Swept Blade Aero-Elastic Model for a Small Wind Turbine

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Outline

- Background on optimized/advanced rotors
- Numerical modeling tools
- Case study
- Summary of results

Need for Advanced Rotors

- Sweep introduces bend/twist coupling that can reduce loads at fixed rotor diameter size

OR

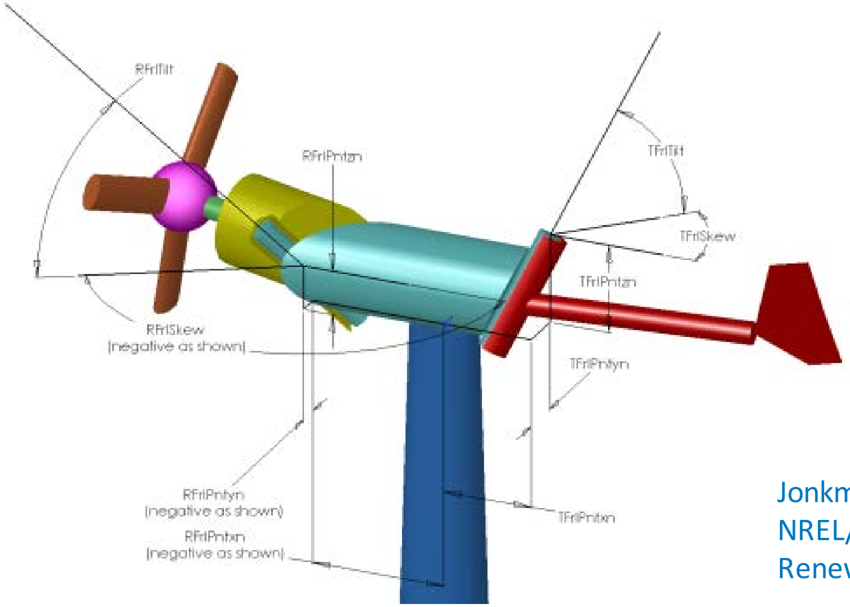
- Increase rotor diameter at same loading level

⬇

- Reduce material
- Optimize utilization
- Reduce the levelized cost of energy (LCOE)

CAE Tools: FAST and ADAMS

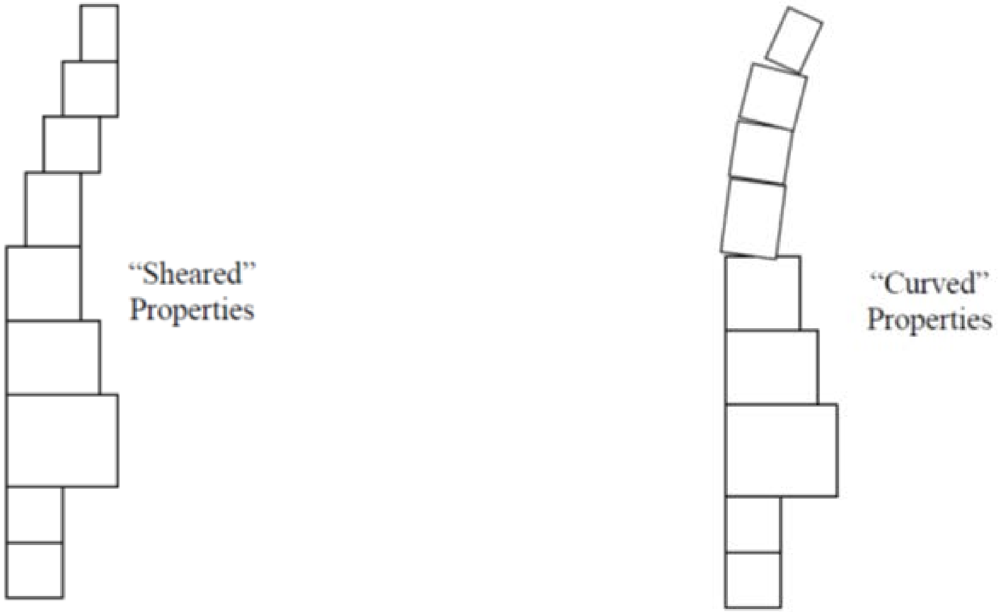
- **MSC ADAMS – Multibody Dynamics:**
  - Commercial product
  - Can be coupled to Aerodyn (FAST module) –
  - FAST has a translator to convert FAST input to ADAMS input
  - Highly customizable with user's controller library (requires a bit of programming)
  - Highly flexible – virtually any horizontal axis wind turbines
  - High fidelity – as many degrees of freedom as the user requires



Jonkman, J.; Buhl, M. (2005). "FAST User's Guide," NREL/EL-500-38230. Golden, CO: National Renewable Energy Laboratory.

