Progressive Dynamical Drive Train Modeling As Part of NREL Gearbox Reliability Collaborative

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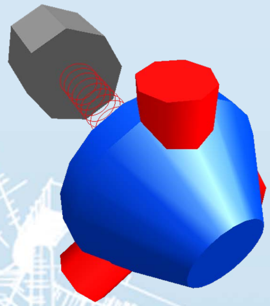
Abstract

The Gearbox reliability Collaborative (GRC) seeks to develop a model representative of the current standards in the industry that can be extrapolated to a large number of turbines with different sizes and dimensions, but with the same configuration. Thus, the GRC's analysis and experimentation is performed on a carefully selected, preexisting machine with a significant operating history. This approach assures that the information revealed by the testing and analysis will be more valuable and relevant to the current industry.

The GRC analysis also seeks to integrate several numerical models that capture the dynamical nature of the drive train into the drive train design process. These dynamical models which are progressively complex aim to reveal new insight into the internal forces inherent to the dynamical behavior of the drive train. Additionally, the progressive nature of these models allows them to be validated by comparing models of less complexity to models of higher complexity, thus eliminating error in the model development. These models will allow for the filtration of sensitive information between the different parties of the design process; therefore, ultimately increasing transparency.

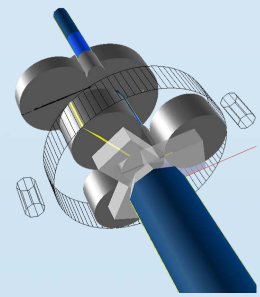
Stage I: Two-mass Oscillator

- The two-mass oscillator, is the simplest simulated form of the drive train.
- It is a simple, two-mass torsional vibration system in which one mass represents the rotor and one mass represents the generator.
- The entire drive train is represented by a torsional spring damper connection.
- This rudimentary approach is used by many aeroelastic simulation codes.



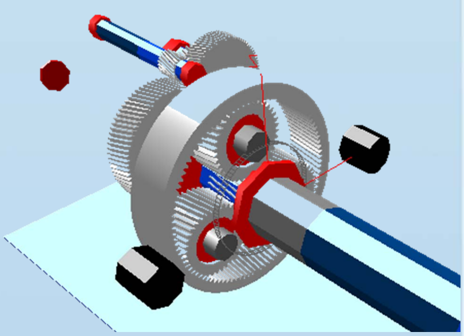
Stage II: Torsional Multi-body

- This model accounts for the torsional compliances of each individual stage of the gearbox, as well as, each individual shaft.
- It also accounts for the changes in torque and angular velocities generated by the gearbox.
- The overall response of the drive train should be similar to the response observed in the first model.



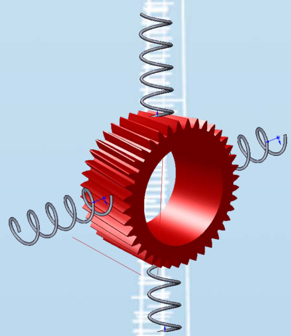
Stage III: Gear Elements

- This model implements gear elements capable of accounting for backlash, gear tooth contact and changes in center distances.
- The joints in this model have a single degree of freedom that only allows rotation.
- The compliances and clearance contribution of the bearings are neglected.



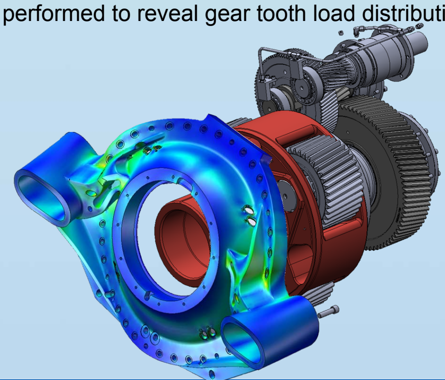
Stage IV: Bearing Compliance

- This model adds degrees of freedom to the joints in the stage III model.
- The joints are constrained by the use of force elements that represent the stiffness of the bearings.
- This model better represents the bearing load distribution, and gear misalignment.



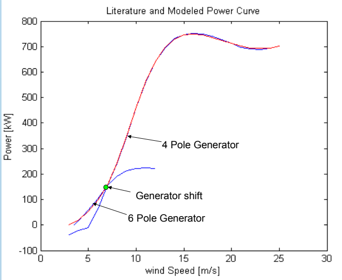
Stage V: High Fidelity Semistatic

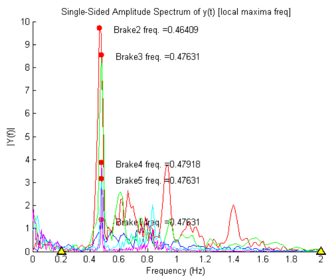
- The stage of highest complexity includes a full finite element model of the gearbox.
- Housing deformation will be modeled to account for the overall misalignment of the internal components of the gearbox.
- High fidelity gear finite element analysis will be performed to reveal gear tooth load distribution.

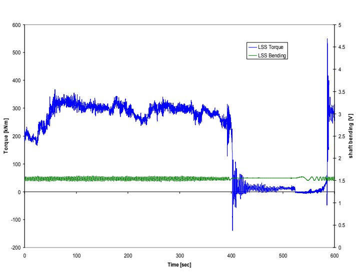


Validation

- The different models and parameters calculated were validated with data collected from the field
- Validation included:
  - Airfoils and power curve characteristics
  - Modal behavior of the blades and tower
  - Natural frequency and drive train stiffness
  - Inertial characteristics of the generator







Load Generation

- Relevant load cases were generated in the aeroelastic software FAST_AD
- The load cases included:
  - Braking maneuvers
  - Fault loads cases
  - Turbulent conditions
- The load cases are imported into the models of higher fidelity
- The integration of FAST_AD and the multibody system models results in a comprehensive analytical tool.