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Gears — FZG test procedures —

Part 2: FZG step load test A10/16, 6R/120 for relative scuffing load-carrying capacity of high EP oils

Engrenages — Méthodes d'essai FZG —

Partie 2: Méthode FZG A10/16, 6R/120 à paliers de charge pour évaluer la capacité de charge au grippage des huiles à valeurs EP élevées

Reference number
ISO 14635-2:2004(E)

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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 14635-2 was prepared by Technical Committee ISO/TC 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

ISO 14635 consists of the following parts, under the general title *Gears — FZG test procedures*:

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

— *Part 2: FZG step load test A10/16, 6R/120 for relative scuffing load-carrying capacity of high EP oils*

Part 3, *FZG test method A/2,8/50 for semifluid gear greases*, is under preparation.

Introduction

The types of gear failures which may be influenced by the lubricant in use are scuffing, low-speed wear and the gear-surface fatigue phenomena known as micropitting and pitting. 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 test procedures specified in this and the other parts of ISO 14635 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 ISO 14635-1 is typical for the majority of applications in industrial and marine gears. This part of ISO 14635 is related to the relative scuffing load-carrying capacity of oils of very high EP properties, as used for the lubrication of automotive driveline components. Other FZG test procedures for the determination of low-speed wear, micropitting and pitting load-carrying capacity of gears are already in a late state of development. They may be added later to ISO 14635 as further parts.

Gears — FZG test procedures —

Part 2:
FZG step load test A10/16, 6R/120 for relative scuffing load-carrying capacity of high EP oils

1 Scope

This part of ISO 14635 specifies a test method based on an FZG[1)] four-square test machine to determine the relative load-carrying capacity of high EP oils defined by the gear surface damage known as scuffing. This test method is useful for evaluating the scuffing load capacity potential of oils typically used with highly stressed cylindrical gearing found in many vehicle and stationary applications. It is not suitable for establishing the scuffing load capacity potential of oils used in highly loaded hypoid bevel gearing applications, for which purpose other methods are available in the industry.

NOTE This method is technically equivalent to CEC L-84-02.

2 Normative references

The following referenced documents are indispensable for the application 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, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO 4287, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters*

ISO 4964, *Steel — Hardness conversions*

ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO 14635-1, *Gears — FZG test procedures — Part 1: FZG test method A/8,3/90 for relative scuffing load-carrying capacity of oils*

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

[1)] FZG = Forschungsstelle für Zahnräder und Getriebebau, Technische Universität München (Gear Research Centre, Technical University, Munich), Boltzmannstraße 15, D-85748 Garching, Germany.

3 Terms and definitions

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

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

NOTE 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.

3.2
scuffing load-carrying capacity
⟨of a lubricant⟩ maximum load which can be sustained under a defined set of conditions

NOTE It is the minimum load stage at which the failure criteria given in Clause 4 is reached. See Table 1.

3.3
FZG test condition A10/16,6R/120
test condition where A10 is the particular tooth form of the test gears, according to Tables 2 and 3, 16,6 is the speed at the pitch circle, in metres per second, "R" indicates the reverse direction of rotation (wheel drives pinion) and 120 is the initial oil temperature in degrees Celsius, from load stage 4 onward in the oil sump

3.4
failure load stage
load stage reached when the sum of the damage to the 16 pinion teeth exceeds 100 mm^2 in total area damaged

NOTE See Clause 4 and Table 1.

3.5
high EP oils
lubricants containing chemical additives appropriate for improving their scuffing load capacity

NOTE 1 EP = extreme pressure.

NOTE 2 These oils typically exceed the limits of the FZG test according to ISO 14635-1.

4 Failure criteria

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 include a tendency to high levels of dynamic loading owing to an increase of vibrations, which usually leads to further damage by scuffing, pitting or tooth breakage.

Because of the particular gear design and test loads used, an interference area typically results at the tip of the pinion and root of the mating wheel. This area is usually about 1 mm in length (profile direction) on the pinion and across the entire face width. Examples of various levels of distress occurring with this test are shown in Annex A. The effect of the surface distress in these two regions is addressed as follows.

a) For the purpose of the visual rating for scuffing, the top 1 mm near the tip of the pinion is not included in the assessment until the damage extends below that level. The rated damage region is then expressed as the total area scuffed over all 16 pinion teeth (see Figure 1). The failure load stage is reached when the sum of the damage to the 16 pinion teeth exceeds 100 mm^2 in total area damaged.

b) For a valid test, the wheel shall be visually checked for signs of excessive wear after each pass load stage, as this could alter the results of the test. If there is evidence of wear in the dedendum of the wheel, then the gear shall be weighed to the nearest milligram (0,001 g) [see Annex A, d)]. The test may be considered valid only if the loss in mass of the wheel is ⩽ 20 mg: if the loss in mass of the wheel exceeds 20 mg, the test shall not be considered valid.

