Gear Lubrication — Stopping Micropitting by Using the Right Lubricant

Different high-performance gear oils were examined on an FZG back-to-back gear test rig to determine if changeover to these high-performance gear oils could stop micropitting formation which occurred with other industrial gear oils. The test results showed that high-performance gear oils using advanced additive technologies can react at the surface of the tooth flanks after an oil change and stop further micropittingformation. The micropitting area stagnates.

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MICROPITTING FORMATION IS OFTEN REPORTED TO OCCUR IN FIELD APPLICATIONS EVEN THOUGH INDUSTRIAL GEAR OILS WITH A HIGH MICROPITTING LOAD-CARRYING CAPACITY ARE USED. SUCH OILS OFFER GOOD MICROPITTING PROTECTION DETERMINED IN THE LOAD STAGE TEST OF THE MICROPITTING TEST ACCORDING TO FVA 54/7 [5], BUT SHOW A LOW ENDURANCE MICROPITTING PERFORMANCE. THEREFORE, THE POSSIBILITY OF STOPPING MICROPITTING FORMATION, WHICH OCCURRED WITH THESE GEAR OILS, WAS INVESTIGATED BY USING HIGH-PERFORMANCE GEAR OILS.

DUE TO ADVANCED ADDITIVE TECHNOLOGIES, THESE HIGH-PERFORMANCE GEAR OILS SHOW A HIGH MICROPITTING LOAD-CARRYING CAPACITY IN THE MICROPITTING LOAD STAGE TEST AS WELL AS A HIGH ENDURANCE MICROPITTING PERFORMANCE.

MICROPITTING GEAR FAILURE

Micropitting is a type of fatigue failure occurring on hardened tooth flanks of highly loaded gears. Figure 1 shows typical limits of the load-carrying capacity for case hardened gears according to Niemann [7]. This failure consists of very small cracks and pores on the surface of tooth flanks. Micropitting looks greyish and causes material loss and a change in the profile form of the tooth flanks, which can lead to pitting and breakdown of the gears. A typical micropitting gear failure of an industrial gearbox is shown in Fig. 2. In this case, misalignment was the reason for micropitting formation..

The formation of micropitting depends on different influences. Besides material, surface roughness, and geometry of the tooth flanks, it is the lubricant and the operating conditions which have a major influence on micropitting formation. See Table 1.

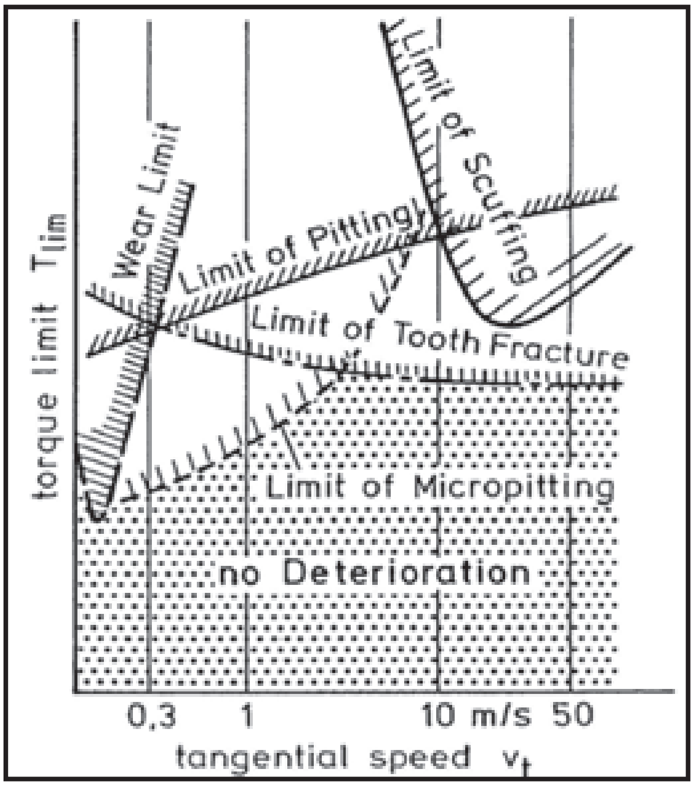

Fig. 1: **Typical limits of the load-carrying capacity for case hardened gears.**

In modern gearboxes, the gears are often highly loaded and run under conditions of mixed lubrication. In this case, the tooth flanks of the mating gears are not fully separated by the lubricant film and the additives of the lubricant have to protect the tooth flanks against micropitting formation.

