



Improving Bearing Life in Harsh Environments

Winter Wind 2024

Do the main bearings get's cold feet in the snow, or what happens ?

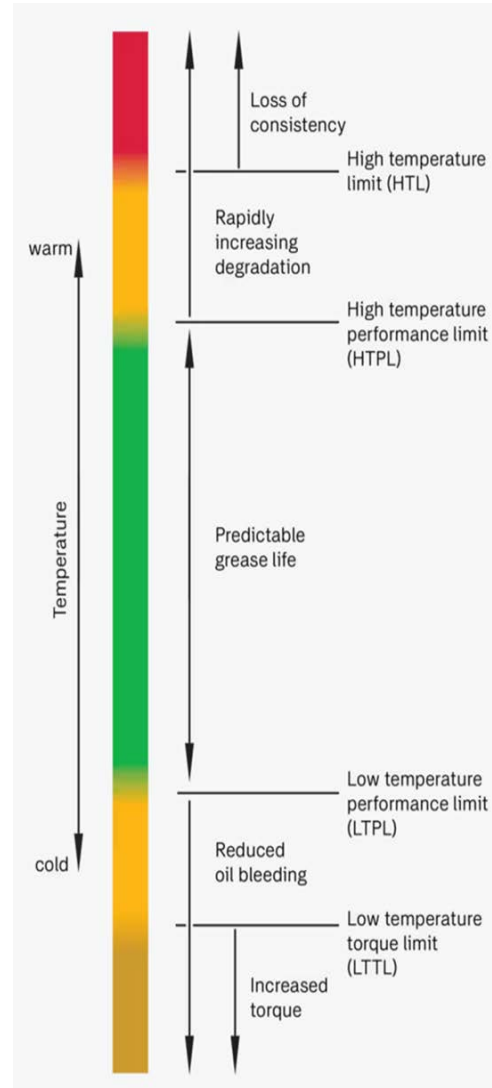
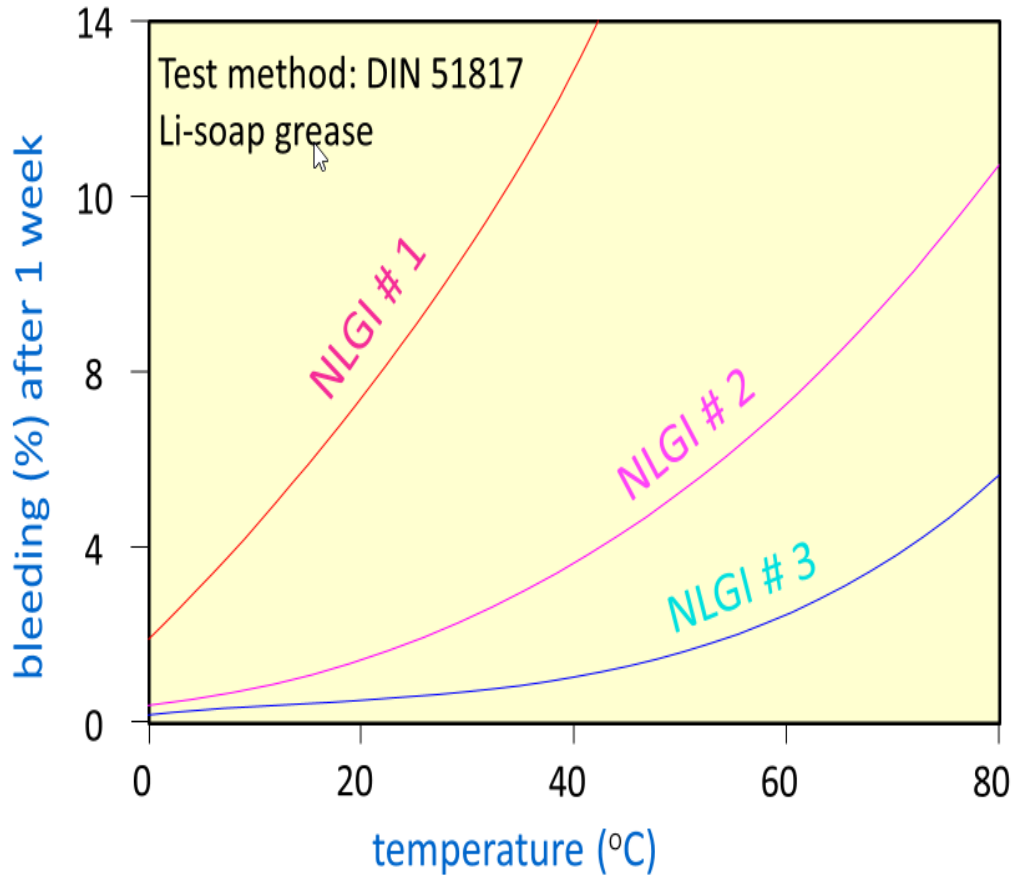


Why is operation of main bearings in cold condition different.

