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Lubricants for Wind Turbines Part 2

Gear Oils-Demands and Characteristics

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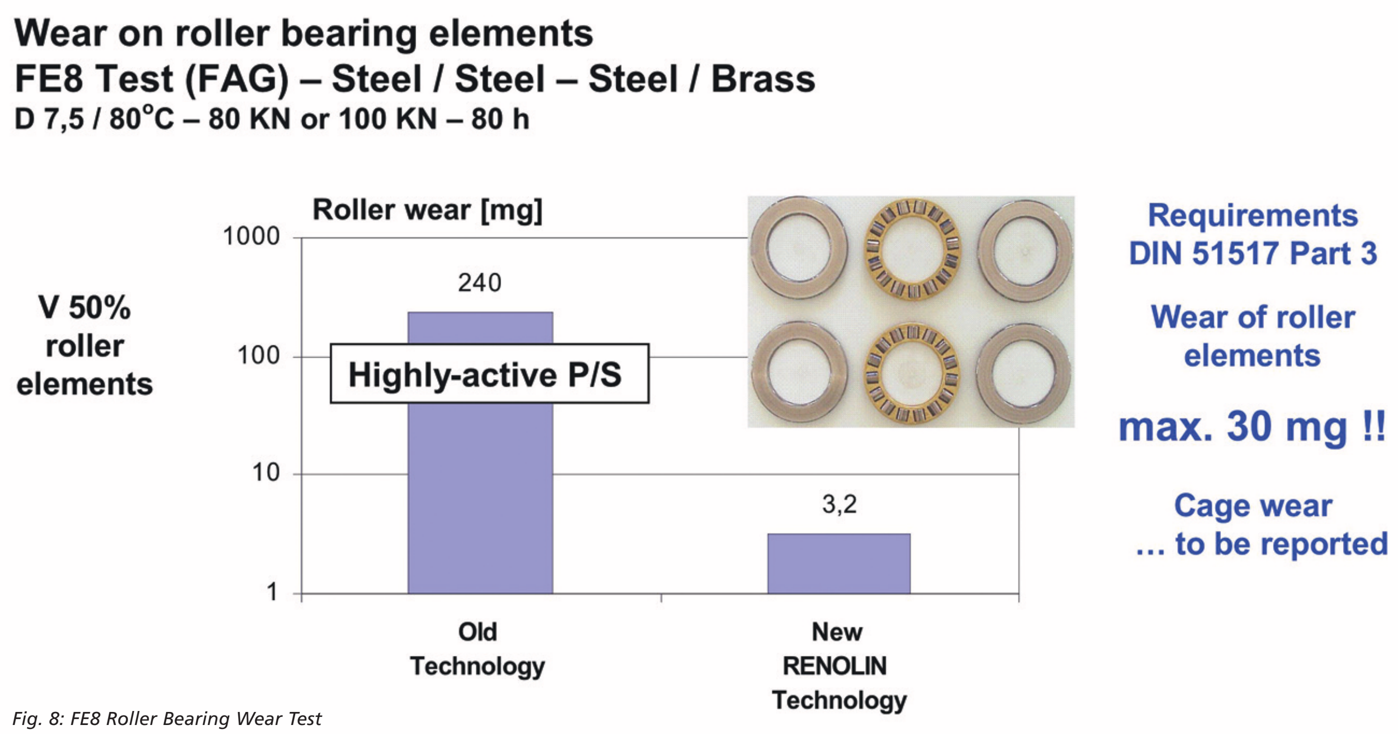


Fig. 8: FE8 Roller Bearing Wear Test

7. Special Tests for Wind Turbine Gear Oils

FAG Wind Turbine Four-Stage Test (Schaeffler-FAG)

The FAG FE8 four-stage test was specially developed for wind turbine gear oils. In the past (about 10 – 15 years ago), gear oils contained highly-active phosphorous-sulphur compounds. In the FE8 test rig, these generated roller wear rates of 200-300 mg. These days, industrial gear oils are formulated with mild phosphorous-sulphur compounds to meet the roller wear specifications of less than 30 mg (Figure 8).

The FAG FE8 four-stage test attempts to replicate different load and mixed friction conditions at different speeds, temperatures and test parameters.

Stage 1 can be described as a short-term test and is performed on the FE8 test rig according to DIN 51 819, Parts 1 to 3 at 80 KN axial load, 80°C for a duration of 80 hours.

Stage 2 describes a fatigue test with moderate mixed friction and is performed on the FE8 test rig at 75 rpm, 100 KN axial load, 70°C for a duration of 800 hours.

Stage 3 is a so-called fatigue test under EHL conditions (10 bearings). The test is performed in the FAG Test Rig L11 at 9000 rpm, an axial load of 8.5 KN, about 80°C and for a duration of 700 hours.

