Assessing Tribological Aspects of Gearbox Reliability in Wind Turbines

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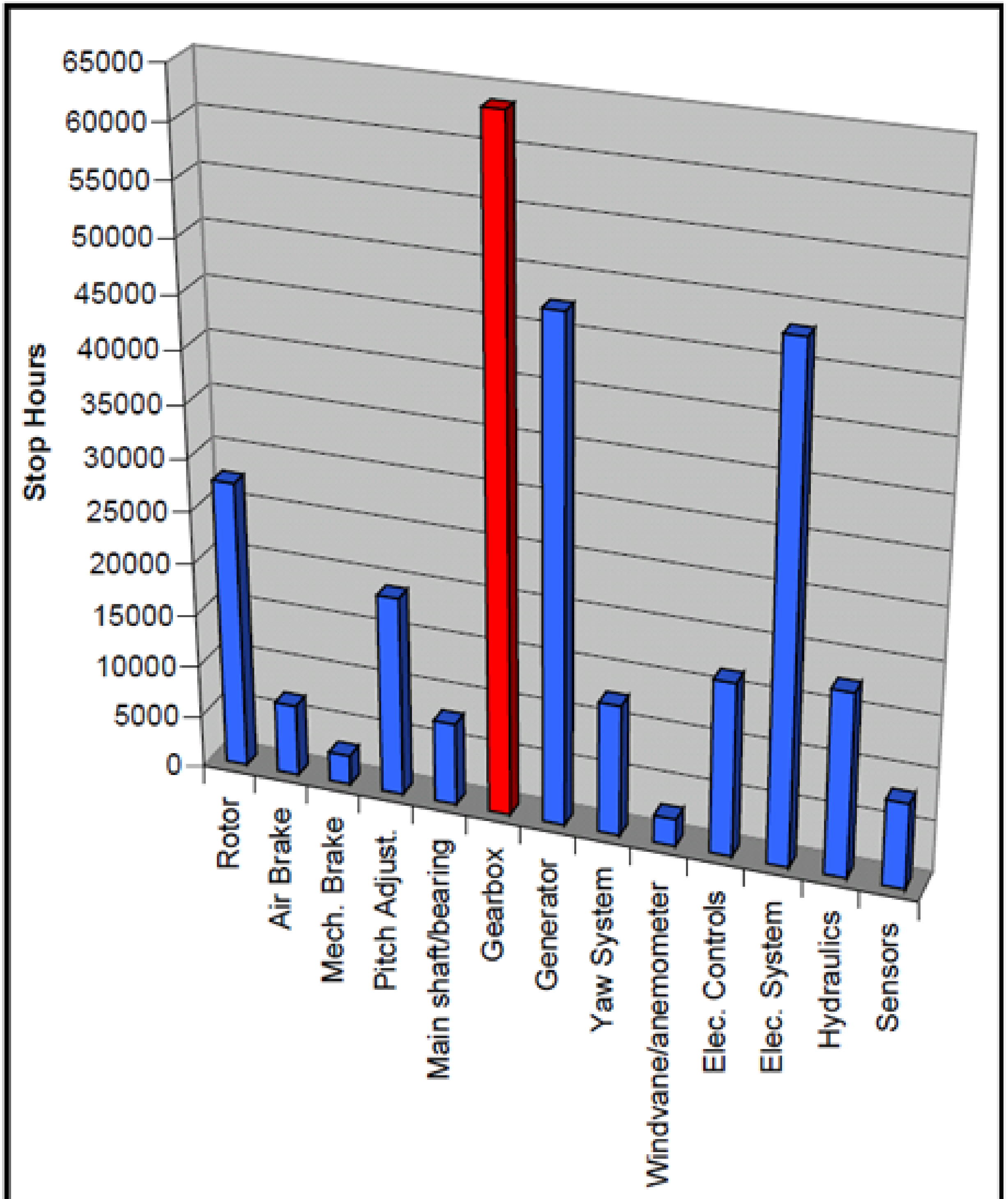
F. Oyague, Drivetrain Modeling, NREL, 2009



Downtime hours accumulated from 2003 to 2007 for wind turbines in Germany

Gearbox failures have substantially increased the cost of wind power; improvements are needed to make the technology ***economically*** competitive.

Gearbox Reliability Collaborative (GRC)

The goal of the GRC is to understand the root causes of gearbox failures.

A primary initiative is the confidential dissemination of information related to field failures for analysis by the group.

Observations of the basic problem
Butterfield, Musial, McNiff

1) Generic - opportunities to collaborate

2) Spans power spectrum-scalable

3) Deficiencies in design, not quality

4) Initiates in bearings, spreads to gears

The goals of this project are to: 1) understand the effects of wind specific factors on the lives of gear-box bearings; 2) identify design solutions for impr-oved reliability of the drivetrain.

