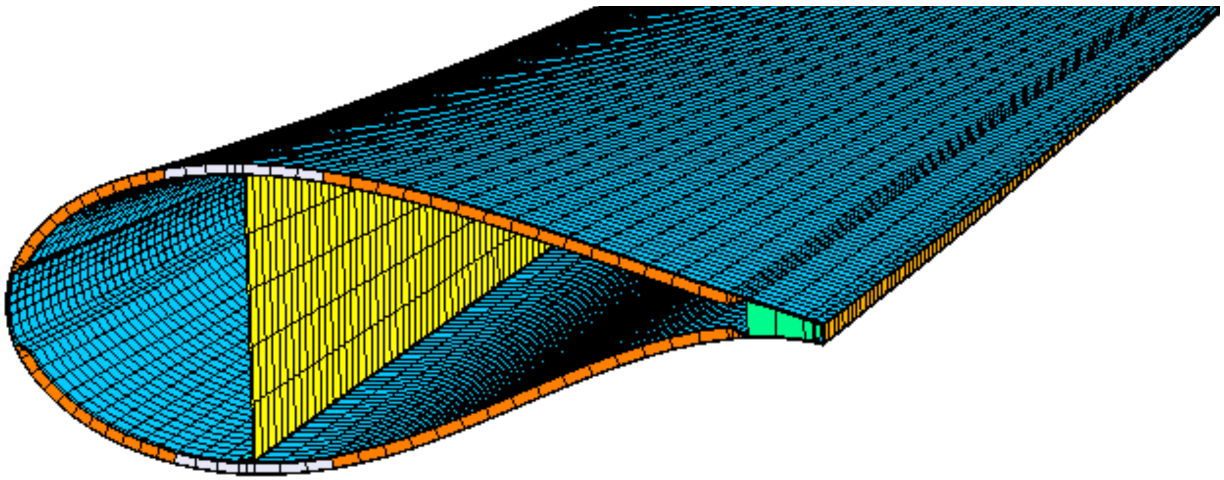
Rapid FEA of Wind Turbine Blades

Summary of NSE Composites' structural analysis capabilities for blades



NSE "bladeMesher"
in-house software

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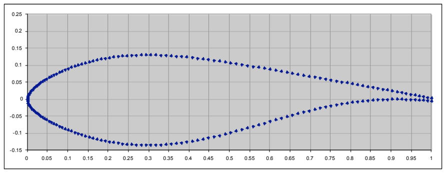
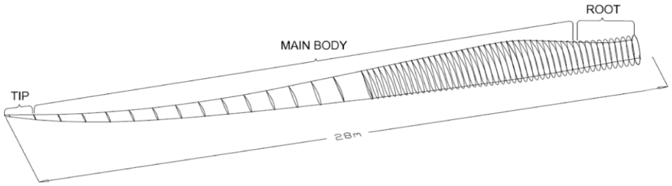
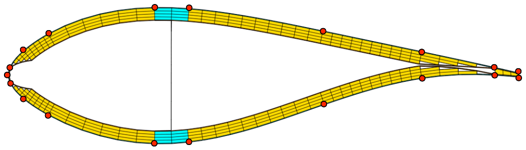
Airfoil Data



