

INFORMATION



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Short Test Procedure for the investigation of the micro-pitting load capacity of gear lubricants

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DGMK-FZG micro-pitting short test

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Summary:

The FVA-FZG-micro-pitting test GT-C /8.3/90 is well established as the standard test method for evaluating the micro-pitting characteristics of lubricants used in gear drives. This test provides precise results, but it requires relatively high costs and is quite time consuming. Unfortunately an effective and consistent short test method is not yet available. Therefore the FVA-FZG-micro-pitting test should be supplemented by a standardized short test method that is able to classify candidate lubricants analogous to the FVA-FZG-micro-pitting test.

Within the scope of the DGMK research project 575 the DGMK-FZG micro-pitting short test GFKT-C/8.3/90 was developed and tested with lubricants, whose classification in the standard FVA-FZG-micro-pitting test is well known.

The new DGMK-FZG micro-pitting short test (abbreviated as GFKT-C/8.3/90) categorises candidate lubricants in classes of micro-pitting load capacity analogous to the FVA-FZG-micro-pitting test. These classes correlate well with the classes of the FVA-FZG-micro-pitting test. Regarding the general tendency, as expected the average maximum profile deviation after load stage 9 of the DGMK-FZG micro-pitting short test decreases with increasing micro-pitting load capacity of the oil according to the FVA-FZG-micro-pitting test. The correlation between the average maximum profile deviation and the failure-load stage of the FVA-FZG-micro-pitting test is good.

Consequently the DGMK-FZG micro-pitting short test, as a supplement to the available standard test method, represents a standardized short test method, that is qualified for the differentiation of varying candidate lubricants in terms of micro-pitting load capacity.

1 Purpose of the test

The DGMK-FZG micro-pitting short test GFKT-C/8.3/90 (abbreviated as GFKT) represents a supplement to the available FVA-FZG-micro-pitting test, that is the standard test method to specify the characteristics of lubricants concerning their micro-pitting load capacity. The GFKT can be realized on any standard FZG test rig according to DIN 51354 with splash lubrication. The micro-pitting test can be used to determine quantitatively the influence of lubricants (especially additives), the lubricant temperature and other influential factors on micro-pitting development. Due to the minimized running time and the small volume of candidate lubricant required for splash lubrication, the GFKT is a adequate method for the development of optimised lubricants and additives as well as the efficient evaluation of used lubricants. The GFKT is qualified for the differentiation of various lubricants in terms of their micro-pitting load capacity. It categorises candidate lubricants in the load capacity classes GFKT-low, GFKT-medium and GFKT-high.

2 Scope and designation of the micro-pitting test

The GFKT is designated similarly to the FVA-FZG-micro-pitting test by test gear type / circumferential speed / and lubricant temperature in accordance with the selected test conditions (e.g.: standard test: GFKT-C/8.3/90; GFKT = micro-pitting short test). The operating conditions (circumferential speed and lubricant temperature) may be suitably adapted in the DGMK-FZG micro-pitting short test for the comparative testing of lubricants for a large variety of applications. The designation above intends to differentiate between the various test options, which are carried out according to the same test sequence, but with different test conditions (circumferential speed and lubricant temperature).

3 Description of the test procedure

The GFKT is a step test running in load stages 3 (running-in), 7 and 9. The capability of the gear lubricant tribological system to resist micro-pitting is determined under specified operating conditions (lubricant temperature, circumferential speed) as a failure-load stage.

3.1 Test conditions

Table 1 shows the standard conditions for the GFKT. The oil sump temperature is controlled by a thermostat. **Table 2** contains the torque on the pinion and the Hertzian contact stress of the load stages of the test.

Pinion speed n_1 , rpm	approx. 2250 ¹⁾
Circumferential speed v at working pitch circle, m/s	$0.00383 \cdot n_1$
Driving gear	Pinion
Lubrication	Splash lubrication, approx. 1.5 l in the test gear box
Oil sump temperature	90 ± 2 °C ²⁾
Running time during running-in (LS 3)	approx. 1 h = $1.3 \cdot 10^5$ Pinion cycles
Running time per load stage in the load stage test	approx. 16 h = $2.1 \cdot 10^6$ Pinion cycles
¹⁾ Circumferential speed approx. 8.3 m/s ²⁾ Alternatively, oil sump temperature 60°C depending on the lubricant application	

Table 1: Test conditions in the GFKT-C/8.3/90

Load stage	Pinion torque [Nm]	Hertzian contact stress at pitch point p_c [N/mm ²]
3 (running-in)	28.8	510.0
7	132.5	1093.9
9	215.6	1395.4

Table 2: Load stages of the GFKT-C/8.3/90

3.2 Test procedure

At the beginning of the DGMK-FZG micro-pitting short test procedure the oil sump temperature should surely meet the test conditions (normally 90°C). At the beginning of the running-in load stage 3 a slightly lower oil sump temperature (80°C) is tolerable.

The test procedure starts with the running-in process in load stage 3 for 1 hour. Subsequently the intrinsic load stage test begins. A run in load stage 7 is followed by a run in load stage 9¹, each with a running time of 16 hours. After the run of load stages 7 and 9 the test gears must be dismantled for measuring the profile shape of three teeth evenly distributed over the circumference of the pinion.