Stage 4 involves a deposit test at higher temperatures in the presence of water. This modified PM paper-making machine oil test from FAG is performed on a special FAG test rig at 750 rpm, an axial load of 60 KN, at up to 140°C for a duration of 600 hours.

Testing of the suitability of oils for roller bearings

- Stage 1: Short-term wear test under extreme mixed friction
- Stage 2: Fatigue test under moderate mixed friction
- Stage 3: Fatigue test under EHL conditions
- Stage 4: Residue formation test at increased temperature with water added

FAG **Example: RENOLIN UNISYN CLP 320**

Summary result wind turbines - 4 stage test

	criterion	test	result	
Stage 1*	wear at boundary lubrication	FE8-80h	1,0	passed
Stage 2**	fatigue beh. at mixed friction cond.	FE8-800h	1,0	passed
Stage 3***	fatigue behaviour at EHL-cond.	L11-700h	1,0	passed
Stage 4***	fatigue behaviour and residues with water added	FE8-WKA	1,0	passed
		summery :	**1,0**	**passed**

Fig. 9: FAG Wind Turbine Four-Stage Test

oil designation: Renolin Unisyn CLP 320

tests: acc. to SKF specification "gear oil recommendation"

results: see enclosure 1

evaluation:

Renolin Unisyn CLP 320	SKF roller test (roller)	+/-	foaming characteristics	+
	SKF roller test (oil)	+/-	SKF Emcor dist. H20	+
	SKF oil film ageing test	+	0,5% NaCl-solution	+
	copper protection	+	pourpoint	+
	FE 8 test	+	cleanliness	+
	oxidation stability	+	filterability	+

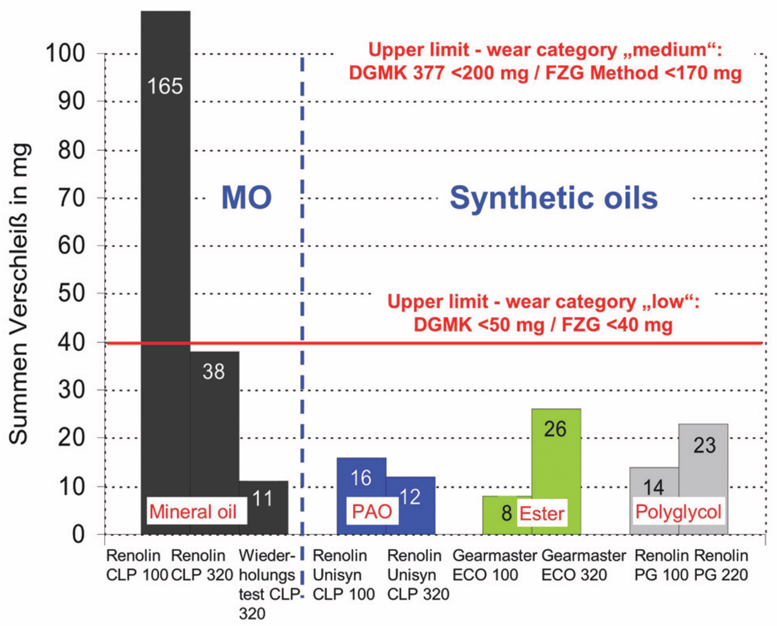
Test passed: + Test failed: -

Fig. 10: SKF Specifications for Wind Turbine Gear Oils – SKF Test Report on Fuchs Renolin Unisyn CLP 320

A wind turbine gear oil must pass all these different test procedures with good results. Figure 9 shows a summary of the FAG wind turbine four-stage test (with an example of results of a tested wind turbine gear oil).

SKF Specifications for Wind Turbine Gear Oils

In its WTGU specification for wind turbine gear oils, the company SKF placed an emphasis on the high chemical and thermal stability of the lubricant. To summarise, it can be noted that SKF focuses on chemical stability (SKF Roller Test, SKF Oil Film Ageing Test) along with FE8 performance (wear protection), filtration and corrosion protection (Figure 10).



The results in the Slow Speed Wear Test confirm the positive effect of the higher operating viscosity of synthetic gear oils with regard to wear protection

Fig. 11: Slow-Running Wear Behaviour of Industrial Gear Oils

AMERICAN NATIONAL STANDARD ANSI/AGMA 9005-E02

Table 2 - Minimum performance requirements for antiscuff/antiwear (EP) oils

Property	Test method: ISO/ASTM	Requirements										
Viscosity grade	3448/D2422	32	46	68	100	150	220	320	460	680	1000-3200	>3200
Viscosity @ 40°C, mm²/s	3104/D445	See table 4										Report[1)]
Viscosity @ 100°C, mm²/s	3104/D445	Report[1)]										
Viscosity index [2)], min.	2909/D2270	90								85		Report[1)]
Bulk fluid dynamic viscosity @ cold start-up[3)], mPa·s, max.	None/D2983	150 000										

A.14 Viscosity - dynamic (Brookfield)

Based on the experience of automotive gear manufacturers, the same critical Brookfield viscosity limit of 150,000 cP has been proposed for industrial gear applications. Because of the wide variety of field conditions, the temperature for the maximum Brookfield viscosity is not specified in this standard. Rather, the temperature should be specified by the end user and it should relate to the lowest actual lubricant temperature at cold startup.

