

Presented by

**REWITEC
GmbH**

April 2022

**Higher reliability and longer
lifetime for gears and bearings
in wind turbines**

Agenda

- ⇒ Company and products
- ⇒ Technology
- ⇒ Scientific tests
- ⇒ Examples of application
- ⇒ Gearbox and bearing lifetime calculation
- ⇒ Conclusion



The challenges of unscheduled maintenance costs remain



⇒ Calculation mistakes, environmental conditions, missing or even wrong maintenance can cause unforeseen breakdowns



Maintenance represents
25 % of the total wind
turbine cost over its
lifetime



Unscheduled
maintenance represents
30 - 60 % of total
maintenance costs

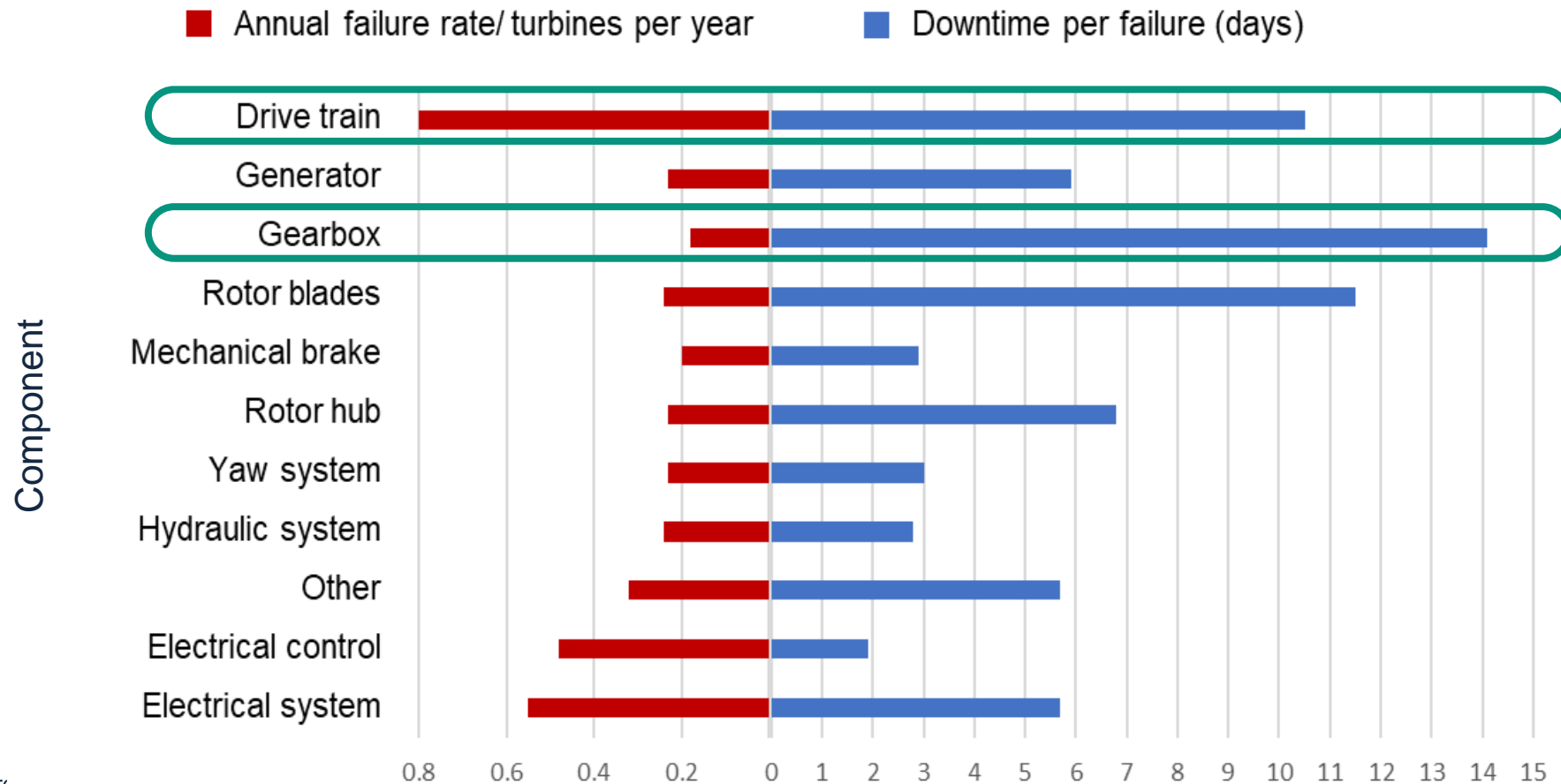


Up to **14 days** needed
to repair a gearbox or
bearings - more than
any other component

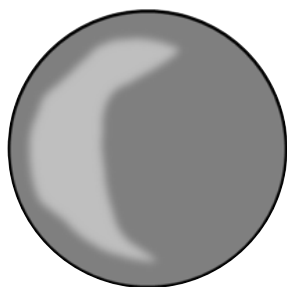


Average cost to repair
a gearbox failure is
380,000 \$

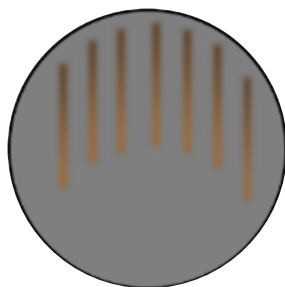
Wind turbine reliability remains an issue



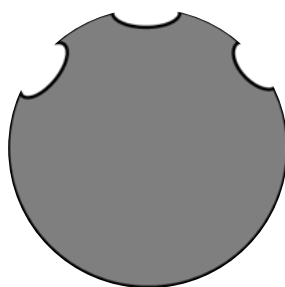
Typical damage to gears & bearings



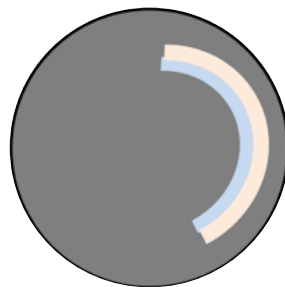
Micropitting/
Grey staining



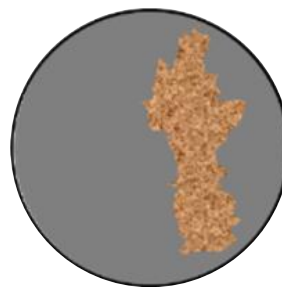
Fretting
corrosion



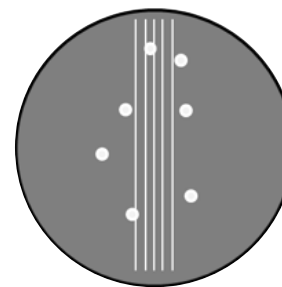
False
brinelling



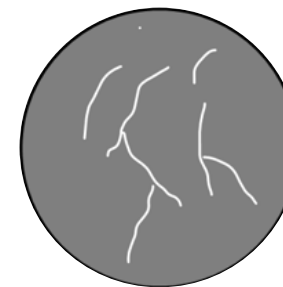
Smearing and
scuffing



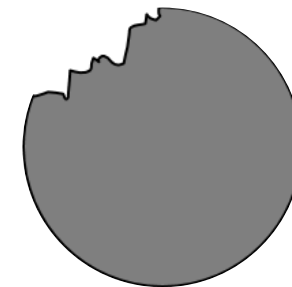
Chemical
corrosion



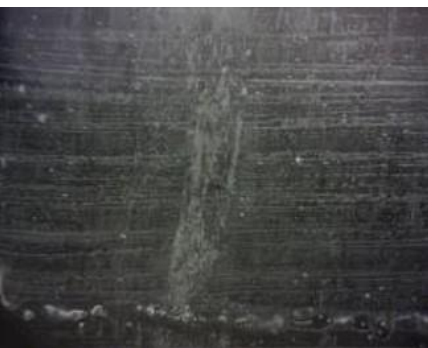
Electric
damage



White etching
areas/cracks



Macropitting



Company and products

Key facts about REWITEC

- ⇒ Founded in 2003
- ⇒ Close cooperation with universities and research institutes
- ⇒ Supported by the German Government
- ⇒ Patents in Europe, China, USA
- ⇒ Acquisition by CRODA in 2019



About Croda

⇒ Manufacturer of high-performance ingredients and technologies: development, production and distribution of speciality chemicals.



