INTERNATIONAL STANDARD

ISO 14635-2

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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
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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)*

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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 $\leqslant$ 20 mg: if the loss in mass of the wheel exceeds 20 mg, the test shall not be considered valid.

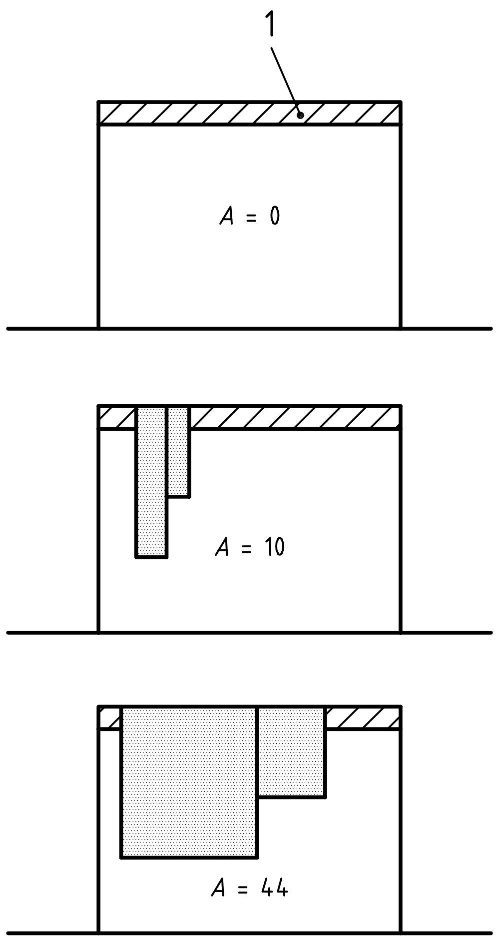
See Table 1.

Table 1 — Test criteria

Pinion failure area A mm^2	**Wheel wear** Δm mg	**Result**
$\leqslant$ 100	$\leqslant$ 20	PASS
$\leqslant$ 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/mm^2

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

Table 3 — Manufacturing details of FZG test gears type A10

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/mm^2 to 1 250 N/mm^2 (determined in accordance with ISO 4964 based on Brinell hardness). Retained austenite should be nominally 20 %.
Gear accuracy grade	Q5 according to ISO 1328-1.
Arithmetic roughness of flanks Ra	Ra is separately determined for left and right flanks, measured each at three flanks per gear across the centre of the tooth parallel to the pitch line; measuring-parameters according to ISO 4287: measured length l_t = 4,8 mm, cut-off length λ_c = 0,8 mm, velocity v_t = 0,5 mm/s using a skid.
	Average roughness (relating to manufacture batches of min. 100 gear sets) Pinion: Ra = 0,35 µm ± 0,1 µm Gear: Ra = 0,30 µm ± 0,1 µm
	Maximum roughness (average of 3 measurements according to the described method and valid for 95 of 100 tested gears) Pinion and gear: Ra = 0,5 µm
Grinding	Maag criss-cross grinding (15° method), 154 r/min of generating stroke drive
Flank modification	None.

7.2 Heating device

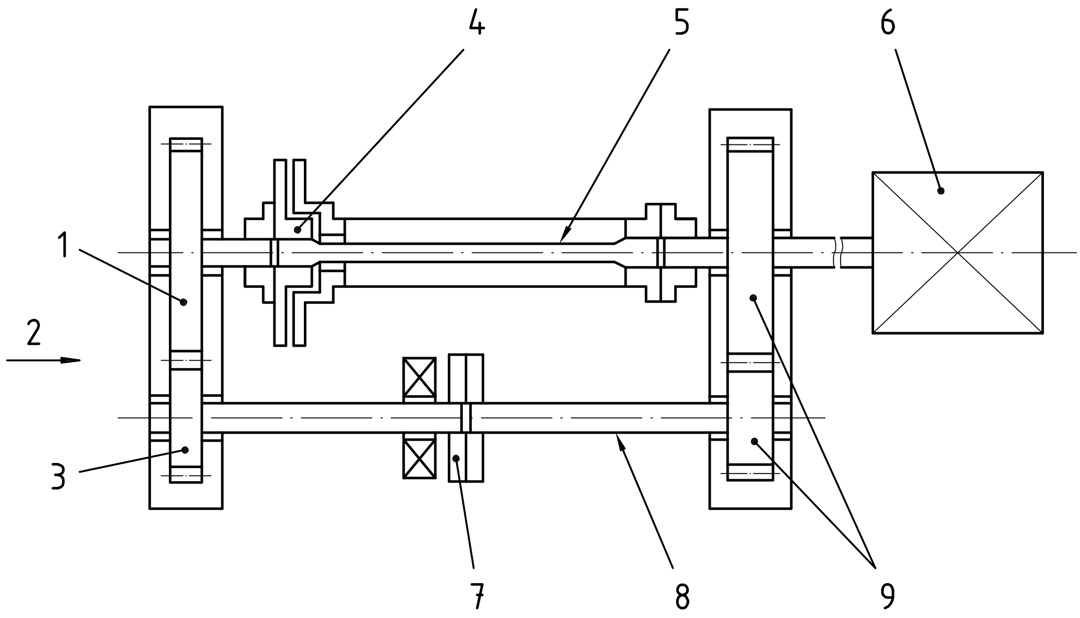
A suitable oven or heating device is required to warm the test gears to 60 °C to 80 °C for assembling on the shafts.