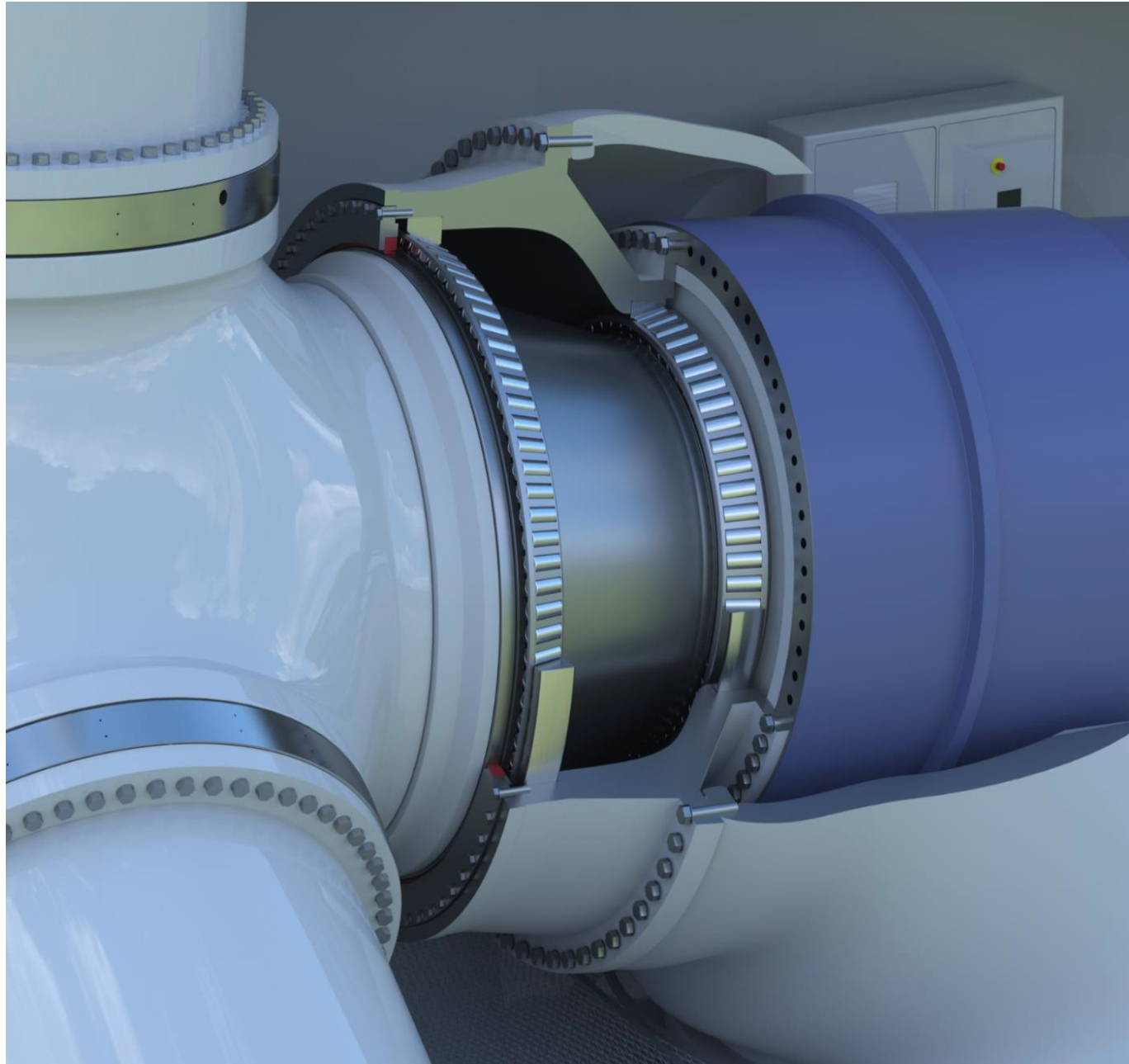


- Bearings in cold ambient will run colder than normal. Main Bearing close to the hub will be colder than rear bearing and gearbox bearings.
- During stand still and idling of the wind turbine, the bearing temperature can be close to the actual ambient temperature.
- Internal heating systems in the wind turbine can have a limited operation if no external power is available for a long time.
- Lubricant changes properties, oil viscosity increases, grease becomes more consistent (Stiff) and bleeds less.

Why is operation of main bearings in cold condition different.



- Diagram to the left shows grease bleeding, as a function of temperature. As it can be seen grease bleeds less oil at low temperatures.
- Low oil bleeding will result in less oil in the contact between the roller and the bearing raceway, and by this mixed lubrication causing metal to metal contact.
- Such operation will decrease the bearing life and increase the risk of stand still marks/false brinelling.



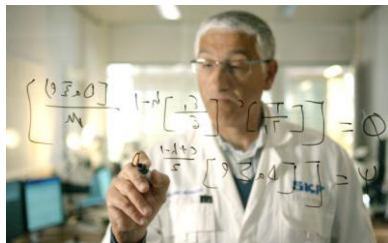
Why do SKF Durapro works better when Cold

- SKF DuraPro for wind turbine main shafts is an application specific offer which is applied for increasing reliability and offering higher performance
- Assortment: TRB+TRB, DRTRB+CRB (single and multi-row), Nautilus. Later SRB's will come as well
- All cages and heat treatments used in wind main shaft bearings can be applied.

SKF DuraPro for wind turbine main shaft

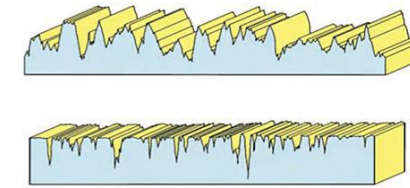
- Bearing features and performance overview-

- Material & heat treatment improvements with 1-2 HRC harder raceways, increased material fatigue properties, better wear resistance and lower impact of contaminations (indents).



