Reducing wind turbine gearbox and bearing failures

Words: Nick Weldon, Technical Marketing Manager, Croda Europe Ltd

Around the year 2000, wind turbines of around 1MW and 70m in diameter were common but 20 years later, giants are now being installed. This is especially so offshore, where barriers to installation are lessened. Siemens Gamesa's latest 14MW offshore wind turbine, with its 222-meter rotor diameter, dwarfs its immediate predecessors and even larger turbines are planned[1].

A 14 MW wind turbine can power around 9,000 homes and so as wind turbines get larger, the effect of any breakdown is magnified by the immediate loss of significant generating capacity. Wind farm owners want to maximise their return on investment and so want to have turbines with the best possible uptime, reduce maintenance and replacement costs, and to minimise any failures and unplanned maintenance.

Historically, wind turbines have had reliability issues, with multiple studies indicating both gears and bearings having a significant impact on reliability[2,3,4]. While improvements have been made, a recent review found that gearbox problems could be attributed to about 0.2 and 0.6 failures per wind turbine per year onshore and offshore respectively[5]. This means for a farm of 500 turbines, one wind turbine gearbox can be expected to fail onshore, and about three offshore in any one 5-year period.

Costs come not just from the need to replace the failed part, but also from the downtime, the labour, planning and logistics. One study estimated the total cost to replace a gearbox to be more than €250,000 with additional costs if the gearbox has to be sent off site to be refurbished and then re-installed at a later date[6].

Why wind turbine gears and bearings fail

There are multiple reasons for failures and can include:

1. High costs of maintenance: one insurer reported that 25% of all insurance claims are linked to poor maintenance with high costs cited as a reason why owner/operators skip essential work[7].
2. Extreme forces within individual components, coupled with massive variations in output, can cause loads to be concentrated on specific areas, putting additional strain on already stressed parts.

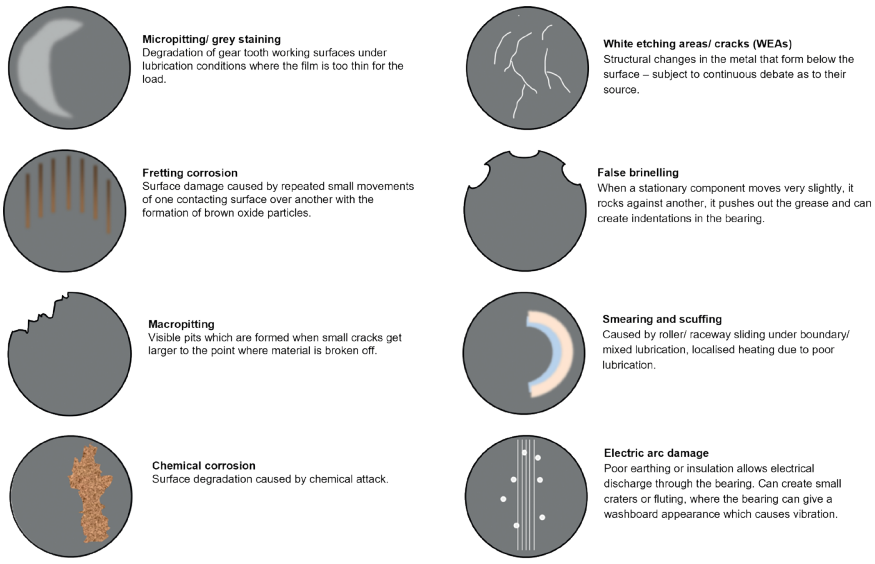

Figure 1: some of the main damage and failure modes within wind turbine gears and bearings

3. Environmental factors such as rain and salt ingress contaminating lubricating oils and greases.
4. Extreme temperature changes altering seal performance.

These factors can cause specific wear patterns to develop; figure 1 details some of the main damage and failure modes within wind turbine gears and bearings.

More modern turbines have software to monitor their performance so potential issues can be spotted earlier. But what are the options to repair equipment once potential or actual damage has been identified? One option that has already been applied to more than 3000 turbines globally is to use REWITEC™ as an alternative to repair, replacement or taking the wind turbine out of service completely.

REWITEC™ surface technology

REWITEC is a lubricant concentrate that is added up-tower, directly to the existing wind turbine oil or grease and helps to maximise return on investment.