For increasing the accuracy of the test result it is recommended to repeat the test procedure on the reverse side teeth flanks of the test gears.

3.3 Test gears

The GFKT operates with the same test gears as the FVA-FZG-micro-pitting test. The gears with the geometry "FZG-C", type "C/GF" used here are balanced with regard to sliding velocity. **Table 3** shows the geometrical gear data.

Dimension	Symbol	Value	Unit	
Centre distance	a	91.5	mm	
Effective tooth width	b	14.0	mm	
Working pitch diameter	Pinion	d_{w1}	73.2	mm
	Wheel	d_{w2}	109.8	mm
Tip diameter	Pinion	d_{a1}	82.46	mm
	Wheel	d_{a2}	118.36	mm
Module	m	4.5	mm	
Number of teeth	Pinion	z_1	16	-
	Wheel	z_2	24	-
Addendum modification factor	Pinion	x_1	0.1817	-
	Wheel	x_2	0.1715	-
Pressure angle	α	20	°	
Working pressure angle	α_{wt}	22.44	°	
Helix angle	β	0	°	
Reference diameter	Pinion	d_1	72.0	mm
	Wheel	d_2	108.0	mm
Base diameter	Pinion	d_{b1}	67.66	mm
	Wheel	d_{b2}	101.49	mm
Transverse contact ratio	ϵ_α	1.46	-	
Tooth correction	Without tip relief and root relief, no longitudinal crowning			

Table 3: Details of type "FZG-C" test gears for the DGMK-FZG micro-pitting short

¹ If the failure criterion defined in chapter 3.6 is exceeded after the run of load stage 7, the run in load stage 9 will not need to be realized obligatorily. But a result after the run in load stage 9 allows the comparison of the average maximum profile deviations after this load stage. Therefore the run in load stage 9 is generally recommended.

Table 4 shows the data concerning the gear material, heat treatment and accuracy.

Material	16 MnCr 5 according DIN 17210
Heat treatment	The test gears are case-carburized, surface hardness 750 HV 1, in the area of the tooth flank. Case hardening depth at 550 HV 1: 0.8-1.0 mm (after grinding), core strength 1000-1250 N/mm ² . The zone close to the surface shall have no residual austenite content visible in the microscope (<20%).
Gear accuracy grade	5 according to DIN 3962, $f_f \leq 5 \mu\text{m}$. Span of pinion: $34.779^{+0.11}_{-0.135}$ mm, measured over 3 teeth. Span of wheel: $35.252^{+0.11}_{-0.135}$ mm, measured over 3 teeth. Permissible tolerance R_w : each 0.01 mm
Roughness R_a of tooth flanks	$0.5 \pm 0.1 \mu\text{m}$ measured in involute direction
Grinding	Maag 0°-grinding

Table 4: Design parameters of „C/GF“ test gears

3.4 Test machine

FZG test gear rig according to DIN 51354 as for the FVA-FZG-micro-pitting test with splash lubrication is used.

3.5 Assembly of test gears

Analogous to the FVA-FZG-micro-pitting test the wheel (24 teeth) is mounted on the motor shaft. The pinion is the driving gear.

3.6 Failure criterion and classification in GF-classes

The profile shape of the tooth flanks are measured in new condition and after running in load stages 7 and 9 according to chapter 4. If the average profile deviation f_{fm} exceeds the limiting value of $7.5 \mu\text{m}$, the end of the test will be reached. The load stage after which the

average profile deviation exceeds the failure criterion, is recorded as failure-load stage. According to **Table 5** the candidate lubricants are classified in the micro-pitting load capacity classes GFKT-low, GFKT-medium and GFKT-high.

GF-class according to the GFKT	Failure-load stage SKS_{GFKT} in the GFKT
GFKT-low	$SKS_{GFKT} = \text{load stage (KS) 7}$ (f_{fm} after KS 7 > $7.5 \mu\text{m}$)
GFKT-medium	$SKS_{GFKT} = \text{KS 9}$ (f_{fm} after KS 9 > $7.5 \mu\text{m}$)
GFKT-high	$SKS_{GFKT} > \text{KS 9}$ (f_{fm} after KS 9 < $7.5 \mu\text{m}$)

Table 5: Classification in GF-classes according to the GFKT

4 Determination of the profile deviation f_{fm}

4.1 Measuring the involute

The profile shape of three teeth of the pinion evenly distributed over the circumference is measured after the run in load stages 7 and 9. The profile deviation f_f is determined according to DIN 3960. The actual involute of the new test gear (i.e. the involute of the actual base circle) shall be used as the reference line in the profile diagramme. **Figure 1** exemplifies the profile shape of the same tooth flank in new condition and after the run of load stage 9 in the GFKT. In new condition the flank shows a maximum profile deviation f_f of $2.5 \mu\text{m}$. After the run of load stage 9 a significant profile deviation development occurs. The maximum deviation f_f amounts to $11 \mu\text{m}$.

If the average value f_{fm} of the three measured values exceeds the critical value ($7.5 \mu\text{m}$) the failure-load stage will be reached.

