T12 - Wind Turbine Drivetrain Reliability Assessment and Remaining Useful Life Prediction (Technology Commercialization Fund - TCF)

Technology RD&T and Resource Characterization - Materials, Manufacturing, and Design Innovation

Shawn Sheng

NREL

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FY21 Peer Review - Project Overview

Project Summary:

- NREL developed a reliability assessment and remaining useful life (RUL) prediction methodology by targeting bearing axial cracking, the top failure mode experienced by gearboxes in the field.
- This project aims to validate the methodology using data collected from one testing wind plant through an industry collaboration, potentially speeding up the technology adoption by the industry.
- The project was awarded in August 2019 and most work reported is conducted in FY20. The period of performance is extended to FY21 to account for delays caused by data sharing from partners.
- Models for tapered roller bearings (TRBs) were developed as a new intellectual contribution from this project.
- Project partners include WindESCo and a turbine manufacturer.

Project Objective(s) 2019-2020:

- Develop physics domain models based on wind plant, turbines, and gearboxes under investigation.
- Preliminary reliability assessment and analysis based on actual supervisory control and data acquisition (SCADA) system data and failure records collected from the testing plant.

Overall Project Objectives (life of project):

- Validation of the reliability assessment and prognosis tools developed by NREL based on testing plant data.

Project Start Year: FY19
Expected Completion Year: FY21
Total expected duration: 2 years

FY19 - FY20 Budget: $67,561

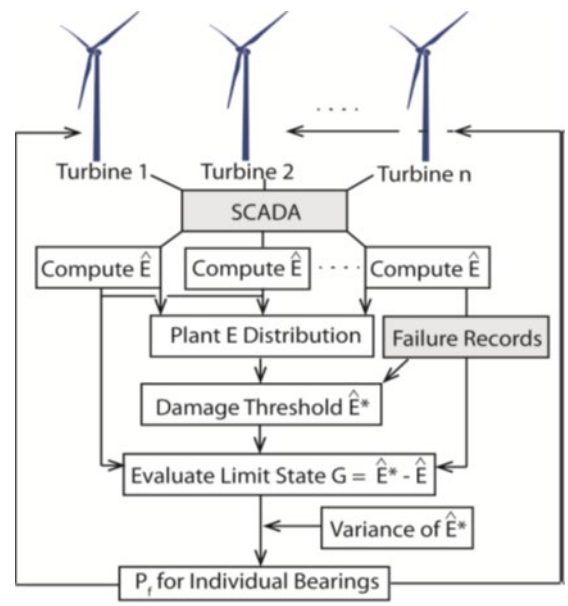Key Project Personnel: Shawn Sheng, Yi Guo, and Lindy Williams

Key DOE Personnel: Mike Derby, Brad Ring, Lillie Ghobrial, and Tyler Christoffel

Project Impact

- **High operations and maintenance cost** for wind industry and can account for 10% (land-based) to 50% (fixed-bottom offshore) of reduction in levelized cost of energy.

- The newly developed modeling tools for tapered roller bearings were an unexpected **intellectual contribution** outside the original project plan, validated against theoretical results and led to a **new software record**.

- Through validation efforts under this project, the reliability assessment and RUL prediction methodology can be **adopted by the industry sooner and more broadly**, leading to reduced cost of energy.

- 6%
- 23%
- 71%
- ■ axial cracks
- ■ spalling
- ■ pitting
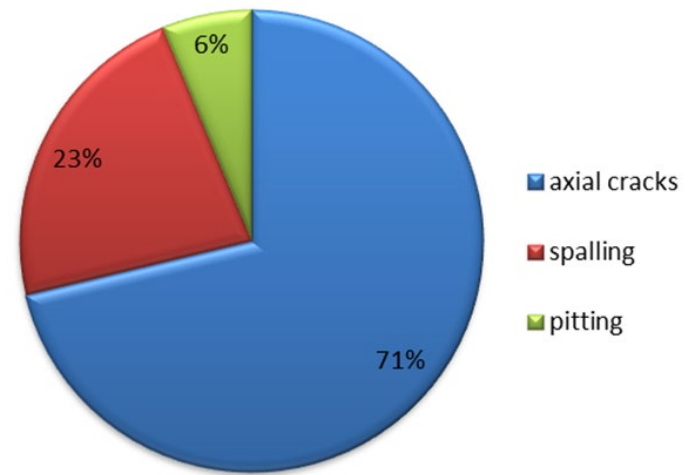
Top Gearbox Bearing Failure Modes

Program Performance – Scope, Schedule, Execution

- ## Scope & Schedule:
  - Added **new model development** for tapered roller bearings
  - **Delayed by data collection** from partners and other industry stakeholders
 - **Extended period of performance** to FY21 and **adjusted milestones** with DOE WETO approval