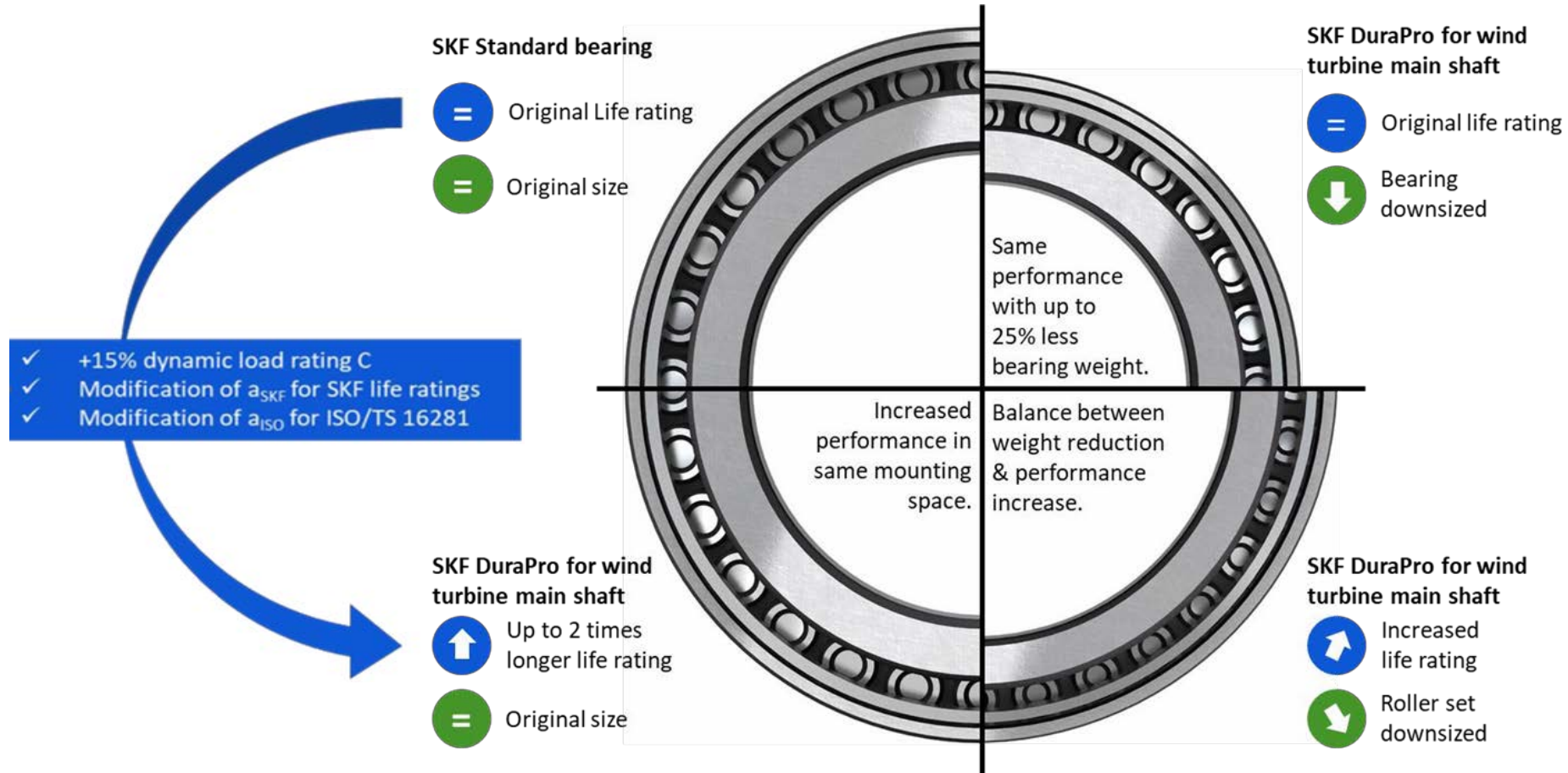
→ Dynamic load rating C increased by up to 15% which results in combination with a_{SKF} and a_{ISO} adjustments in an up to doubled calculated bearing life compared to standard bearings.

- Improved raceway roughness and raceway topography optimized for performance in mixed lubrication conditions enables upgraded micro load distribution, improved film build-up and reduced risk for micro pitting.



- Roller/raceway contact with optimized contact conditions, application specific logarithmic profile and superior load distribution.
- Improved surface quality on rings and rollers with reduced surface imperfection tolerance.
- Optimized roller/flange contact for TRB's.

SKF DuraPro for wind turbine main shafts



Comparison: SKF DuraPro for wind turbine main shaft vs. SKF standard bearings

SKF DuraPro for Wind Turbine Main Shafts

Example: Comparison of SKF DuraPro for wind turbine main shaft vs. SKF standard bearings for 8-10 MW wind turbine.

SKF standard Bearing (8-10MW):

d/D/B: 2300/2800/265 mm
 Weight: 3.5 to
 C_{dyn} : 14 690 kN
 L_{10mrh} : 1 000 000 h