Friction
modifiers



Ester
base oils



Surface
additives



Anti- wear
additives



Gearbox
additives



Greases

Target markets



⇒ Wind energy

- ⇒ Onshore
- ⇒ Offshore



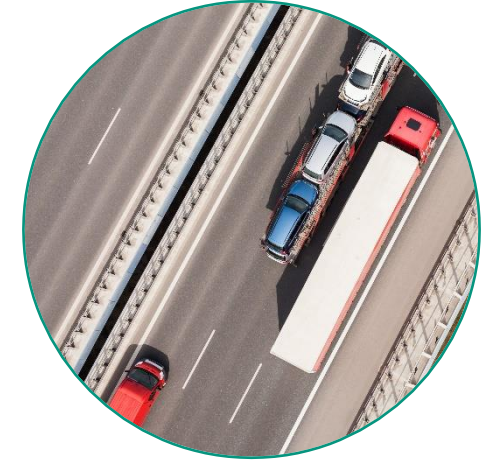
⇒ Industry

- ⇒ Steel
- ⇒ Cement
- ⇒ Mining
- ⇒ Oil, Gas



⇒ Marine

- ⇒ Shipping
- ⇒ Barges
- ⇒ Yachts
- ⇒ Submarine



⇒ Automotive

- ⇒ Consumer
- ⇒ OEM
- ⇒ Motorcycles
- ⇒ Racing
- ⇒ Classic cars

Examples of application

⇒ Over 3,000 successfully treated wind turbines globally



DuraGear™



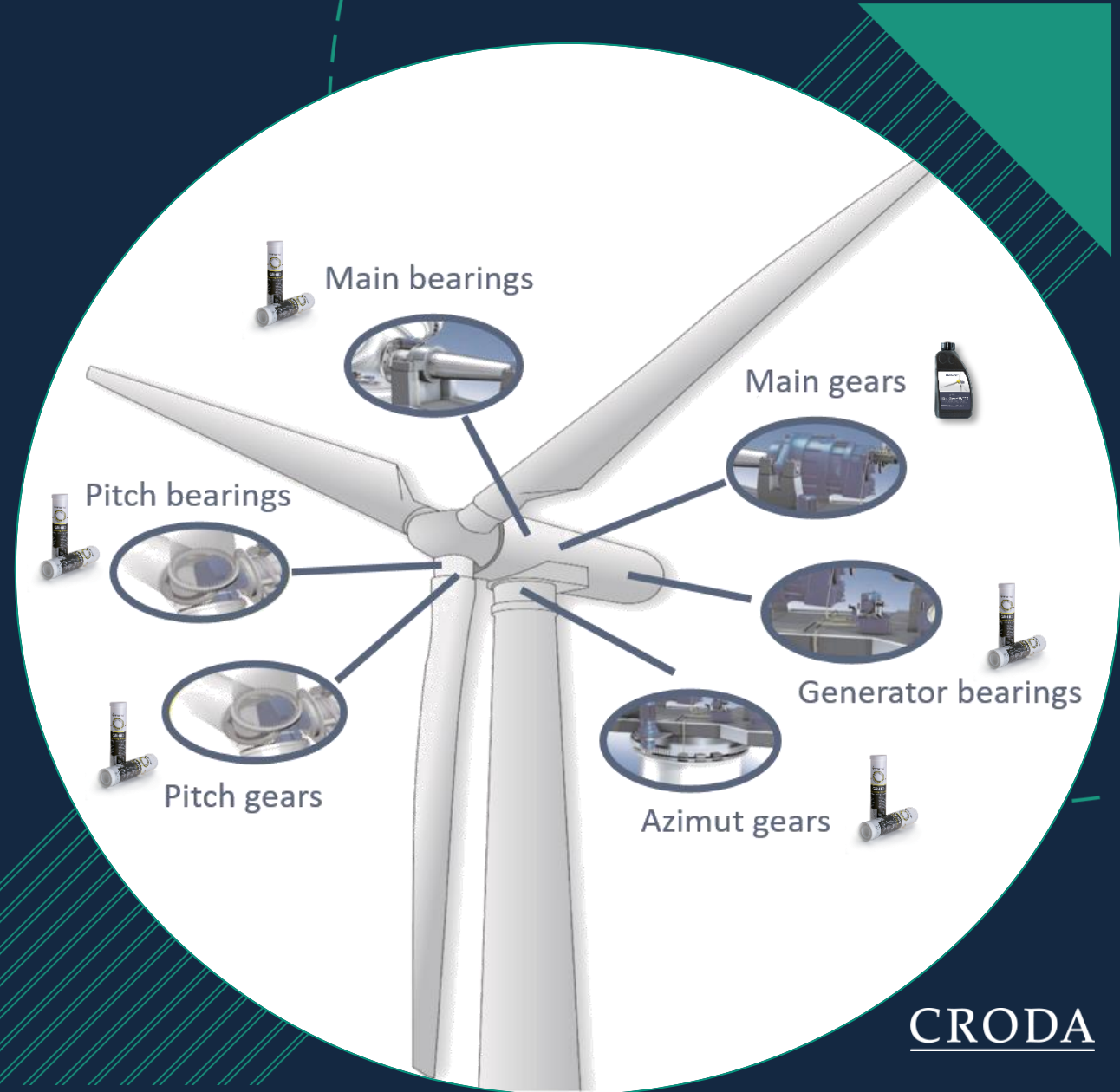
Gears



GR400



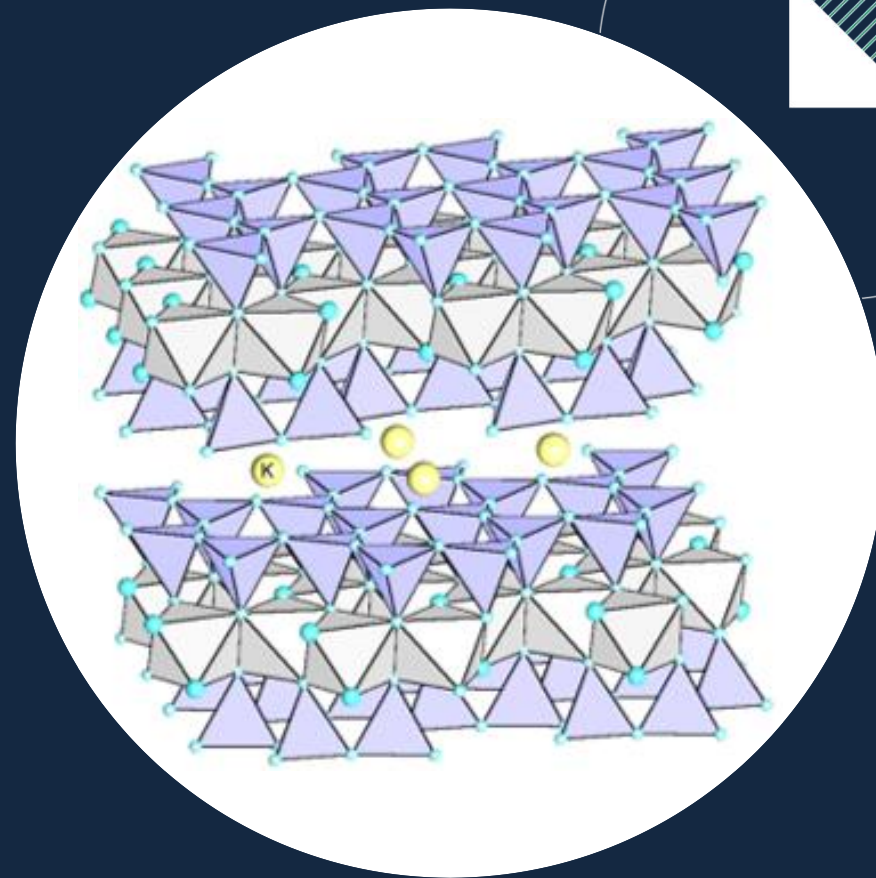
Bearings



REWITEC technology

Phyllosilicate based particle additive

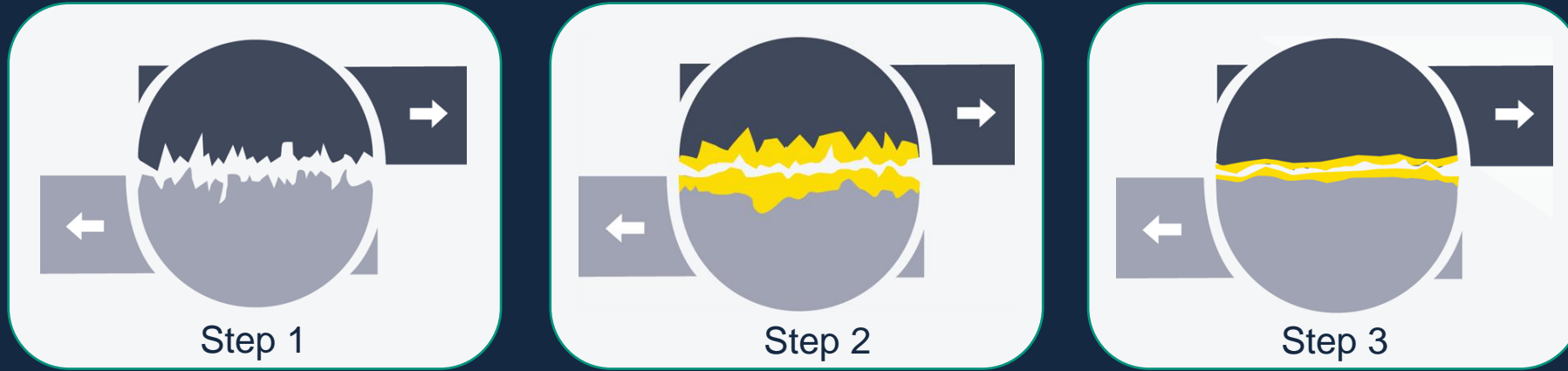
- ⇒ Platelet-shaped particles with layered crystal structure
 - ⇒ Si-O and Al-O based layers
 - ⇒ Strong *covalent* bonds within the layer
 - ⇒ Weak *van der Waals* interaction between the layers
- ⇒ Easy shearing between the layers
 - ⇒ **Friction reduction**
- ⇒ Big specific area with high adsorption ability
 - ⇒ covering the surface, filling the holes
 - ⇒ **Protective, repairing and smoothing effect**
- ⇒ Particle size $d_{90} = 4 \mu\text{m}$
- ⇒ Soft material: Mohs Hardness Scale 2.5 (like fingernail!)



Our scientific paper:

- ⇒ "Tribological properties of a phyllosilicate based microparticle oil additive"
- ⇒ Chizhik et al., Wear 426–427 (2019) 835–844

How REWITEC works



Significant reduction of friction, wear, roughness and temperature

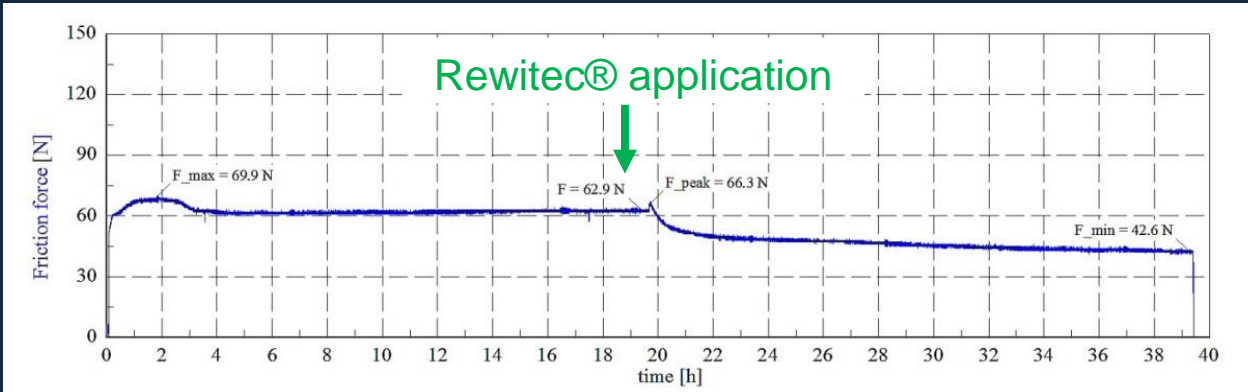
⇒ Advantages:

- ⇒ Compatibility to all common lubricants
- ⇒ Temperature independent
- ⇒ No chemical interactions with other lubricant parts
- ⇒ Low dosage

Scientific tests

2-Disc assembly rolling wear test – gear oils

- ⇒ Stress value: 1 GPa (normal force 2150 N)
- ⇒ Rotating speed: 424 rpm / 339 rpm, slip 20 %
- ⇒ Test-duration: 39,3 h
- ⇒ Temperature: oil inlet temperature 60 °C
- ⇒ Friction coefficient: μ =normal force/friction force



Castrol Optigear Synthetic X320



Supported by:



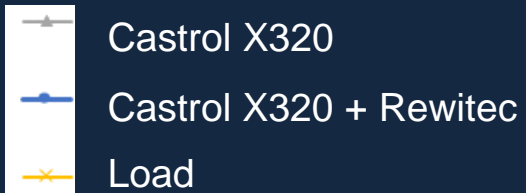
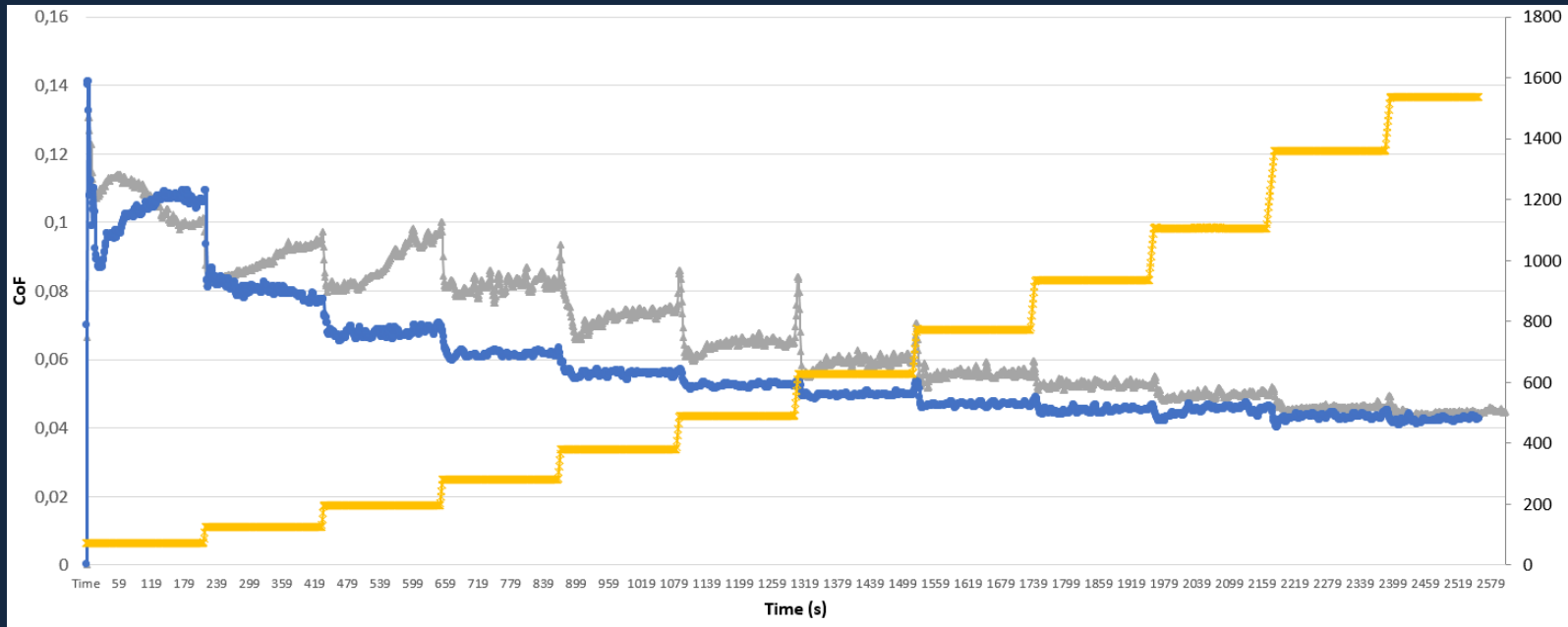
Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