A.12 Pour point

Pour point is an indicator of the lowest temperature at which an oil flows under the influence of gravity. Pour point should not be used as the only indicator of the low temperature limit at which a lubricant may function acceptably. Initial agitation by gears, ...

... [10] is used to determine pour point. It is recommended that the pour point of the oil used should be at least 5°C lower than the minimum ambient temperature expected.

Fig. 12: Low Temperature Viscosity – Threshold Values According to AGMA 9005-E02

8. Low-Speed Wear Behaviour of Industrial Gear Oils

Gearboxes in wind turbines usually have slow and faster-running stages. The low-speed wear behaviour of industrial gear oils must be considered. This feature can be examined using the DGMK 377 method and/or the FZG method. At a peripheral speed of 0.05 to 0.57 m/s and a high Hertzian stress (load stage 12), this involves determining total wear per test stage in mg. Figure 11 shows a comparison of industrial gear oils based on mineral oils, polyalphaolefins, esters and polyglycols. The high Viscosity Index of synthetic oils and the correspondingly thicker lubricating film during the test can significantly lower the low-speed wear when compared to mineral oils.

9. Low-Temperature Viscosity of Industrial Gear Oils

Industrial gear oils in wind turbines have to perform under a number of different conditions and temperatures. The question of which maximum viscosity is permissible is still vigorously discussed in various specialist journals. Following the automotive sector, a low temperature specification threshold of 150,000 mPa*s has been accepted in some circles. However, the behaviour of gear oil formulations with regard to the pourpoint should also be considered (Figure 12).

As far as the low-temperature viscosity of mineral oils is concerned, it should be remembered that very large viscosity deviations (measured values compared to calculated values) can occur near to the pourpoint. In principle, the given viscosity values for temperatures under 0°C should be those actually measured.In the case of fully-synthetic, polyalphaolefin-based gear oils, a relatively good correlation exists between the calculated and the measured viscosity values even for temperatures of -10°C, -20°C and -30°C.

Method	Standard	RENOLIN UNISYN CLP 220	RENOLIN UNISYN CLP 320
V-40 Brookfield [mPas]	**DIN 51398 / DIN ISO 9262 / ASTM 2893**	**290.000**	**530.000**
V-35 Brookfield [mPas]		**115.000**	**220.000**
V-30 Brookfield [mPas]		**55.000**	**100.000**
V-25 Brookfield [mPas]	**Repeatability: 8-10 % depending on level !**	**31.000**	**55.000**
V-20 Brookfield [mPas]		**16.000**	**30.000**
V-15 Brookfield [mPas]		**10.000**	**17.000**
Pourpoint [°C]	**DIN ISO 3016**	**-42**	**-42**
V 40 [mm²/s]	**DIN EN ISO 3104**	**220**	**320**
V 100 [mm²/s]		**26,7**	**35,0**
VI	**DIN ISO 2909**	**155**	**155**

flowability limit in autmotive gear oil specs: **max. 150.000 mPas!**

Flowability limit of RENOLIN UNISYN CLP 220: ~ -35°C
Flowability limit of RENOLIN UNISYN CLP 320: ~ -30°C

low pourpoint, relatively high viscosity at low temperatures

Fig. 13: Low Temperature Viscosities of Industrial Gear Oils based on Polyalphaolefins

Figure 13 shows the low temperature viscosity (dynamic viscosity in mPa*s) of fully-synthetic, polyalphaolefin-based ISO VG 220 and ISO VG 320 gear oils taking into account the permissible (and presently controversial) threshold viscosity of 150,000 mPa*s.

10. Conclusion

This article discusses the specifications of wind turbine gear oils from a lubricant manufacturer's and component manufacturer's point of view.

The highest demands are made on the technical performance of such gear oils with regard to mechanical-dynamic wear protection, chemical stability and long-term stability. Comprehensive manufacturer, DIN and ISO tests must be passed, and compliance with roller bearing and gearbox manufacturers' specifications must be given before a wind turbine gear oil is approved. Such testing activity generates high testing and laboratory costs.

Apart from laboratory trials in mechanical-dynamic test rigs, qualifying oils must pass coç field trials in various ambient conditions. Wind turbine gear oils are mostly based on fully-synthetic base fluids with polyalphaolefins predominating. Wind turbine gear oils are specialties with the highest quality demands. Specific testing and specification criteria are currently being critically discussed, especially with regard to elastomer and chemical compatibility.

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LINK
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