MICOPITTING LOAD-CARRYING CAPACITY

The micropitting load-carrying capacity of gears can be calculated according to ISO TR 15144-1 [4], where the influence of lubricant, operating conditions, and surface roughness is considered with the specific lubricant film thickness.

For this purpose, the specific lubricant film thickness of a practical gear is compared with a minimum required specific lubricant film thickness. The latter is the specific film thickness where no micropitting risk is given for a lubricant and

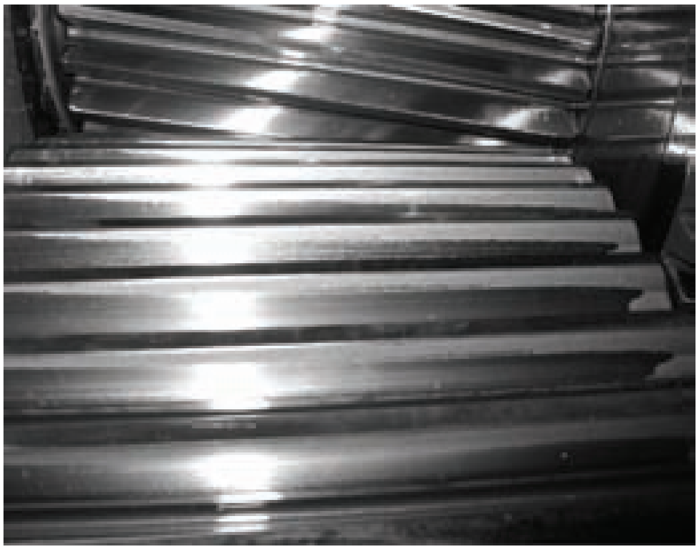

Fig. 2: **Micropitting gear failure of an industrial gearbox.**

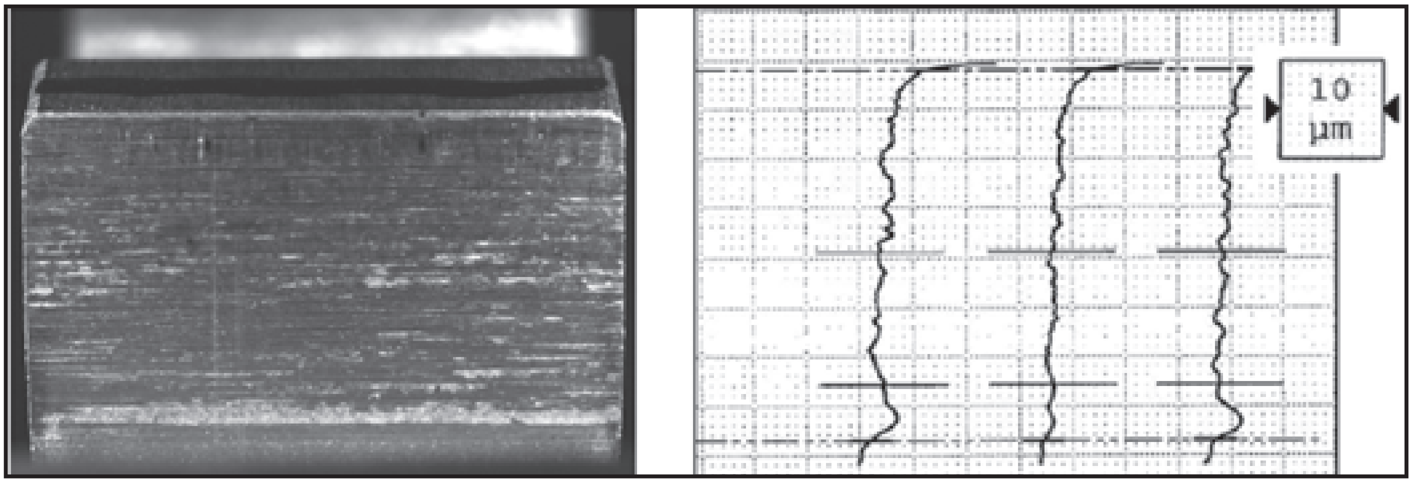

Fig. 3: Pinion type C-GF with measurement of the profile, nearly no micropitting failure.