7.3 Revolution counter

A suitable counter shall be used to control the number of revolutions (cycles) during each load stage of the test. The counter should be capable of shutting down the test machine at the appropriate number of revolutions.

7.4 Balance

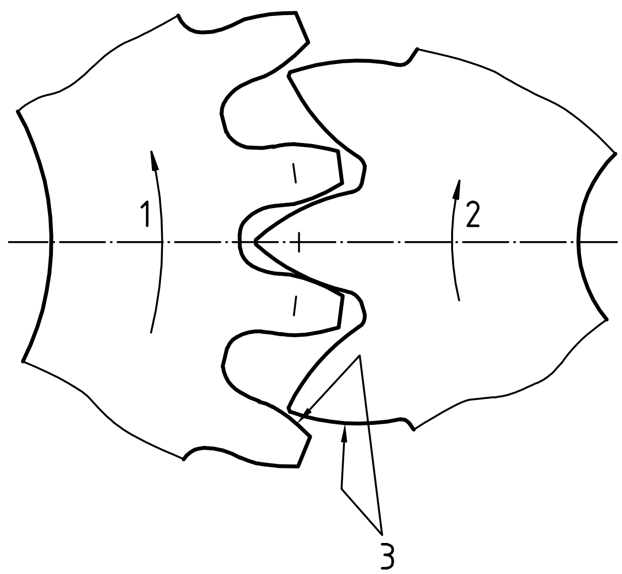
A suitable balance of a minimum weighing capacity 1,3 kg and with accuracy to the nearest to 0,001 g shall be used to determine the mass of the test wheel.



Key

1 wheel
2 view A
3 pinion
4 torque measuring coupling
5 shaft 2
6 drive motor
7 load coupling
8 shaft 1
9 slave gears

Figure 2 — Schematic section of the FZG gear test machine



Key

1 wheel
2 pinion
3 action tooth flank

Figure 3 — Mounting of the FZG test gears of type A10 (view A)

8 Preparation of apparatus

8.1 Flush the test gear case twice with petroleum spirit, ensuring that the bearings are cleared of any previous oil, and air dry with a clean, water-free air line.

8.2 Clean the test gears in petroleum spirit and air dry, using protective gloves.

8.3 Visually inspect the test gears for corrosion, rust or any other damage. Reject the gears if so damaged.

8.4 Weigh the wheel to the nearest 0,001 g.

8.5 For easier mounting, heat both test gears and bearing races to between 60 °C and 80 °C with the heating device.

8.6 Assemble the test gear box (except the top cover) with the pinion on shaft 1 (right-hand side) and the wheel on shaft 2 (left-hand side) as shown in Figure 3.

8.7 Switch drain cock to the CLOSED position.

8.8 Fill the test gear box with nominal 1,25 litre of test oil.

8.9 Plug in the heater.

8.10 Fit and secure the top cover to the test gear box.

8.11 Apply load stage 12 (see ISO 14635-1) using the 0,5 m radius position for 2 min to 3 min without running the motor, in order to bring the test gears and the clearances in the system into the correct working position.