Planform Data



Material Definition Data



"bladeMesher"
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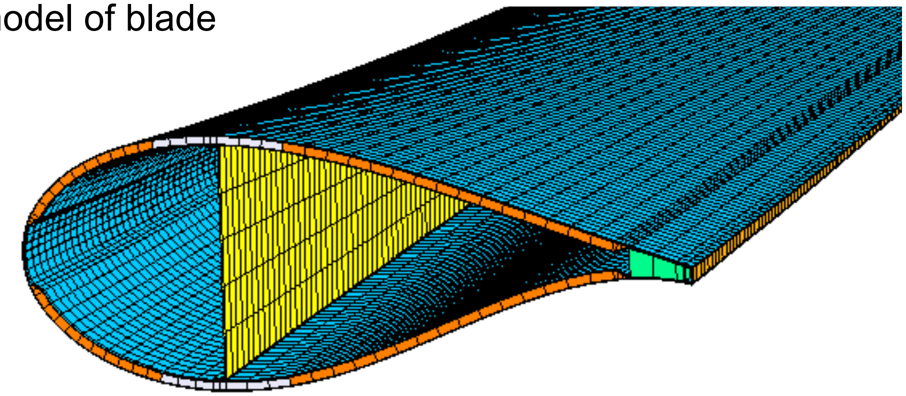
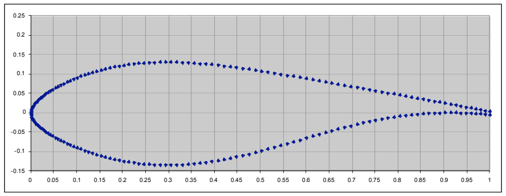
Full 3D solid FE model of blade

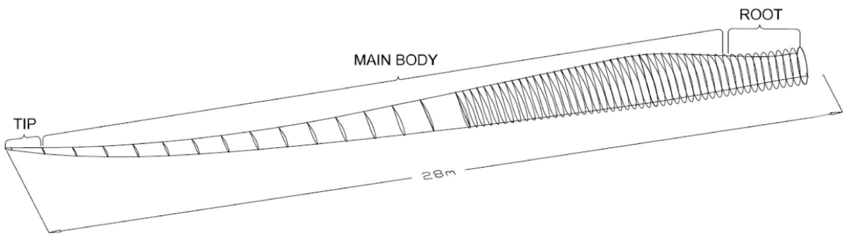


NSE 'bladeMesher' Inputs

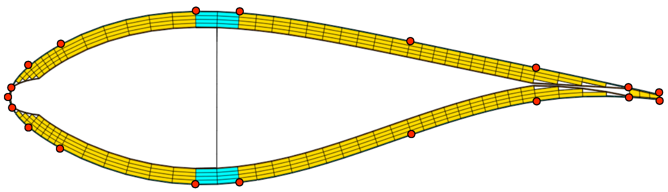
- Airfoil Data
  - *normalized airfoil data and chord length at each airfoil*
  - *spanwise location of each airfoil*



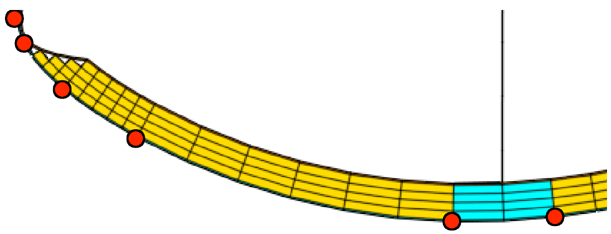
- Planform Data
  - *leading edge placement of airfoils*
  - *spar web location(s)*
  - *airfoil twist angle*



- Material Definition Data
  - *thickness and location of each material at all unique locations along the span.*