FAST2ADAMS

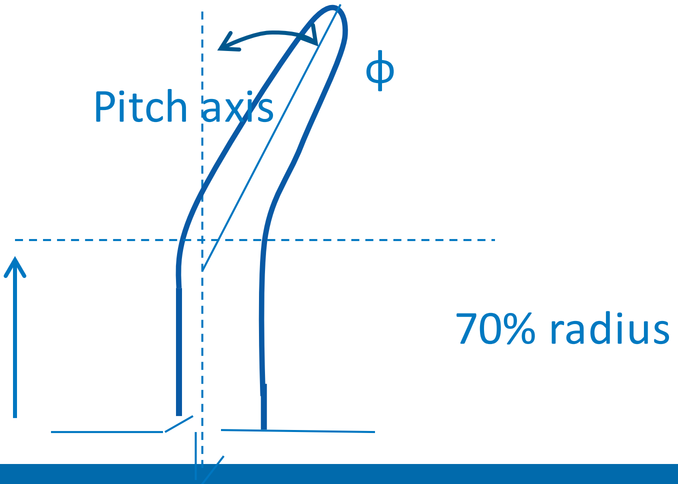
- **Original preprocessor would use the sheared approach:**
  - Leads to inaccurate representation of aerodynamic and inertial loads
- **New preprocessor follows curved properties of blade elements:**
  - Higher fidelity and physically consistent results
  - Improved accuracy



Larwood, S. (2009). "Dynamic Analysis Tool Development for Advanced Geometry Wind Turbine Blades," U.C. Davis Ph.D. Dissertation.

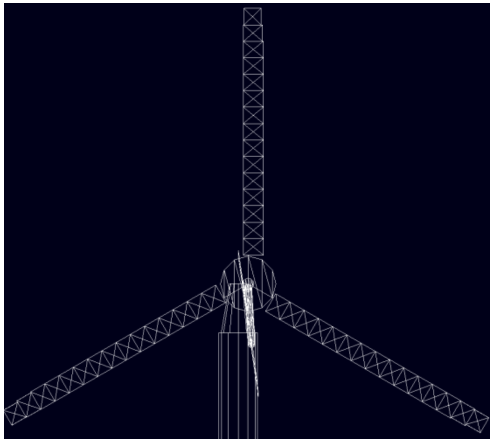
Case Study

- FAST input model of a small wind turbine converted to ADAMS model using FAST2ADAMS
- NREL Small Wind Research Turbine (SWRT) baseline
- Design load cases (DLCs): 1.1 from IEC 61400-2
  - Normal Turbulence Model
  - Wind Speed = 8–16 m/s
- Five configurations: baseline and 0, 5, 10, 15, and 20 degree sweep angles
- Study blade and tower moments
  - Maximum blade and tower loads (max in 10 minutes)
  - Blade tip clearance
  - Damage equivalent loads (fatigue) – blades and tower