Proposed Work

A. Collect relevant load data from NREL Gearbox Reliability Collaborative; Q1

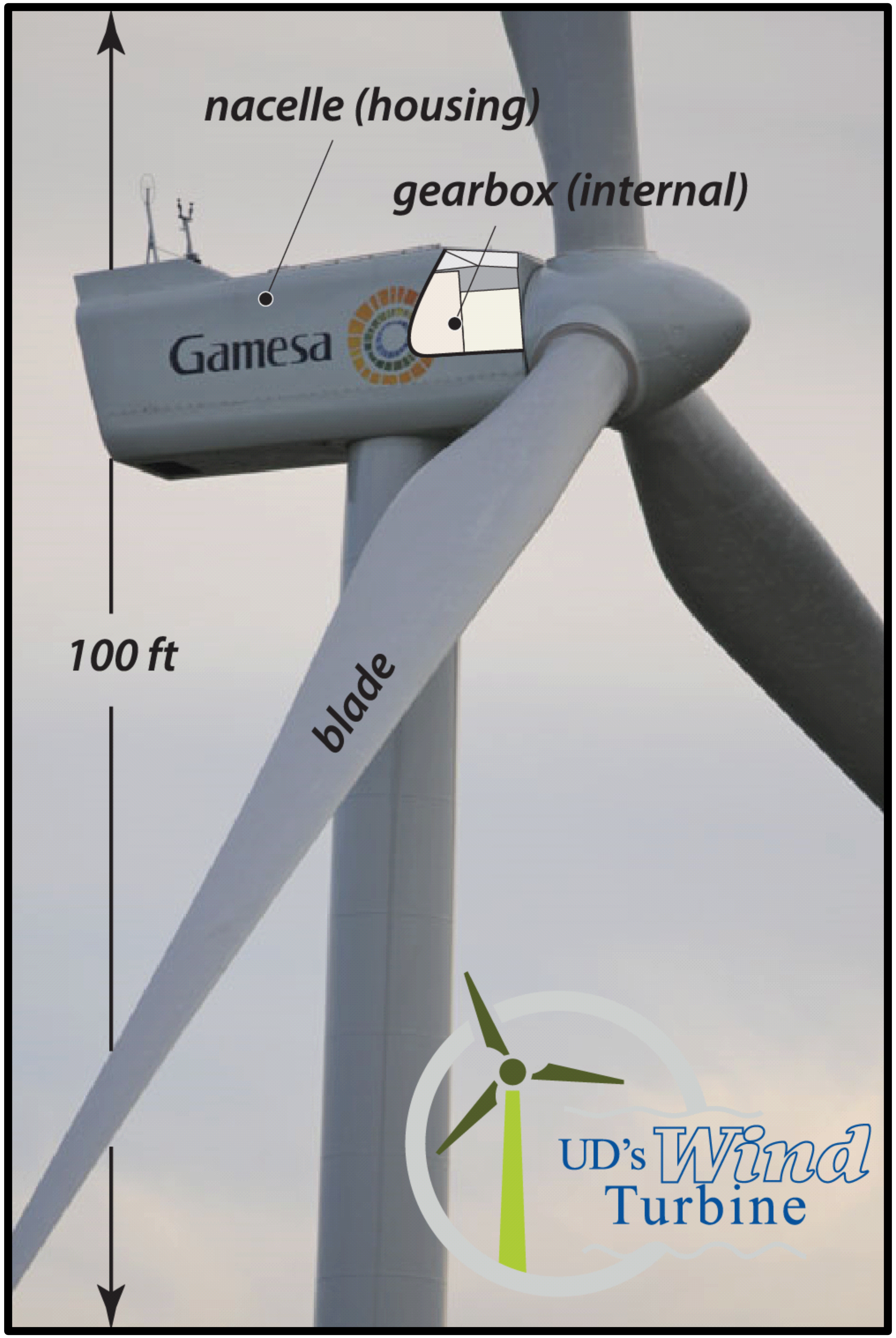
B. Reliability experiments - *Custom tribometry to assess and understand failure sensitiviy to lubricant, contaminants, and loads; Q3-6*

