occur, due to absence or breakdown of a lubricant film between the contacting tooth flanks of mating gears, typically caused by high temperature and high pressure. Scuffing is most likely when surface velocities are high. Scuffing 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 3 to entry: Risk of scuffing damage varies with the properties of gear materials, the lubricant used, the surface roughness of tooth flanks, the sliding velocities and the load. Consequences of scuffing of high-speed gears include a tendency to high levels of dynamic loading due to increase of vibrations, which usually leads to further damage by scuffing, pitting or tooth breakage.

3.2
FZG test condition A/8,3/90
test condition where A is the particular tooth form of the test gears, according to Table 1, 8,3 is the speed at the pitch circle, in metres per second, and 90 is the initial oil temperature in degrees Celsius, from load stage 5 and onward in the oil sump

Note 1 to entry: The direction of the rotation of the gears is shown in Figure 3.

3.3
failure load stage
load stage in which 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: Examples of flank damages for the purpose of the test method are shown in Figure 1.

4 Brief description of method

4.1 General principle

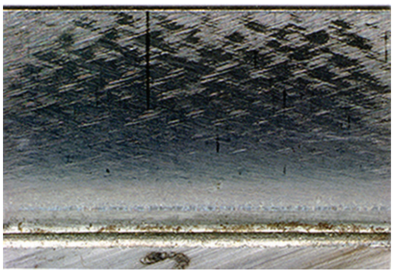
A set of test gears as defined in Clause 5, Tables 1 and 2, is run with the test lubricant at constant speed for a fixed number of revolutions using dip-lubrication mode. Loading of the gear teeth is increased in steps outlined in Table 3. Beginning with load stage 5, the initial oil temperature is controlled between (90 ± 3) °C. During the test run of each load stage, the oil temperature is allowed to rise freely. After load stage 4, 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 criteria has been met or when load stage 12 is run without meeting the failure criteria.

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

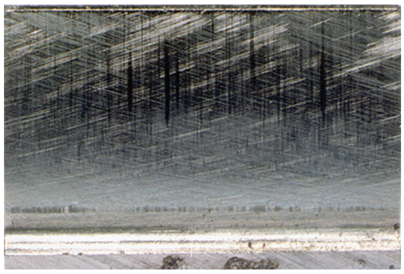
NOTE It has been assumed by the compilers of this test method that anyone using the method will either be fully trained and familiar with all normal engineering and laboratory practice, or will be under the direct supervision of such a person.

WARNING — When the rig is running, there are long loaded shafts and highly stressed test gears turning at high speed and precautions shall be taken to protect personnel.

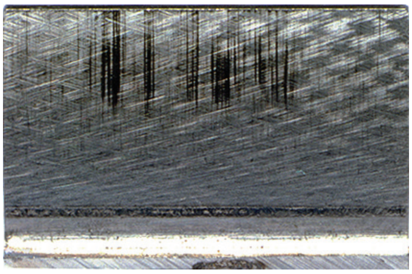
WARNING — Protection from noise is also highly recommended.



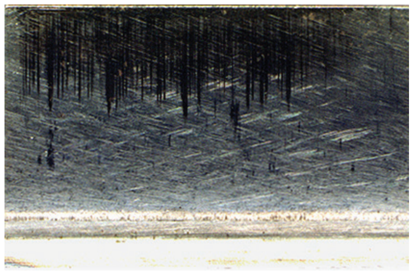
a) No failure marks



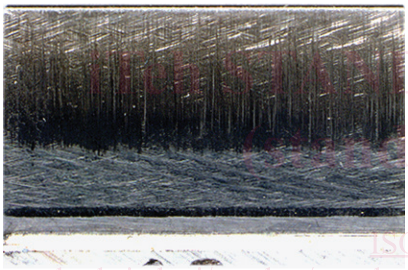
b) No failure marks



c) Approx. 5 mm failure marks

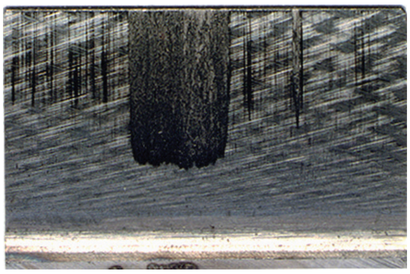


d) Approx. 15 mm failure marks

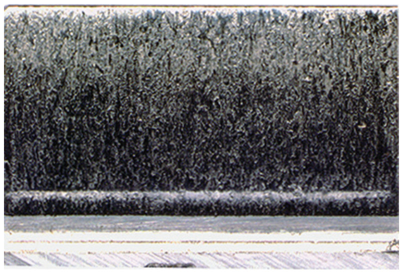


e) 20 mm failure marks

f) Approx. 2 mm failure marks



g) Approx. 6 mm failure marks



h) 20 mm failure marks

NOTE 1 This figure describes the typical pinion tooth flank changes occurring in FZG 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.

NOTE 2 The colours represented in the electronic file of this document can be neither viewed nor printed as true representations. Only copies of this document printed by ISO can be guaranteed to represent the true colours.

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

4.2 Precision

The precision of the method has been evaluated according to ISO 5725-2 with three oils (two reference oils and one oil from the market). The failure load stage of these oils covered the range 5 to 12 inclusive.

Values of repeatability, *r*, and reproducibility, *R*, as defined in ISO 5725-2, for this test procedure are:

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 Tables 1 and 2 shall be used for testing. Each pair of test gears may be utilized twice for testing, using both tooth flanks as load-carrying flanks.

5.2 Cleaning fluid

Petroleum spirit 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	8,3	m/s
Addendum engagement	pinion	e_{a1}	14,7	mm
	wheel	e_{a2}	3,3	mm
Sliding speed at tooth tip	pinion	v_{ga1}	5,56	m/s
	wheel	v_{ga2}	1,25	m/s
Specific sliding at tooth tip	pinion	ζ_{E1}	0,86	
	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/mm^2

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