Oil	Friction reduction	Roughness reduction
Castrol Optigear Synthetic X320	33 %	41 %
Mobilgear SHC XMP 320	35 %	44 %
Klübersynth GEM 4-320N	40 %	54 %
Fuchs Unisyn CLP 320	36 %	50 %
Amsoil PTN 320	46 %	18 %
Shell Omala S4 GX 320	42 %	25 %
Klüberbio EG 2-150	55 %	40 %
Fuchs Pentosin EG FFL-7A	41 %	35 %
Automotive racing gear oil	55 %	40 %

SRV – FZG simulation

Temperature: 98°C
Frequency: 50 Hz
Stroke Length : 4 mm



Testing concept for gear oils

Step tests with modified parameters

Hertzian surface pressure [N/mm ²]	FZG load step	SRV® normal force [N]
146	1	7
295	2	28
474	3	73
621	4	126
773	5	195
929	6	282
1080	7	381
1223	8	489
1386	9	628
1539	10	774
1691	11	934
1841	12	1107
2040	13	1360
2170	14	1538

SRV® Technology Platform 10 Excellence in Tribology

⇒ 12 % wear reduction with REWITEC

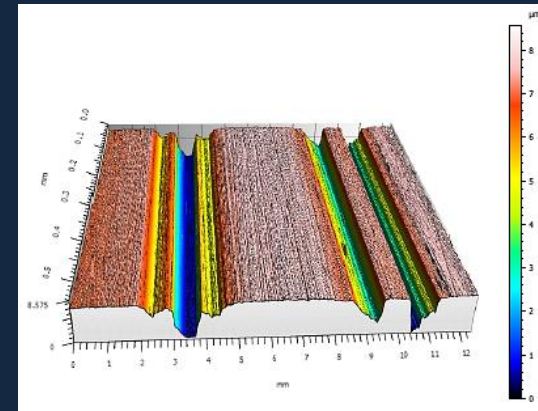
⇒ Up to 30 % friction reduction with REWITEC

FE-8 roller bearing test

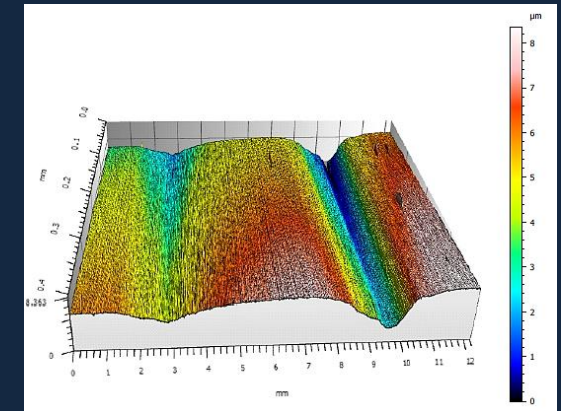
- ⇒ Speed: 7.5 rpm
- ⇒ Test duration: 80 h
- ⇒ Temperature: 80°C
- ⇒ Load: 80 kN

Advantages with REWITEC:

- ⇒ 17 % less wear
- ⇒ Smoother surface
- ⇒ Better load distribution
- ⇒ Protection for rolling elements and rings



Castrol X320 **without**
REWITEC®

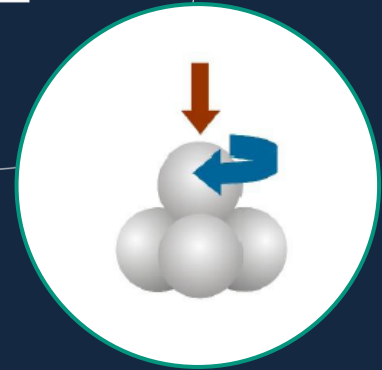


Castrol X320 **with**
REWITEC®

4 Ball test bench – grease test

According to DIN 51350 part 2 (welding force) / 3 (wear test):

Test load: 2000 – 12000 N / 300 N
 Rotating speed: 1450 rpm
 Test-duration: 1 min / 60 min



Test Rig	Test Method	Lubricant	Non Seizure Load [N]	Weld Load [N]	Wear Scar [mm]
VKA	Weld Load DIN 51350 Part 2	Mobil SHC Grease 681 WT	2000	2200	1.15
	Wear Scar DIN 51350 Part 3	Mobil SHC Grease 681 WT – modified with Rewitec	2400	2600	1.16

Advantages with REWITEC:

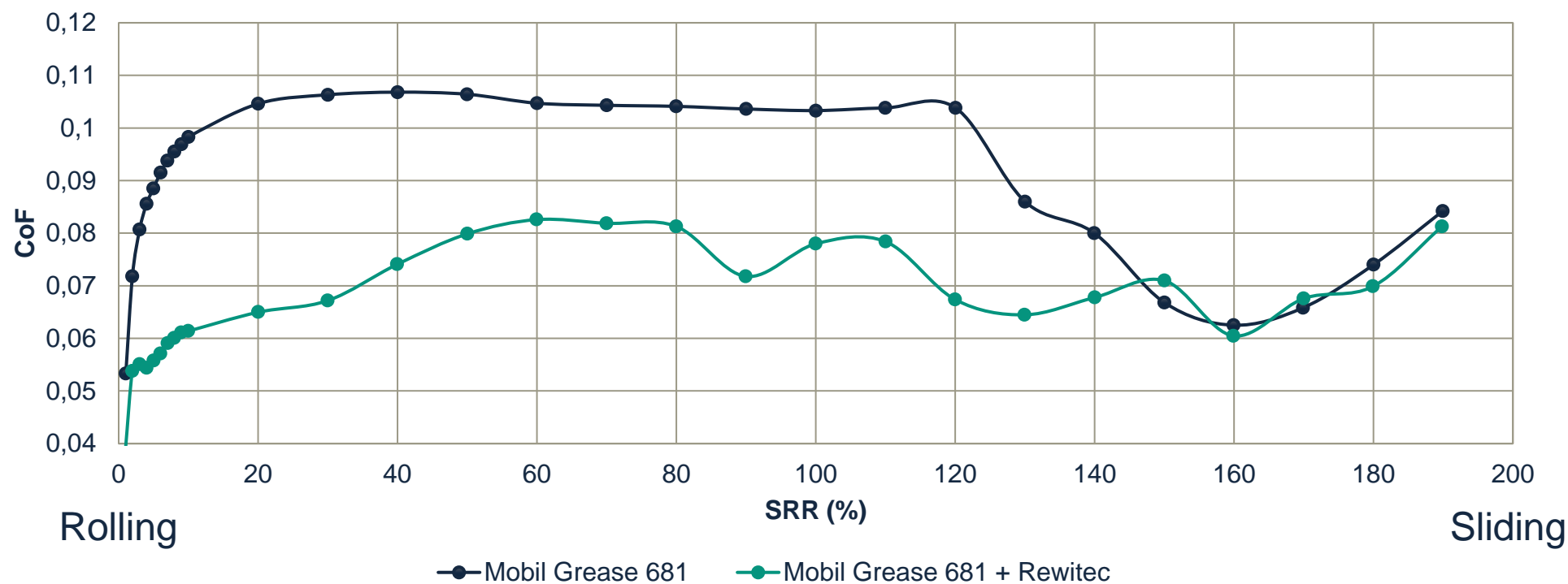
- ⇒ 17 % higher non seizure load
- ⇒ 15 % higher weld load

MTM test bench - grease test



⇒ Load: 70 N
⇒ Temperature: 23°C
⇒ Time: 172 s

700 mm/s



⇒ Up to 38 % friction reduction with Rewitec

False-Brinelling test – For pitch bearing evaluation

- ⇒ Frequency: 25 Hz
- ⇒ Oszillation angle: $\pm 0.5^\circ \rightarrow \pm 3.0^\circ$
- ⇒ Axial load: 3 kN to 4 balls (750 N per ball)
- ⇒ Temperature: room temperature
- ⇒ Test bearing: ARKL Type 51206 with 4 rolling elements

Fuchs LX460



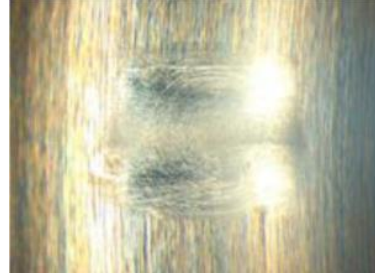
pre-damaging
(1.3 h; $\pm 0.5^\circ$)

Fuchs LX460



Run after the damaging
(3 h; $\pm 3^\circ$)

Fuchs LX460 + **REWITEC™**



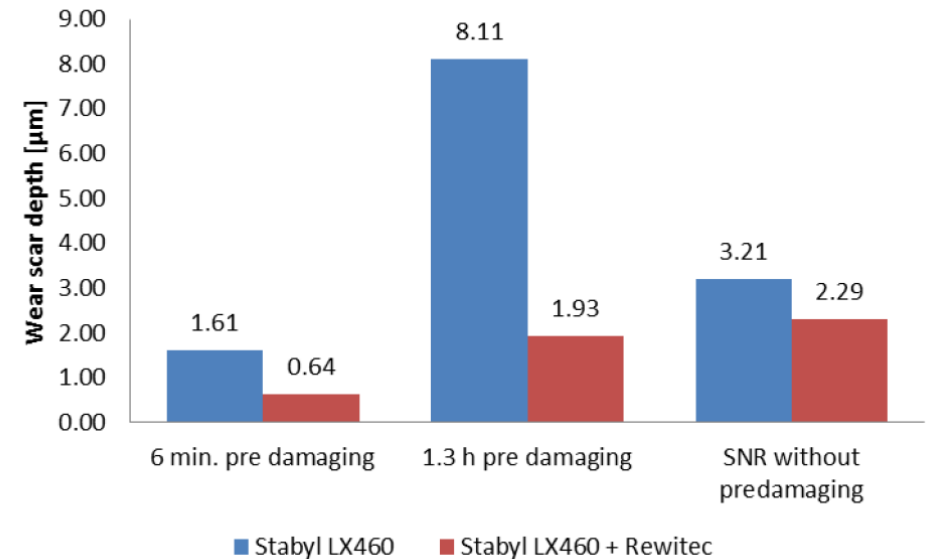
Test Rig



Test specimen



Static loading



Examples of application

Gearbox application procedure

- ⇒ Determine oil volume in the system
- ⇒ Determine filter model and type
- ⇒ Climb tower
- ⇒ Insert REWITEC™ run-in filter – 30 micron SS
- ⇒ Shake REWITEC™ W100 bottle to ensure mixed from settling
- ⇒ Take inspection cover off gearbox & pour W100 into gearbox
- ⇒ Replace inspection cover & run turbine
- ⇒ Return to turbine after 500 running hours & replace original filter
- ⇒ Reapplication every 2-5 years based on gearbox & operating conditions
- ⇒ DATA COLLECTION: Before & After – Impressions (see picture), CMS, borescope, & oil analysis



