Wind turbine energy generation: reliability problems and solutions

Wind turbine reliability remains an issue

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While wind is enjoying significant growth, studies confirm that wind turbines suffer from reliability issues: The EU's RELIAWIND study found that electrical systems accounted for the highest failure rate, but gearbox failures accounted for the highest amount of downtime (14 days)[1].

The National Renewable Energy laboratory found that the majority of wind turbine gearbox failures are caused by bearings (76.2%) and gears (17.3%)[2]. Figure 1 displays the annual failure rate and downtime per failure by component.

The costs of maintenance

Maintenance is essential to prevent failures but ongoing operation and maintenance is costly, representing around 25% of the total cost of the wind turbine over its lifetime[4]. These high costs cause some wind turbine owners to skip maintenance: Insurer G-Cube cited the top cause of a claim as poor maintenance, at 24.5% of total claim costs, with claims involving gearbox failure costing on average $380,000 to rectify[5].

Introducing REWITEC

Here we present our technology, REWITEC,

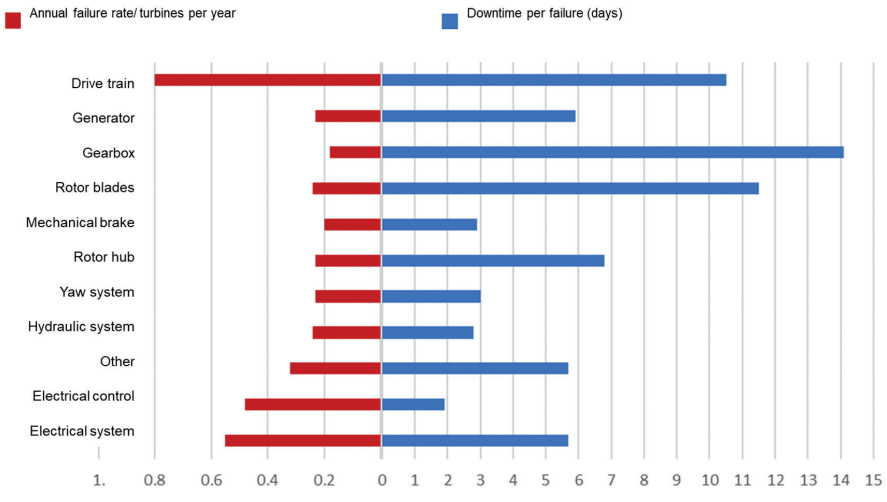
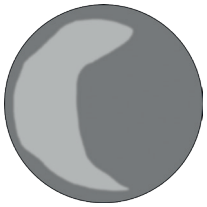


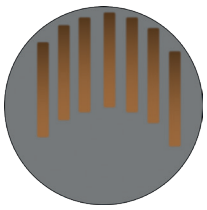
Figure 1: Annual failure rate and downtime per failure by component, adapted from[3]

Some common damage modes in wind turbines gearboxes and bearings



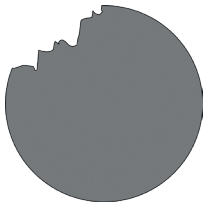
Micropitting/ grey staining

Degradation of gear tooth working surfaces under lubrication conditions where the film is too thin for the load.



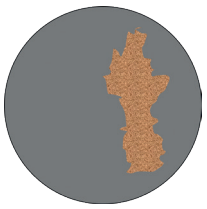
Fretting corrosion

Surface damage caused by repeated small movements of one contacting surface over another with the formation of brown oxide particles.



Macropitting

Visible pits which are formed when small cracks get larger to the point where material is broken off.

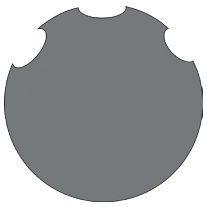


Chemical corrosion

Surface degradation caused by chemical attack.

White etching areas/ cracks (WEAs)

Structural changes in the metal that form below the surface – subject to continuous debate as to their source.

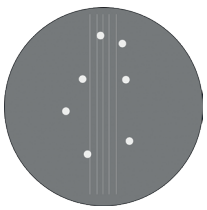


False brinelling

When a stationary component moves very slightly, it rocks against another, it pushes out the grease and can create indentations in the bearing.

Smearing and scuffing

Caused by roller/ raceway sliding under boundary/ mixed lubrication, localised heating due to poor lubrication.