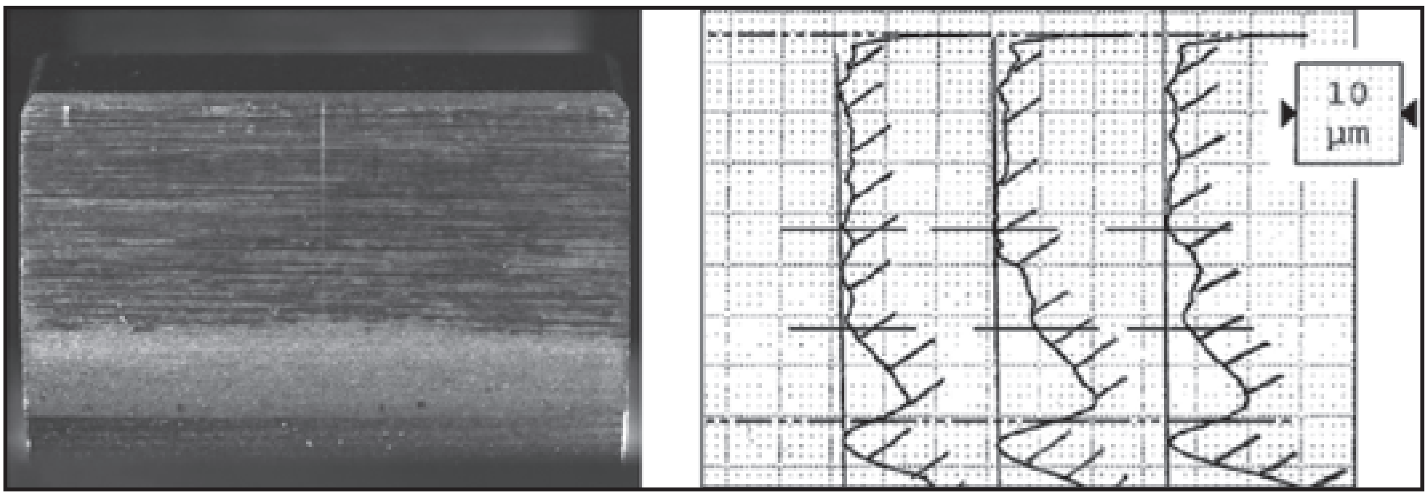

Fig. 4: Pinion type C-GF with measurement of the profile, micropitting failure in the range of the failure criterion.

can be determined by performing a micropitting test according to FVA 54/7 [5].

STANDARD MICROPITTING TEST

The micropitting test according to FVA 54/7 [5] consists of a load stage test and an endurance test. Test gears type C-GF run at a circumferential speed of 8.3 m/s and a lubricant temperature of 90°C or 60°C. The load and the test periods are varied.

In the load stage test, the load is increased stepwise from load stage LS 5 to load stage LS 10 with a running time of 16 h per load stage. After the load stage test, an endurance test with a

lubricant	chemistry of the base oil viscosity of the oil type and amount of additives
tooth flank surface	roughness surface texture surface hardness
operating conditions	normal and frictional load circumferential speed temperature

Table 1: Influences on the micropitting load-carrying capacity.

Load stage	Pinion torque, T_1, Nm	Hertzian pressure, p_C, N/mm^2
LS 5	70.0	795.1
LS 6	98.9	945.1
LS 7	132.5	1093.9
LS 8	171.6	1244.9
LS 9	215.6	1395.4
LS 10	265.1	1547.3

Table 2: Load stages of the micropitting test.

Product	ISO VG	Base oil	DIN 5157, AGMA 9005 designation	Micropitting load-carrying capacity according to *FVA 54/7*	
				$\vartheta_{oil} = 90°C$	$\vartheta_{oil} = 60°C$
Klüberoil GEM 1-320 N	320	Mineral oil	CLP, EP oil	GFT-high	GFT-high
Klübersynth GEM 4-320 N	320	Polyalphaolefin	CLP HC, EP oil	GFT-high	GFT-high
Klübersynth GH 6-320	320	Polyglycol	CLP PG, EP oil	GFT-high	GFT-high

Table 7: Oil data of the high-performance gear oils.

