Raising the bar for wind turbine lubrication

New lubricant specification requirements for industrial gear applications are among the key challenges facing transmission and bearing OEMs.

By the Afton Chemical Industrial Team

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The standard industrial gear sectors into which transmission and bearing OEMs sell their equipment include the mining, cement, food and beverage, automotive, chemical, woodworking and material handling industries. In the late 1990s, there were few transmission OEMs and no bearing OEMs with specifications in place for lubricants used in these industrial gear sectors.

One of the first European industrial gear lubricant specifications was published in 1996 by Flender AG in Germany. This specification has the notation QMA.BO and lists the performance requirements for lubricants used in standard industrial transmissions with helical gears, bevel helical gears, planetary gear units or worm gears units or, alternatively, using gear motors. A summary of the testing required in the current version of this specification, QMA.BO Revision 6, is shown in Table 1. Once approved the lubricant is listed in the Flender recommended lubricants list BA7300.

Table 1. Testing required in the QMA.BO Revision 6 Flender specification.

- DIN 51517-3 issue January 2004
- Compatibility with internal coating P22-8050
- Compatibility with liquid sealing material Loctite 128068
- Compatibility with elastomer seals material NBR and FKM, static and dynamic
- Flender foam test
- FVA 54/7 micropitting test
- FZG scuffing test A/16.6/90 (by agreement)

After the OPEC oil embargo in the 1970s and the resulting rise in the price of oil, there was a large investment in Europe in the early 1980s into use of wind turbines as renewable energy sources. Wind turbines in general generate between 0.6 and 5 megawatts (MW) of electricity depending on their size. With a realized industry growth rate of 35% per annum, the global installed capacity to the end of 2003 was 40,301 MW, with 29,201 MW installed in Europe and the remainder shared between the U.S., India, Japan and China. If we assume that all installed wind turbines are 2.5 MW units, this would correspond to 16,120 wind turbines installed globally.

Fewer than 15% of these wind turbines are based on direct drive technology, which would leave 13,702 2.5MW wind turbines using transmissions. At an average cost of 250,000 Euros per transmission for a 2.5MW wind turbine, this corresponds to a 3425.5 million Euro industry for industrial transmission OEMs today with a predicted installed capacity to the end of 2008 of over 95,000 MW. This is a new lucrative market for transmission OEMs. In 2001, the former wind turbine division of Flender was spun off as a separate company under the name Winergy. Other European OEMs that supply transmissions into standard industrial gear and wind turbine applications are Bosch Rexroth Getriebetechnik, Eickhoff, Hansen Transmissions, Jahnel Kestermann, Metso Drives, MAAG, Renck, Pujol and Zollern-Dorstner. An indication of the market position, and also the split in their business between wind turbine and standard industrial gear applications, is shown in Table 2.

Wind turbines have large blades from 22 meters (72 feet) up to 90 meters (295 feet) long. This corresponds to a rotor diameter of 44 meters (144 feet) up to 180 meters (590 feet). These blades, rotating at low speeds, are connected through the gearing system to a high-speed output generator. This results in a torque through the system of up to 4 million Nm. This extreme torque puts a large amount of stress on the gears and bearings in the wind turbine and on the lubricant which is used to lubricate both the gears and bearings.

Initial mechanical failures for wind turbines in the field were mainly bearing-related. For the large wind turbines, weight is an issue and can lead to distortion and bearing failures under peak loads. In this application the true load on the bearings is unknown, so that the standard calculations for bearing lifetime do not apply. Field failures due to

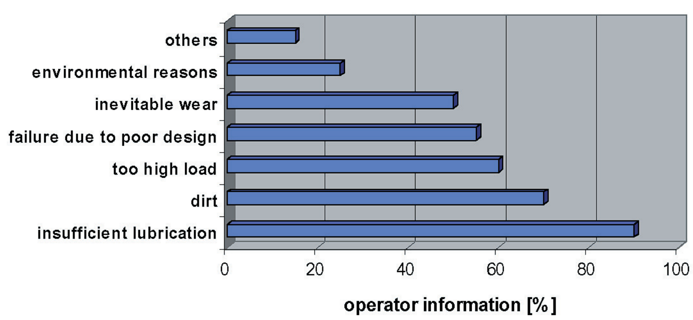
CONTINUED ON PAGE 26

Table 2. OEM market position, split between sales of transmissions for wind turbine and industrial gear applications.