Electric arc damage - caused by poor earthing or insulation allow electrical discharge through the bearing. Can create small craters or fluting, where the bearing can give a washboard appearance which causes vibration.

a microparticle-based lubricant additive that has been proven to repair existing damage and protect the system for the future, improving reliability in wind turbine gears and bearings.

A lifespan of 20 - 30 years is expected for commercial wind turbines. During use, both the gearbox and bearings are affected by wear, to the extent that these components must be replaced over the life of the wind turbine. These replacement components are associated with downtime and loss of generating capacity as well as significantly increasing operation and maintenance costs.

Part of Croda International plc, REWITEC GmbH is a medium-sized German company. We offer an efficient solution for the problems described above. REWITEC develops innovative and patented technology consisting of phyllosilicates in the form of micro and nano particles with several other additives that have a protective and repairing effect.

The particles use lubricant as a carrier to reach the rubbing metal surfaces and to coat damaged areas by adsorption. The new, modified surface is optimized and protected from a tribological point of view, so that surface roughness, friction, wear, and temperature in the system are reduced. This leads to a significant improvement in efficiency and lifespan. In addition to surface protection, the technology reduces friction and thus also the temperature in gearboxes and bearings. REWITEC is being used worldwide, especially in the wind energy sector and we are growing each year.

Based on our more than a decade in the wind industry and having supplied more than 3000 wind turbine treatments, we provide assistance to our customers around the world to address such issues as pitting, run through marks, downtime damage and many other risk factors that can cause wind turbine breakdowns. We offer bespoke solutions, on-site application, and pre- and post-application surface analyses.

REWITEC in action: laboratory test results

Here we focus on independent third-party tests which have been performed with conditions similar to the those found inside wind turbine bearings and gears.

Friction reduction in gears.

The friction process in gears can be simulated by the 2-disc assembly bench with rolling friction with a slip of 20 %. Therefore, numerous tests with different gear oils in combination with REWITEC were tested in this configuration at the University of Mannheim, Germany. These include oils by Castrol, Mobilgear, Klüber, Fuchs, Amsoil and Shell and were analyzed with and without REWITEC. Results show that REWITEC significantly reduces friction, wear, and surface roughness. Figure 2 shows a friction measurement in Fuchs Pentosin EG FFL-7A oil with REWITEC added after 20 hours. The measurement was performed at 60°C with a load of 1 GPa and rotation speeds of 424 rpm / 339 rpm (20 % slip).

A friction reduction of 41 % was achieved by adding REWITEC. The surface analysis of the contact surfaces from the 2-disc tests also shows a protective and repairing effect of REWITEC, so that the surface roughness is significantly reduced, and the surface topography is smoother, leading to a reduction of local load, tribological stress and temperature.

Surface protection in bearings

Standstill damage is a common problem in wind turbines. This occurs in systems where vibrations appear when stationary. Although common lubricants help reduce the damage, they cannot prevent it because of the very poor lubrication due to lack of movement in the system. Adding REWITEC to the lubrication system optimizes classic lubricants: Our silicon-based nano- and micro-particles adsorb onto the steel surface and remain there, even if the lubrication is deficient. We have scientifically analyzed the behaviour of REWITEC-particles through the false-brinelling-test. The experiment results show a significant wear reduction of up to 76%.