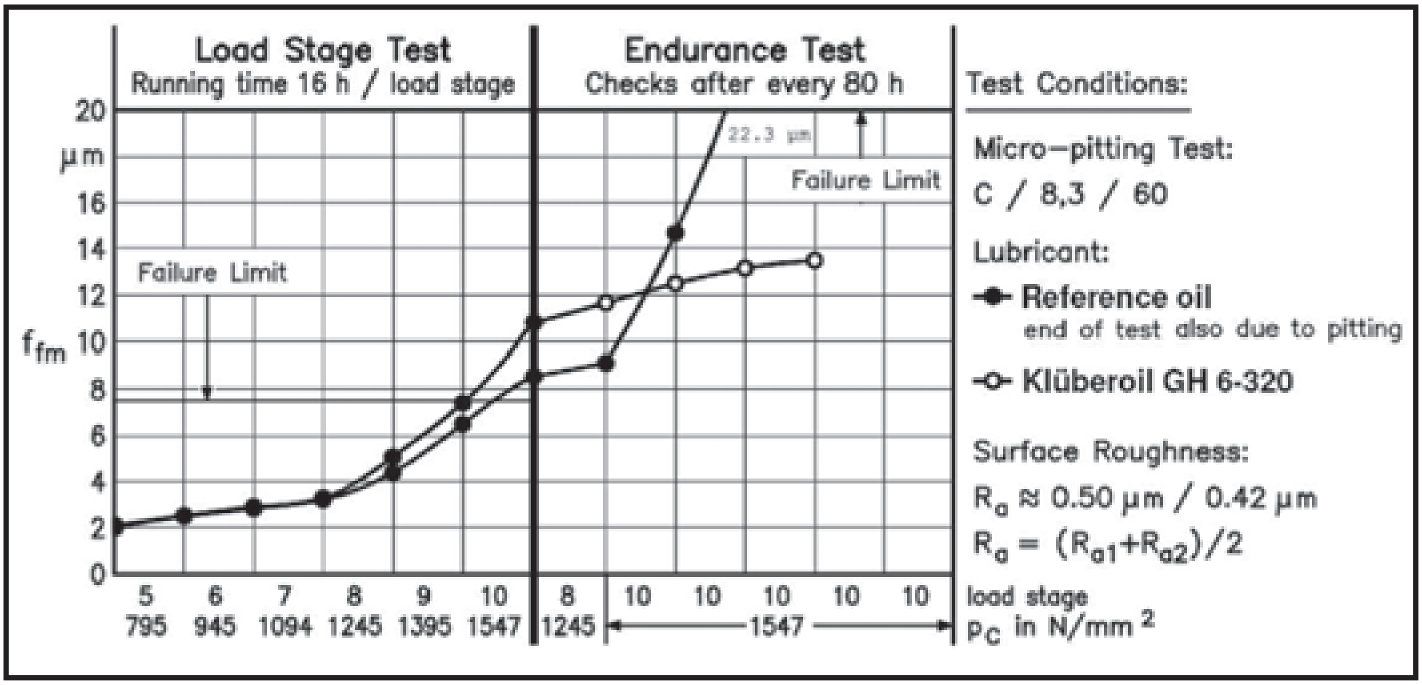

Fig. 9: Stopping micropitting by using a high-performance gear oil (polyglycol).

as well as a stagnation of micropitting formation in the endurance test according to FVA 54/7 [5] by selection of advanced additive technologies.

The new test results showed that high-performance gear oils using advanced additive technologies can react at the surface of the tooth flanks after an oil change and stop further micropitting formation. The micropitting area, which occurred with other gear oils, stagnates after changeover to high-performance gear oils. Therefore, these high-performance gear oils are strongly recommended to stop micropitting formation in field applications.

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1) AGMA 9005-E02: Industrial gear lubrication, 2002
2) DIN 51517-3: Schmierstoffe – Schmieröle – Teil 3: Schmieröle CLP; Minderstanforderungen, 2009
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Description	Failure load stage	Micropitted area	GF-class
Low micropitting load-carrying capacity	≤ LS 7	Sometimes more than 50%	GFT-low
Medium micropitting load-carrying capacity	LS 8 - LS 9	About 30%	GFT-medium
High micropitting load-carrying capacity	≥ LS 10	Less than 20%	GFT-high

Table 3: Classification of test results of the micropitting test.

test gears. The test gearbox and drive gearbox are connected with two torsion shafts. One shaft is divided into two parts and contains a load coupling used to apply the torque (load) through the use of weights hung on the loading arm. A separate oil aggregate contains heating and cooling elements to control the oil temperature as required by the operating test conditions. Before the oil is injected into the gear mesh of the test gears, it is filtered with a 10μm filter.