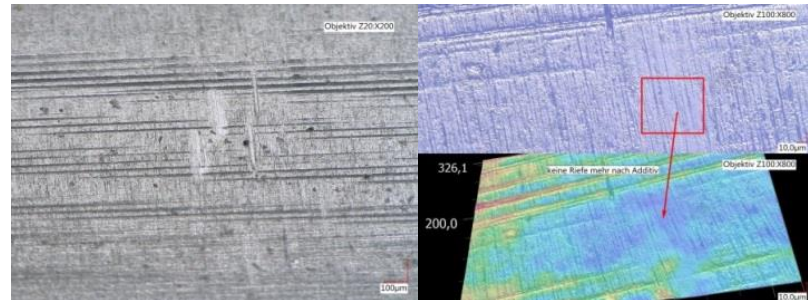
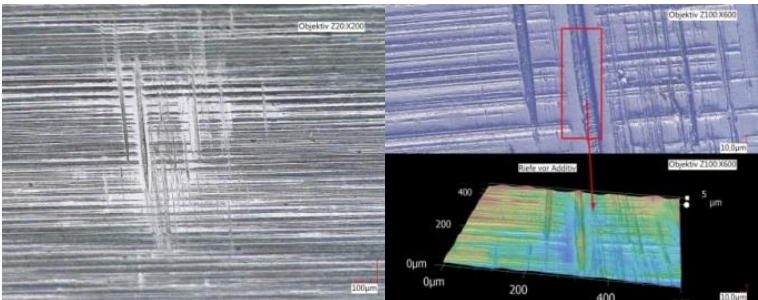
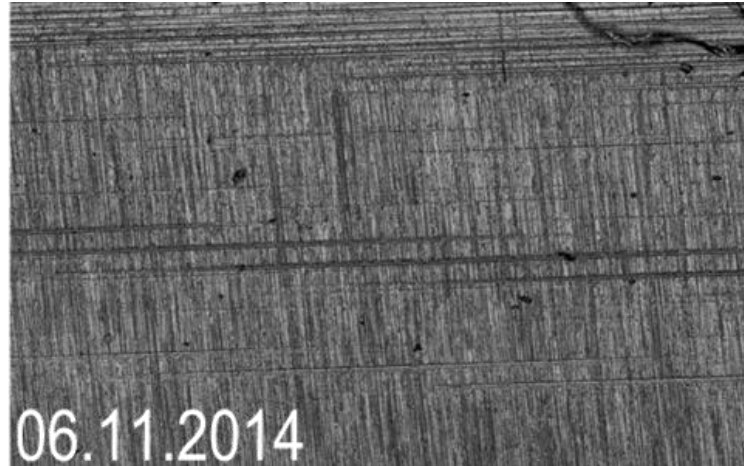
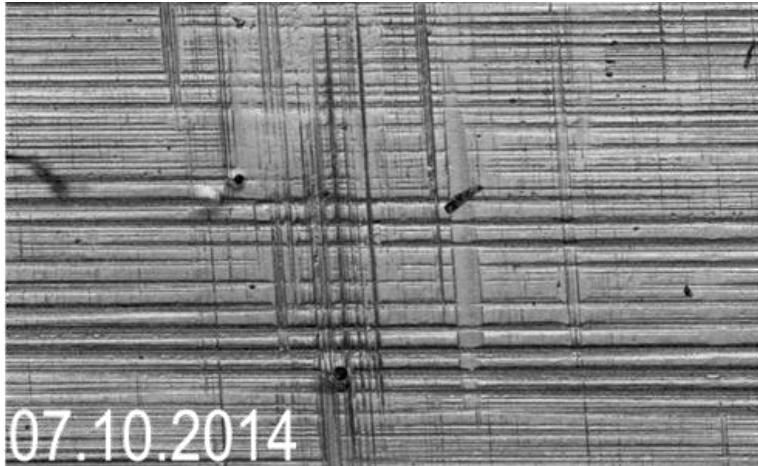
Main bearing application procedure

- ⇒ Determine Grease Volume in the system
- ⇒ Determine Grease Type and Brand
- ⇒ Climb Tower
- ⇒ Determine if Grease is useable
 - ⇒ If Grease Unusable - Flush or Purge bad grease from system
 - ⇒ Top Treat new or usable grease with REWITEC™ GR400 tubes
- ⇒ Run Turbine
- ⇒ Reapplication – Recommend small dosage every year as part of maintenance
 - ⇒ Small dosage = total reapplication every 2-5 years based on gearbox & operating conditions
- ⇒ DATA COLLECTION: Before & After – Impressions (see picture), CMS, Borescope, & Oil Analysis



Examples of application

⇒ Wear development on a Bosch Rexroth gear tooth (GE 1.5 SL) over a period of two years

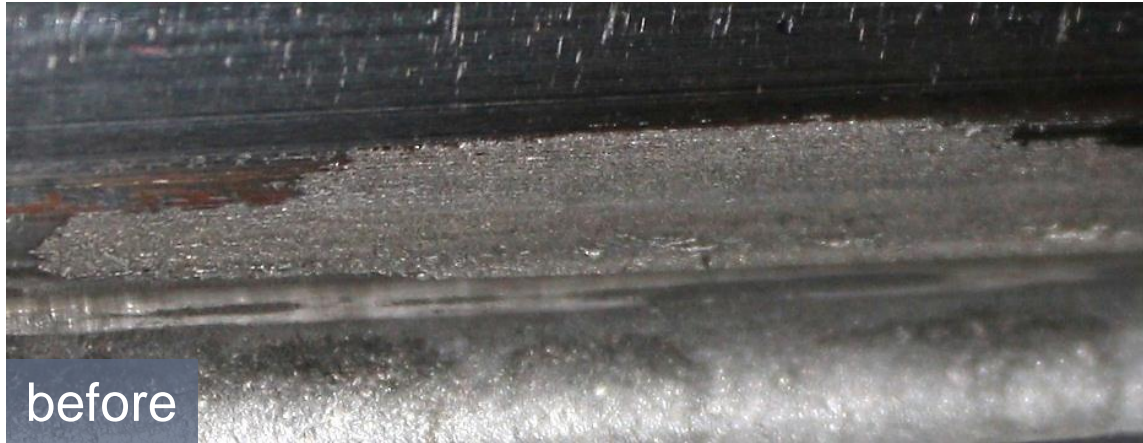


⇒ Run through marks on the tooth flank after 6 weeks and 2 years:

- ⇒ Reduction of the surface roughness and friction force
- ⇒ Improved load carrying capacity
- ⇒ Less stress for the tooth flank

Examples of application

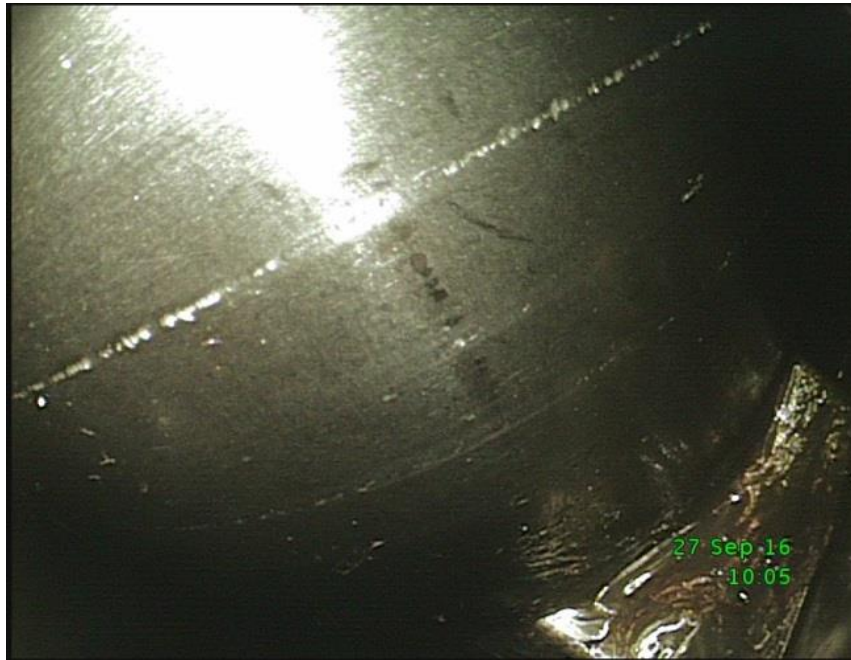
⇒ Wind turbine gearbox CSIC 2 MW VSCF



- ⇒ Significant operational wear visible
- ⇒ In the foot area visible micro pitting
- ⇒ Oxidation visible

- ⇒ Operational wear noticeable reduced
- ⇒ Reduction of micro pitting
- ⇒ The contact pattern is optimized