C. Instrument Lewes Turbine - *Evaluate the loads on a large-scale turbine; Q4*

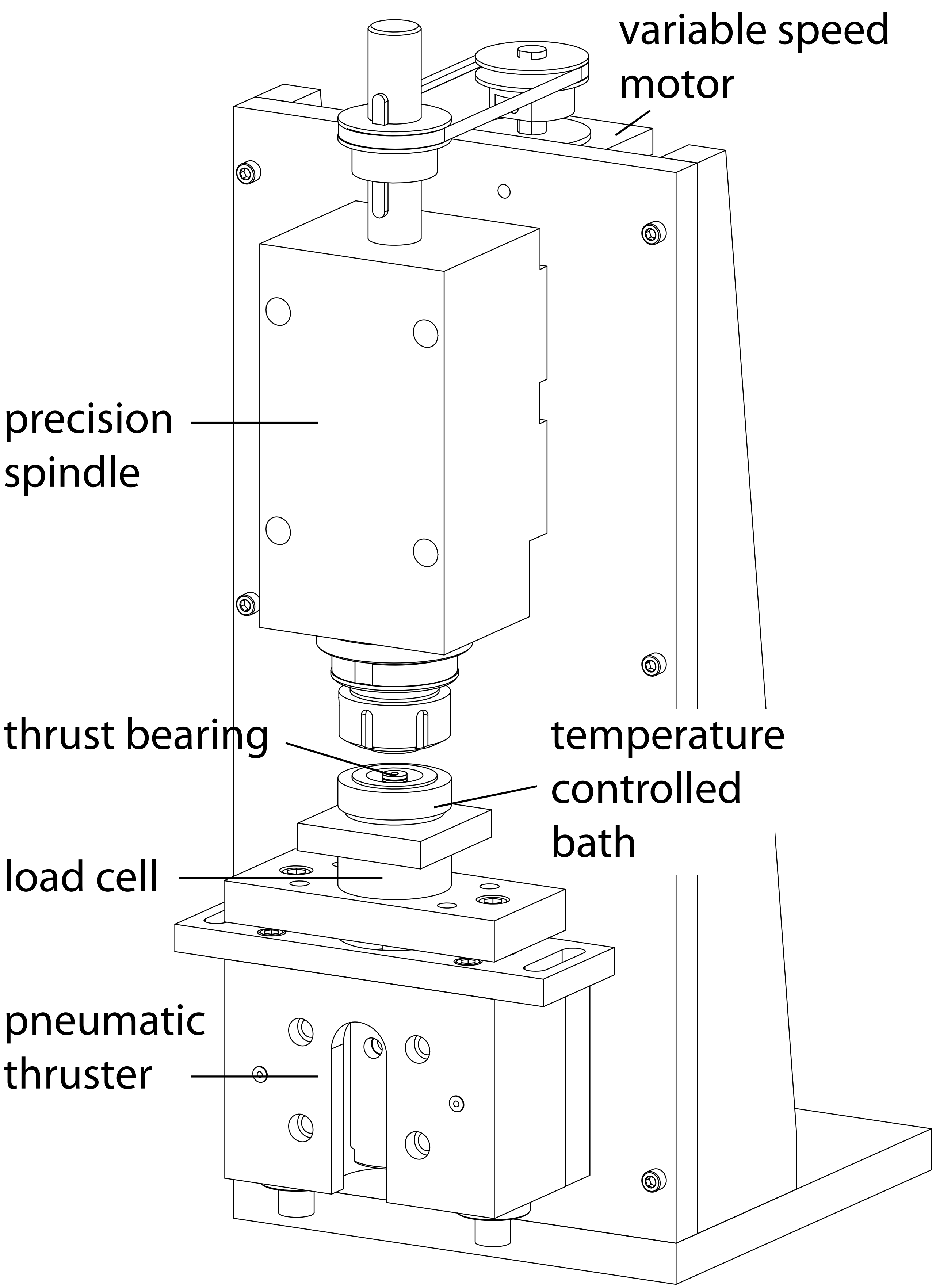
D. Collect Turbine Data; Q4-8

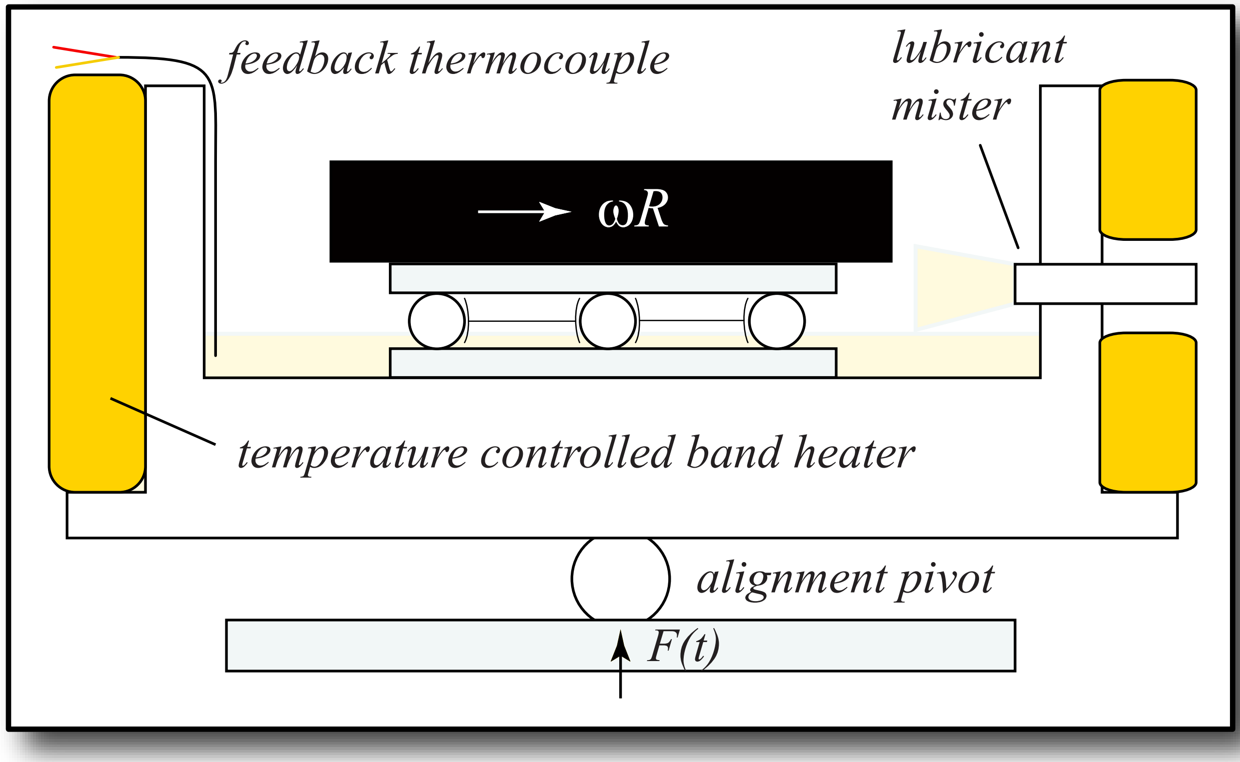
E. Simulation Experiments - *Using reliability data, GRC data and turbine data, evaluate conditions for which failures are most likely; Q7*

F. Develop design strategies - *Use results of simulation experiments to develop strategies to minimize failure probability; Q8*