9 Test procedure

9.1 Apply the first load stage (see Table 4). Using the conditions given in Table 5, start the motor, switch on the heater and run for 21 700 motor shaft revolutions (approximately 7,5 minutes). Repeat the process for load stages 2 and 3.

9.2 At the start of load stage 4, ensure that the oil temperature in the test gear box is between 117 °C and 123 °C, in accordance with Table 5.

9.3 At the end of load stage 4, inspect the pinion for damage, without removing the test gears. Record the tooth condition, using the examples in Figure 1 and Annex A as a guide. If the damage criteria is not reached, the test is continued.

9.4 If the test is continuing to the next higher load stage, ensure that the oil temperature in the test gearbox is between 117 °C and 123 °C. This may be accomplished through the use of appropriate heating or cooling of the test gear box. When the temperature is between 117 °C and 123 °C, the test may be continued. Ensure that cooling devices are turned off during the test.

9.5 Continue the test with step-wise increased load stages (Table 4), inspecting all the pinion teeth after each stage, and cooling to between 117 °C and 123 °C, as specified in 9.4, before applying the next higher load stage.

9.6 Continue with the procedure until the failure load stage according to Clause 4 is reached, but if insufficient damage (< 100 mm^2 scuffing) occurs, terminate the test at the end of load stage 10.

9.7 If the machine is shut down at the end of a load stage for any reason during a test for a period of time before the test is completed and the test oil temperature drops below 117 °C, carry out the following steps before resuming the test.

a) Apply load stage 1, start the motor, switch on the heater and run until the oil temperature reaches 117 °C to 123 °C.

b) Stop the motor, switch off the heater and apply the next load stage in the test sequence after the load stage at which the machine was shutdown.

c) Continue the test according to 9.5 and 9.6, respectively.

9.8 On completion of the test, weigh the wheel to the nearest 0,001 g and calculate the loss of mass, Δm.

Table 4 — FZG load stages

Load stage No.	**Pinion torque** N·m	**Normal tooth load** N	**Hertzian stress at pitch point** N/mm²	**Load coupling loaded with**
1	3,3	99	206	H_1
2	13,7	407	417	H_2
3	35,3	1 044	670	$H_2 + K$
4	60,8	1 799	878	$H_2 + K + W_1$
5	94,1	2 786	1 093	$H_2 + K + W_1 + W_2$
6	135,5	4 007	1 314	$H_2 + K + W_1 + W_2 + W_3$
7	183,4	5 435	1 527	$H_2 + K + W_1 + W_2 + W_3 + W_4$
8	239,3	7 080	1 730	$H_2 + K + W_1 + W_2 + W_3 + W_4 + W_5$
9	302,0	8 949	1 960	$H_2 + K + W_1 + W_2 + W_3 + W_4 + W_5 + W_6$
10	372,6	11 029	2 176	$H_2 + K + W_1 + W_2 + W_3 + W_4 + W_5 + W_6 + W_7$

Weight hangers shall be applied to the 0,5 m radius position.
H_1 = load lever H_1 (light)
H_2 = load lever H_2 (heavy, 0,5 m notch)
K = weight support rod
W_1 to W_7 = weights for weight loading

Table 5 — Test conditions

Duration of each load stage:	21 700 revolutions of the motor (approx. 7,5 min)
Motor speed:	2 910 r/min ± 3 %
Direction of rotation:	Anticlockwise [a]
Initial oil temperature at start of load stage 4 and each subsequent load stage:	(120 ± 3) °C

[a] The direction of the rotation of the gears is shown in Figure 3.

10 Reporting of results

Report the load stage and the corresponding pinion torque at which the failure load stage occurred, according to Clause 4. State the test conditions as A10/16,6R/120. If the test was completed without failure, report “Failure load stage greater than 10” and give the loss in mass of the wheel, expressed in milligrams. If the test is terminated owing to scuffing before load stage 5 was reached, report “Failure load stage less than 5”. For examples of different cases of test validity, see Table 6.