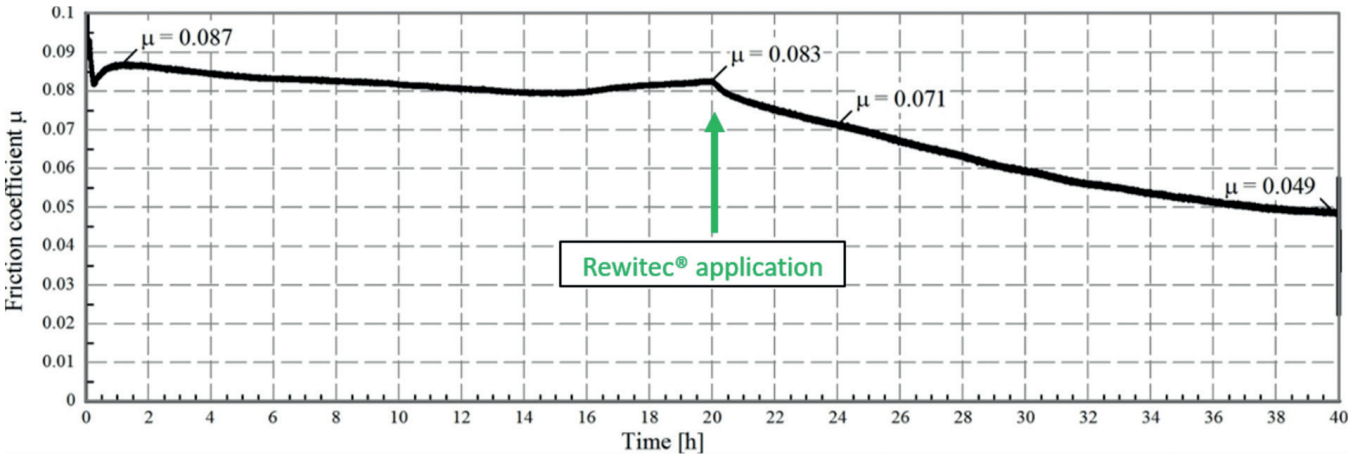


Figure 2: Friction measurement in gear oil Fuchs Pentosin EG FFL-7A with REWITEC® added after approx. 20 hours.

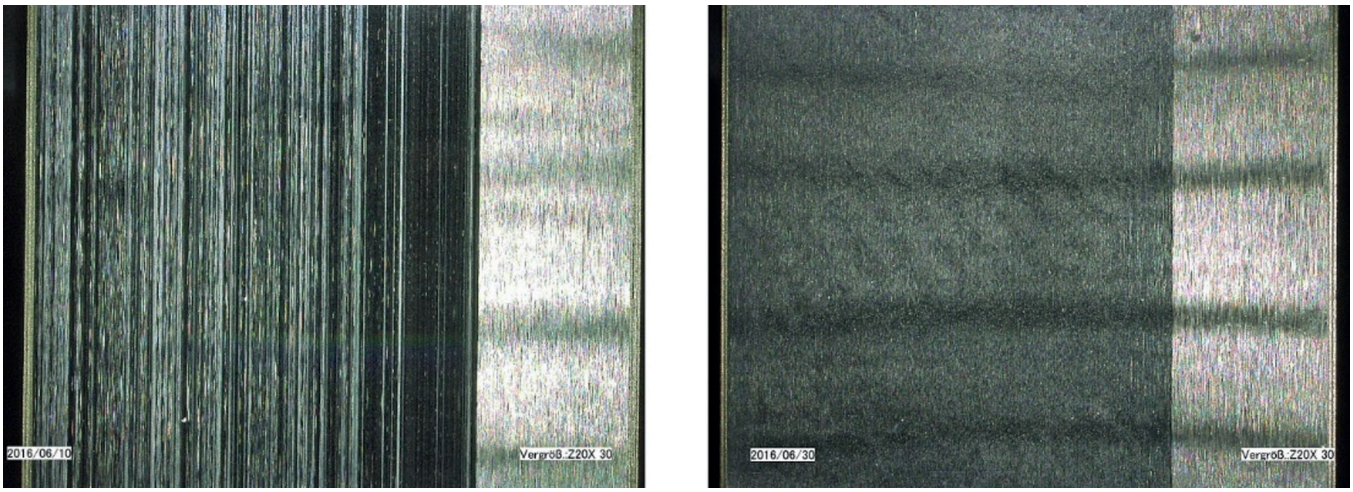


Figure 3: An example of the typical surfaces treated on a 2-disc assembly bench without (left) and with REWITEC (right).

Figure 4: Standstill damages generated through a so called false-brinelling-test without (left) and with (right) the addition of REWITEC.

