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SUPERGEN WIND

Dynamic FE Modelling of Supergen Wind Turbine Blade

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Contents

- Overview of Phase 1 work
- Goals of Phase 2
- Work to date on Phase 2
- Summary

Supergen Phase 1

- Supergen Phase 1 was successful in creating a representation of a wind turbine blade in the ABAQUS FEA code.
- This model was parametric and flexible and could be automatically altered to tune the blade's construction to match desired parameters.
- This was able to be used for static and quasi-dynamic analysis.
  - Included gravity, centrifugal and aerodynamic loads.

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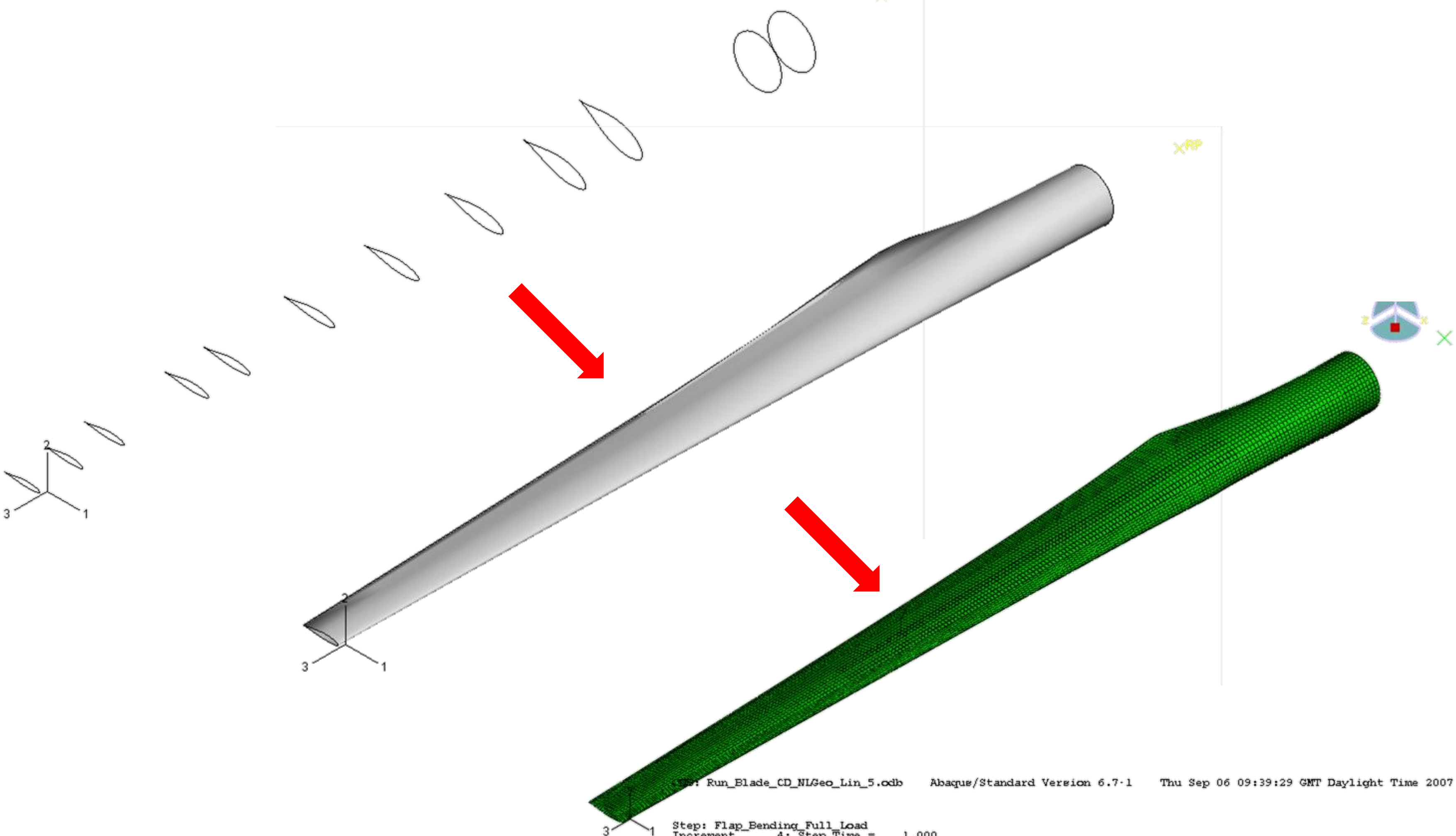
Aerodynamic Surfaces created from a spline through aerofoil sections and then turned into a shell mesh