The patented silicate technology creates a protective layer on the surface of lubricated components, smoothing the surface, reducing friction, wear, surface roughness and temperatures. This translates to a longer lifetime for gears and bearings for both onshore and offshore wind turbines. REWITEC technology can be used in all lubricated moving parts of a wind turbine and is suitable for both gear oils and greases.

REWITEC products have been extensively tested by independent third parties. Treatments for the gearbox oil, as well as the greases used within all wind turbine bearings are available. REWITEC can also be used preventively: the reduction in friction and the resulting smoothing of the surfaces prevents damage and increases service life even in new or nearly new drivetrains.

Effects of REWITEC on wind turbine components

The positive effect of REWITEC has been measured by analysing component surfaces directly up tower. To quantify the effect, surface imprints are taken; these allow the roughness and damage of the metal surfaces of a component to be analysed away from the wind turbine and allows comparison before and after treatment. Two examples from operating wind turbines are shown below.

Before REWITEC application | 6 months after REWITEC application

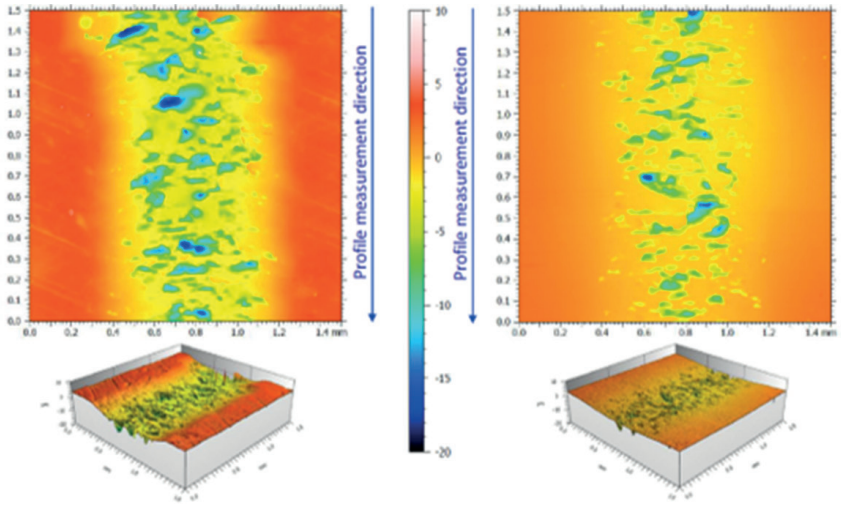

Figure 2: Main bearing surface of a 1.5 MW wind turbine before and 6 months after REWITEC application

Before REWITEC application | 3 months after REWITEC application

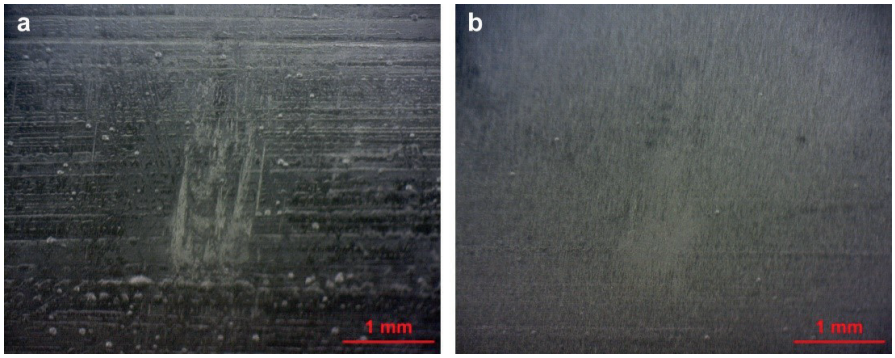

Figure 3: Tooth flank imprints of the high-speed shaft in a wind turbine before and 3 months after the application of REWITEC

Bearing Repair

Figure 2 shows how REWITEC improved the condition of the surface of a 1.5 MW wind turbine main bearing. Roughness has been reduced by more than 50%; the surface is more uniform, which leads to better load distribution and reduced stress on the component. This improves the main bearing reliability and lifetime.