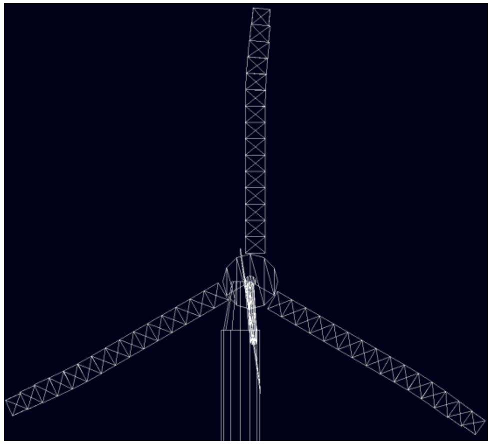


Blade configurations

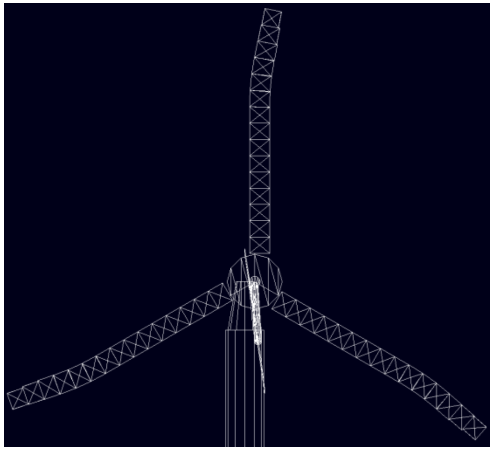
baseline



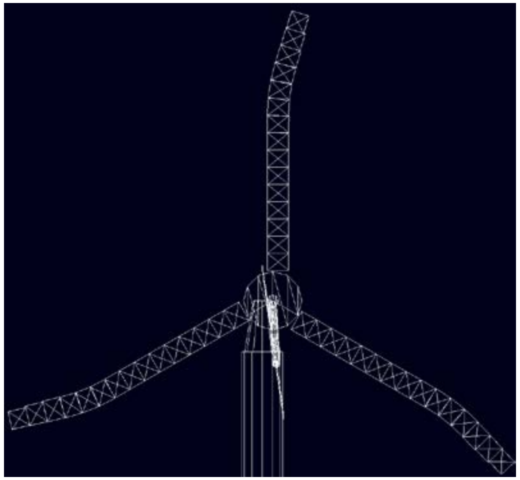
5 deg



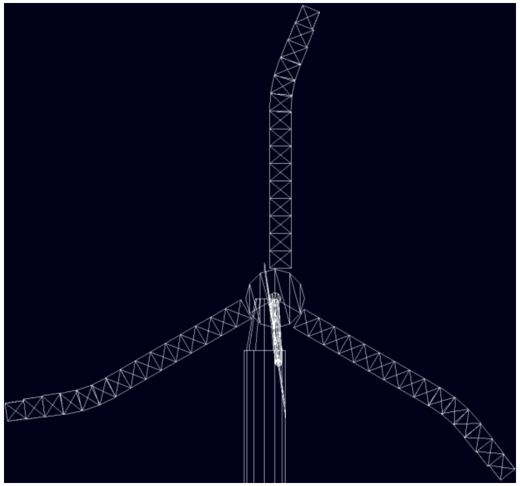
10 deg



15 deg

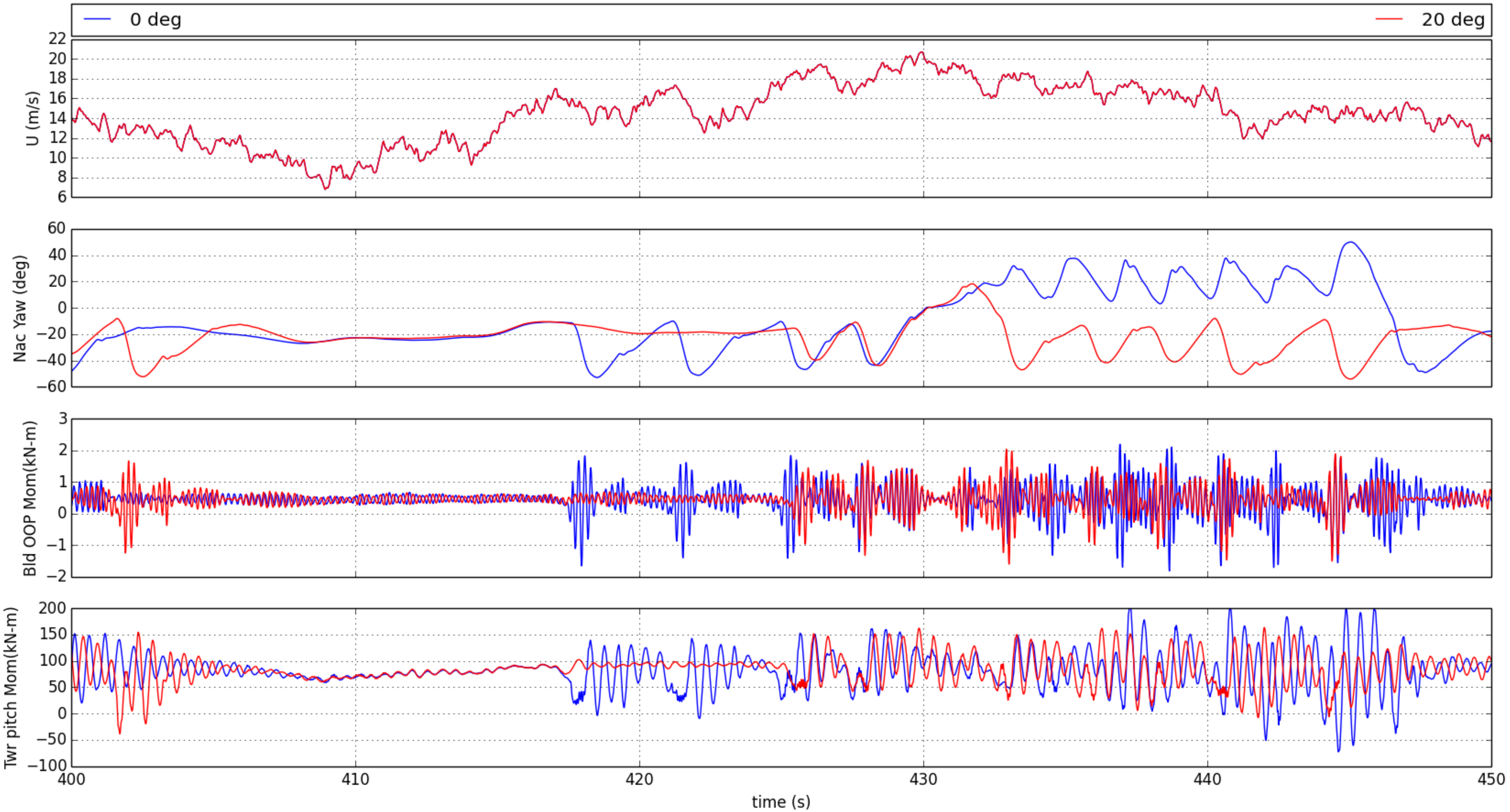