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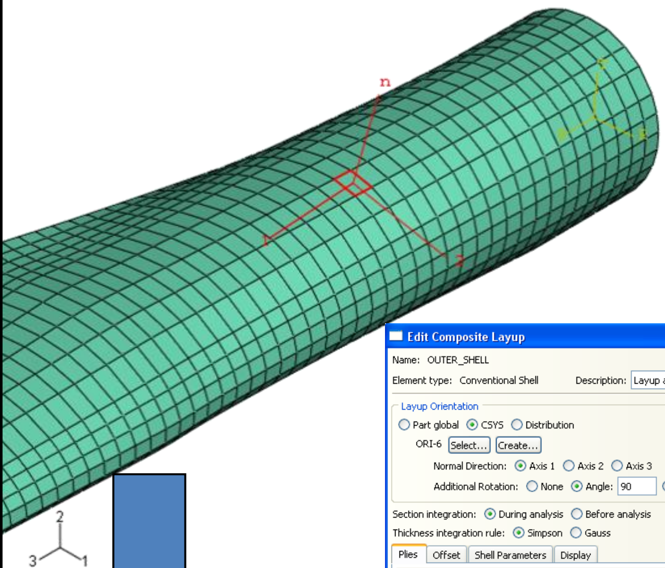
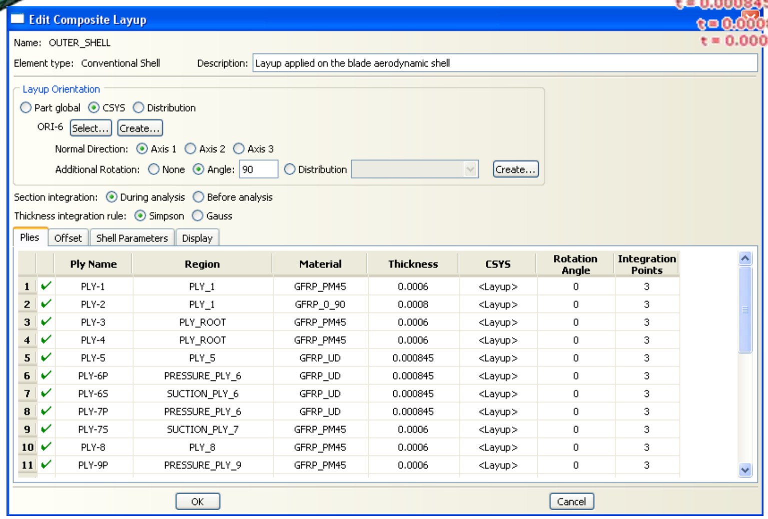
Mechanical properties applied by giving elements material and layup definition





Edit Composite Layup

Name: OUTER_SHELL

Element type: Conventional Shell   Description: Layup applied on the blade aerodynamic shell

Layup Orientation

Part global CSYS Distribution

ORI-6 Select... Create...

Normal Direction: Axis 1 Axis 2 Axis 3

Additional Rotation: None Angle: 90 Distribution Create...

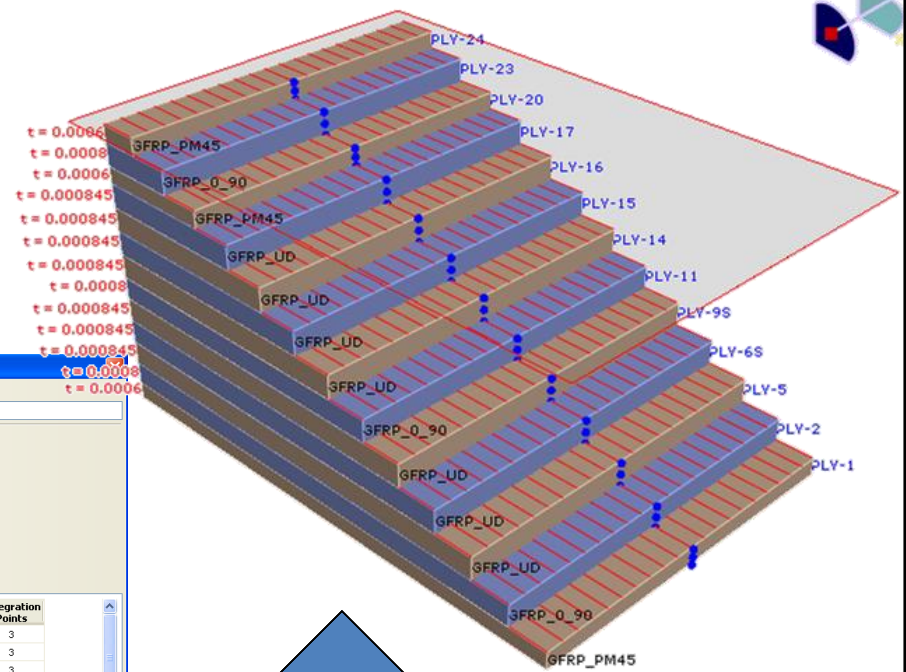
Section integration: During analysis Before analysis