In order to investigate if micropitting can be stopped, test gears type C-GF of the standard micropitting test according to FVA 54/7 [5] are used. The geometrical data and manufacturing details of the test gears type C-GF are shown in Table 4 and Table 5.

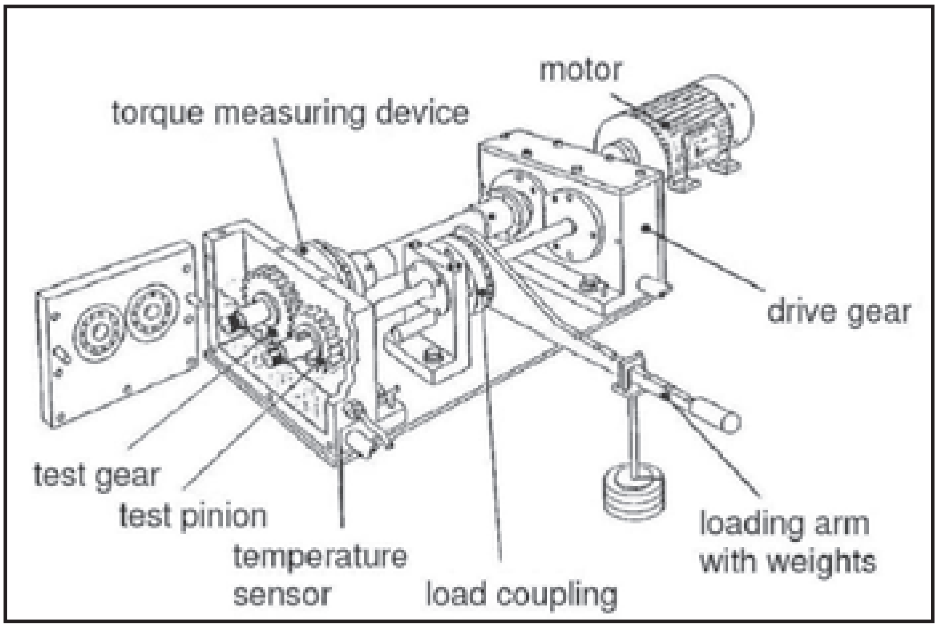

Fig. 6: FZG back-to-back gear test rig.

Dimension		Symbol	Unit	Numerical value
Shaft center distance		a	mm	91.5
Module		m	mm	4.5
Number of teeth	Pinion	z_1	—	16
	Wheel	z_2	—	24
Effective face width		b	mm	14
Pressure angle		β	deg.	0
		α	deg.	20
Profile shift coefficient	Pinion	α_w	deg.	22.44
	Wheel	x_1	—	0.1817
Tip diameter	Pinion	x_2	—	0.1715
	Wheel	d_{a1}	mm	82.46
Transverse contact ratio		d_{a2}	mm	118.36
Tooth correction	Pinion	ε_α	—	1.44
	Wheel	Without tip and root relief, no longitudinal crowning		

Table 4: Geometrical data of the test gears type C-GF.