20 deg



Bending Moments

- Time series 0 deg and 20 deg sweep at 14 m/s wind



U: streamwise velocity   Nac Yaw: Nacelle Yaw

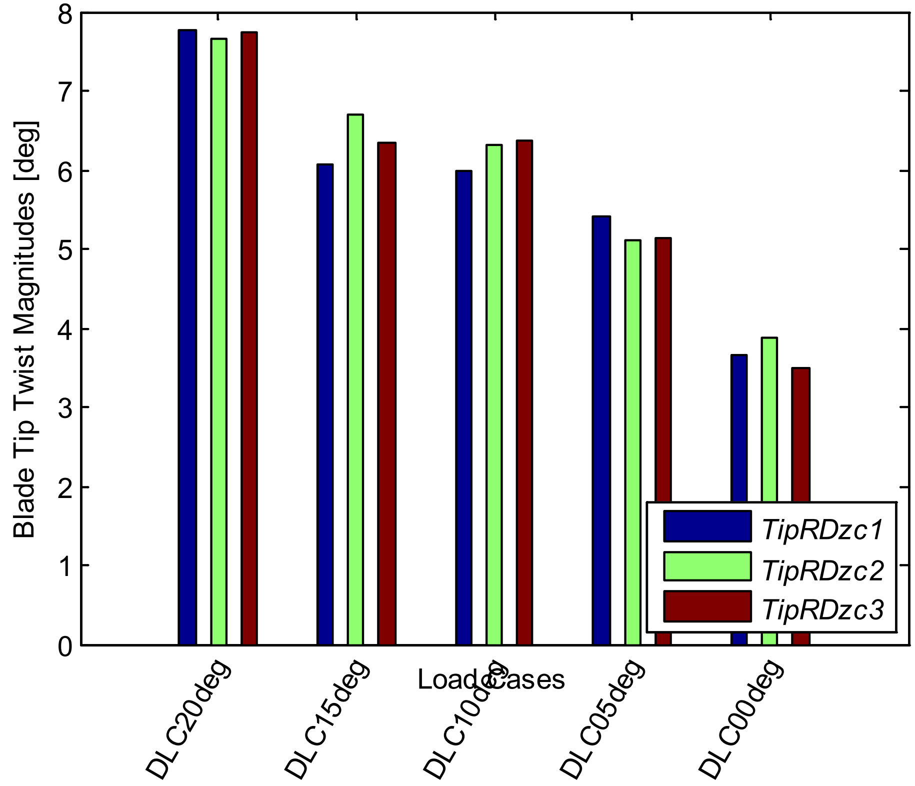
Bld OOP: blade root out-of-plane bending moment   Twr Pitch Mom: tower pitch moment