Coating and analysis of a main bearing GE 1.5 wind turbine

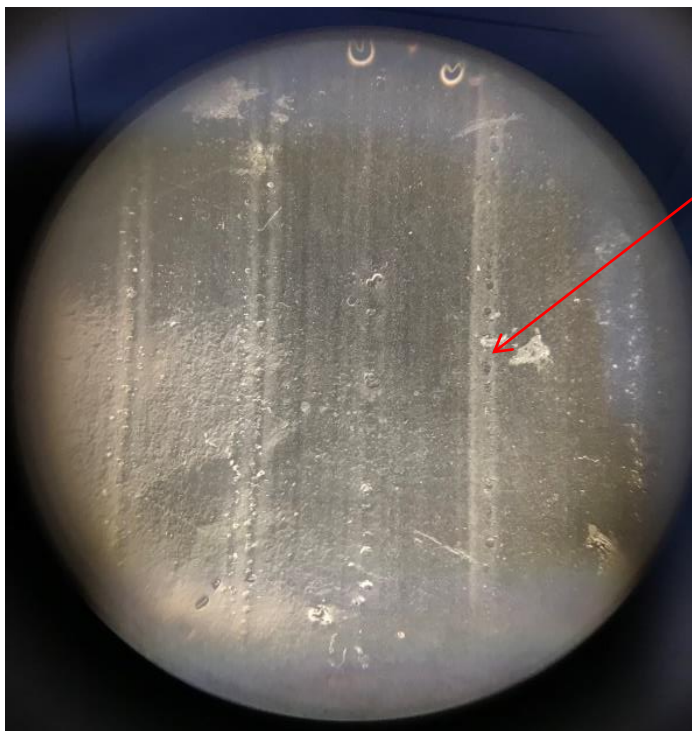


⇒ Picture: main bearing roller 18 months **before** REWITEC™ treatment

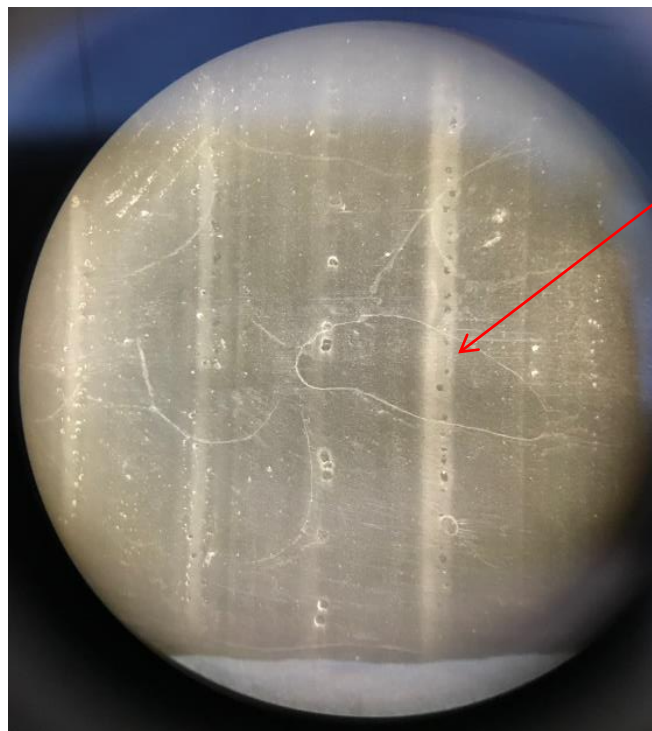


⇒ Picture: main bearing roller 5 months **after** REWITEC™ treatment

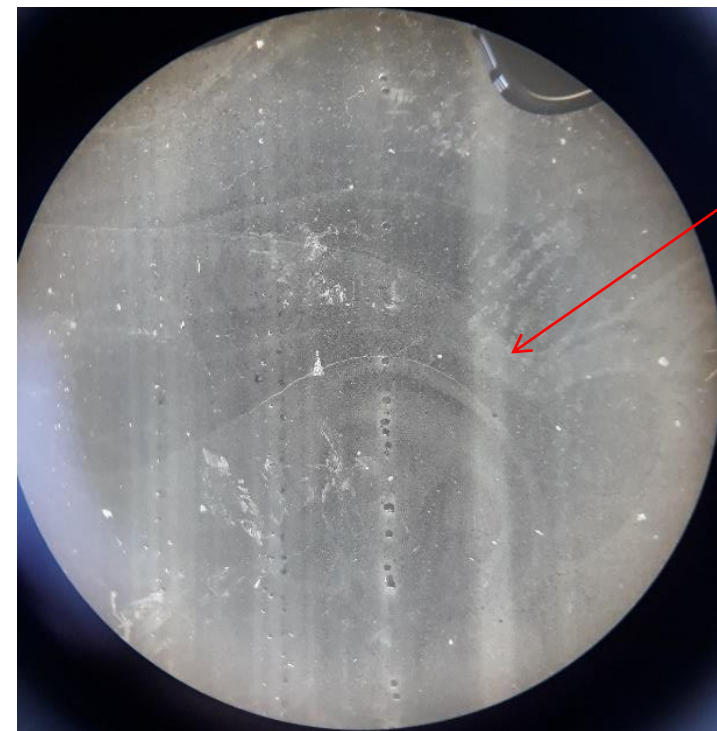
Coating and analysis of a main bearing (outer ring) GE 1.5 wind turbine



⇒ Picture: Before wind turbine was treated with REWITEC™

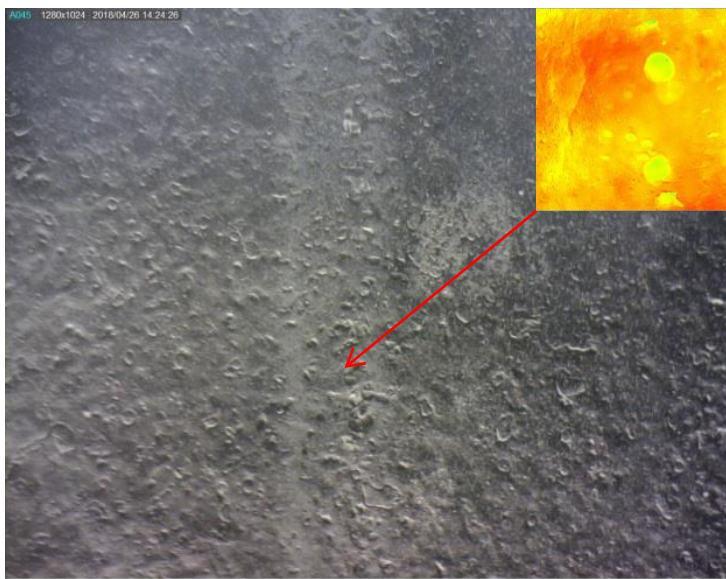


⇒ Picture: 5 months after wind turbine was treated with REWITEC™



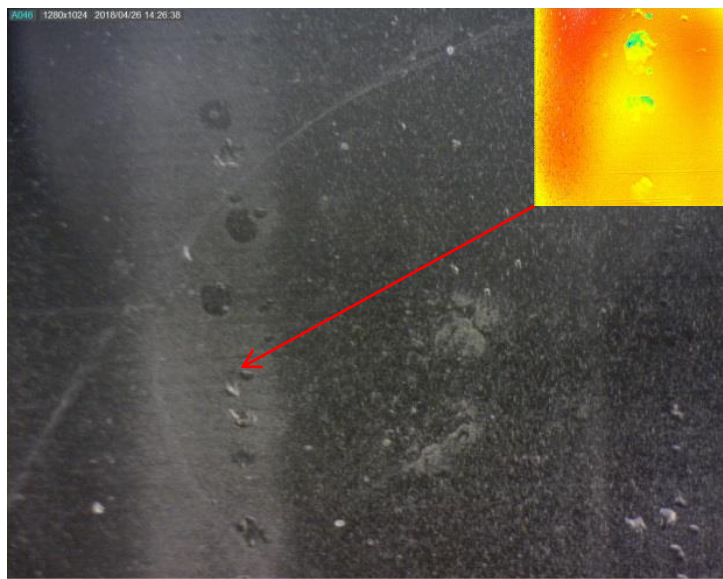
⇒ Picture: 12 months after wind turbine was treated with REWITEC™

Coating and analysis of a main bearing (outer ring) GE 1.5 wind turbine



⇒ Picture: Before wind turbine was treated with REWITEC™

⇒ $R_a = 0,556 \mu\text{m}$ (within the track)



⇒ Picture: 5 months after wind turbine was treated with REWITEC™

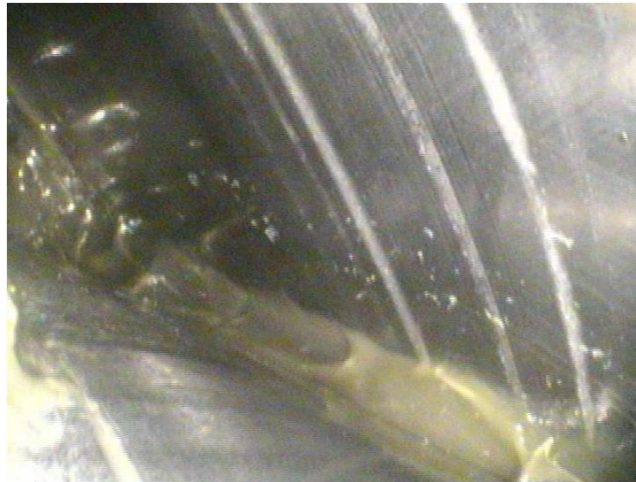
⇒ $R_a = 0,403 \mu\text{m}$ (within the track)



⇒ Picture: 12 months after wind turbine was treated with REWITEC™

⇒ $R_a = 0,225 \mu\text{m}$ (within the track)

Main bearing (outer race) GE 1.5 wind turbine



⇒ **Before** wind turbine was treated with REWITEC™

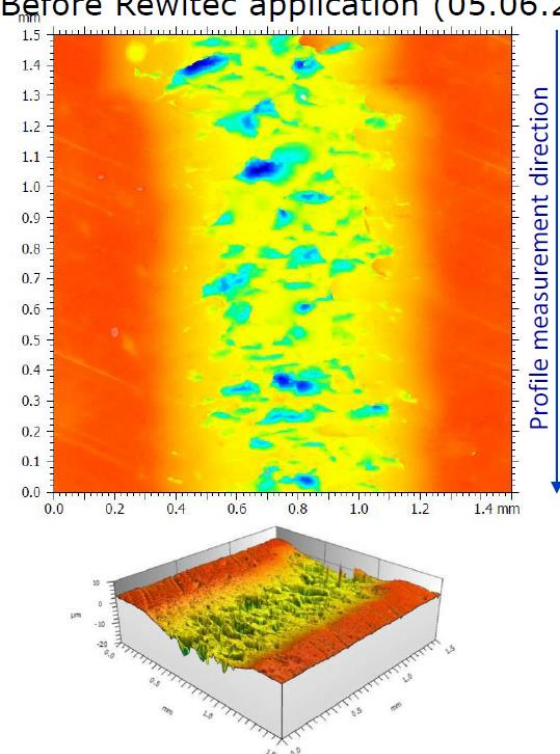


⇒ 6 months **after** wind turbine was treated with REWITEC™

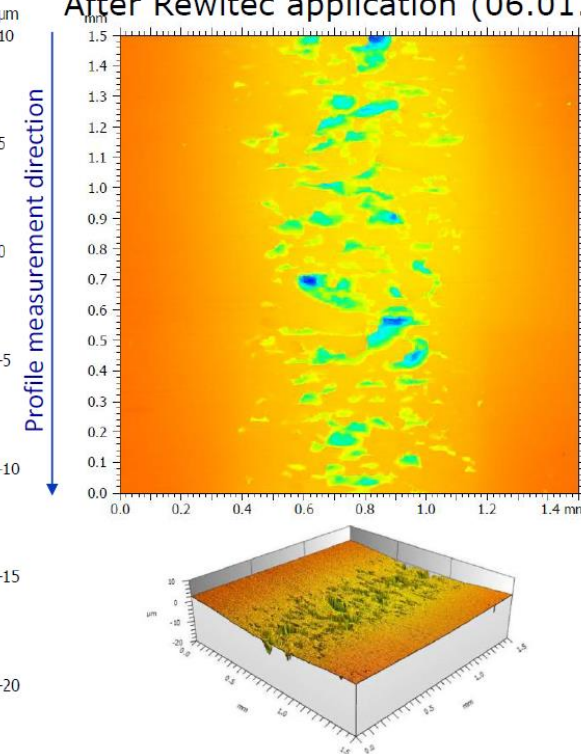
Coating and analysis of a main bearing GE 1.5 wind turbine

Roughness	Before	After	Difference
S_a	3.00 μm	1.47 μm	- 51 %
R_a	0.789 μm	0.600 μm	- 24 %
			- 18 %

Before Rewitec application (05.06.20)



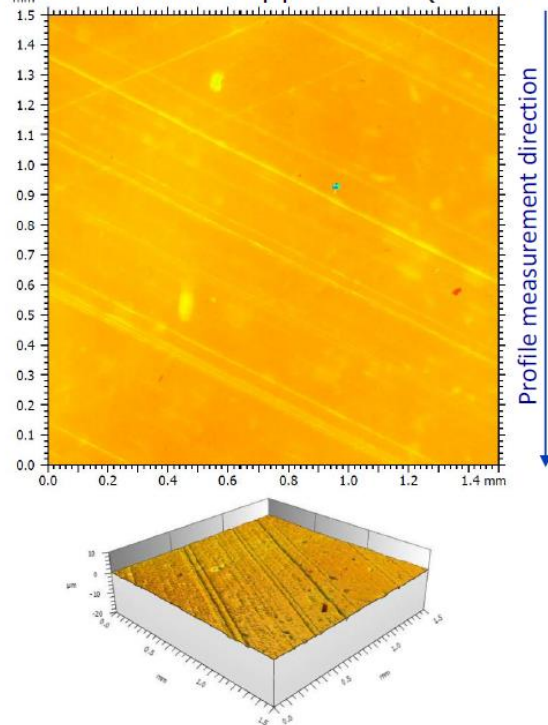
After Rewitec application (06.01.21)



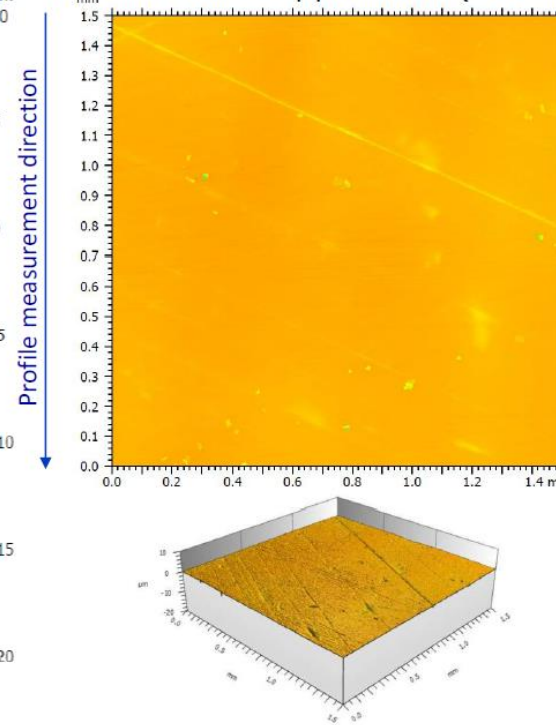
Coating and analysis of a main bearing GE 1.5 wind turbine

