Drivetrain reliability collaborative seeks gearbox failure causes, solutions

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Wind plant operators disassemble and inspect a General Electric Transportation System wind turbine gearbox for damage. NREL researchers are working to understand and develop solutions to gearbox failures. Credit: Jonathan Keller, NREL

On the outside, wind turbines appear as sleek, minimalist structures that punctuate rolling hillsides. But inside many wind turbines, a gearbox is hard at work converting the relatively slow rotations of the turbine's blades into the high speeds needed to generate electricity in a cost-effective manner.

Gearboxes are designed to do this important work for 20 years or more, but often, they must be repaired or even completely replaced several years earlier. The most common reason for this is a failure mode attributed to axial or white-etching cracks (WECs) in the rolling-element bearings inside a gearbox.

Because they lead to unplanned maintenance, downtime, and higher-than-anticipated costs at wind power plants, gearbox failures will continue to cause problems for wind plant operators as wind turbines increase in size and are installed offshore.

That is why, with funding from the U.S. Department of Energy Wind Energy Technologies Office, National Renewable Energy Laboratory (NREL) and Argonne National Laboratory (Argonne) researchers have teamed with industry partners such as SKF, Winergy, General Electric, and Afton Chemical to understand the causes of axial cracking, create a design life equation that accounts for it, and develop and validate solutions to reduce this and other causes of gearbox failure.

"We're trying to figure out the main driver of axial cracking," said

Jonathan Keller, a senior engineer at NREL and principal investigator of the Drivetrain Reliability Collaborative. "A combination of factors is probably at play, but which is most important? Which causes axial cracking to happen fastest? And which of these causes can we most easily correct?"

NREL researchers replace an existing gearbox (front) with a fully instrumented Winergy gearbox and SKF main bearing in the U.S.-Department-of-Energy-owned GE 1.5-megawatt wind turbine at NREL's Flatirons Campus. Credit: Dennis Schroeder, NREL

To reproduce the phenomenon in a lab, Argonne researchers used a benchtop testing rig to simulate rolling and sliding between the roller and inner ring within the bearing. Under a typical load, this sliding resulted in axial cracking. The team also determined that certain chemical additives in the lubricant, and separately, the presence of electrical current across the bearing surface, can also contribute to this axial cracking failure.

One promising theory is that axial cracking is related to dynamic operating conditions in wind turbines that can result in high bearing stress and slip of the rolling elements. To create and measure these conditions, Keller and other NREL researchers outfitted a 1.5-megawatt wind turbine at NREL's Flatirons Campus with tailored instrumentation to gather experimental data at scale.

"Our findings confirmed that bearing slip under heavy loads occurs during wind turbine operations as a result of factors such as bearing design, load, speed, lubrication, and temperature," Keller said. "Using these data, we developed a roller sliding model that is scalable to different turbine and gearbox platforms and a probability of failure model that fills an industry gap in evaluating component reliability. Next, we'll work to improve the accuracy of the probability of failure model."

This will include collecting a greater amount of historical data from

plants where failures attributed to WECs have occurred, modeling the data, and adjusting the models to account for the major drivers of WECs. Doing so will allow the team to identify the most viable methods of preventing or minimizing axial cracking.

"Our goal is to ultimately help reduce wind plant operation and maintenance costs and increase wind plant productivity," Keller said. "We invite industry representatives to reach out to us so we can pinpoint exactly what's causing gearbox failures at wind facilities."

More information: Yi Guo et al. Validation of combined analytical methods to predict slip in cylindrical roller bearings, *Tribology International* (2020). DOI: 10.1016/j.triboint.2020.106347

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