Power and Furling

- The mean power has not shown more than 5% variation across the numerous configurations
  - Note: This finding needs to be revised as the aerodynamic model does not include cross-flow effects
- Furling impact on same order or greater than sweep impact
- Furling standard deviation slightly reduces with sweep

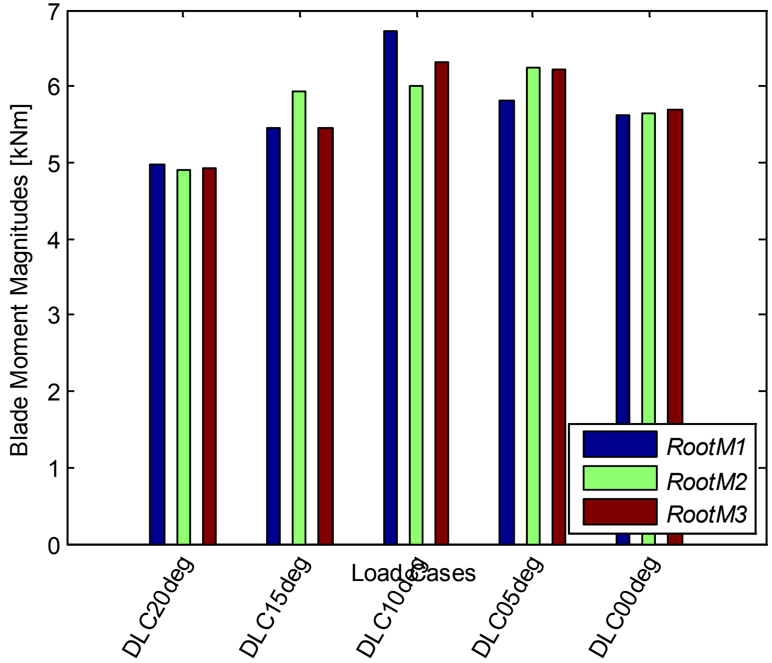
Maximum Blade Twist Angle from DLC 1.1

- **Blade-tip twist**



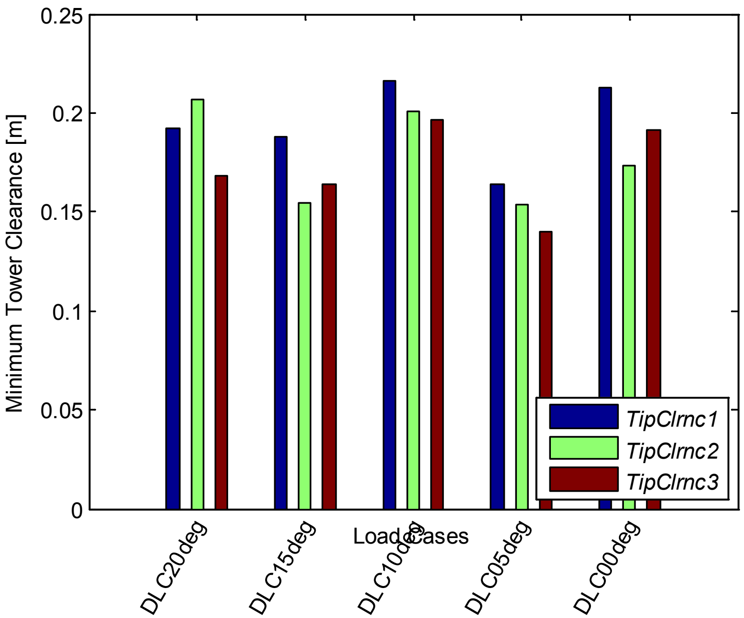
- **20 deg sweep doubles the twist at the blade tip**