High-speed shaft gear repair

The same imprint technique was used to analyse a gear on the high-speed shaft of a 1.5MW wind turbine. Figure 3 displays a micrograph of the imprint before and three months after treatment with REWITEC. The first imprint (a) was taken before the application of REWITEC. It shows running traces and notable micropitting. The second imprint (b) was taken three months after the treatment. The same area of the tooth flank is clearly visible: The micropitting is repaired and there are no running traces. There is a significant improvement in the surface condition, and this ensures that loads are spread more evenly, and surfaces are protected from additional stress and wear.

Effects of REWITEC in laboratory-based tests

Gears

As well as analysing in the field, laboratory tests have been carried out to understand how REWITEC performs in a controlled environment. A '2disk' test rig from Optimol Instruments was used in order to understand how REWITEC affects friction. The 2disk is an industry standard testing system that allows very high loads to be applied to moving metal

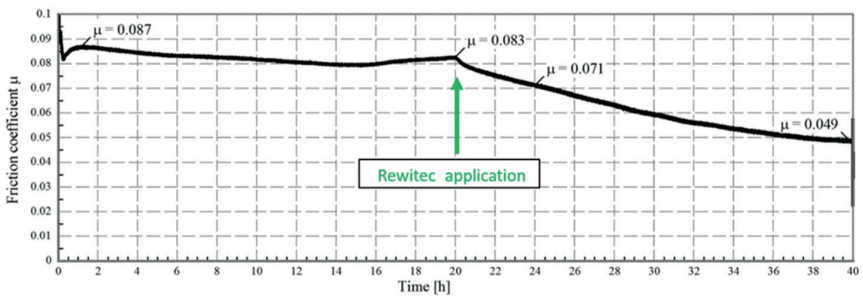

Figure 4: Friction measurement in industry standard wind turbine gear oil with REWITEC added after 20 hours using a 2disk test rig

Disk surface without REWITEC

Disk surface with REWITEC

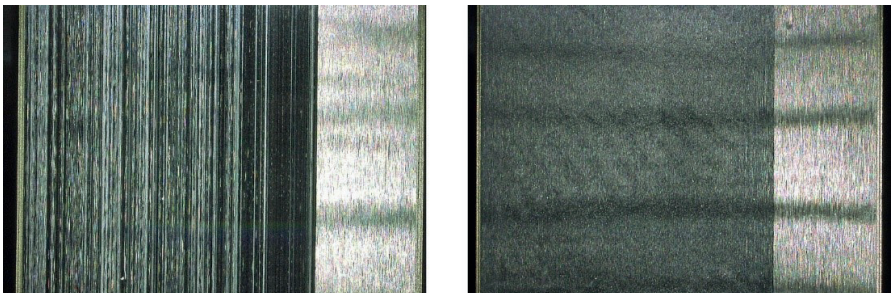

Figure 5: An example of the typical surfaces treated on a 2disc test rig with and without the addition of REWITEC

surfaces, replicating the extreme forces experienced by wind turbine components.

The system tested was set up to replicate the forces experienced in a wind turbine gearbox with an industry standard wind turbine gear oil. Figure 4 shows how friction was reduced by 40% after REWITEC was introduced to the system; REWITEC significantly reduces friction, wear and surface roughness.

Figure 5 displays the discs from the test. REWITEC significantly reduces surface roughness.

Wind turbines do not just suffer damage while they are moving and generating. Standstill damage, caused by vibration when stationary, is the result of small movements occurring back and forth within the drivetrain. The small movement range prevents the lubricant from working, causing false brinelling and fretting damage (as shown in figure 1). Adding REWITEC optimises the existing standard lubricants: the technology adheres to the steel surface of component and protects it, even if it experiences poor lubrication.

Figure 6 shows how REWITEC products protect the surface during a false brinelling tests, and reductions in wear of up to 75% were measured.

Bearings

In order to understand the effect of REWITEC on bearings, a specialised friction testing system called a mini traction machine (MTM) was used in a series of tests. Bearings have a complex set of movements within a wind turbine that can be a mixture of rolling and sliding.

Figure 7 shows the measured friction with and without REWITEC in a standard wind turbine grease across a range of rolling and sliding conditions. The level of friction was reduced by up to 40%.