	Split in business (% Turnover)		Market position w.r.t Wind turbine gears sales
	Wind turbine	Standard Industrial Gear	
Bosch Rexroth Getriebetechnik	50	50	4
Eickhoff	70	30	3
Hansen Transmissions	>50	<50	2
Jahnel Kestermann	50	50	6
Metso Drives	Not available	Not available	5
Winergy	100	0	1

(Photo courtesy of Richard Karbacher, Schaeffler Group).

Figure 1. Reasons for bearing failure.



(Data courtesy of Cornelia Haag, SKF)

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Table 3. Requirements for gear oils in wind turbine gearboxes.

- Oil operating time up to 5 years
- Filterability
- No sludge formation
- Wear resistance
- Cleanliness during operation
- Corrosion resistance
- Oxidation stability
- Decrease/avoid air bubbles
- Start-up temperature -20C/-40C
- Temperature resistance up to 120C
- Biodegradability
- High VI
- Avoid slippage
- Wide operating temperature
- Scuffing load and micro pitting carrying capacity
- Wide speed range
- WGK 1
- High circulation with low volumes

(Data courtesy of Cornelia Haag, SKF)

Table 4. Summary of the bearing tests in the FAG specification.

Test	Description	Rig	Duration
Step I	Wear behavior at boundary lubrication	FAG FE-8	80 hrs
Step II	Fatigue behavior under mixed friction conditions	FAG FE-8	800 hrs
Step III	Fatigue behavior under EHL conditions	FAG L-11	>= 700 hrs
Step IV	Fatigue behavior and residue forming with water added	FAG FE-8	>= 600 hrs

chemical attack of the gear oils on the bearing cage also occurred.

The first and second largest bearing manufacturers worldwide are SKF and FAG/INA, respectively. FAG and SKF published specifications for gear oils used in wind turbine gearboxes in January 2003 and February 2004, respectively.

These specifications, summarized in Tables 3 and 4, contain dynamic bearing tests designed to evaluate the ability of industrial gear oils to prevent bearing wear and fatigue under different lubrication regimes (FAG Step I to III tests).

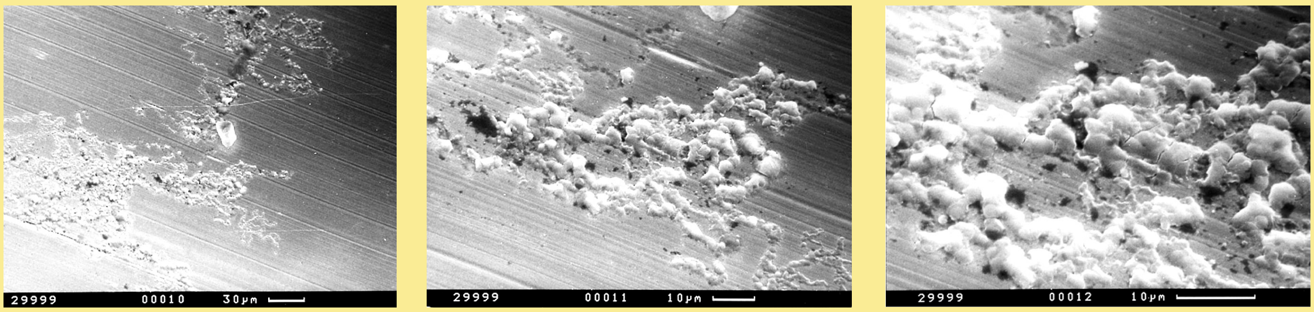
The FAG specification also includes a dynamic bearing test to evaluate the residue-forming tendencies of gear oils when low levels of water are present (FAG Step IV).

The SKF specification contains a dynamic bearing corrosion test which is run on the gear oil mixed with either standard water or with saltwater. The testing with saltwater is to mimic the problems seen with saltwater corrosion of bearings in off-shore wind farms. Most of the transmission OEMs have

Table 5. Summary of the bearing tests in the SKF specification.