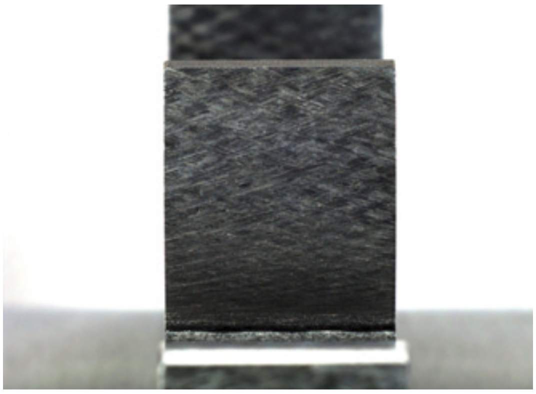
Table 6 — Example results for test conditions

Example	**1**	**2**	**3**
Failure load stage	8	> 10	—
Wheel mass loss after LS 10	—	16 mg	30 mg
Valid test	Yes	Yes	No

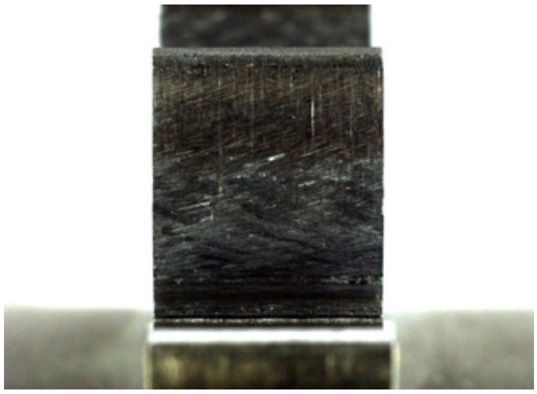
The changes may also be recorded photographically. Any corrosion or deposits should be recorded in the test report (see Annex B).

Annex A
(informative)

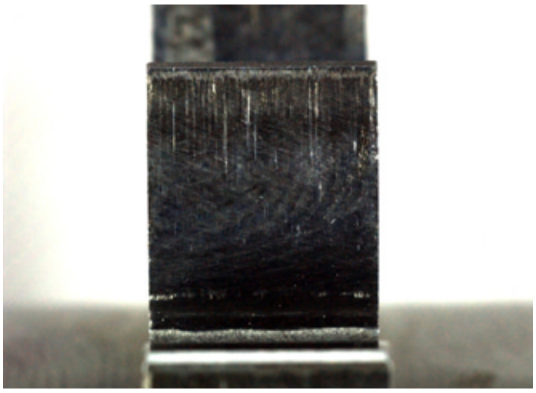
FZG A10-type gear tooth face changes (flank damages)