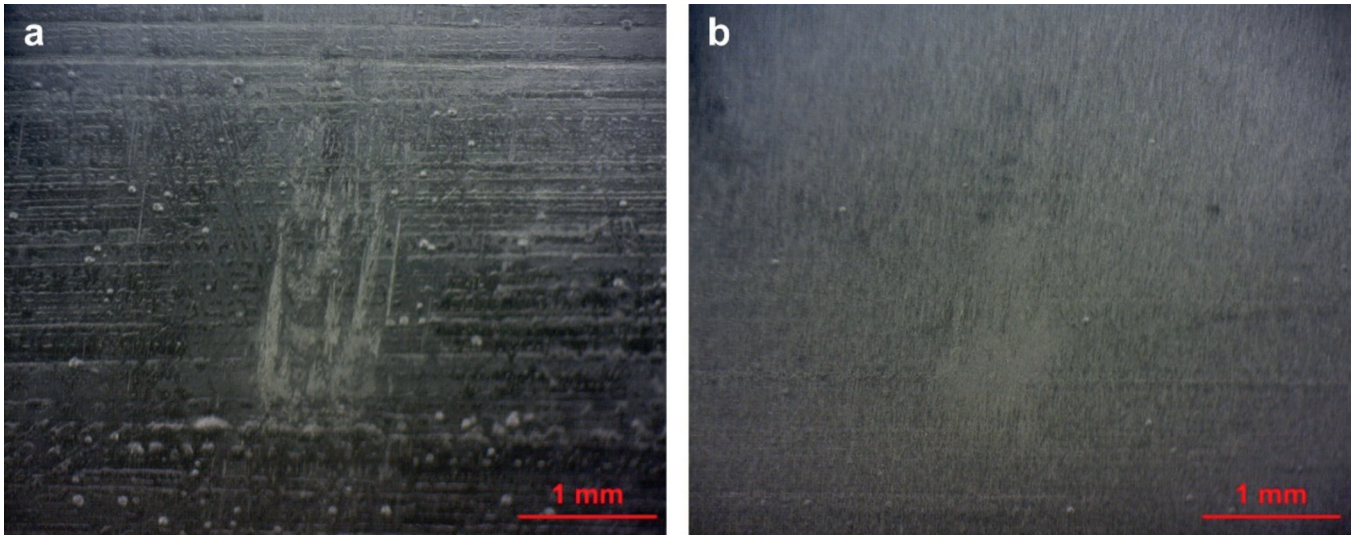


Figure 5: Tooth flank imprints of the high-speed shaft in a wind turbine before (A) and 3 months after the application of REWITEC (B).

REWITEC in action: field tests

It is necessary to analyse and to compare the steel surfaces in the system before and after the treatment. We use replica set technology by REWITEC to perform the surface analysis of gears or bearings by making imprints of areas of the surface with high precision and reliability. The subsequent analysis of the imprints with light microscopy provides valuable tribological information about the surface condition.

Tooth flank surface damage on a high-speed shaft

Figure 5 displays the tooth flank surface of a high-speed shaft in a 1.5MW wind turbine. The first imprint (A) of the high-speed shaft was taken before the application of REWITEC. It shows running traces and notable micro pitting. The second imprint (B) was taken three months after the product application. The same area of the tooth flank is clearly visible: Micro pitting is repaired and there are no running traces. There is a significant improvement in the surface condition. This surface modification ensures more homogenous load distribution in the system and this protects the surfaces. The REWITEC application was successful and achieved its aim: repairing and the protection of surfaces.

Main bearing damage

The main bearing from a 1.5 MW GE wind turbine was analysed (Figure 6). To analyse the wear development over a period of one year, we made several surface imprints. The roughness before treatment was R_a = 0.556 µm. Five months after the application, the roughness was reduced by 28 % to R_a = 0.403 µm. At the third measurement 12 months after application, roughness was reduced by 60 % to R_a = 0.225 µm. We show that the structure and roughness of the surfaces are significantly improved. That means less stress on the mechanical components and a substantial increase in the lifetime.

Conclusion

Wind turbines form a cornerstone of the world's efforts to reduce carbon emissions from electricity generation. Wind turbine technology is maturing, and prices are reducing, but the technology still suffers from reliability issues. 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.

REWITEC technology repairs 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 lower tribological stress. These effects provide a longer lifetime, better reliability, and higher efficiency, thus making wind turbines last longer.

www.REWITEC.com

[1] Final Publishable Summary of Results of Project ReliaWind, ReliaWind Project Nr 212966

[2] https://grd.nrel.gov/#/stats

[3] NREL Gearbox Reliability Collaborative Update, Sheng, Keller & Glinsky, 2013

[4] https://www.irena.org/documentdownloads/publications/re_technologies_cost_analysis-wind_power.pdf

[5] http://www.gcube-insurance.com/news/gcube-top-5-us-wind-energy-insurance-claims-report/

Figure 6: Main bearing imprints of wind turbine GE1.5 MW before (left), 5 months after the application of REWITEC (middle) and 12 months after the application of REWITEC (right).