Maximum blade load and Tower Clearance Statistics from DLC 1.1



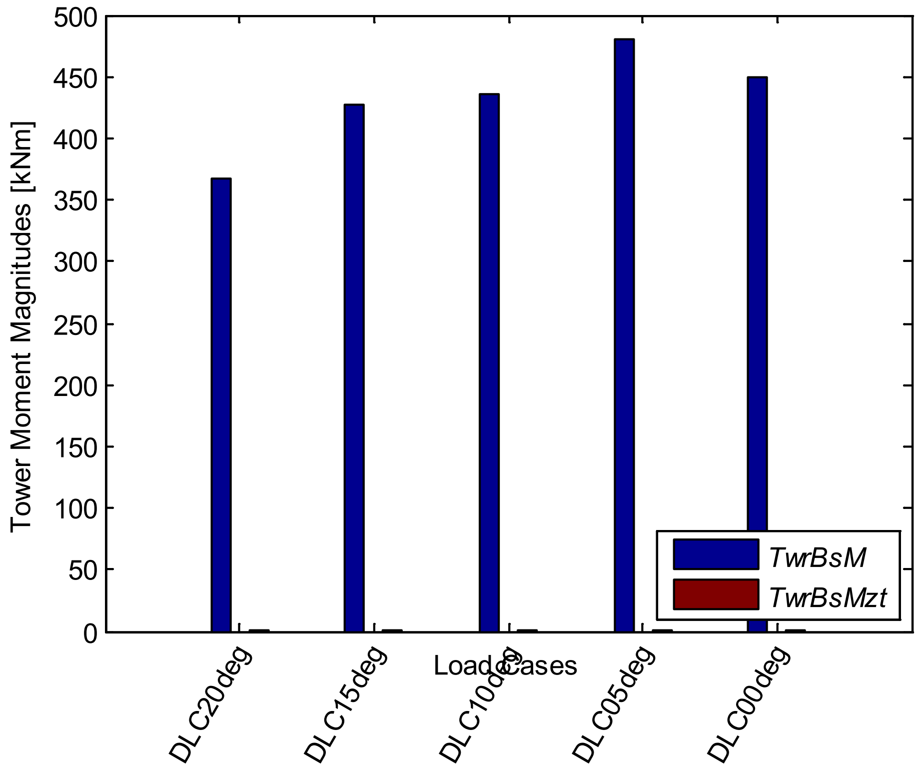
- Blade root bending moment
- 20 deg sweep mitigates maximum blade moment by ~15%
- 10 deg sweep increases maximum blade moment by ~15%