SKF Standard bearing

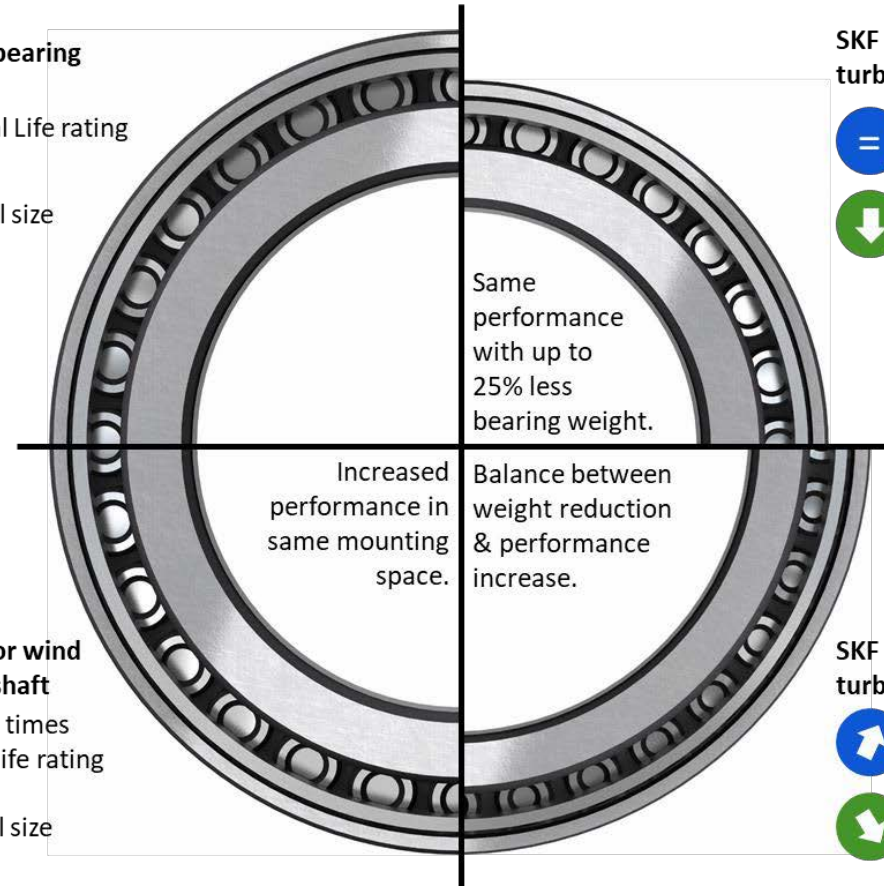
- Original Life rating
- Original size

SKF DuraPro for wind turbine main shaft

- Original life rating
- Bearing downsized

SKF DuraPro for wind turbine main shafts bearing (8-10MW):

d/D/B: 1900/2350/265 mm
 Weight: 2.6 to (-25%)
 C_{dyn} : 15 020 kN (+2%)
 L_{10mrh} : 1 020 000 h (+2%)



SKF DuraPro for wind turbine main shaft

- Up to 2 times longer life rating
- Original size

SKF DuraPro for wind turbine main shaft

- Increased life rating
- Roller set downsized

SKF DuraPro for wind turbine main shafts bearing (8-10MW):

d/D/B: 2380/2800/265 mm
 Weight: 2.95 to (-16%)
 C_{dyn} : 15 800 kN (+8%)
 L_{10mrh} : 1 250 000 h (+20%)

SKF DuraPro for wind turbine main shafts bearing (8-10MW):

d/D/B: 2300/2800/265 mm
 Weight: 3.5 to
 C_{dyn} : 16 890 kN (+15%)
 L_{10mrh} : 1 900 000 h (+90%)

Testing

- Intense research, development and testing have led to the creation of SKF DuraPro for wind turbine main shafts.
- SKF DuraPro for wind turbine main shafts was tested in the most extensive endurance test campaign with large size bearings ever made in SKF history with >32'000 total hours(3.6 Years) on test rigs.
- SKF DuraPro for wind turbine main shafts officially released by the SKF bearing life scientists based on these results.



SKF Sven Wingquist Test Center



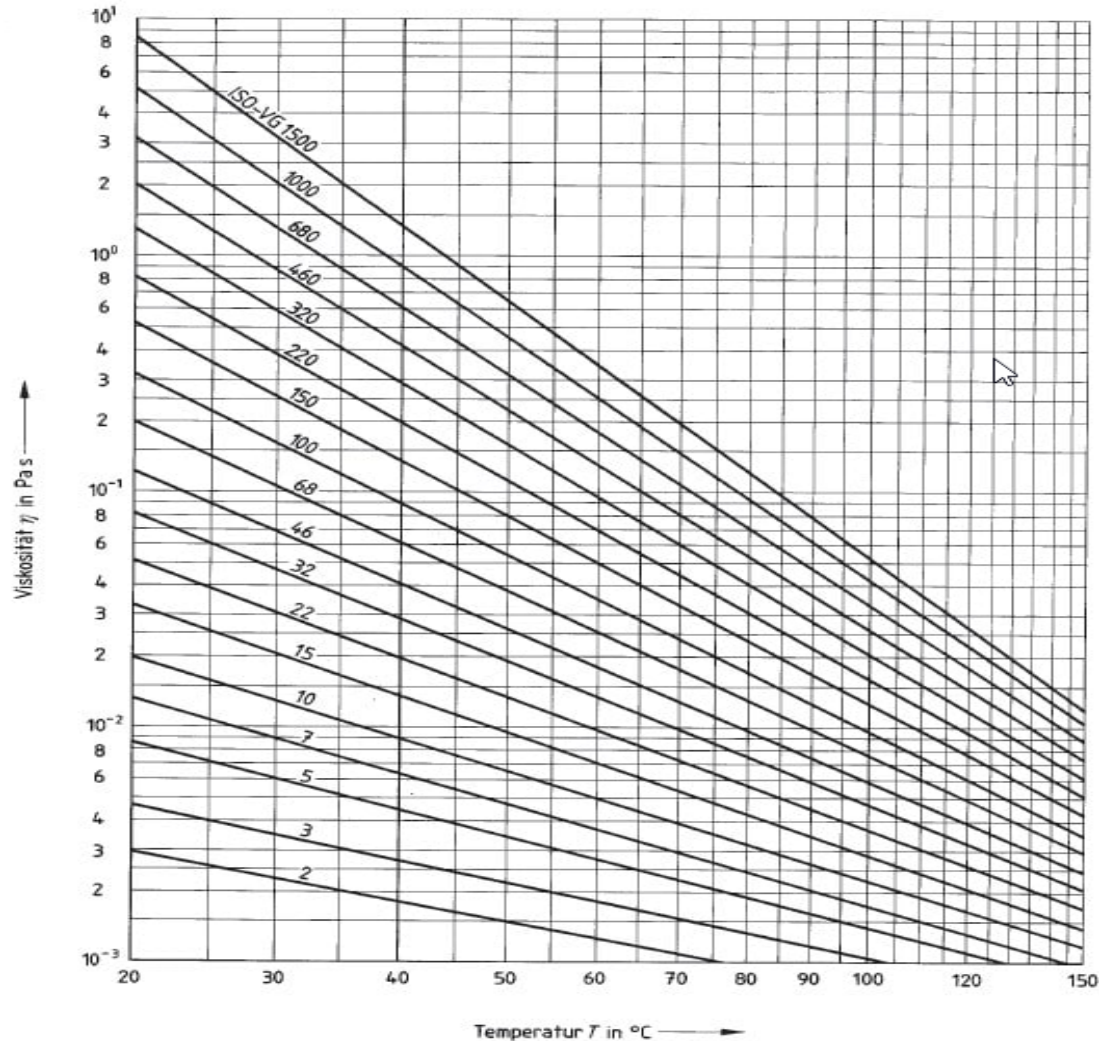
SKF DuraPro for wind turbine main shafts