Q2: Thrust Bearing Tribometer





Features

temperature control
continuous access to samples
controllable loads and speed

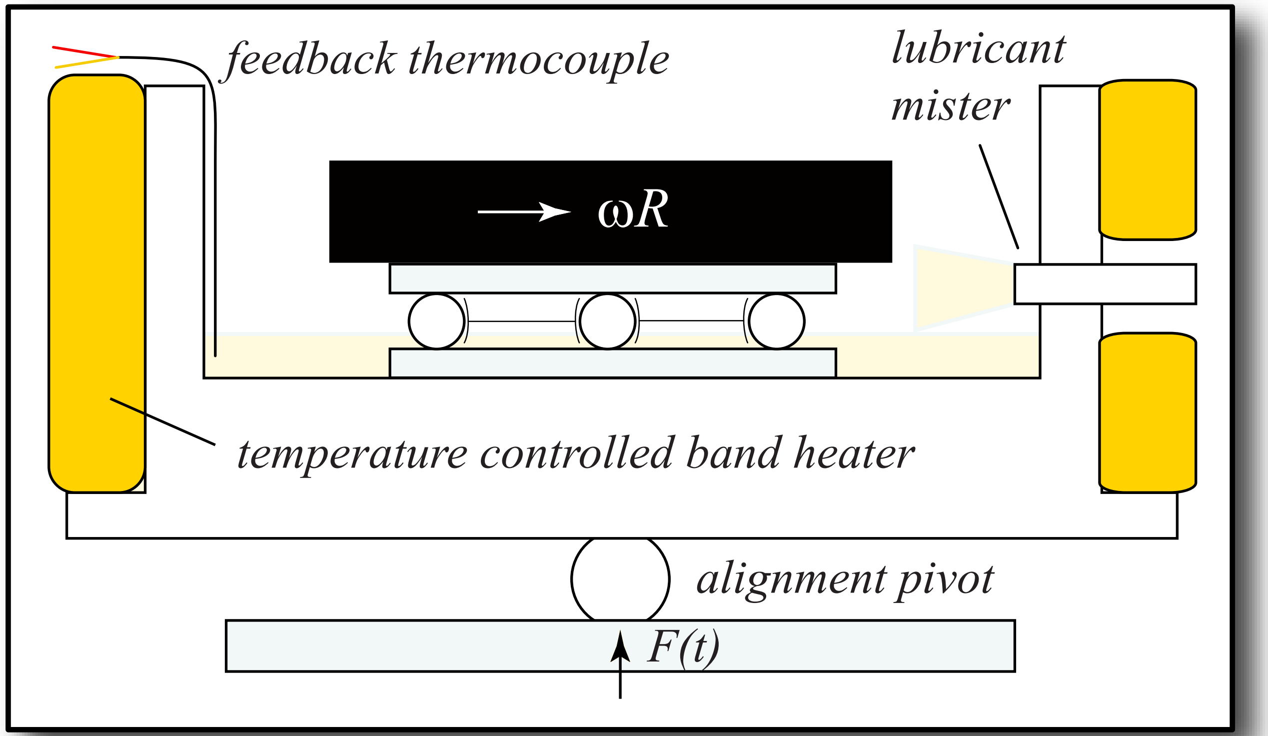
Initial Variables of Interest

lubricant, water, debris, dynamics
salt, lubricant degradation

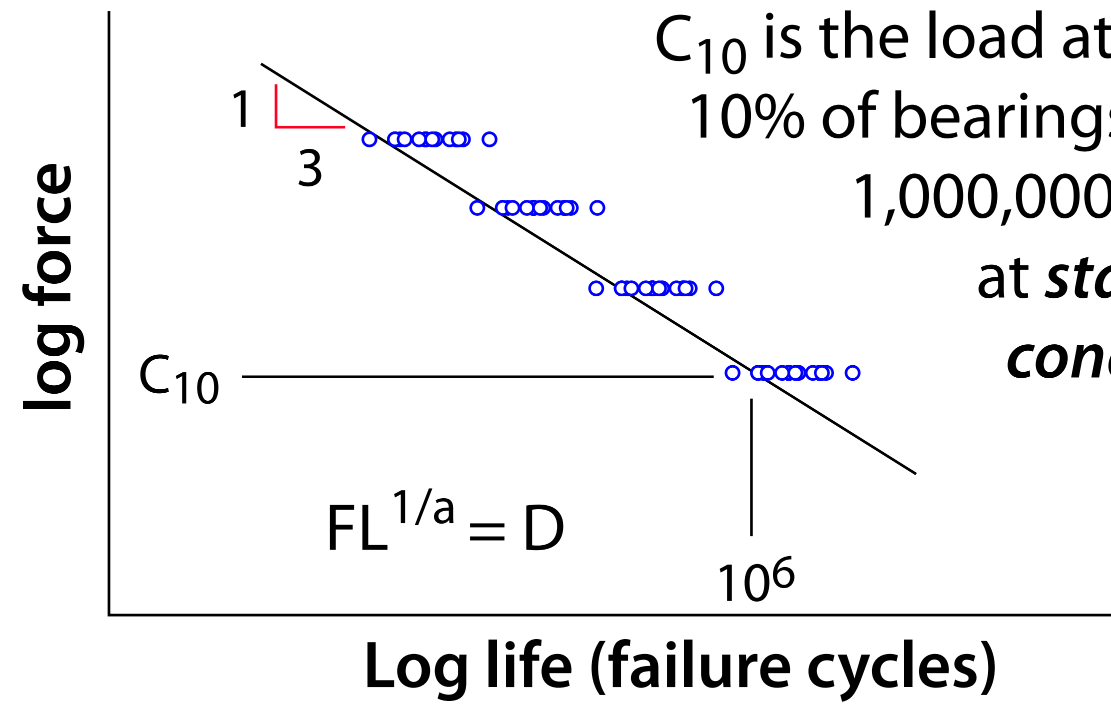
Analysis Methods

Interrupted wear measurements
condition monitoring (Wereley, force noise)
failure mode (scuffing, spalling, abrasion)