Roughness	Before	After	Difference
S_a	0.266 μm	0.159 μm	- 40 %
S_z	22.2 μm	11.6 μm	- 48 %
R_a	0.145 μm	0.064 μm	- 56 %
R_z	1.31 μm	0.767 μm	- 41 %

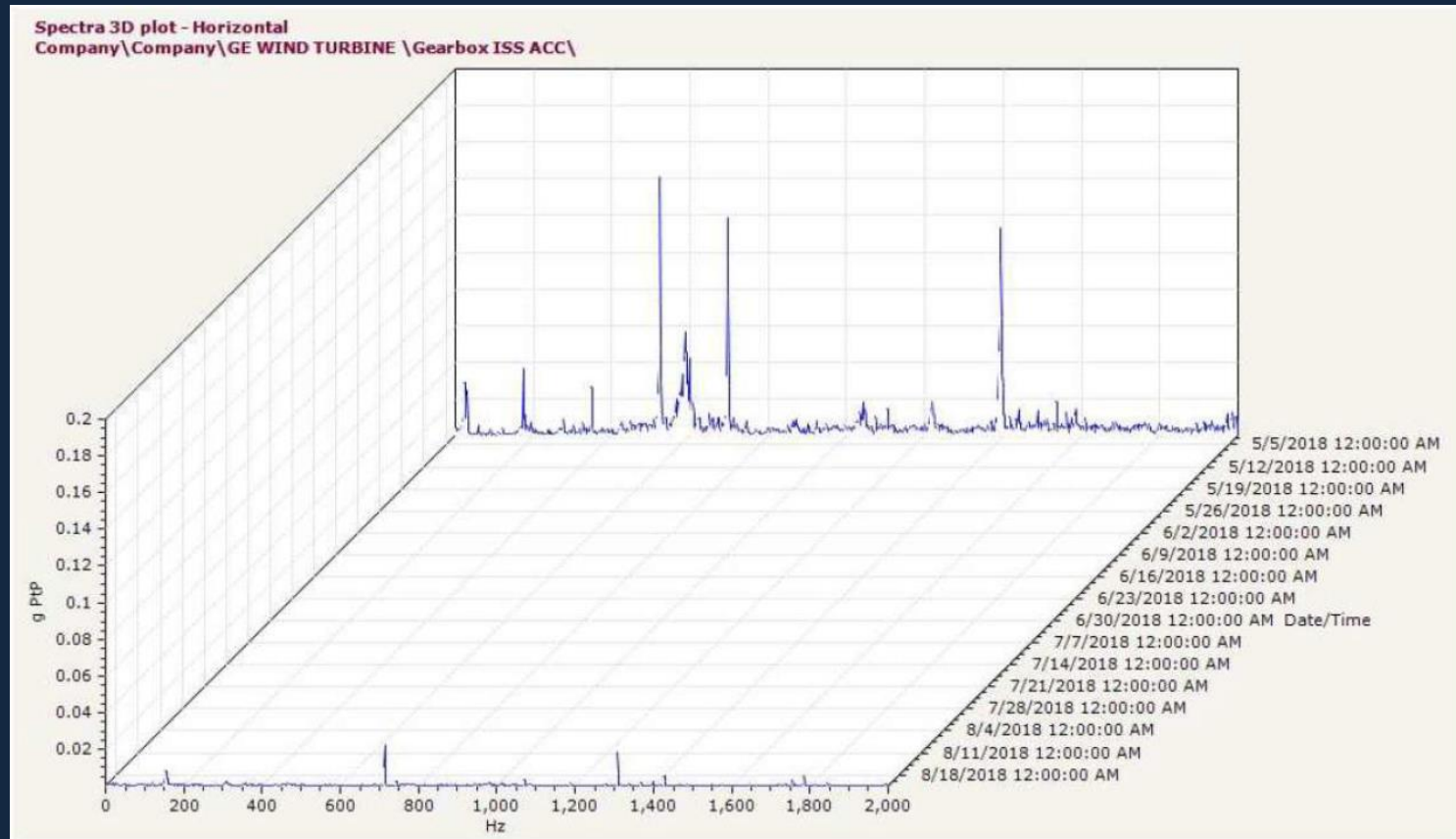
Before Rewitec application (05.06.20)



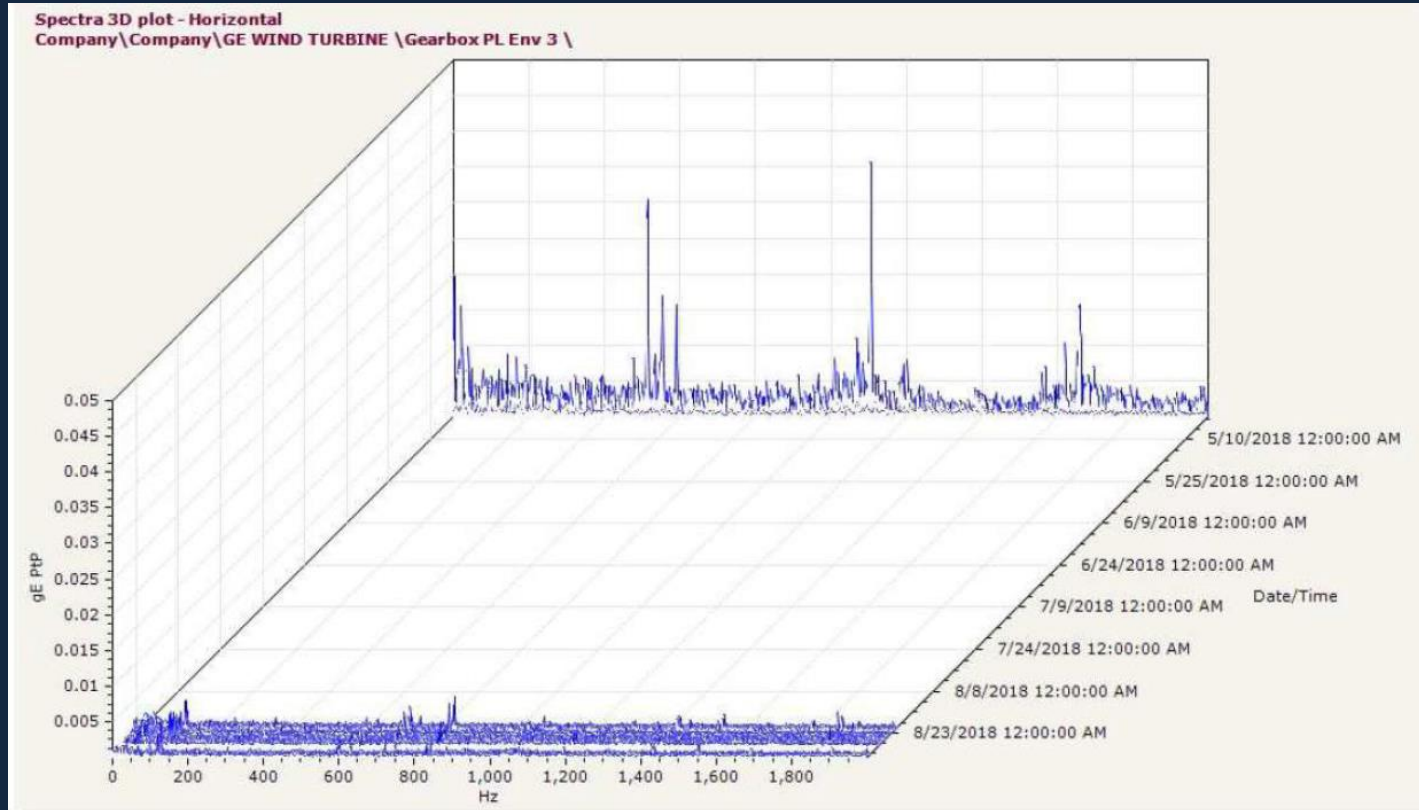
After Rewitec application (06.01.21)