- ✓ Longer design life with the same mounting space
- ✓ Enables keeping bearing size down in higher turbine rating projects and upgrades
- ✓ Improved robustness under mixed conditions that can happen when grease is cold
- ✓ Increased fatigue life implemented in ISO/TS 16281 rating life successfully audited by Det Norske Veritas (DNV)

And how about the gearbox, does it get's cold feet's as well ?



Why is operation of gearbox bearings in cold condition different.

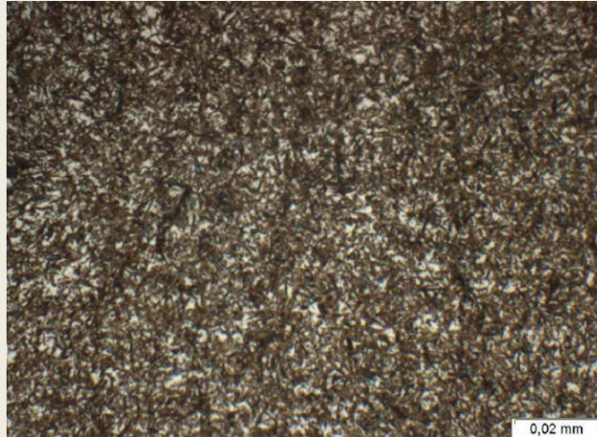


- Diagram to the left shows oil viscosity as a function of temperature. As it can be seen the oil gets much thicker when it is cold..
- At some point, the oil passes its pour point, and becomes like butter !
- When the oil is thick, the bearings will no longer be properly lubricated ! So, the bearings need to be robust against marginal lubrication (Low Kappa)

Tailored steel and heat treatment in Gearbox Bearing

SKF DuraPro for wind turbine gearboxes properties...

- Fine microstructure / fine precipitates



- Tailored level and fine distribution of retained austenite
 - Higher surface hardness
 - Compressive residual stresses

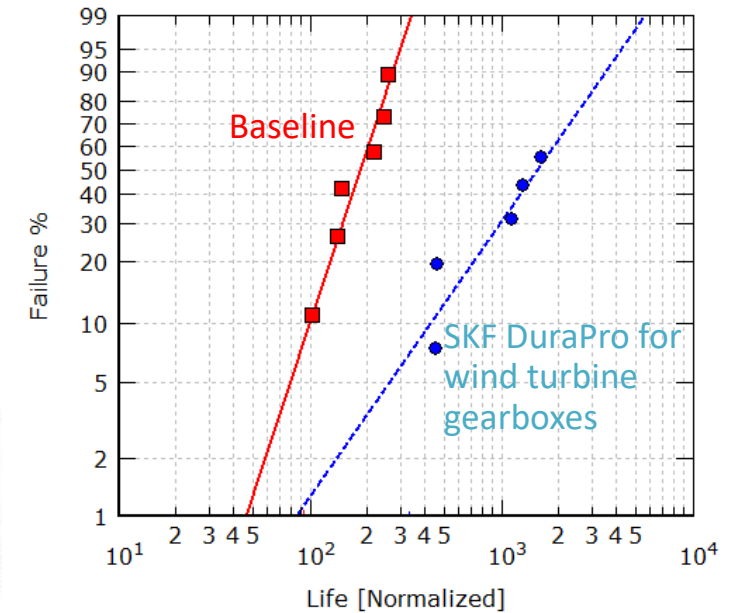
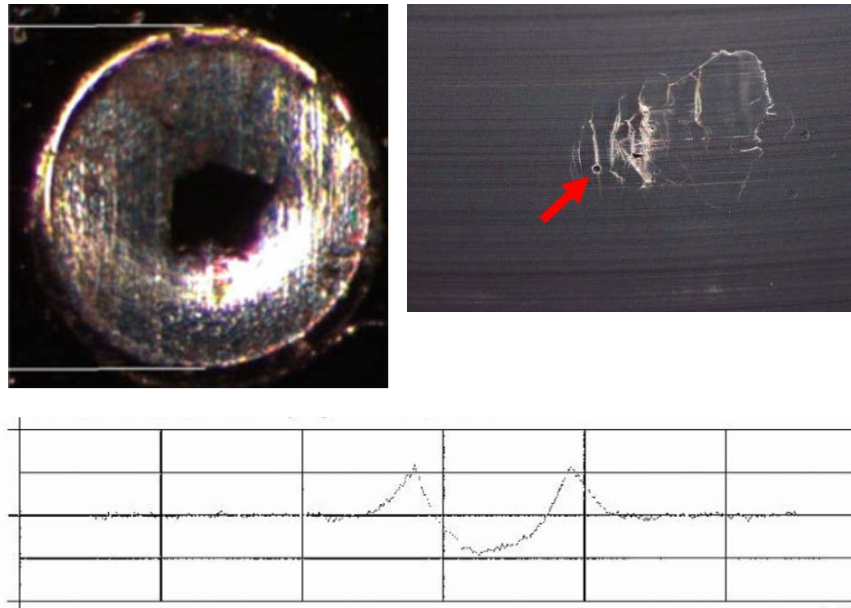
Dedicated bearing tests show **increased surface-initiated fatigue life**