- ## Execution:
  - **Filled lubricant information gap** by engagement with the lubricant supplier
  - **Efficiently developed the new taper roller bearing models** within a month after all needed data became available
  - **Updated damage threshold** based on actual failure records from the testing site
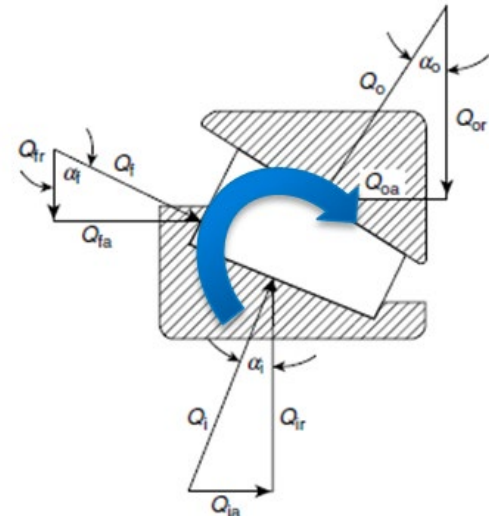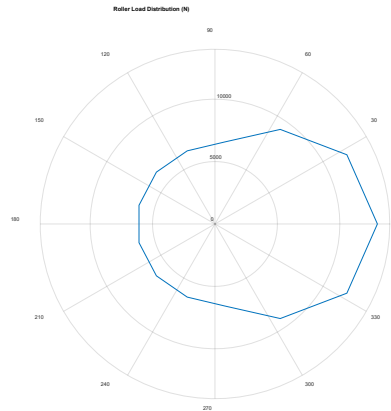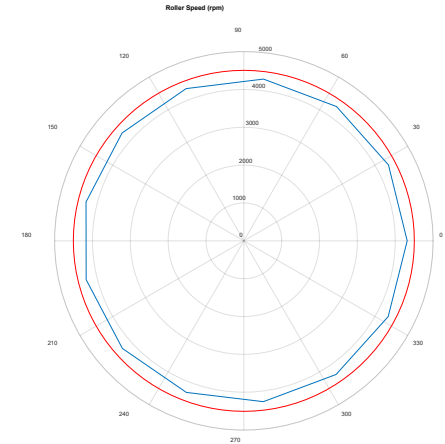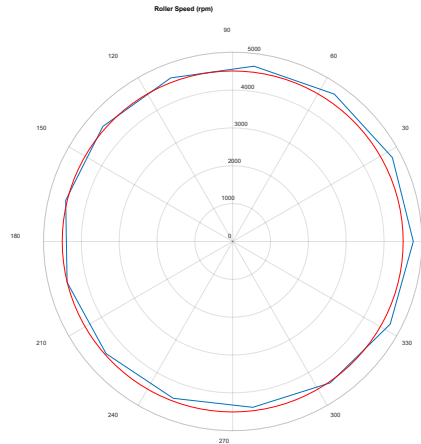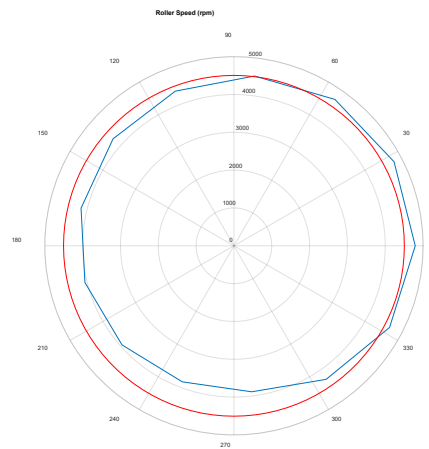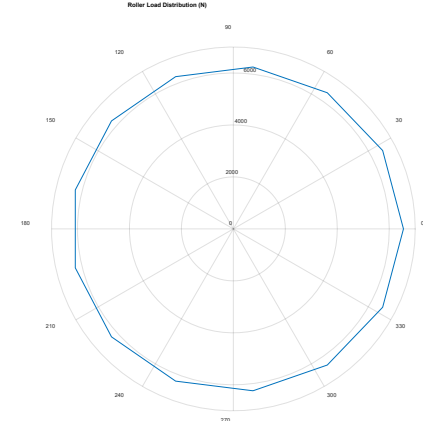
Case 1: Radial Load only
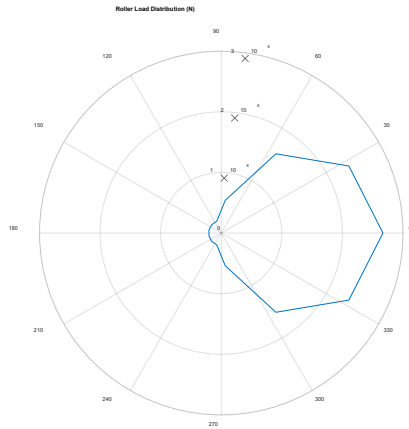
Case 2: Combined Radial/Axial

Case 3: Axial Load only
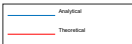
- Theoretical speed is defined as the pure rolling speed
- Good agreements between modeled and theoretical results

Project Performance - Upcoming Activities

- **Two remaining milestones:**
  - Complete gearbox high speed stage bearing reliability assessment and prediction of the investigated wind plant using actual failures rates by Q1, FY21
  - Deliver reliability assessment and prognosis modeling and prediction analysis results to WindESCo and WETO, and complete a project closeout report using DOE Office of Technology Transitions template by Q2, FY21

- **Deliver a public facing presentation** jointly with WindESCo at Drivetrain Reliability Collaborative annual meeting

- **Publish an NREL news story** highlighting this project

- **Continue with validation** of the newly developed models under AOP

- **Explore licensing opportunities** for the physics-domain models with major bearing manufacturers.

Stakeholder Engagement & Information Sharing

- Close engagements with project partner WindESCo and the turbine manufacturer:
  - Data from the testing wind plant shared by both parties
  - Regular project meetings
- Other parties interacted with:
  - Bearing suppliers, a lubricant provider, and wind plant owners and operators.
- Outreach through annual drivetrain reliability meetings and news releases.
- Future scientific publications:
  - Incorporate findings through this project when appropriate.

Key Takeaways and Closing Remarks

- ## Data sharing is extremely challenging in wind industry
  - Even some parties are willing they may not have complete set of appropriate data to support various R&D efforts

- ## Need to regularly check assumptions
  - Cylindrical roller bearings assumed all along until found out to be wrong for the gearboxes investigated at the testing site

- ## It is necessary to convert reliability improvements to monetary metrics with reduced uncertainties to better impact the industry.

Photo by Dennis Schroeder / NREL #21882