Q3: Effect of Lubricant and Contaminants on Life

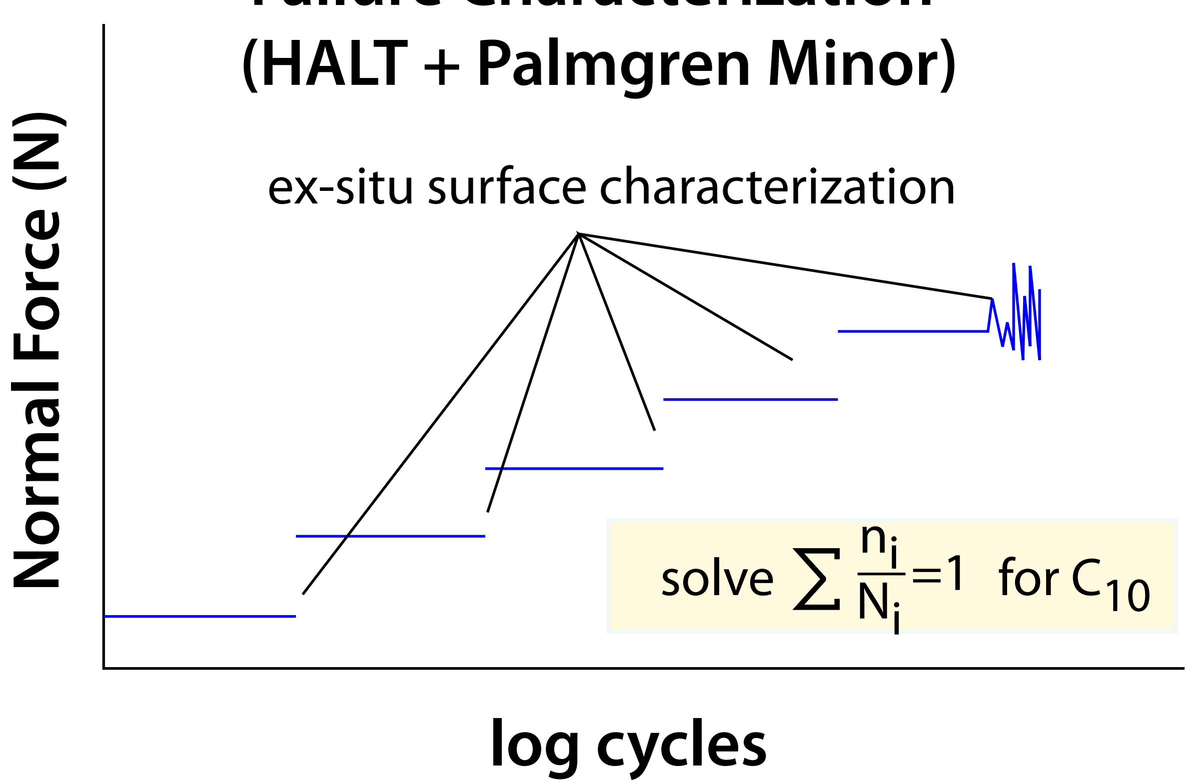


Failure Characterization



C_{10} is the load at which 10% of bearings fail at 1,000,000 cycles at ***standard conditions***

Failure Characterization (HALT + Palmgren Minor)



solve $\sum \frac{n_i}{N_i} = 1$ for C_{10}

Benchmarking

Test	lubricant	contaminant
1	None	None
2	Mineral oil	None
3	Castrol standard	None
4	Mineral oil	1% water
5	Mineral oil	1% salt water
6	Mineral oil	0.1% nanoparticle
7	Mineral oil	0.1% microparticle

Goals: observe evolution, determine failure mode, determine C_{10}

Q4: Instrumenting the UD G90 for Research and Teaching

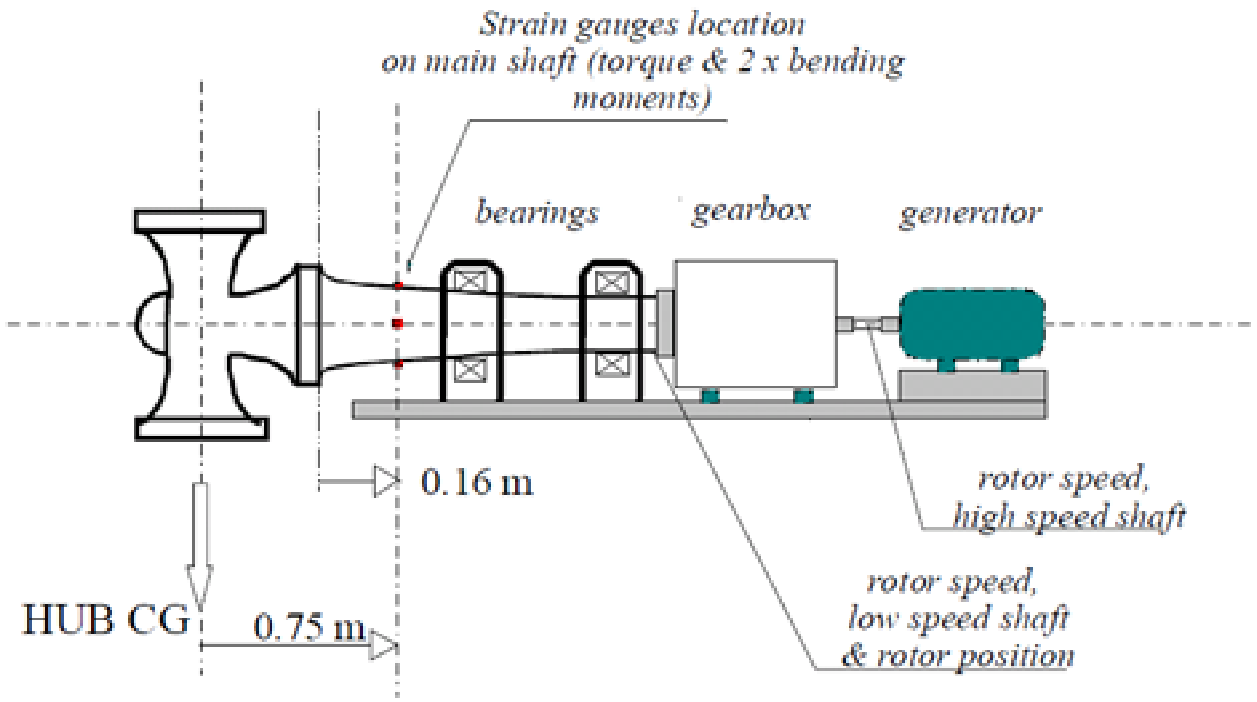


Figure 3: Structural load measurements on the main shaft of the NTK 500/41 wind turbine.