Test with pre-dented raceway to evaluate reduced lubrication conditions and particle contamination

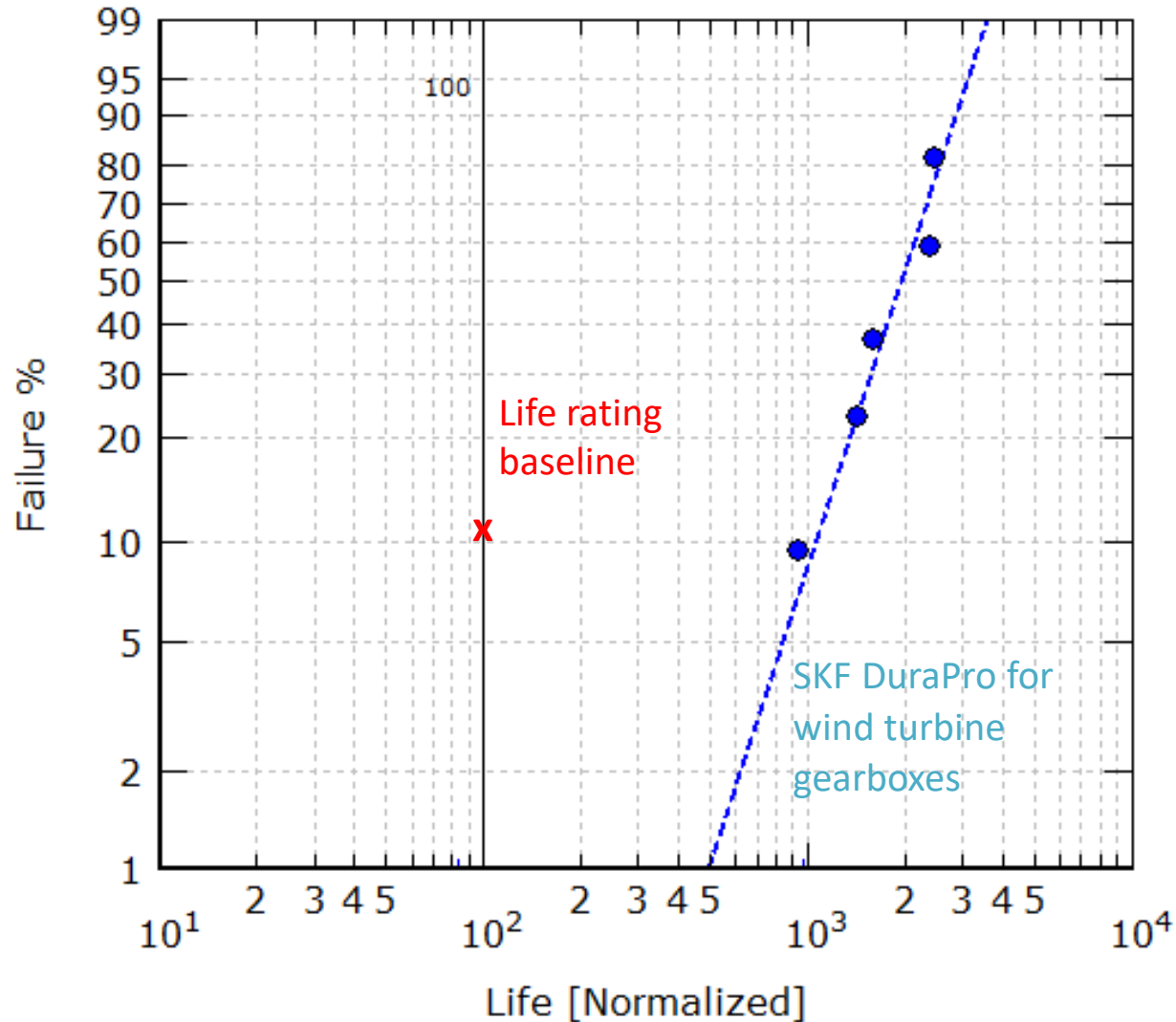
Testing of typical Tapered Roller Bearing from HS-S for 2MW range

- Baseline: SKF Explorer / black-oxidized / ...
- SKF DuraPro for wind turbine gearbox

➔ **Conclusion: in reduced lubrication condition and particle contamination, significant life increase achieved**