A light-microscope shall be used to check the tooth flanks to ensure that the material loss was caused by micro-pitting (matt, evenly grey appearance of the damaged area without any orientation or marks in the direction of the sliding speed) and not by wear in the contact with the mating wheel tip edge.

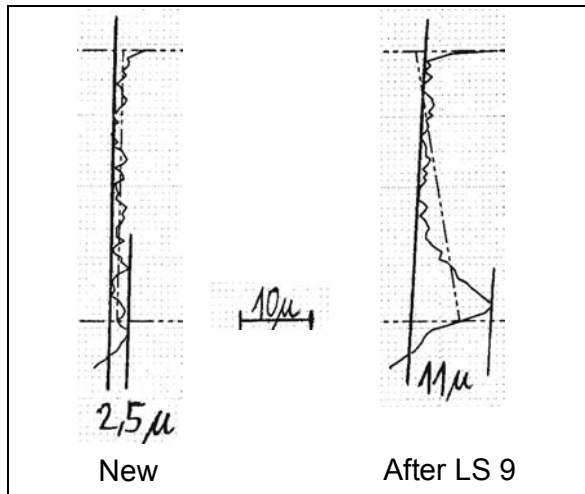


Figure 1: Profile shape of a tooth flank in new condition and after load stage 9 of the GFKT

5 Comparability of the results of the DGMK-FZG micro-pitting short test to the results of the standard FVA-FZG-micro-pitting test

The DGMK-FZG micro-pitting short test categorizes candidate lubricants concerning their micro-pitting load capacity in the classes GFKT-low, GFKT-medium and GFKT-high. The FVA-FZG-micro-pitting test classifies in load capacity classes GFT-low, -medium and -high. Results of gear oils from the market place investigated in the DGMK research project 575 show that the classes of the DGMK-FZG micro-pitting short test correspond well to the classes of the standard FVA-FZG-micro-pitting test.

6 Examples for test runs

Figure 2 shows test runs using lubricants with different levels of micro-pitting load capacity. The progression of the average maximum profile deviation f_{fm} is demonstrated over the load stages in the GFKT. The three curves represent candidate lubricants of the micro-pitting load capacity classes GFKT-low, GFKT-medium and GFKT-high.

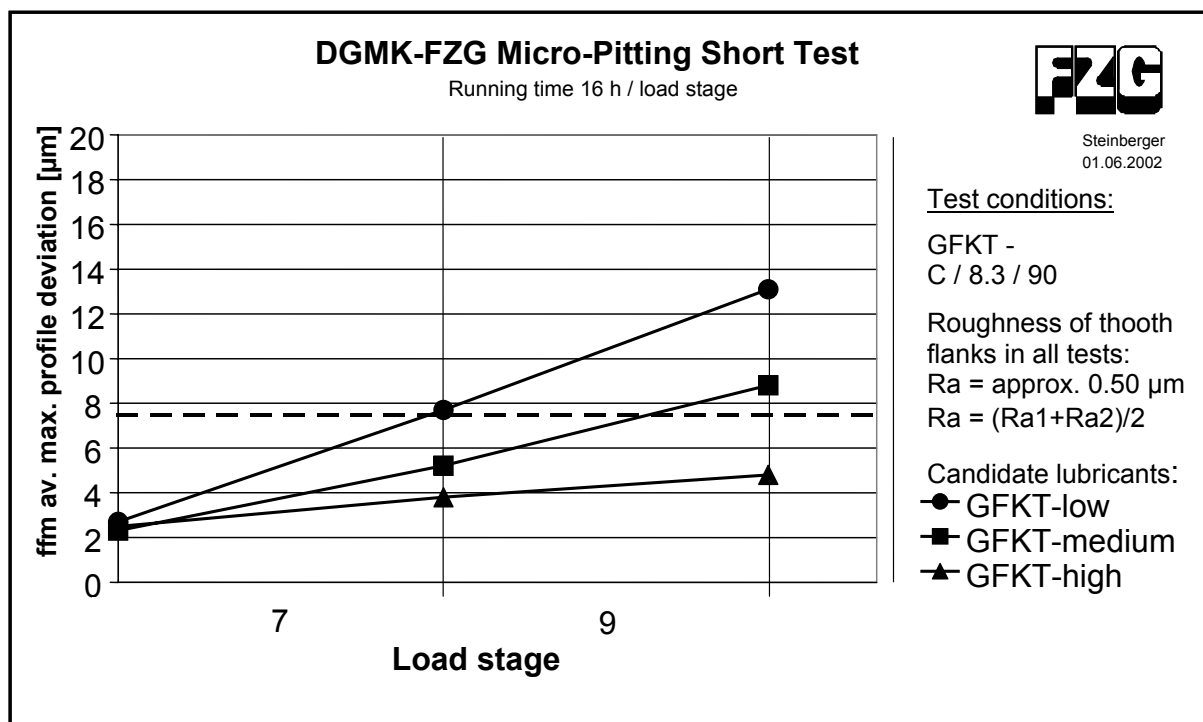


Figure 2: Average maximum profile deviations f_{fm} of the test pinions