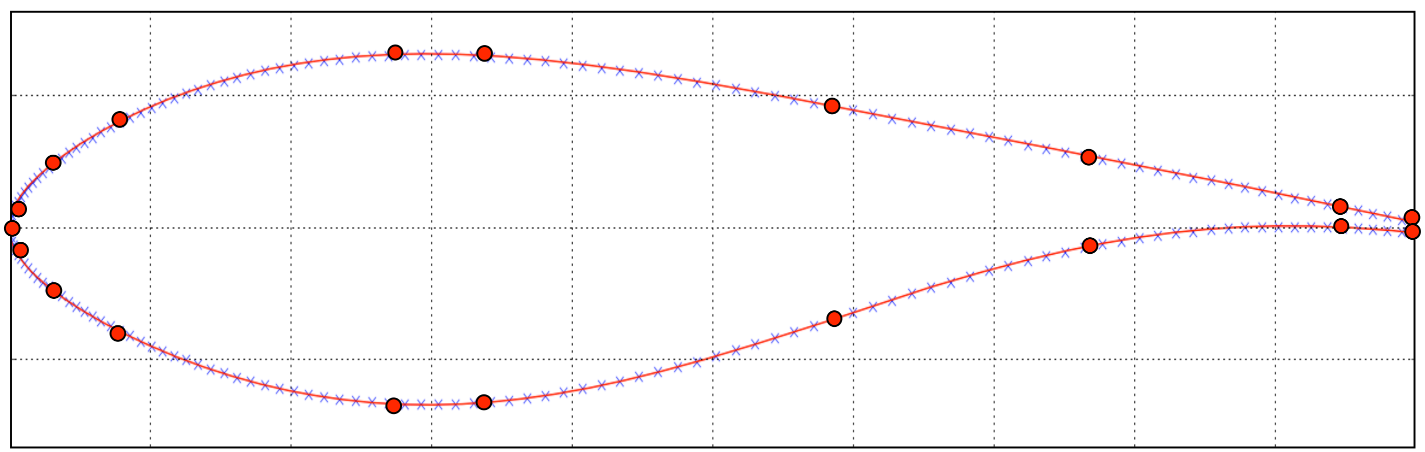


- FE Mesh Density
  - *chordwise mesh density for each segement*
  - *spanwise mesh density*
  - *through-thickness mesh density of core and spar caps*



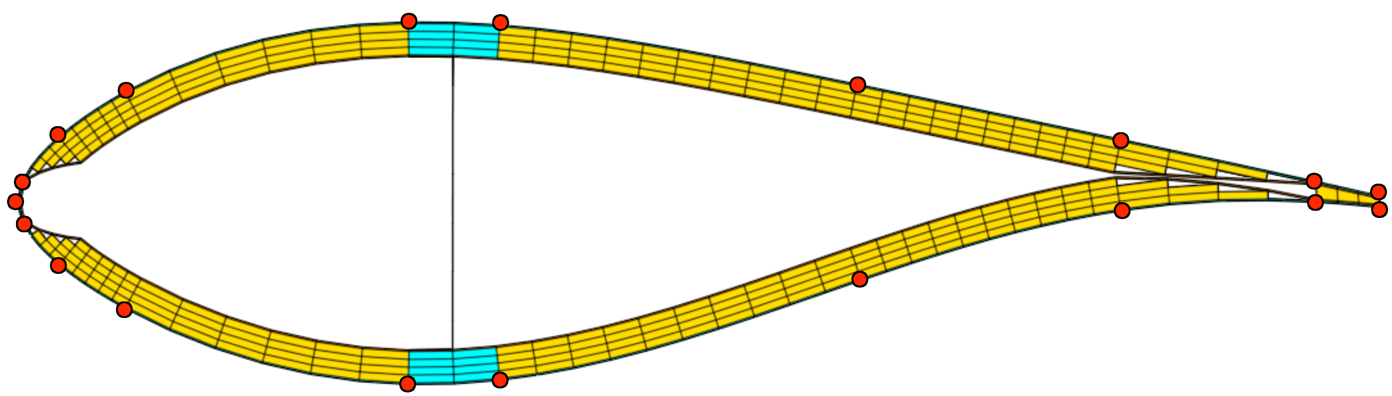
NSE 'bladeMesher' - OML Definition

- The airfoils are splined, as needed, to generate a complete shape definition. An equal number of points is defined based on the splines for each airfoil. Spanwise splines are generated through all points on the airfoils, producing the outer mold layer (OML), or "lofted" shape of the blade.
- Splined airfoils are then generated at all desired spanwise locations using the spanwise splines and based on the user-defined spanwise mesh density.
- Key node locations are defined on the OML based on the material definition data and using the airfoil splines.
- Key node locations between material definition locations are linearly interpolated, providing a smooth variation of material width in the spanwise direction.
- The locations of all "exterior" nodes on the OML are then defined using the airfoil splines and the user-defined mesh density between key nodes.