Test	Description	Rig	Duration
SKF roller test	Chemical and thermal stability at 100 C	SKF in-house	8 weeks
Copper corrosion	DIN EN ISO 2160 at 120 C	Laboratory test	3 and 24 hrs
FAG FE-8	DIN 51819	FAG FE-8	80 hrs
SKF Emcor Test	acc. ISO 11007	SKF Emcor	
SKF Filterability Test		SKF in-house	< 15 minutes
Additional / Optional tests			
For gear boxes without cooling			
SKF roller test	Chemical and thermal stability at 120 C	SKF in-house	8 weeks
For Off-shore applications			
SKF Emcor Test 0.5% NaCl	acc. ISO 11007	SKF Emcor	

Figure 2. Corrosive attack on bearings in FAG Step III Test.



(Photos courtesy of Richard Karbacher, Schaeffler Group) now included these specifications from the bearing OEMs in their specifications.

There also have been wind turbine field problems due to excessive micropitting on the gear teeth. All the latest OEM specifications require that the FZG micropitting testing, according to FVA 54/7, is run not just at the standard test temperature of 90 C but also at 60 C, as this is approximately the temperature of the gearbox reservoir in wind turbines with cooling systems.

Another reported problem in the field is blocking of the gearbox filters. There are many lubricant-related sources of deposits that can block filters. For example, sludge is created due to thermal or oxidative decomposition of the lubricant, precipitates formed due to the poor solubility of the fresh additive system over time or poor solubility of the additive system after use at elevated temperatures in the presence of water and/or contaminants. OEMs like Winergy are now looking to the suppliers of the filters such as Hydac and to the oil and additive companies to work together to identify a filtration test that can predict poor performance in the field.

Regardless of the reason for the precipitate formation, there is a common result (apart from filter blocking and additive depletion), namely the reduction in the ability of the oil to prevent foaming and separate away from water. The antifoam additives used to give protection against foaming and the demulsifiers used to allow the oil to separate out water are very surface active. If any precipitate falls out of the oil, these antifoam and demulsifiers also will fall out with the precipitate. As a first step, Winergy has included in their specification a variation on the dynamic Flender foam test developed by Hydac.

The oil is evaluated for foaming at various temperatures between 0 C and 60 C, but the oil is also filtered through a 5-micron filter and the testing is rerun. This ensures that the antifoam system is not depleted on use and after filtering.

The common tests in the specifications published in the last year from the transmission OEMs, who supply into the wind turbine sector listed in Table 2, are shown in Table 6 (*see page* 28).

These new specifications also are being used by the OEMs to approve lubricants for