REWITEC was also tested in another industry standard wind turbine gear oil using an FE8 test. This is a specialist bearing test, designed to determine the wear behaviour of lubricants on roller bearings and using it, the effect of REWITEC on surface roughness was measured. Figure 8 shows the results after profilometry analysis with and without treatment with REWITEC. With the REWITEC treatment (right image), the metal surface is smoother and less damaged. This leads to a better load distribution and longer bearing life. A reduction in wear of 20 % was measured. Figure 9 shows photographs of the same metal surfaces. The left image shows much deeper wear tracks compared to the surface lubricated with a REWITEC treated oil.

Surface without REWITEC

Surface with REWITEC

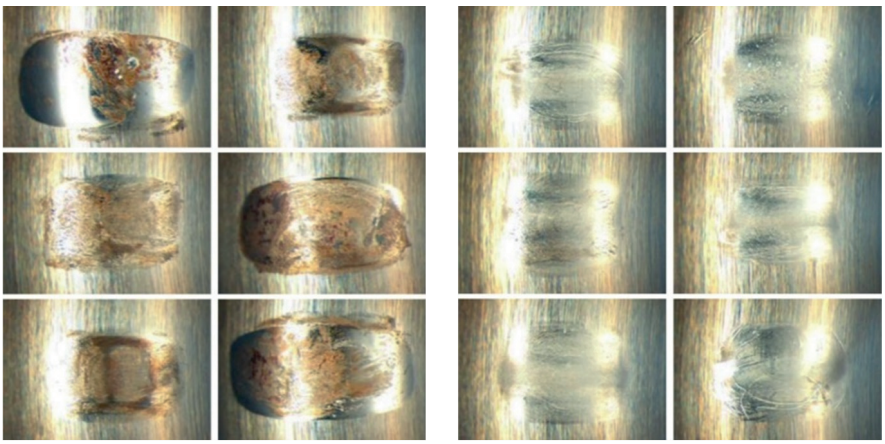

Figure 6: Standstill damages generated with a false-brinelling-test without and with the addition of REWITEC.

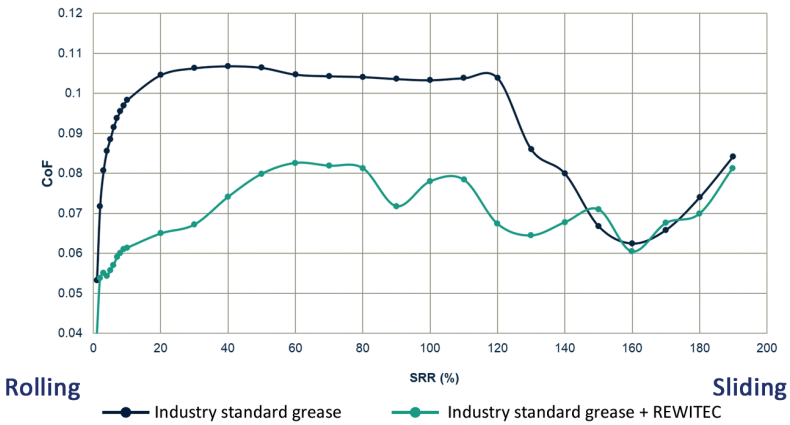

Figure 7: Coefficient of friction at different rolling/sliding ratios in industry standard wind turbine grease without (blue) and with (green) REWITEC.

> ‘Wind turbine owners and operators want their turbines to generate as much of the time as possible, to reduce maintenance costs and to prevent failures.’