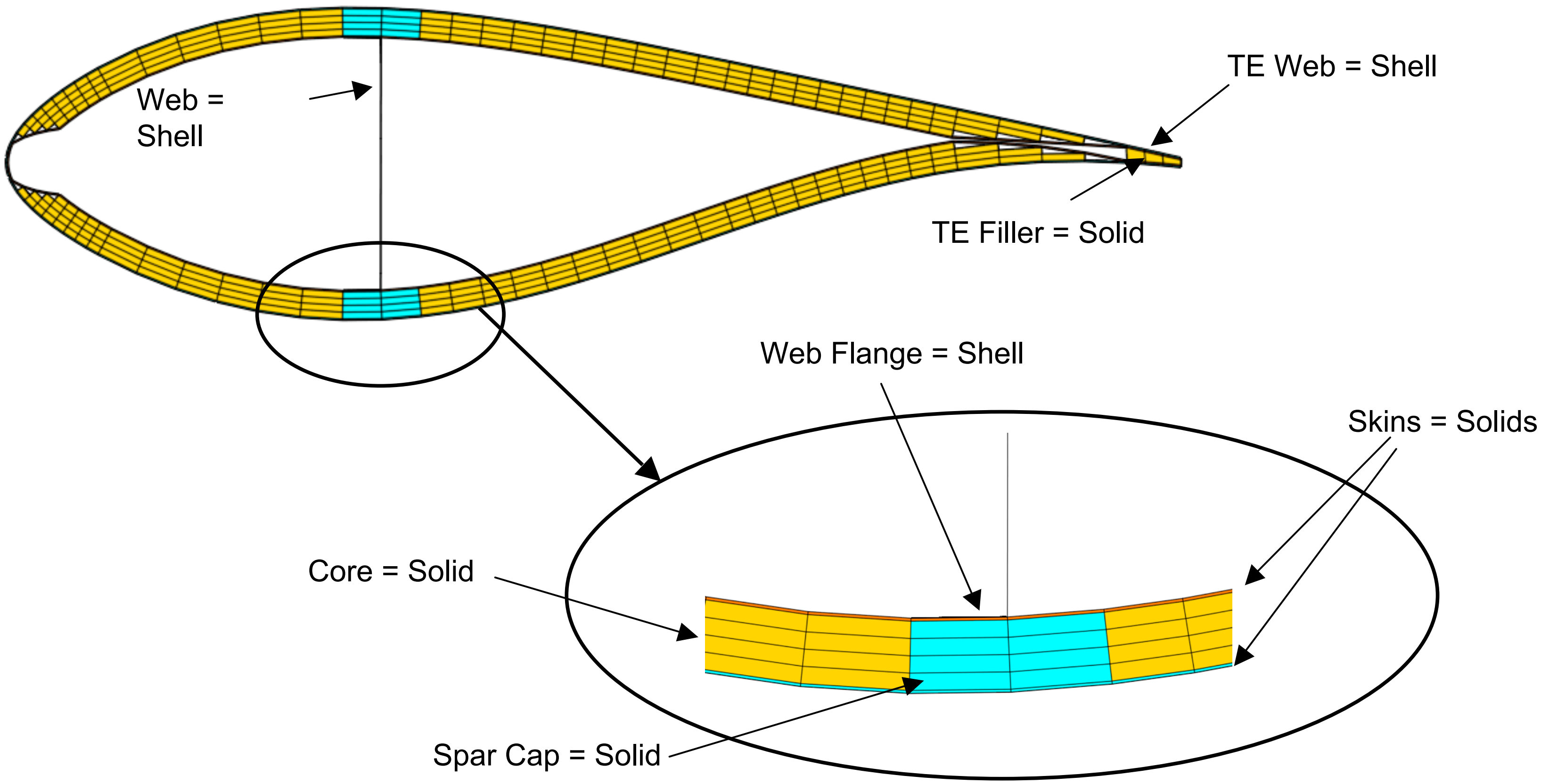
NSE 'bladeMesher' - 3D Mesh Definition

- Spanwise material and thickness changes can be defined to occur over a single element length (default) or over a set distance, whichever best represents the actual blade construction.
- The "interior" nodes are then generated by projecting inward, normal to the OML, based on the material definition at each location:
  - *skin only regions*
  - *skin + core/spar cap regions*
  - *core ramp regions*
  - *spar web locations*
- The number of nodes through the thickness is user-defined.
- Elements are then defined based on the nodes and material properties assigned for each type of material.