Dedicated bearing tests show increased subsurface-initiated fatigue life



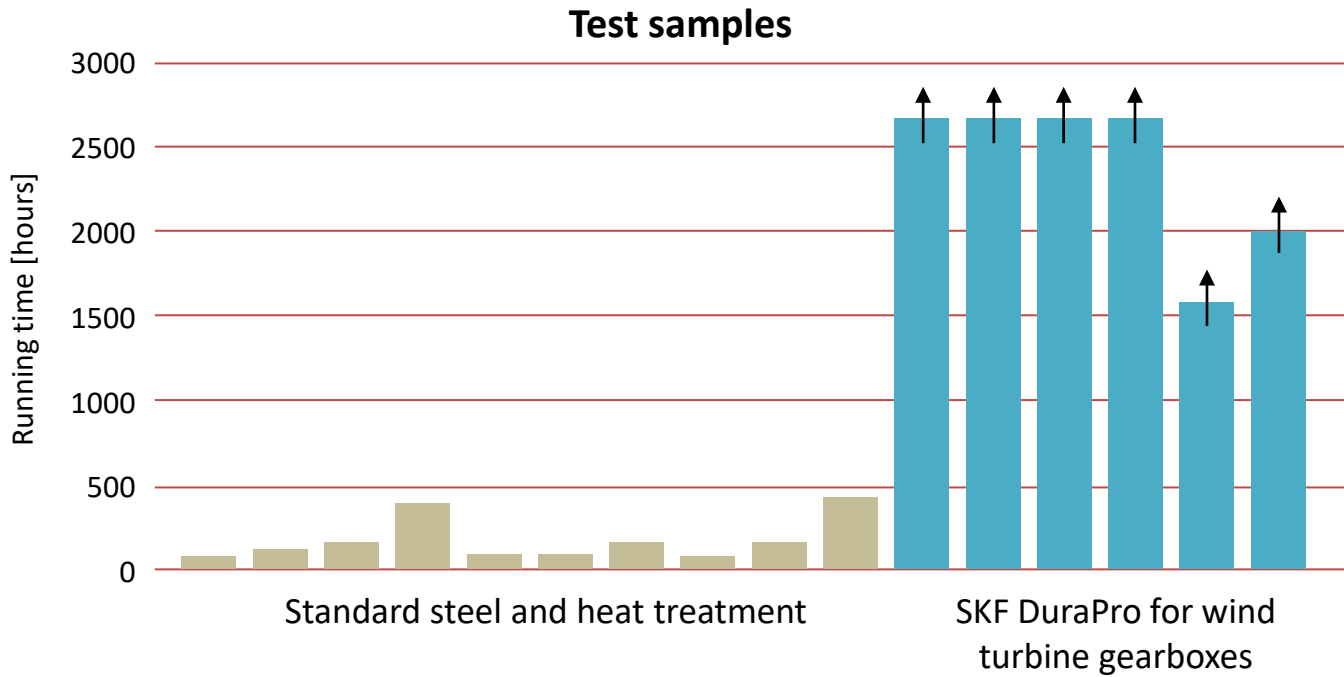
Testing at high kappa

Testing of typical HS-S bearing for 2MW range

Comparison with calculated advanced L₁₀ life rating

➔ **Conclusion: bearing life is significantly longer than calculated life rating of a SKF Explorer bearing**

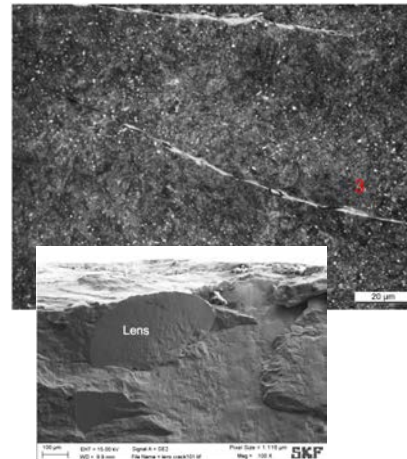
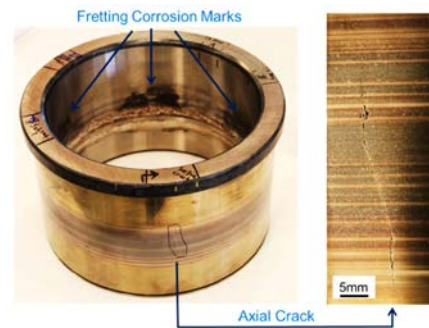
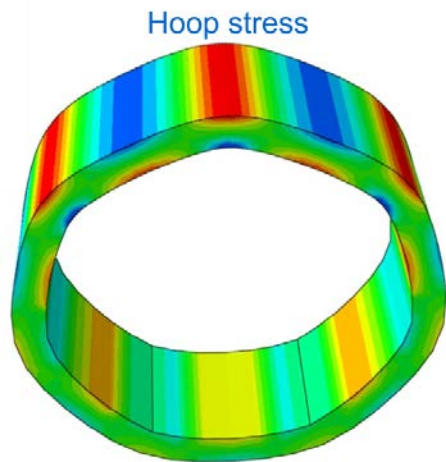




