Integrated Life Management of Wind Turbine Bolts

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EPRI

MISSION: Advancing safe, reliable, affordable, and clean energy for society through global collaboration, science and technology innovation, and applied research.

Leading Collaborative Energy R&D Around the World

EPRI advances energy technologies and informs decision-making through ~$420M in collaborative annual research involving nearly 400 entities in ~40 countries - spanning the generation, delivery, and use of electricity.

ENGAGING

- Utilities
- Academia
- OEMs
- Regulators

LISTENING

- Financial Community
- Policy Makers
- Consumer Advocates
- Media

EPRI's Approach to Wind Research

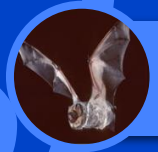
Wind Program

- Flexible & Robust Plant Planning
- Hardware Specs & O&M Strategies
- Reliability & Budget Projections
- Performance & Health Monitoring Algorithms

Environmental Aspects

- Public Acceptance

- Siting & Land Use



- Wildlife Interactions

- End-of-Life Management

Offshore Wind

- Grid Integration and Energy Systems
- Transmission and Collection Systems
- Environmental Aspects
- Wind Generation
- Technology Trends

Integrated Life Management of Wind Turbine Bolts

Blade root-to-pitch bearing (x3)
***AND** Pitch bearing-to hub (x3)*

Hub-to-main shaft

Yaw bearing-to tower top

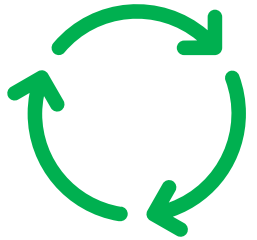
Tower section flanges (x2)

Tower-to-foundation

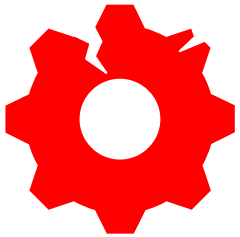
A single wind turbine contains hundreds of fasteners (bolts and studs)

Regular maintenance typically includes:

Break-in
100% pretension check



Annual
10% pretension check



Failure
Extraction & replacement

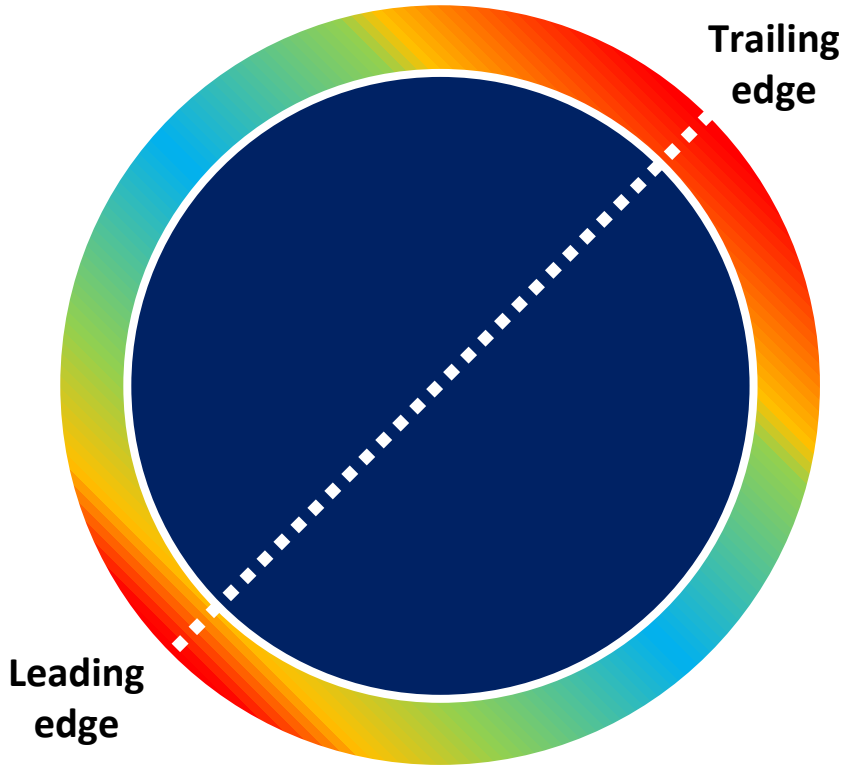
Downtime for a single turbine can be anywhere from 6 hours to **weeks.**

Integrated Life Management of Wind Turbine Bolts

Recently, bolts of newer and larger turbines have been failing at an alarming rate.

Recently failed wind turbine blade root stud, analyzed by EPRI.

Failures are predominant on the leading edge and trailing edge.



- Increased O&M costs
- Increased downtime
- Foreign object damage
- Safety concerns
- Blade liberation
- Negative public perception

Integrated Life Management of Wind Turbine Bolts

Bolt failures have been attributed to many factors!

- Loading
- Joint design
- Bolt design
- Quality specs
- Installation practices
- Maintenance practices
- Combination of any of the above!

Operators trying to mitigate failures

There is a gap in the understanding of the behavior of the blade root-to-hub joint.

! Some turbines are experiencing failures of other components at this joint:

! It's common for manufacturers to update maintenance practices **after installation**.

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- Adhering to recommended (typically yearly) maintenance intervals is useful for avoiding some failure modes, **BUT…**
- There is a need for:
  - ❑ Common QA practices.
  - ❑ Supply chain traceability.
  - ❑ Increased understanding of the dynamics of the blade-root joint.
  - ❑ Understanding of the impact of installation and maintenance practices on fatigue life.

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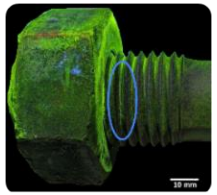
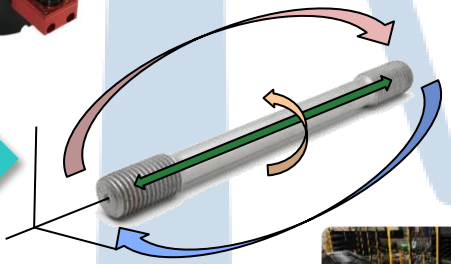
Failure Analysis

Material Analysis



Static Lab Testing

Field Testing



Dynamic Lab Testing

EPRI Approach

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