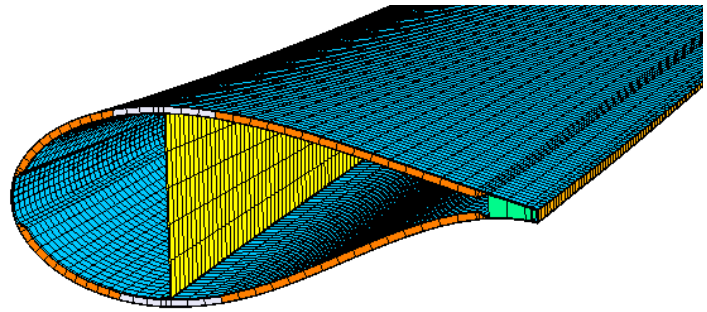
FE Model Details - Example

- The skins and spar caps are made from solid (brick) elements and use average orthotropic properties derived from the ply buildup at each location.
- The core is made from solid elements and may be either isotropic (e.g., foam) or orthotropic (e.g., honeycomb)
- The webs and flanges are layered composite shell elements.

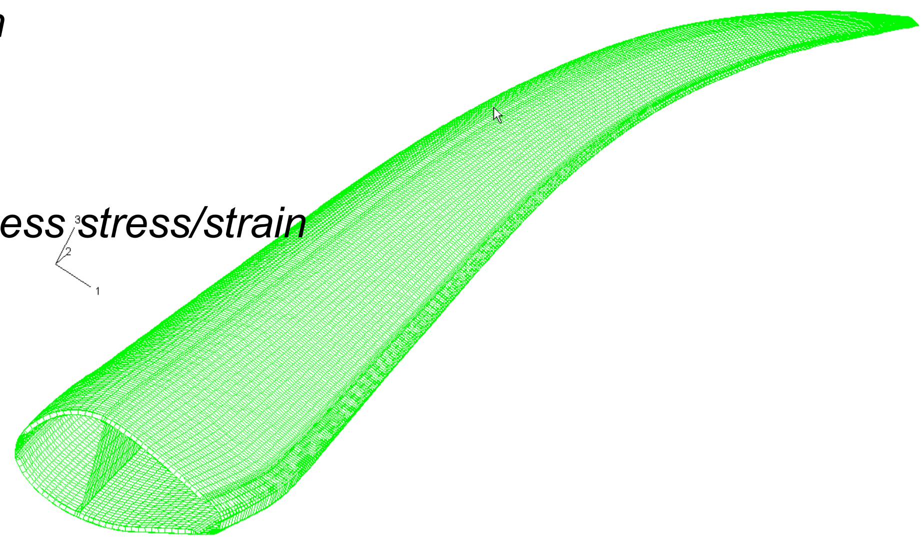


NSE ‘bladeMesher’ Output

- Full 3D FE Mesh of Blade
  - *solid elements for skins, core, spar caps*
  - *shell elements for spar webs and trailing edge close out*
  - *user defined mesh density*