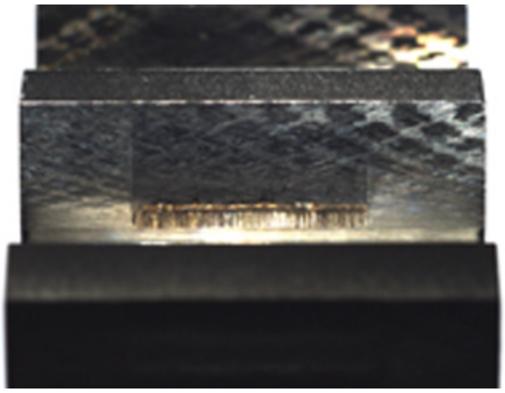
a) New pinion flank



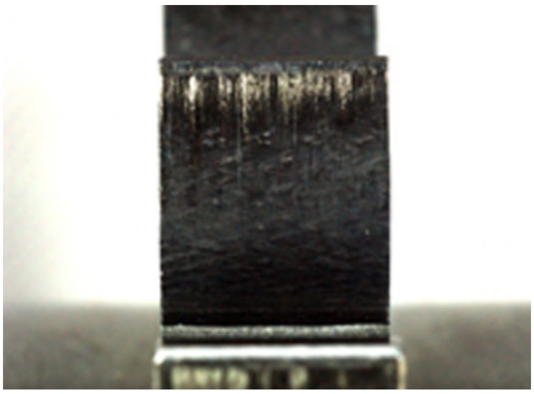
b) No failure



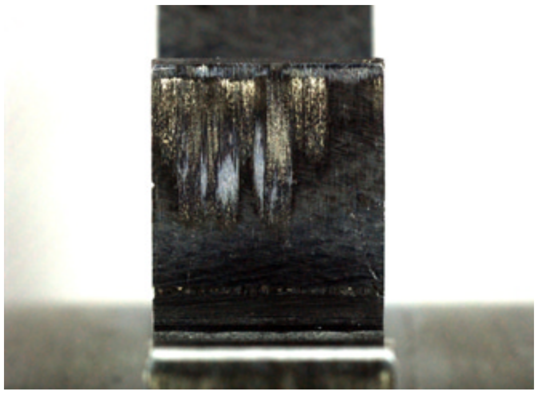
c) No failure



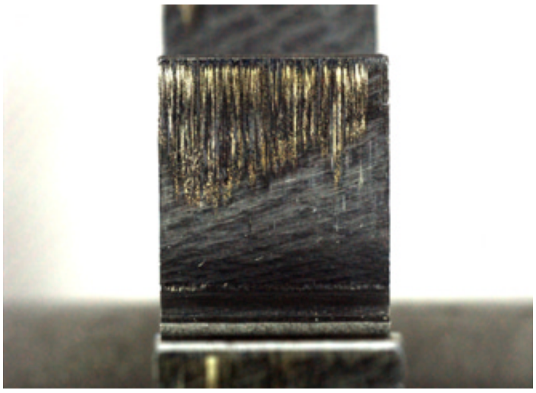
d) Wear mark in wheel dedendum: test invalid if mass loss $>$ 20 mg



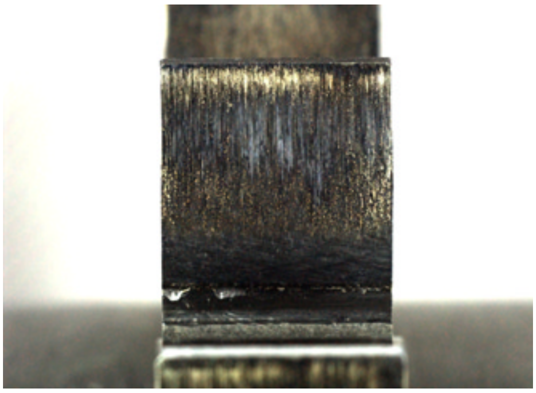
e) A = 16 mm



f) A = 40 mm^2



g) A = 45 mm^2



h) A = 70 mm^2

Annex B
(informative)

Typical FZG test report sheet

Company Name *Company Logo*

ISO 14635-2

Gears — FZG test procedures

Part 2: FZG test method A10/16, 6R/120

TEST REPORT

Lubricant: ....

Origin: ....

FZG Test No: ....

FZG Test Gear Set No.: ....

FZG Test Gear Flank: ....

TEST RESULT:

Valid test (Yes/No): ....

Failure load stage: ....

Pinion torque T_1 at failure load stage: .... N·m

Wheel mass loss at end of load stage 10: .... mg

Remarks:

....

....

Date: Signature:

Annex C
(informative)

Checklist for maintenance of FZG gear test rig

C.1 How to recognize malfunction

C.1.1 Distribution of scuffing marks

Frequently, an indication of maintenance of the machine being required is given by the distribution of scuffing marks across the face width of every tooth and around the circumference after every gear-oil test.

Uneven distribution of scuffing marks across the face width indicates uneven load distribution, and because of elastic deformations, this is more likely at low load stages than it is at high load stages. Fig. C.1 shows the scuffing mark distribution for perfect running operation, as well as for misalignment and tumbling error indicating the malfunction.

C.1.2 Tooth contact pattern

From time to time (e.g. after every twentieth test), or after indication of load maldistribution, the contact pattern should be checked either by using soot or Prussian blue. Under no-load conditions, the tooth contact pattern should be uniformly distributed and should cover 70 % or more of the active flank area.

C.1.3 Tests with reference oil

From time to time (e.g. after every fortieth test), a duplicated scuffing test with minimum of one of the two reference oils for the test is recommended. Deviations from the typical scuffing load stage of the reference oil, high scattering between the two tests and regular increase or decrease of scuffing load stage as compared to former reference-oil tests can indicate a malfunction.

Organizations such as CEC have defined reference oils for comparison testing.

C.1.4 Other indications

Noise and vibrations, temperatures, bearing play, wear etc. should be checked.

C.2 Parts that need maintenance

C.2.1 Test gear box

C.2.1.1 Shafts

Bearings shall have a light shrink fit on the shafts. Bearings shall not slide on or off the shaft at same (ambient) temperature of bearing and shaft. Indication of a slack fit are circumferential wear or even scoring marks on the shaft and the inner diameter of the bearing when the inner race of the bearing slides on the shaft during operation.