Robustness against premature failures and WECs – stress driven

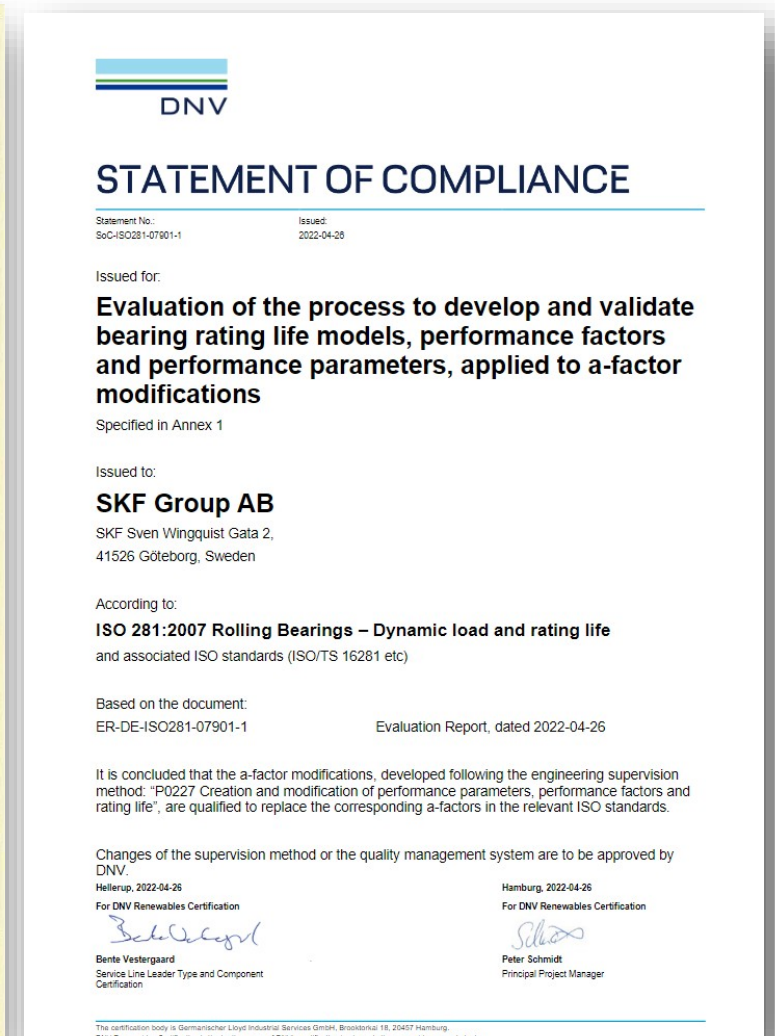
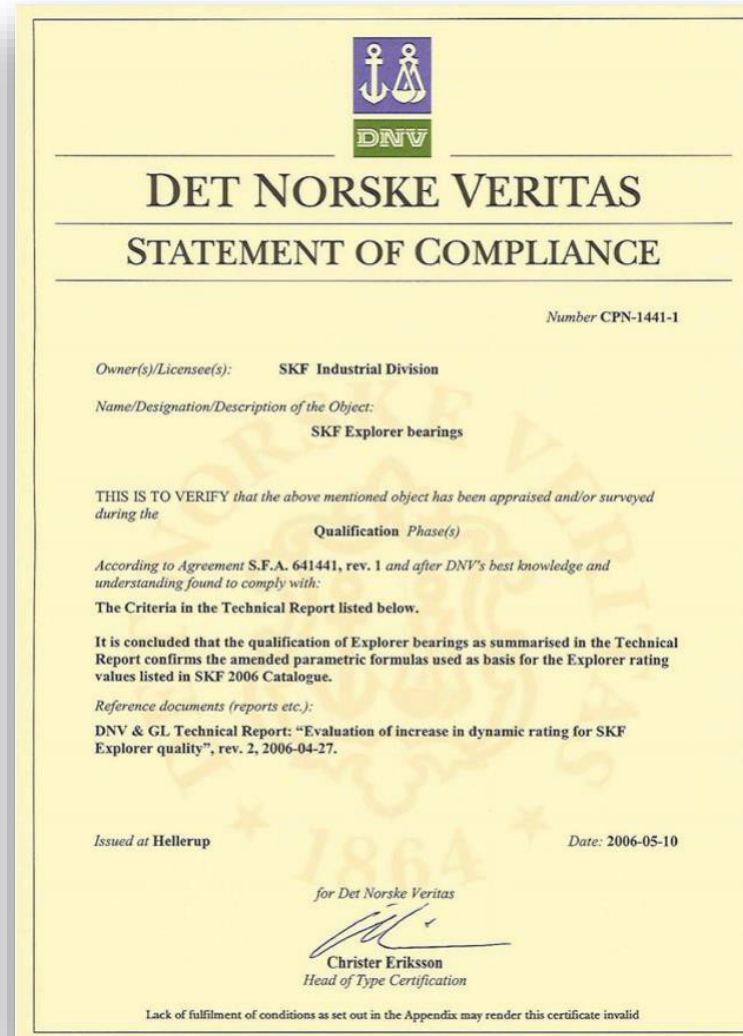
Premature failures with WECs can be reproduced by applying increased tensile stresses in the ring

- Test used to evaluate robustness of different solutions against premature failures and WECs
- Standard steel & HT run 178hrs on average
- No failures of SKF DuraPro for wind turbine gearboxes, in 6 tests running at least 1500hrs



Two DNV Statements of Compliance are valid:

1. DNV SoC confirms the validity of the Explorer Bearing. Same process was used when developing parametric formulas for the Durapro
2. DNV SoC confirms the evaluation of the process to develop and validate bearing rating life models, performance factors applied to a-factor modifications.



Conclusions

1. Bearings in Harsh environments are sensitive to getting cold, as the lubricant will not function as it does at normal operation temperatures.
2. Improved hardness and surface finishing helps, when the bearing operates when it's cold.
3. These features are combined in the SKF Durapro bearings, that are developed and manufactured for the specific wind turbine application.



SKF®