- Accurate Material Variations
  - *representative variation in skin, spar cap, and core thicknesses and/or material properties*
  - *continuous variation in spar cap width*
- Benefits of 3D Solid FE Model
  - *complete 3D visualization of blade*
  - *accurate in-plane and through-thickness stress/strain results*
  - *accurate twist performance (no shell offset issues)*
  - *any leading edge shape (no shell normal angle limitations)*
  - *possible to analyze adhesive joint layers and predict joints stresses.*

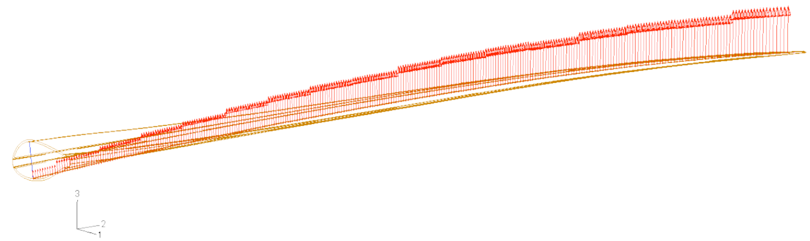


FEM Output

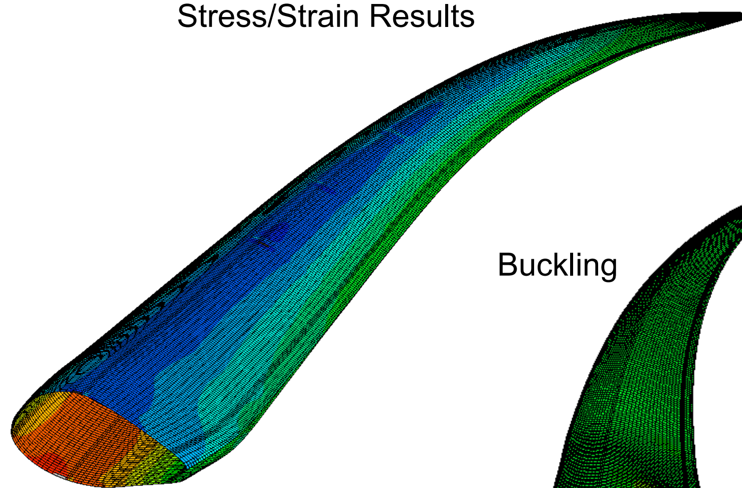
- Once loads and boundary conditions have been defined, the following types of analysis can be performed:
  - *linear or nonlinear geometry*
  - *Eigenvalue (linear) buckling*
  - *nonlinear buckling/collapse*

- FEM Results
  - *deflection and twist predictions*
  - *stress/strain results including accurate analysis at structural details*
  - *buckling stability predictions*
  - *equivalent beam properties*

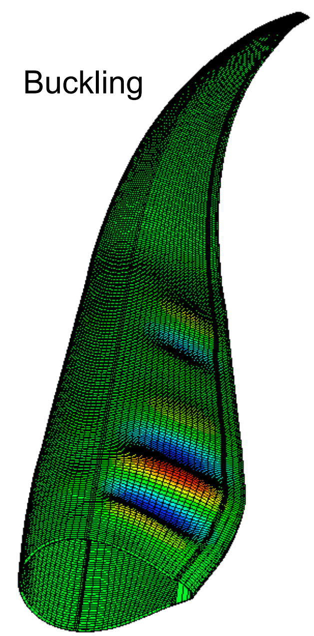
Loads



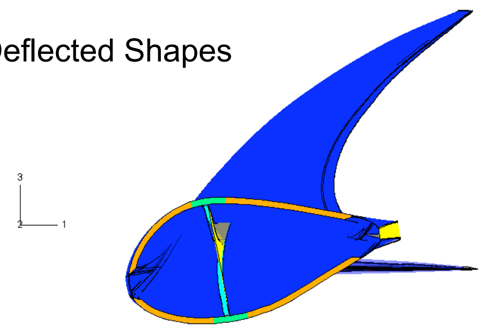
Stress/Strain Results



Buckling



Deflected Shapes



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NSE "bladeMesher"