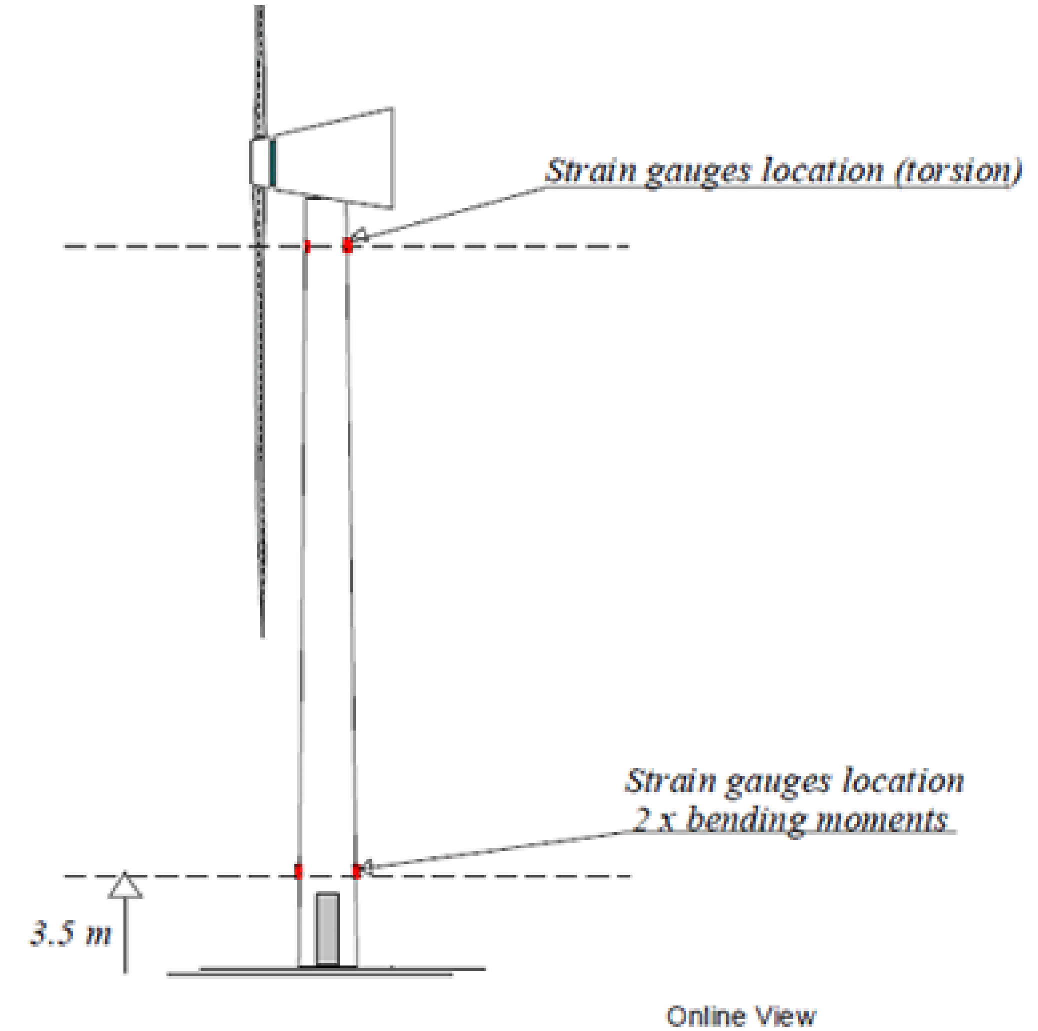


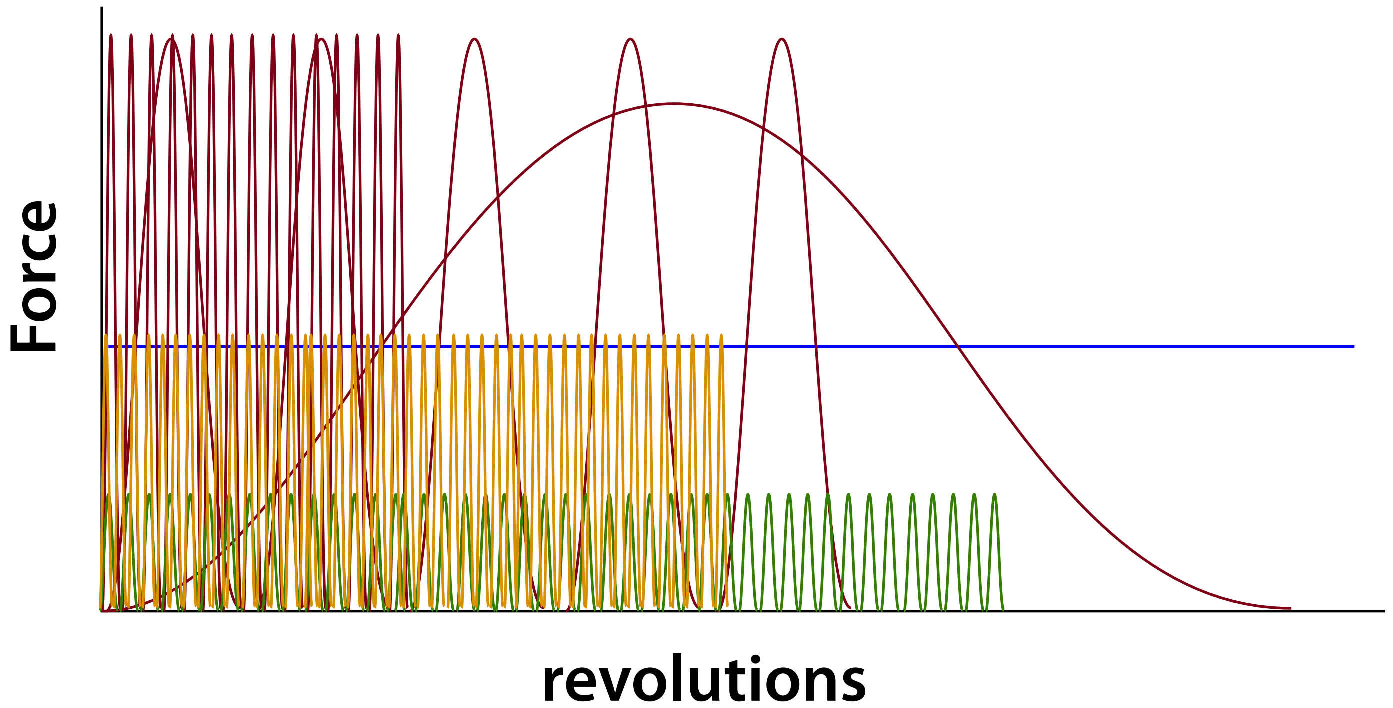
Figure 4: Structural load measurements in the tower of NTK 500/41 wind turbine.