Gears shall have a slight shrink fit on the shafts. They shall not easily slide on or off the shaft at same temperature of gear and shaft. Possible slight fretting corrosion on the shafts is not harmful and can be polished off the shaft using, for example, a chrome polish. Tangible wear marks on the shaft cannot be tolerated.

Hard-chrome shafts tend to show spalling in the vicinity of the keys. Spalling up to approx. 5 mm width all along the key can be tolerated.

A tangible wear groove under the shaft seal leads to leakage even when seals are replaced.

C.2.1.2 Bearings

Bearings shall have an adequate small amount of play. Bearing life is normally not limited by pitting but by excess wear.

Bearings shall have a slight shrink fit on the shaft (see also C.2.1.1) and a slide fit with small clearance in the bore (see C.2.1.5).

C.2.1.3 Keys

Keys shall not be worn or show any plastic deformation. They should fit into the shaft with a small clearance, tilting of the key in the shaft is not allowed.

C.2.1.4 Spacer rings

The spacers between bearings and gears should be hardened and plane-parallel ground. These faces shall not show fretting or scoring marks, grooves or burrs.

Due to the bearing configuration, hubs or spacers that are too wide can cause a compressive force in the bearings.

Check if shafts of unloaded machine are easily turnable, check inner races of bearings for axial thrust. Check the temperature in the oil sump after each load stage of standard test A/8,3/90; normally 90 °C is not exceeded in the first six load stages.

C.2.1.5 Gear box and front cover

The outer race of the bearing in the gear box and front cover shall have a sliding fit with no detectable radial clearance.

The sealing surface (front and top, gear box and cover) shall be flat without burrs or scratches. It is essential not to trap dirt particles during mounting.

All threads in the gear box shall be in good condition.

C.2.1.6 Seals

In case of leakage, check seals and seal race on the shafts (see C.2.1.1). Seals shall not slide on the shaft with the key groove unprotected; otherwise the sealing lip might be destroyed.

C.2.2 Connecting shafts and flanges

C.2.2.1 Load coupling

The two halves of the load coupling shall be easily twistable against each other. If this is not possible, check the centring pin in the shafts, the faces of the load coupling and the T-slot guidance of the bolts. Remove fretting corrosion and lubricate parts if necessary.

Tighten bolts using a torque-indicating wrench set to T = 100 N·m. Replace broken bolts immediately. Do not operate rig with missing bolts.

C.2.2.2 Torque-measuring device

Easy twisting with low friction shall be possible. Check the bearing in the measuring coupling:

Roller bearings shall not show deep rippling marks. Journal bearings shall slide easily, therefore check lubrication.

C.2.2.3 Load coupling support bearing

Control for frictionless motion and proper lubrication. Change is only very seldom necessary.

C.2.2.4 Torsion shaft

Replacement is only necessary when plastic deformation has occurred.

After tooth breakage or any other possible overloading, check torsion shaft for alignment of key slots.

Check the screws of the tube that is over the torsion shaft for a tight fit.

C.2.2.5 Flanges

All flanges should have a slight shrink fit on their shafts. Minor fretting corrosion is tolerable.

C.2.3 Slave gear box

For shafts, seals, keys etc. see C.2.1.

C.2.3.1 Slave gears

Check slave gears for pitting, scuffing or wear. Replace or turn slave gears when pitting or scuffing is visible or tangible wear marks occur.

C.2.3.2 Lubrication

Check the oil level and fill up to approximately the centre of shafts if necessary.

Use an industrial gear oil quality with extreme-pressure (EP) ingredients of type CKC or CKD as defined in ISO 6743-6, meeting the requirements specified in ISO 12925-1. ISO viscosity grade 220 is recommended.

API GL 4 quality lubricants of SAE J 306 grade 90 may also be used.

Change the oil depending on operating hours, at least once a year.

C.2.4 Other parts

C.2.4.1 Heating

Check that the heating elements function properly. Check “heater on” and “heater off” functions of temperature-measuring device.

C.2.4.2 Flexible coupling

Check if the flexible-coupling plastic blocks are in good working order.