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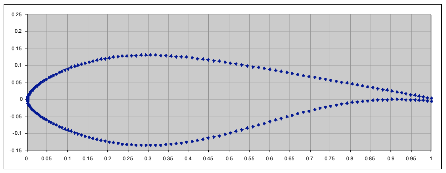
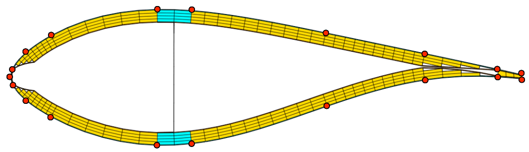
INPUT

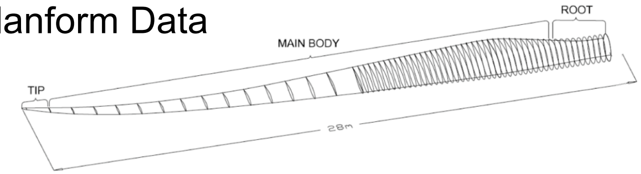
Airfoil Data



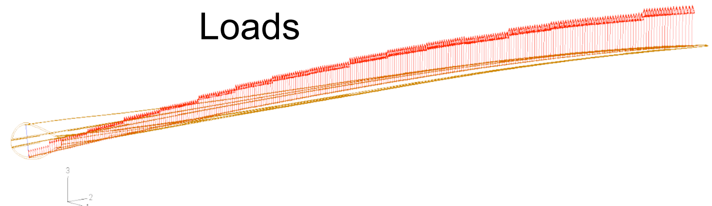
Material Definition



Planform Data

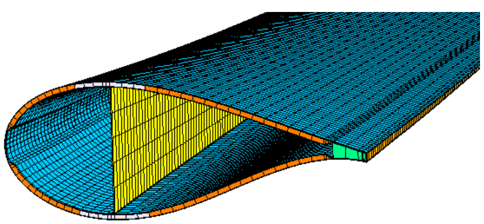


Loads

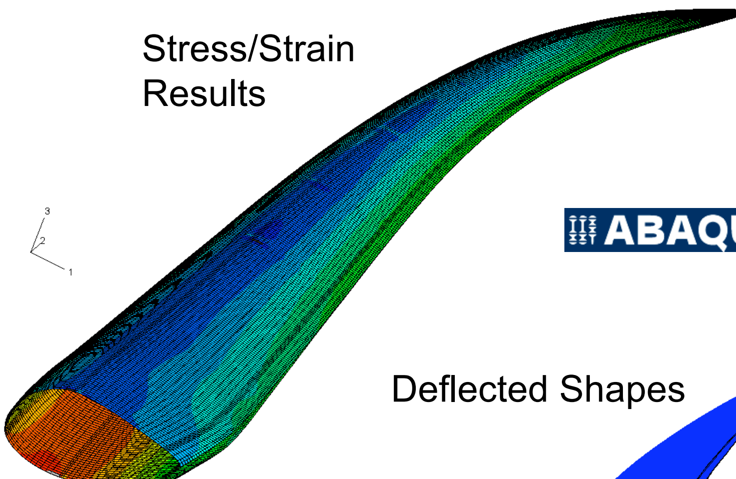


OUTPUT

Full 3D solid FE mesh of blade



Stress/Strain Results



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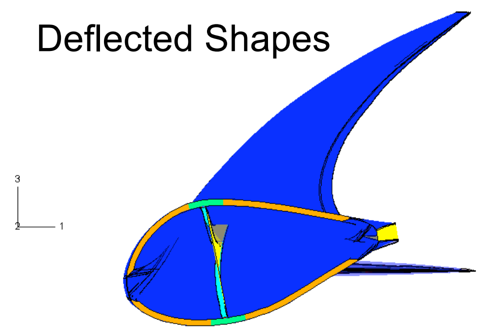
Deflected Shapes



Buckling