Tower clearance almost unaffected



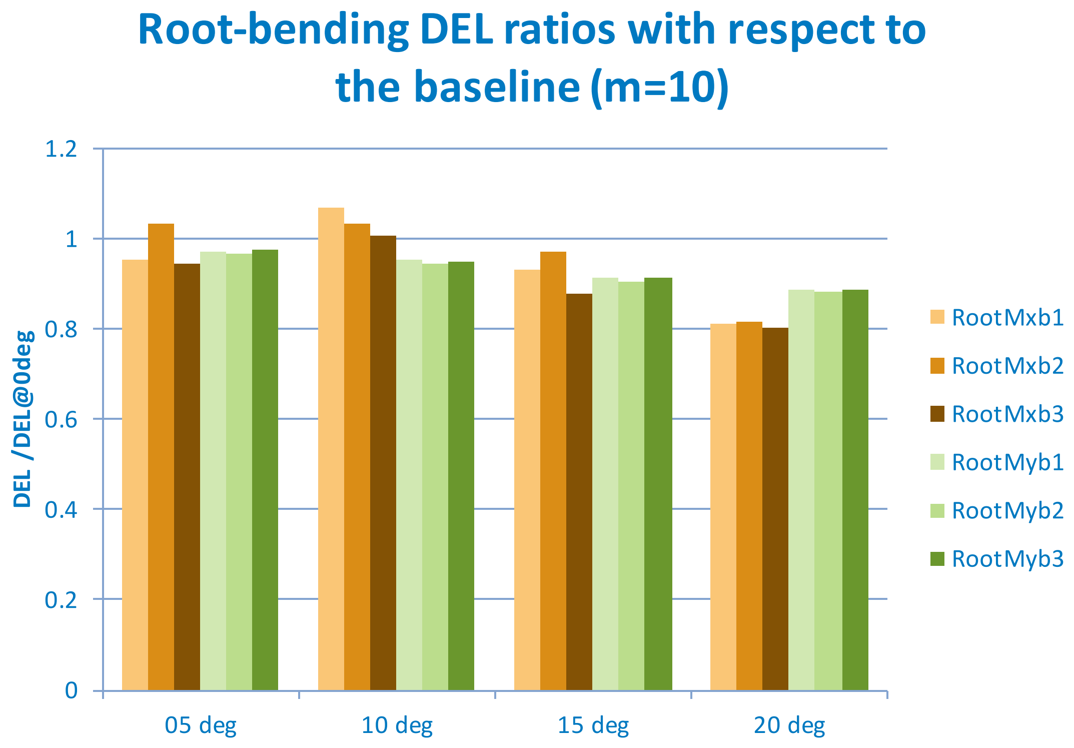
Maximum tower Load from DLC 1.1

- **Tower-base bending moments**
- **Twenty degree sweep mitigates max tower moment by ~15%**
- **Five degree sweep increases maximum tower moment by ~10%**