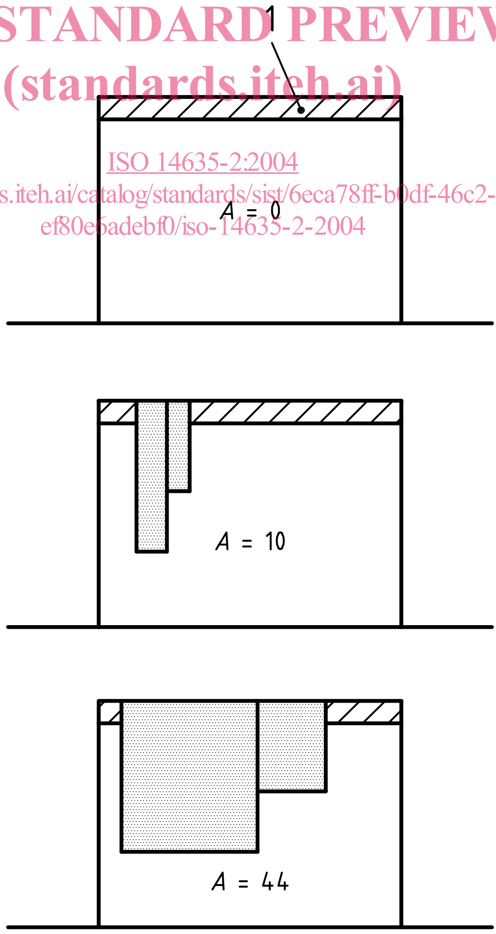
See Table 1.

Table 1 — Test criteria

Pinion failure area A mm^2	**Wheel wear** Δm mg	**Result**
⩽ 100	⩽ 20	PASS
⩽ 100	> 20	INVALID [a]
> 100	Not required	FAIL

[a] No statement on the scuffing load is possible.

Area in square millimetres



Key

1 exclusion zone (1 mm)

Figure 1 — Schematic of distress rating for pinion

5 Brief description of method

5.1 General principle

A set of test gears as defined in Tables 2 and 3 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 4. Beginning with load stage 4, the initial oil temperature is controlled between 117 °C and 123 °C. During the test run of each load stage, the oil temperature is allowed to rise freely. After load stage 5, 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 have been met or when load stage 10 has been completed without having been met the failure criteria having been met.

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 precaution shall be taken to protect personnel.

Protection from noise is also highly recommended.

5.2 Precision

The precision of the method has been evaluated according to ISO 5725-2 with two reference oils. The failure load stage of these oils covered the range 5 to 10 inclusive for the step load test.

Values of repeatability (r) and reproducibility (R), as defined in ISO 5725-2, for this test procedures are

r = 1 load stage,

R = 2 load stages.

6 Test materials

6.1 Test gears

A pair of type “A10” test gears with a specification according to Tables 2 and 3 shall be used for testing. Each pair of test gears may be used twice for testing, utilizing both tooth flanks as load-carrying flanks.

6.2 Cleaning fluid

Petroleum spirit conforming to ASTM D 235.

7 Apparatus

7.1 FZG spur-gear test rig

7.1.1 The FZG spur-gear test machine utilizes a recirculating power loop principle, also known as a four-square configuration, to provide a fixed torque (load) to a pair of precision test gears. A schematic view of the test rig is shown in Figures 2 and 3. The slave gearbox and the test gearbox are connected through two torsional shafts. Shaft 1 contains a load coupling used to apply the torque through the use of known weights, defined in Table 4, hung on the loading arm.

7.1.2 The test gearbox contains heating elements to maintain and control the minimum temperature of the oil. A temperature sensor located in the side of the test gearbox is used to control the heating system as required by the test operating conditions.

7.1.3 The test machine is powered by an electric motor of minimum 7,4 kW at a speed of approximately 2 900 r/min. The direction of drive is reversed (anticlockwise when looking on the motor shaft), i.e. wheel drives pinion, as shown in Figure 3. This is the opposite direction of rotation to that of ISO 14635-1.

Table 2 — Details of FZG test gears type A10

Dimension		Symbol	Numerical value	Unit
Shaft centre distance		a	91,5	mm
Effective face width	pinion	b_1	10	mm
	wheel	b_2	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	Degrees
Working pressure angle		α_w	22,5	Degrees
Pitch diameter circumferential speed		v_w	16,6	m/s
Addendum engagement	pinion	e_{a1}	14,7	mm
	wheel	e_{a2}	3,3	mm
Sliding speed at tooth tip	pinion	v_{ga1}	11,16	m/s
	wheel	v_{ga2}	2,50	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	$20{,}8\sqrt{F_{nt}}$ [a]	N/mm²

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