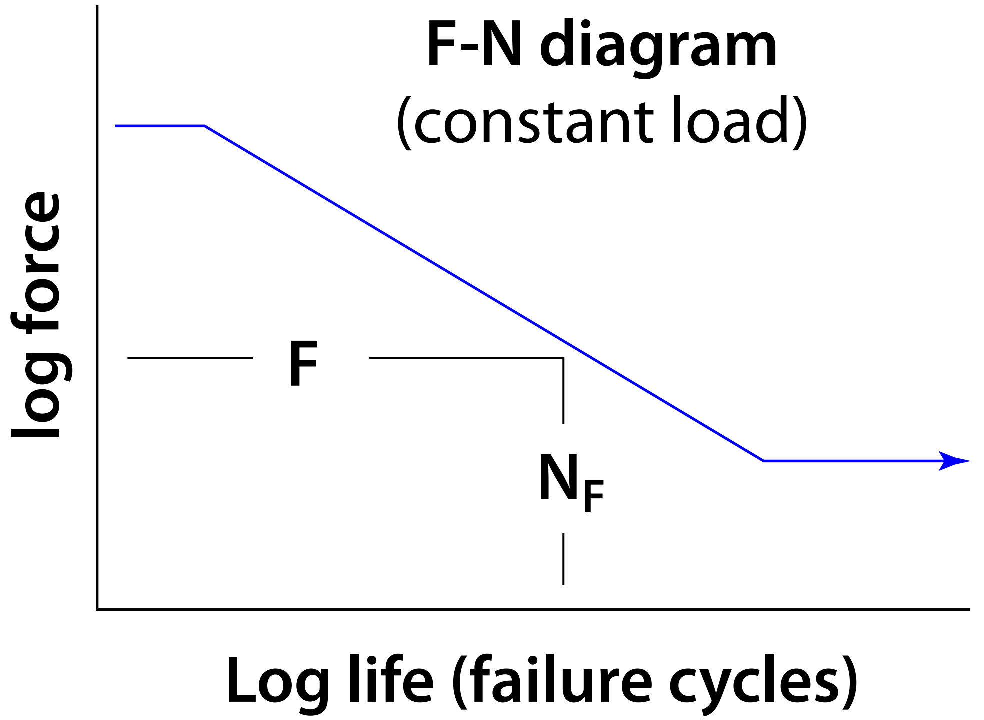
Variable wind loads produce unintended forces and moments on the bearings. By measuring these loads, we can better understand the actual bearing conditions.

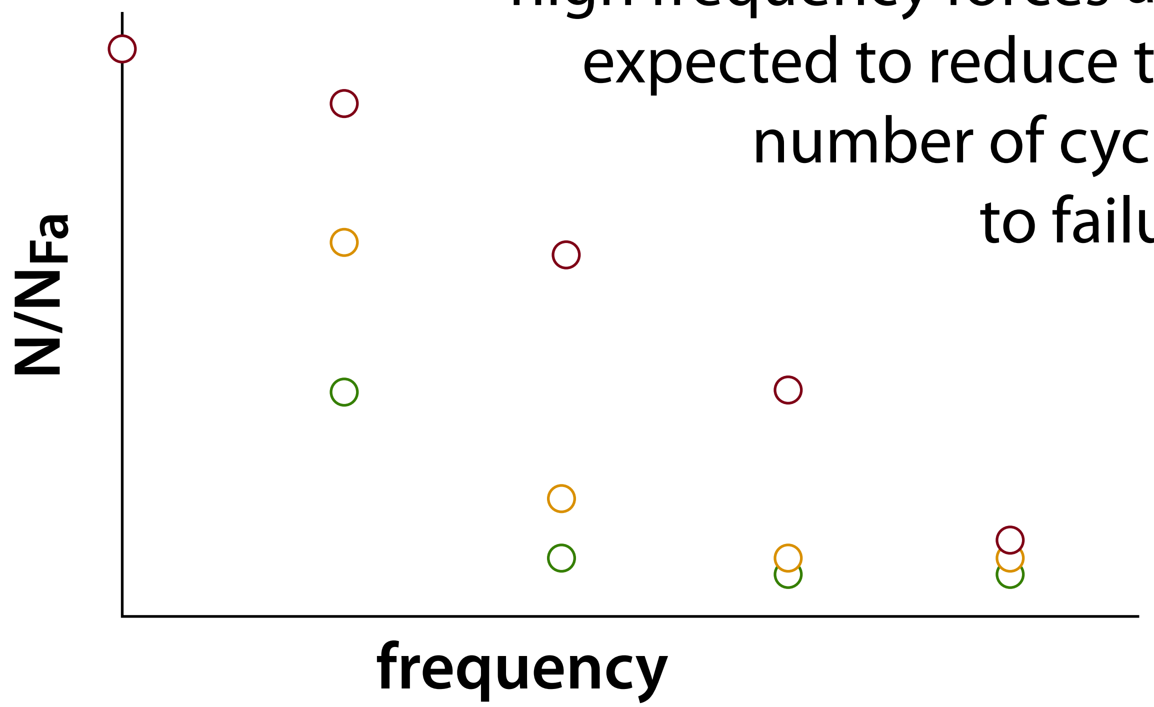
Laboratory failure data will be used to determine the severity of the conditions experienced by the compoents of the drivetrain.