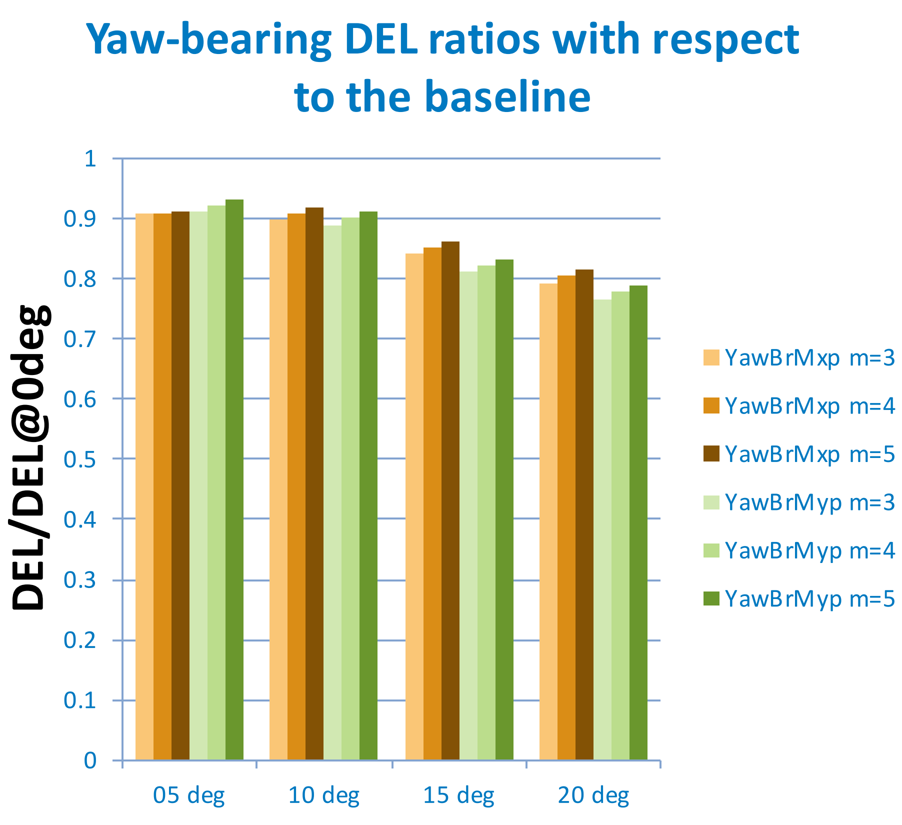
Fatigue Load Statistics from DLC 1.1

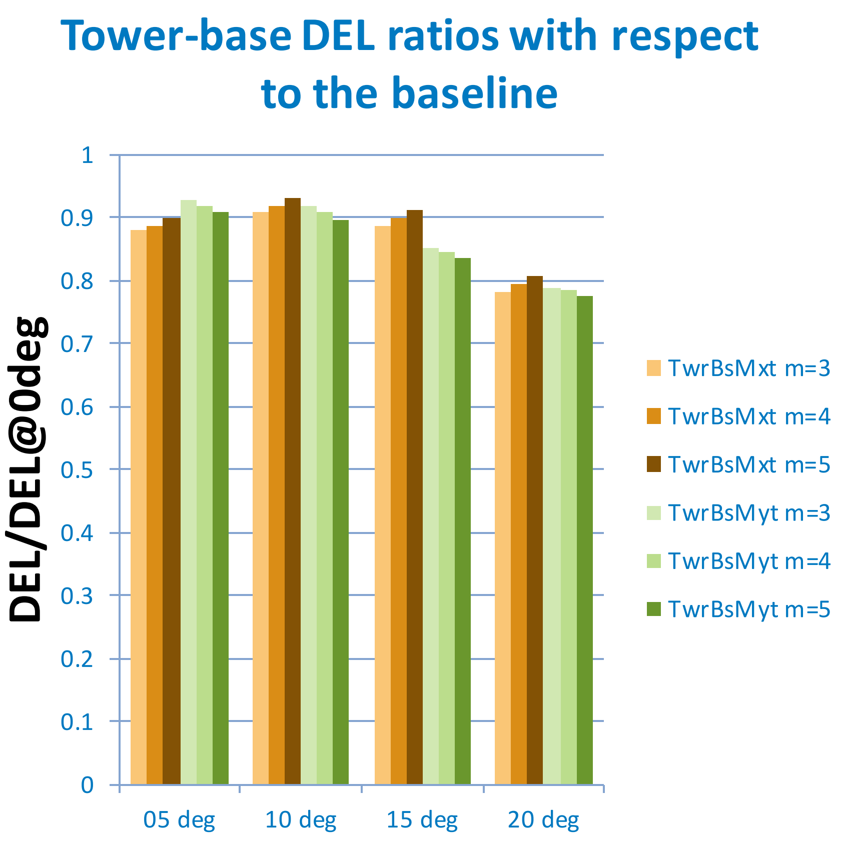
- **Blade root bending moments**
- **Twenty degree sweep mitigates damage equivalent loads (DELs) by ~15% (flap) to 20% (edge)**
- **Ten degree sweep increases DELs by ~5% (edge)**



Case Study – Fatigue Load Statistics from DLC 1.1

- **Yaw-bearing bending moments DELs reduced (shaft life)**
- **Tower-base moments DELs reduced by ~20%**
- **Twenty degree sweep mitigates DELs by ~20%**

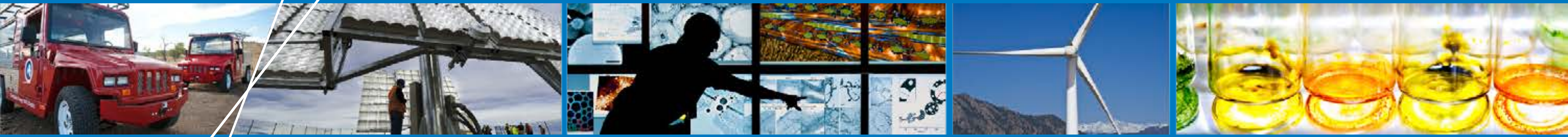




Conclusions

- Preliminary study – further investigation needed
- A new FAST2ADAMS preprocessor is now available for FAST 7.02 that allows for higher fidelity representation of presweep and bend of blades
- A case study on a small wind turbine revealed the capabilities of simulating the effect of blade sweep using ADAMS
  - Results show promising effects in terms of load mitigation:
    - Max. loads decrease by 15% at 20 deg sweep (likely 10%–15%)
    - DELs decrease by 20% at 20 deg sweep (likely 15%–20%)
    - Little effect on power production (same rotor area)→ to be revised with improved aerodynamic modeling and possibly eliminating furling
  - Use sweep to reduce costs by
    - growing the rotor size and/or
    - thinning the blade structure
  - Use caution in selecting amount of sweep, as some angles may create nonlinear effects on the dynamics of the machine and increase loads

For More Information



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