Wind turbine 1.5 MW GE 1.5 SLE ISS Gear

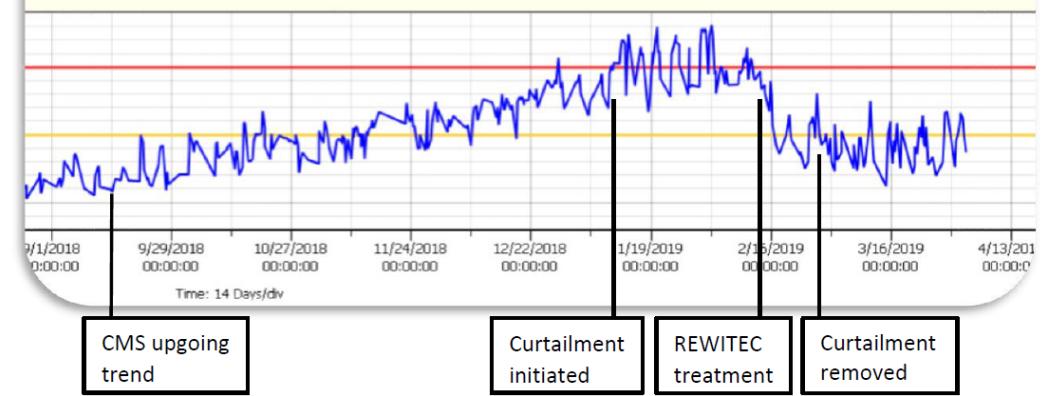


Wind turbine 1.5 MW GE 1.5 SLE Planet Bearing



PLANETARY BEARING MEASUREMENT PRE- TREATMENT IS IN BACK, POST IS IN THE FOREGROUND

Wind turbine 1.5 MW GE 1.5

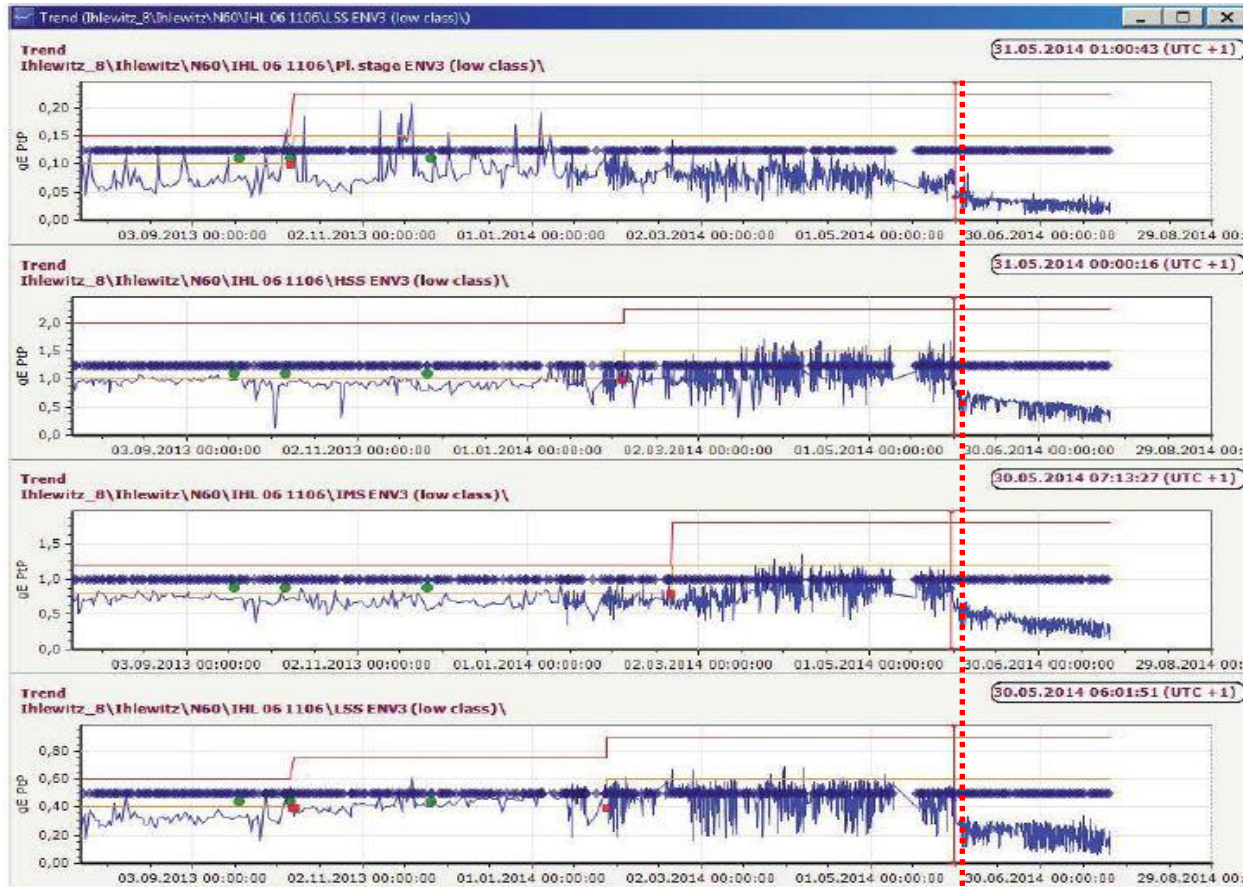


⇒ Before REWITEC™ treatment



⇒ After REWITEC™ treatment

Examples of application



⇒ Goal of application:

- ⇒ Wear protection of a Nordex N60 gearbox by REWITEC™ coating concentrate in May 2014
- ⇒ Protection against further wear and prolongation of lifetime
- ⇒ Analysis via SKF Maintenance Services GmbH

⇒ Results after 2 months:

- ⇒ The report shows a significant difference. Stop of the high vibration level, decrease of the damage frequency.

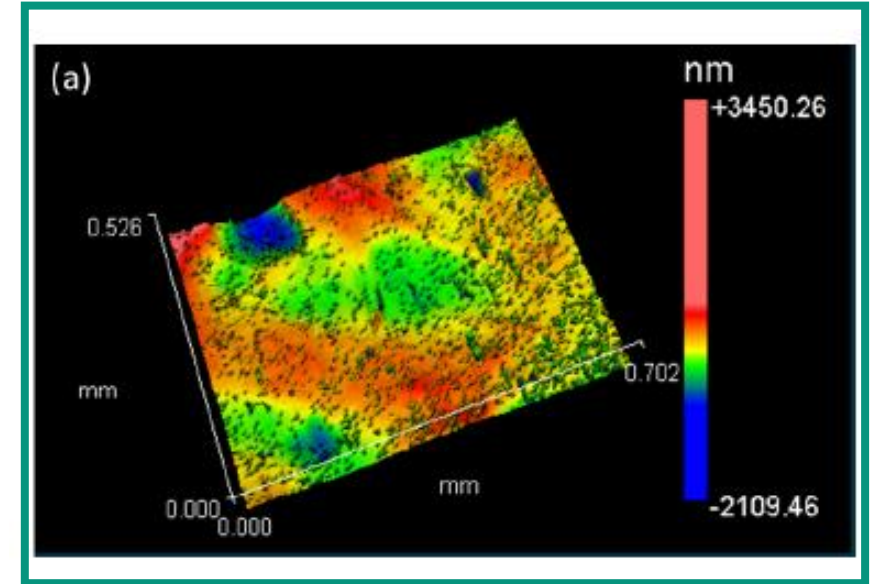
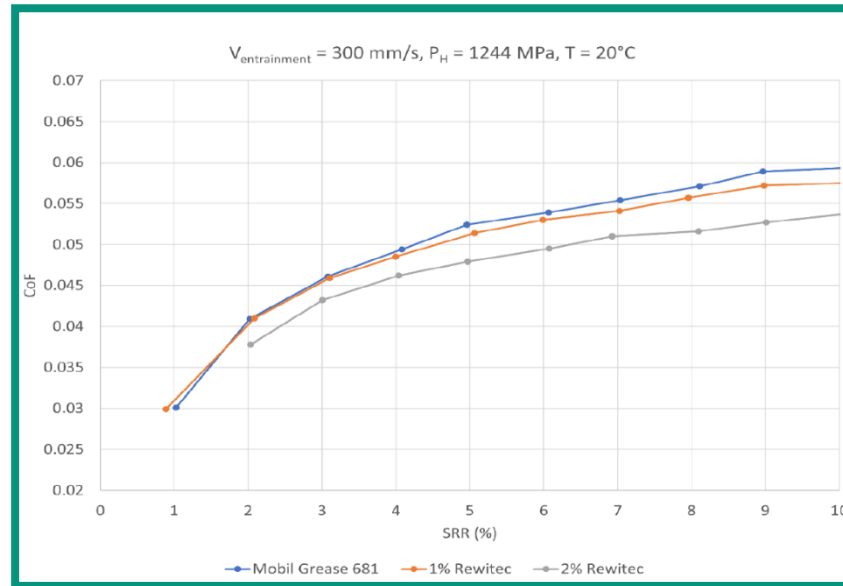
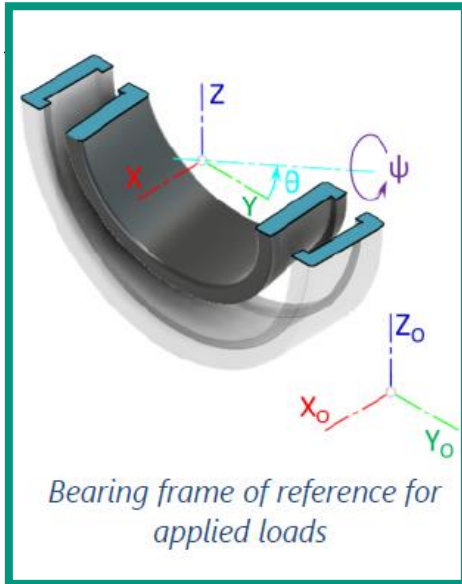
Sentient Science

⇒ Lifetime Calculation
Model by using
REWITEC™



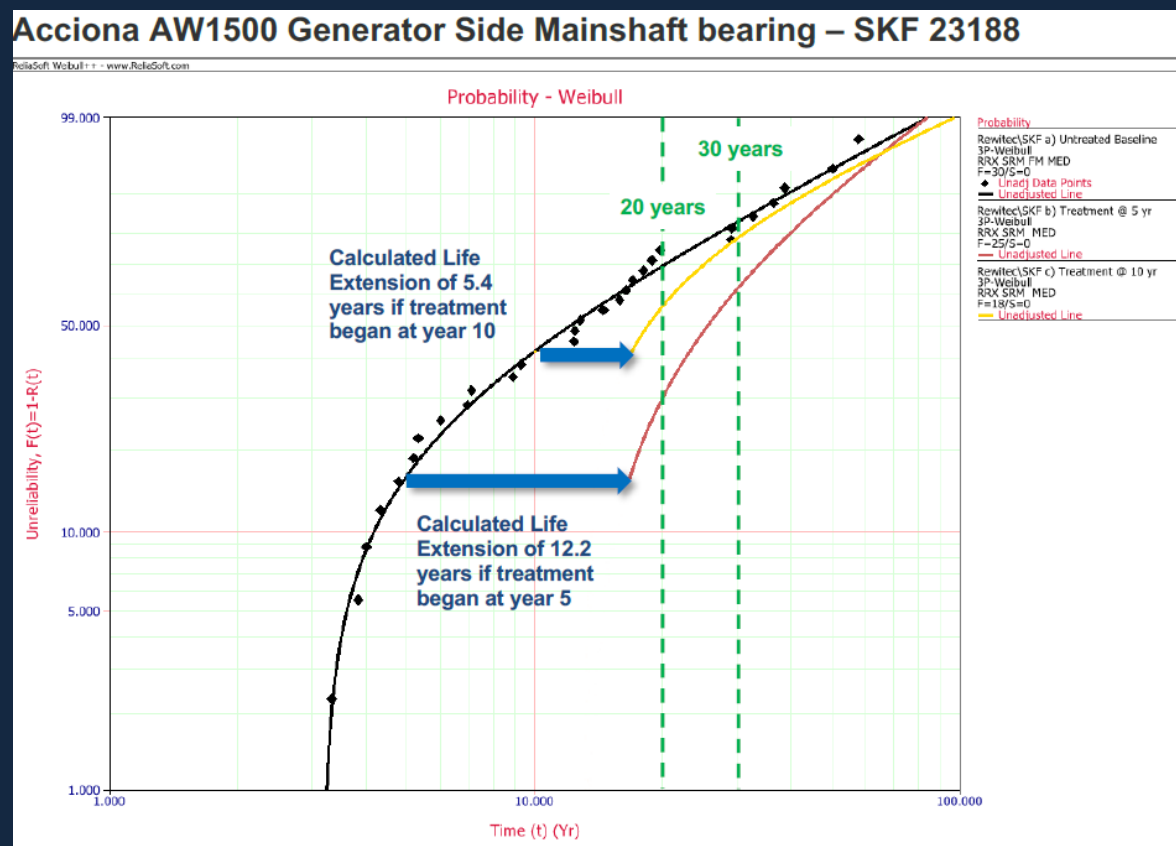
Sentient Science Lifetime Calculation

⇒ Calculation based on bearing geometry, friction coefficient and surface topography:



Sentient Science Lifetime Calculation

⇒ Mainshaft Bearing Life Extension by REWITEC™
GR400 Grease using Sentient Science' DigitalClone®



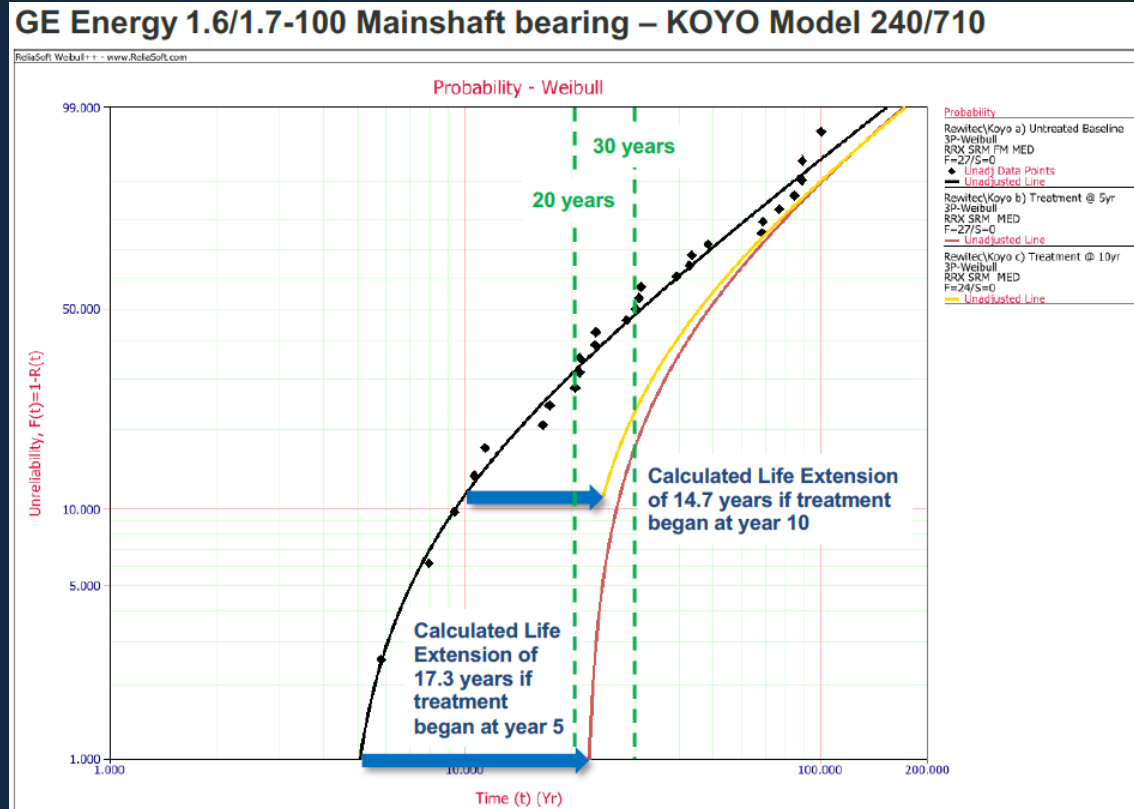
⇒ Results:

- ⇒ Significant reduction in the probability of failure of a main bearing by REWITEC™
- ⇒ Less roughness
- ⇒ Less friction
- ⇒ More even load distribution
- ⇒ Lower local pressure/stress

⇒ The earlier the application, the greater the effect

Sentient Science Lifetime calculation

⇒ Mainshaft Bearing Life Extension by REWITEC™ GR400 Grease using Sentient Science' DigitalClone®



⇒ Results:

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Romax technology

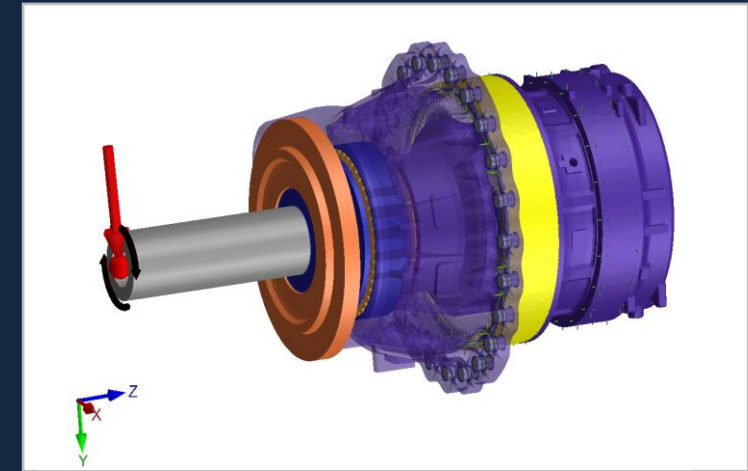
⇒ Bearing life study by Romax
DT software, using ISO
16281 standard



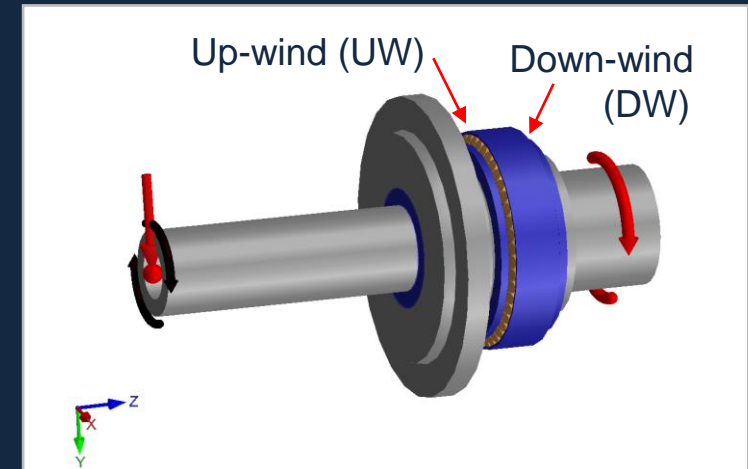
Romax technology Bearing life study

Assumptions:

- ⇒ Main bearings are FAG F-573405 single-row taper roller bearings
- ⇒ Lubricant is Mobil SHC 681 WT Grease
- ⇒ ISO 4406 contamination code – Normal Cleanliness
- ⇒ Temperature = 70 degrees C
- ⇒ Viscosity ratio and contamination factor calculated according to ISO 281
- ⇒ L1 life calculated corresponding to 99% reliability, using a1 modification factor of 0.25



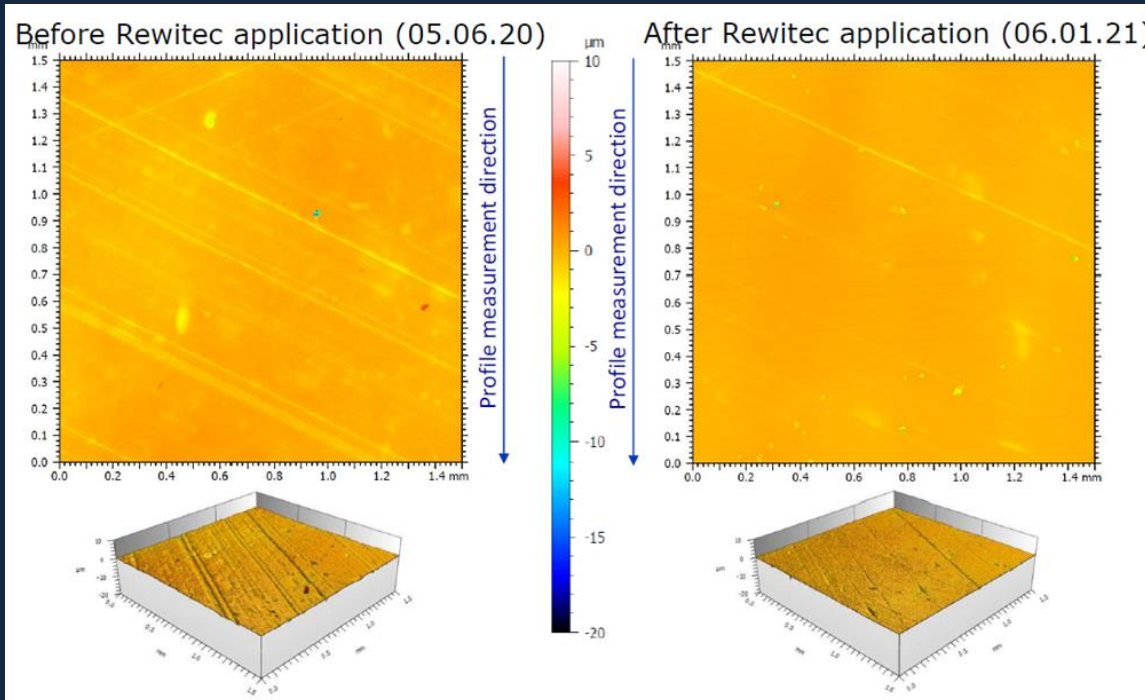
- ⇒ The full WT2000 model simplified version used for the analysis



- ⇒ Simplified version used for the analysis

Romax Bearing life study

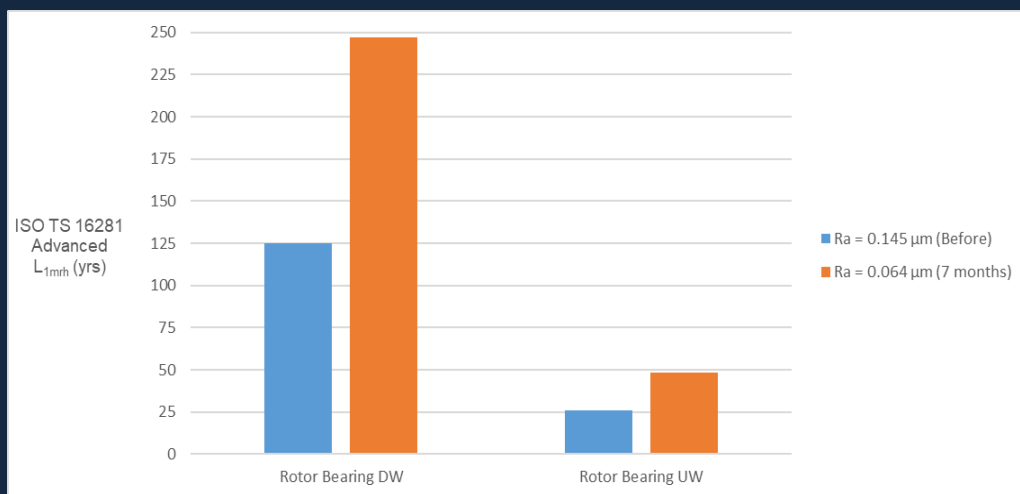
⇒ Surface roughness values before and after the REWITEC grease application



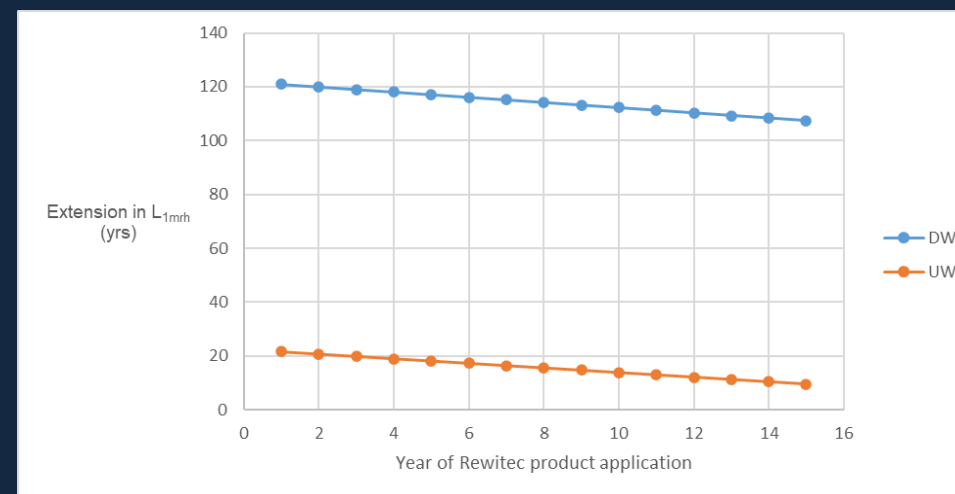
Roughness	Before	After	Difference
S_a	0.266 µm	0.159 µm	- 40 %
S_z	22.2 µm	11.6 µm	- 48 %
R_a	0.145 µm	0.064 µm	- 56 %
R_z	1.31 µm	0.767 µm	- 41 %

Romax Bearing life study

⇒ Mainshaft Bearing Life Extension by REWITEC™ GR400 Grease using Romax DT software



⇒ L₁ life of main bearings



⇒ Life extension of main bearings

	Original life (yrs)	Rewitec application at 5 years		Rewitec application at 10 years	
	- Ra = 0.145 µm	Extended life (yrs)	Life extension (years (%))	Extended life (yrs)	Life extension (years (%))
DW	125	242.1	117.1 (93%)	237.2	112.2 (90%)
UW	26	44.2	18.2 (70%)	39.9	13.9 (53%)

Conclusion

Conclusion

- ⇒ Less surface roughness, friction and temperature in the drive train system means:
 - ⇒ Less stress and wear for the gearbox and bearings
 - ⇒ Less stress for the lubricants
 - ⇒ Repairing and protection effect
 - ⇒ Higher efficiency
 - ⇒ Higher reliability and availability, no downtime
 - ⇒ Significant lifetime improvement
 - ⇒ Cost savings, higher earnings



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imprinting



Component damage
analysis and reporting



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including up-tower
inspections

Recommendations, partners and customers





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If you need more support – Please contact us.

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