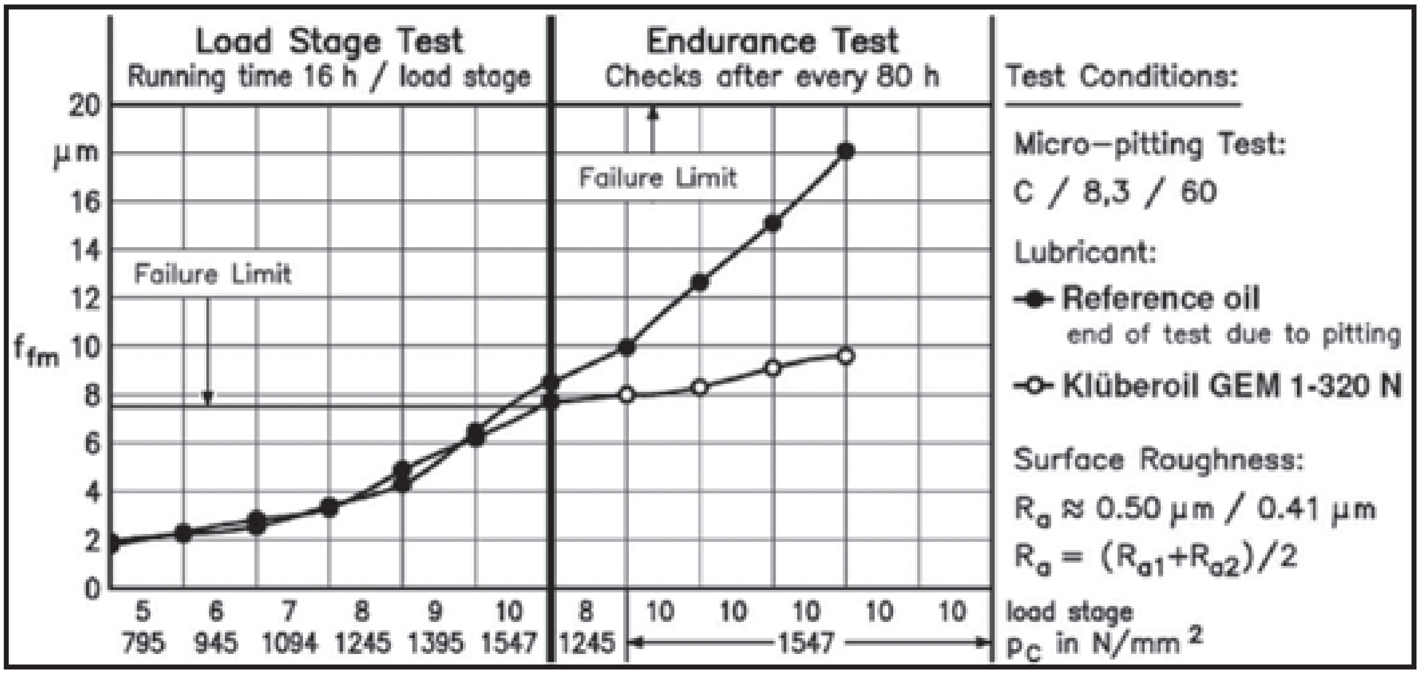

Fig. 7: Stopping micropitting by using a high-performance gear oil (mineral oil).