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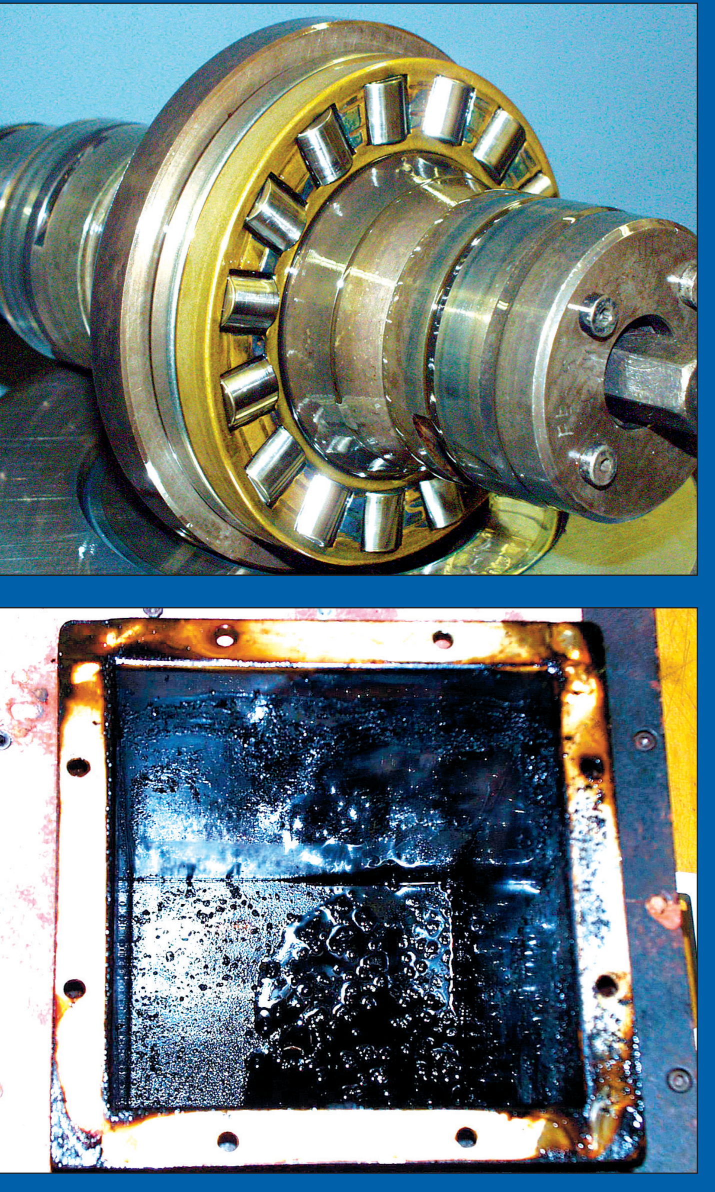
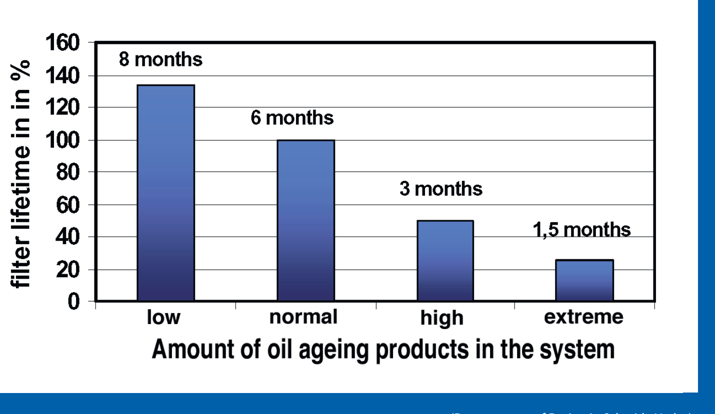
Figure 3. End of test parts from FAG Step IV Test.



(Photos courtesy of Richard Karbacher, Schaeffler Group)

Figure 4. Filterability problems caused by oil aging products



(Data courtesy of Dr. Armin Schmidt, Hydac).

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Figure 5. Foam formation on the oil sump of the gearbox.

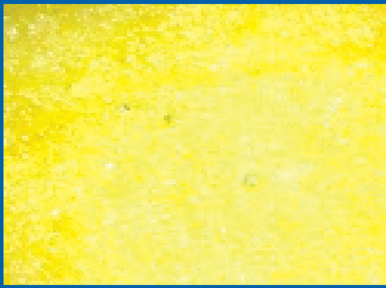
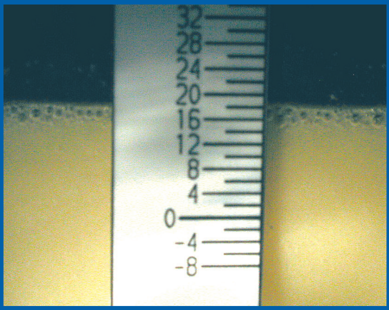


Figure 6. Hydac In-House Tests Filterability Multi-Pass Filterability Tests Assessment with Flender Foam Tester.



(Photos courtesy of Dr. Armin Schmidt, Hydac)

use in standard industrial gear applications. This has significantly raised the bar on lubricant requirements for standard industrial gear applications and also raised the cost of developing new technology meeting OEM requirements. The key challenge in the new specifications is combining good EP properties (to eliminate surface fatigue on the gear teeth) with excellent corrosion and bearings protection. <<

For more information or if you have questions about this article, contact Ian Macpherson, marketing manager-industrial additives for Afton Chemical Corp. in Richmond, Va., at (804) 788-5800.

Table 6. Common requirements in the transmission OEMs new specifications

Test Description
DIN 51517 Part III
FVA 54/7 Micropitting test at 90 C and 60 C => 10 ISO 220VG
FZG Scuffing test A/8 3/90 and double speed A/16.6/90
Freudenberg seals static and dynamic
NBR (Nitrile) and FKM (Flouroelastomer)
Foam test acc. ASTM 892 or flender foam test
Compatibility with all coating and liquid sealing materials
Meets FAC Specification for Wind turbine Applications*
Meets SKF Specification for Wind turbine Applications*

*Required by 60% of the OEMs