Surface profile without REWITEC

Surface profile with REWITEC

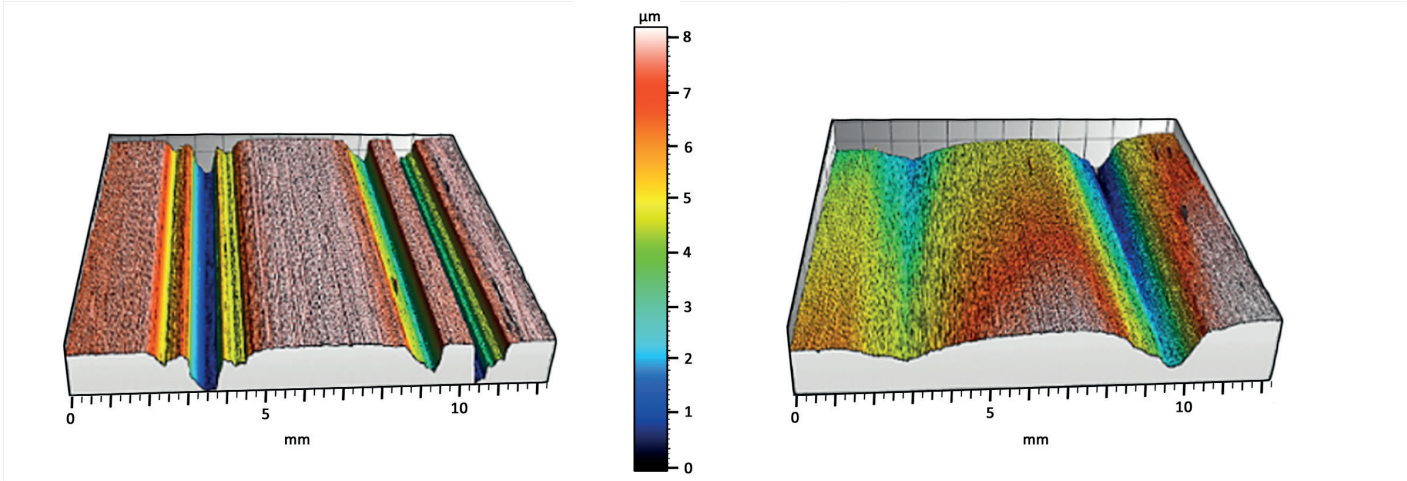

Figure 8: Profilometry analysis of the metal surface after the FE8 test in an industry standard wind turbine gear oil without and with REWITEC

Conclusion

Gears and bearings are not the least reliable component in a wind turbine, but when they fail, they cause significant downtime and repairs can be extremely expensive. Wind turbine owners and operators want their turbines to generate as much of the time as possible, to reduce maintenance costs and to prevent failures.

REWITEC lubricant concentrate products repair existing damage in wind turbine gears and bearings and protects the system for the future. Through surface modification, roughness is significantly reduced, which leads to lower local loads and stresses on lubricated components. It is simple and quick to apply as it is added directly to the existing wind turbine oil or grease, up-tower.

https://www.crodaenergytechnologies.com/en-gb/brands/rewitec

Disc surface without REWITEC

Disc surface with REWITIC

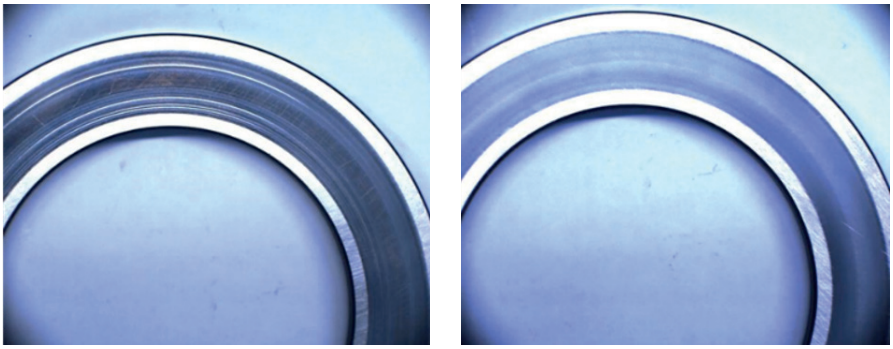

Figure 9: Photographs of the metal surface after the FE8 test in an industry standard wind turbine gear oil without and with REWITEC.

1 https://www.greentechmedia.com/articles/read/siemens-gamesa-takes-worlds-largest-turbine-title

2 https://grd.nrel.gov/#/stats Accessed 18th June 2021.

3 Final Publishable Summary of Results of Project ReliaWind, ReliaWind Project Nr 212966. Available at https://cordis.europa.eu/project/id/212966/reporting. Accessed 14th June 2021.

4 NREL Gearbox Reliability Collaborative Update, Sheng, Keller & Glinsky, 2013

5 Dao, Kazemtabrizi, & Crabtree (2019). Wind Energy. 2019;22: 1848–1871

6 https://www.windpowermonthly.com/article/1086978/gearbox-repair-market-continues-grow Accessed 14th July 2021.

7 http://www.gcube-insurance.com/news/gcube-top-5-us-wind-energy-insurance-claims-report/ Accessed 14th June 2021