This data would be used for an introductory wind power course next Fall.

Planet bearing can encounter significant static and dynamic non-torque loads. Dynamic forces may significantly reduce the life of the bearing. GRC is committed to developing a better understanding of the system dynamics; this study will determine the impact of load dynamics on bearing life.

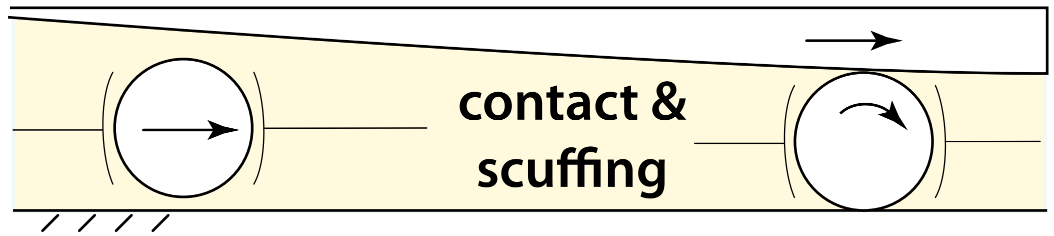


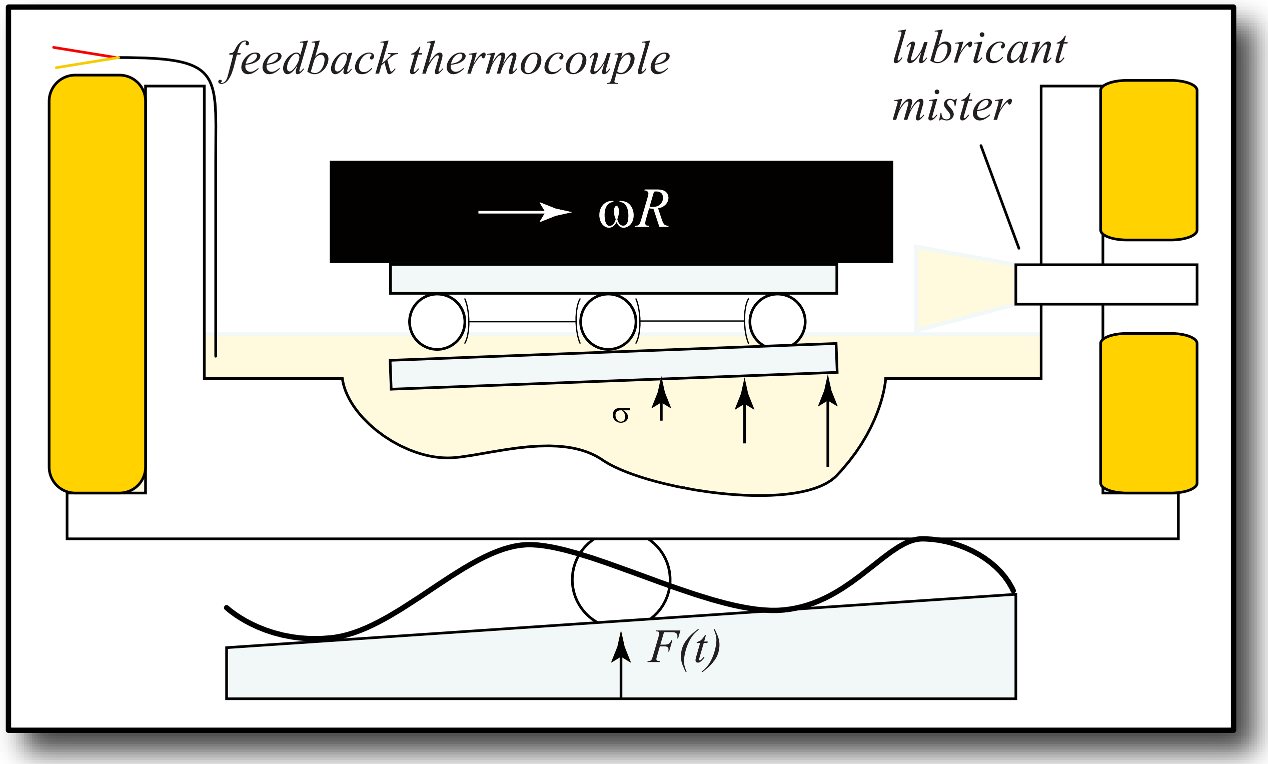




Q6: Effect of Unloading: Implications for High Speed Bearing Life

High speed bearings fail without exposure to significant loads; underloading may actually contribute to failure by requiring rapid acceleration and slip as the ball enters the load bearing area; scuffing failure may be the result.





positional versus global force variation