C.2.4.3 Motor

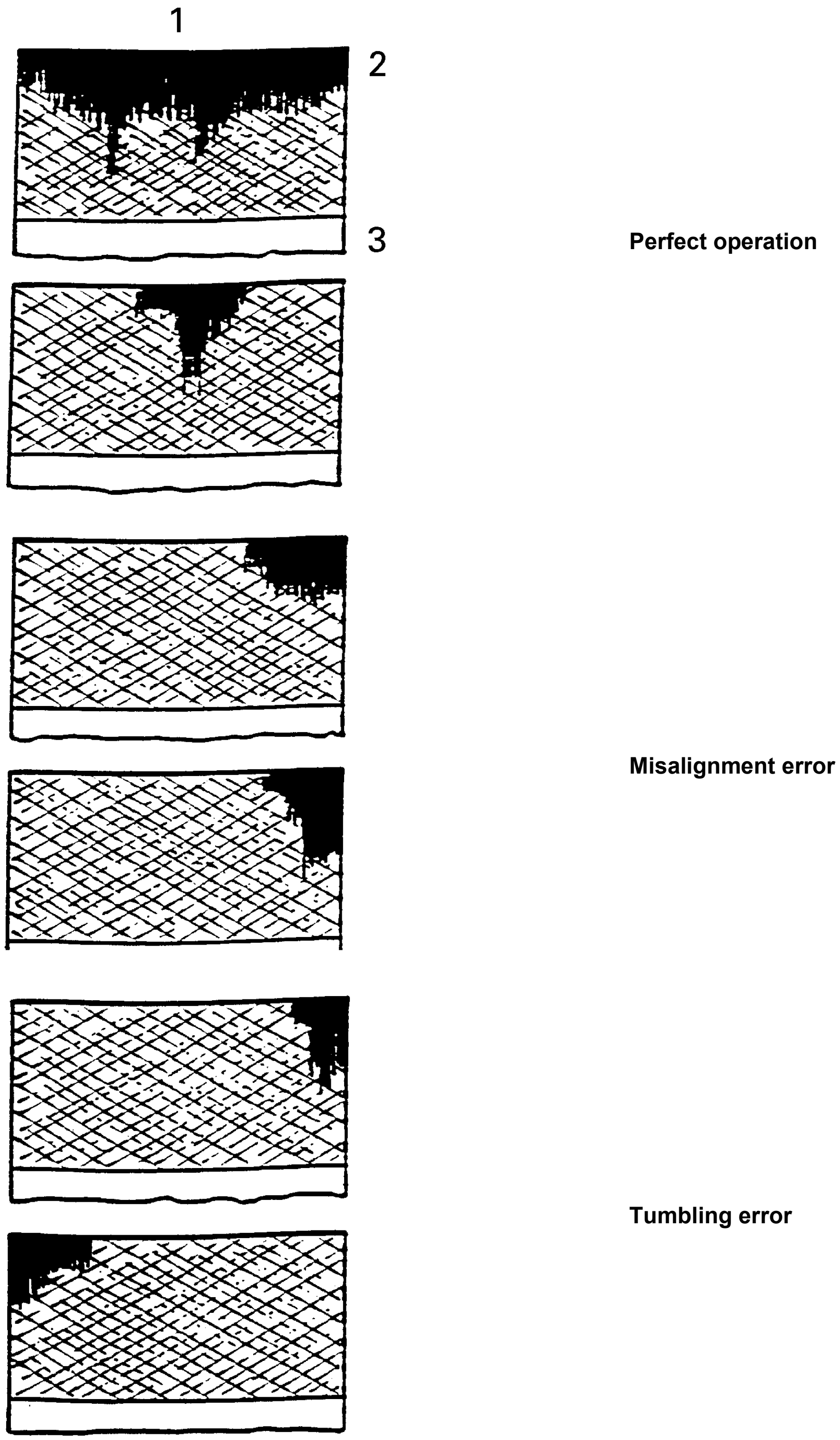
Check any increase in motor noise. Lubricate or replace bearings if necessary.

C.2.4.4 Approximate time intervals

Assuming 60 to 80 test runs per year, the following approximate times for change are typical:

Shafts:		2 years
Bearings:	running oil tests	1 to 2 years
	running grease tests	2 months
Seals:		Viton/1 year
Gear box:		5 to 10 years

Deviations from these figures are possible in a fairly wide range, depending on the operating and lubricant conditions.



Key

1 pinion tooth

2 tip

3 root

Figure C.1 — Scuffing marks indicate machine errors

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