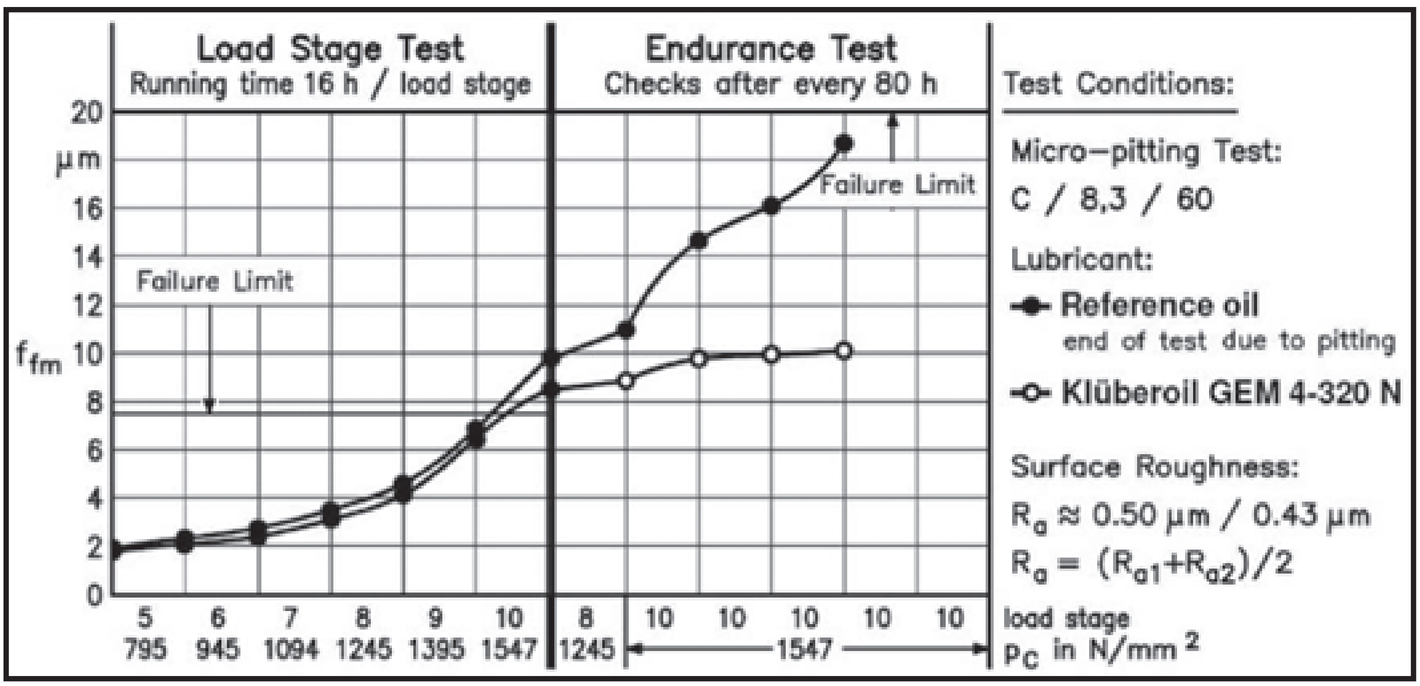

Fig. 8: Stopping micropitting by using a high-performance gear oil (polyalphaolefin).

LUBRICANTS TESTED

A specialty lubricant manufacturer's goal is to supply industrial gear oils on the basis of mineral oil, polyalphaolefin, or polyglycol showing a high micropitting load-carrying capacity of failure load stage ≥ LS 10 in the load stage test as well as a stagnation of micropitting formation in the endurance test according to FVA 54/7 [5] by selection of advanced additive technologies. See also Fig. 5. These industrial gear oils show excellent micropitting protection not only at an oil temperature of 90°C, but also at a lower oil temperature of 60°C, and the advanced additive technologies can react on the surface of the tooth flanks and protect them against micropitting formation.

Additionally, the tests questioned whether micropitting formation occurred with other gear oils and whether changing to high-performance gear oils can stop micropitting. The oil data of the tested gear oils are shown in Table 6 and Table 7. Both the high-performance gear oils and the reference oil are of ISO VG 320 and possess a high micropitting load-carrying capacity

Dimension		Symbol	Unit	Numerical value
Basic material	Pinion	—	—	16MnCr5
	Wheel	—	—	16MnCr5
Surface hardness	Pinion	—	—	750 HV1
	Wheel	—	—	750 HV1
Case hardening depth at 550 HV1	Pinion	—	mm	0.8 - 1.0
	Wheel	—	mm	0.8 - 1.0
Core strength	Pinion	—	N/mm^2	1000 - 1250
	Wheel	—	N/mm^2	1000 - 1250
Flank roughness	Pinion	Ra	µm	0.50 ± 0.10
	Wheel	Ra	µm	0.50 ± 0.10

Table 5: Manufacturing details of the test gears type C-GF.

Product	ISO VG	Base oil	DIN 5157, AGMA 9005 designation	Micropitting load-carrying capacity according to *FVA 54/7*	
				$\vartheta_{oil} = 90°C$	$\vartheta_{oil} = 60°C$
Reference oil	320	Mineral oil	CLP, EP oil	—	GFT-high

Table 6: Oil data of the reference oil.

according to FVA 54/7. All tested gear oils are specified according to DIN 51517 [2], which includes the minimum requirements for industrial gear oils and is similar to AGMA 9005 [1]. For the reference oil, the micropitting load-carrying capacity was only tested at an oil temperature of 60°C because at this oil temperature, it was to be investigated if micropitting formation can be stopped. See also Fig. 7, Fig. 8 and Fig. 9.

TEST RESULTS

For reference oil with a high micropitting load-carrying capacity, but low endurance performance, a load stage test and an endurance test were performed with the first test gears according to FVA 54/7 [5]. The reference oil always showed the test result GFT-high at the end of the load stage test. But in the subsequent endurance test, micropitting formation increased. The endurance test was finished due to pitting formation. Then the load stage test was repeated for the reference oil using new test gears. All repeated test runs of the reference oil showed a good repeatability compared with the first load stage test of this oil. See Fig. 7, Fig. 8, and Fig. 9.

After the repeated load stage test for the reference oil, an oil change to high-performance gear oil on basis of mineral oil with a high micropitting load-carrying capacity as well as a high endurance micropitting performance was conducted. This oil change to a high-performance mineral gear oil using advanced additive technologies stopped micropitting formation compared with the reference oil. This shows that these advanced additive technologies can react at the surface of the tooth flanks after an oil change and build up a new improved reaction layer. Further micropitting formation was stopped and the micropitting area stagnated. See Fig. 7.

The oil change to high-performance gear oil on the basis of polyalphaolefin with a high micropitting load-carrying capacity as well as a high endurance micropitting performance can also stop the micropitting formation compared with the reference oil. The reason for the stagnation of the micropitting areas are, again, the advanced additive technologies in this high-performance polyalphaolefin gear oil. Even after an oil change, these advanced additive technologies can react at the surface of the tooth flanks and build up a new improved reaction layer. See Fig. 8.

Finally, also high-performance gear oil on the basis of polyglycol with a high micropitting load-carrying capacity as well as a high endurance micropitting performance can stop micropitting formation after an oil change compared with the reference oil due to the advanced additive technologies. See Fig. 9.

All endurance tests for the high-performance gear oils on the basis of mineral oil, polyalphaolefin, and polyglycol were stopped after the same running time as the reference oil but without any pitting formation.

CONCLUSIONS

High-performance gear oils on the basis of mineral oil, polyalphaolefin, or polyglycol show a high micropitting load-carrying capacity of failure load stage ≥ LS 10 in the load stage test

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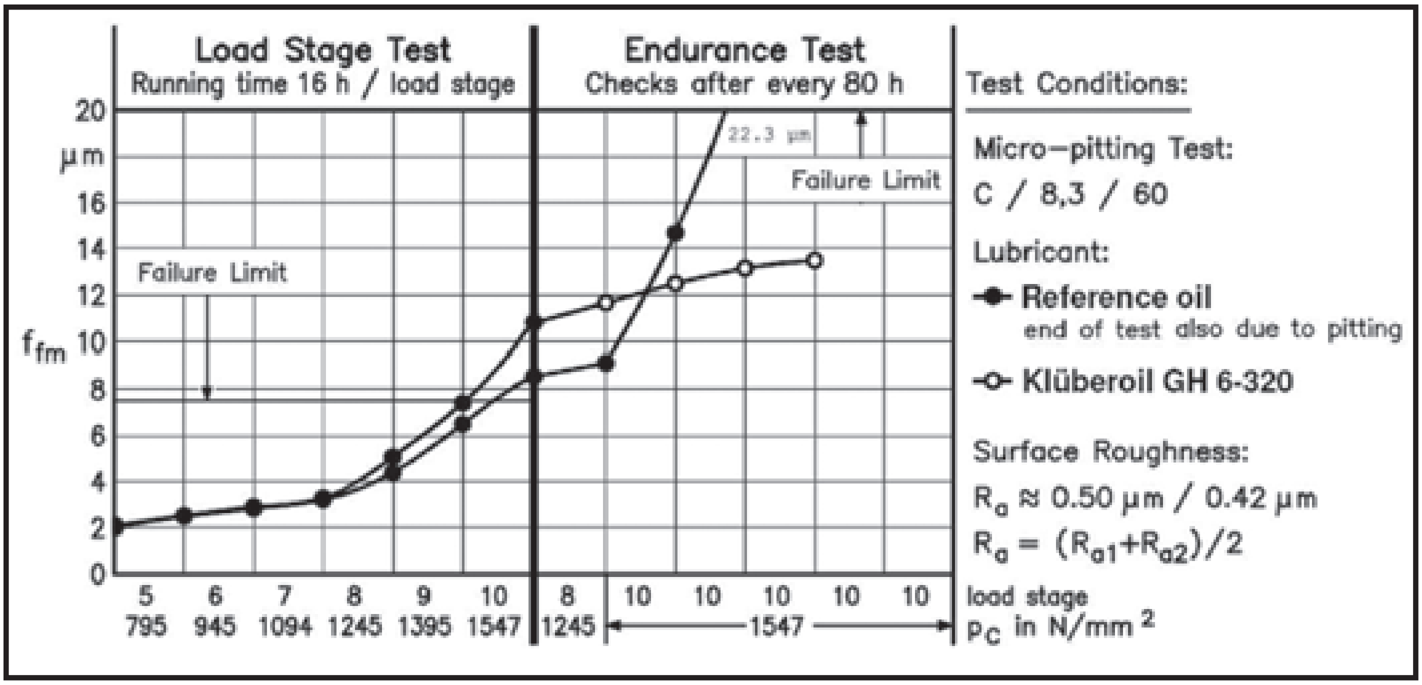

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