Thickness integration rule: Simpson Gauss

Plies | Offset | Shell Parameters | Display

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✔	PLY-1	PLY_1	GFRP_PM45	0.0006	<Layup>	0	3
2	✔	PLY-2	PLY_1	GFRP_0_90	0.0008	<Layup>	0	3
3	✔	PLY-3	PLY_ROOT	GFRP_PM45	0.0006	<Layup>	0	3
4	✔	PLY-4	PLY_ROOT	GFRP_PM45	0.0006	<Layup>	0	3
5	✔	PLY-5	PLY_5	GFRP_UD	0.000845	<Layup>	0	3
6	✔	PLY-6P	PRESSURE_PLY_6	GFRP_UD	0.000845	<Layup>	0	3
7	✔	PLY-6S	SUCTION_PLY_6	GFRP_UD	0.000845	<Layup>	0	3
8	✔	PLY-7P	PRESSURE_PLY_6	GFRP_UD	0.000845	<Layup>	0	3
9	✔	PLY-7S	SUCTION_PLY_7	GFRP_PM45	0.0006	<Layup>	0	3
10	✔	PLY-8	PLY_8	GFRP_PM45	0.0006	<Layup>	0	3
11	✔	PLY-9P	PRESSURE_PLY_9	GFRP_PM45	0.0006	<Layup>	0	3

OK   Cancel



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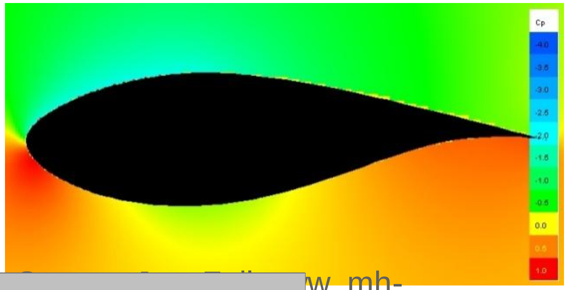
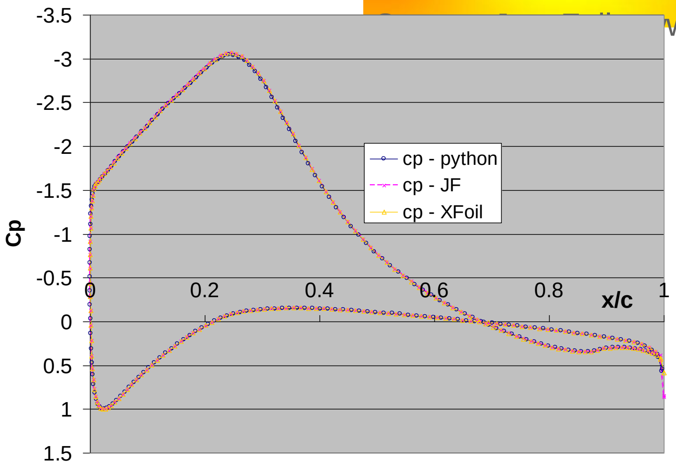
Aerodynamic blade loading

- Aerofoil coordinate files
  Blade design sectional data
  Materials and layups
- Rotor operating conditions
  (RPM, wind speed, wind shear, blade angular position)

→ Blade geometry & mesh

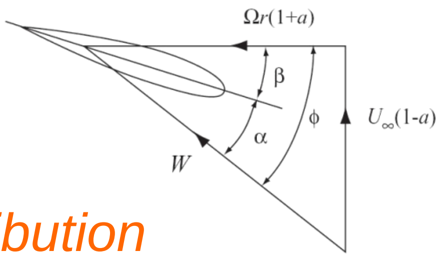


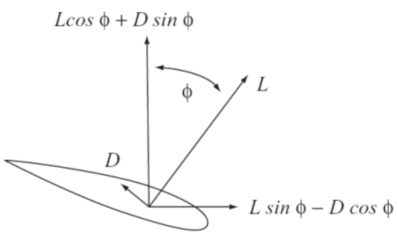


Gravity
+
Centrifugal
+
Aerodynamic

Blade loads automatically calculated & applied to mesh nodes

Potential flow for 2D solution
+
BEM for 1D along blade





Hence specify 3D surface pressure distribution

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Phase 1 Aerodynamic loading

- In phase 1 the aerodynamic loads were calculated as a function of :
  - RPM, wind speed, wind shear, blade angular position
- This was before the structural analysis took place.
  - The aerodynamics loads were calculated using a rigid blade
  - Unable to see the effect of deflection of the blade or change in angle of attack on wind field

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Supergen Phase 1 Blade Model

- Works very well for static and quasi-dynamic analysis.
  - Able to vary geometry, internal structural shape, structural mesh, materials, loads etc.
- It has been problematic to perform a dynamic analysis with this model.
  - Due to the complexity of the model it will always be computationally expensive.

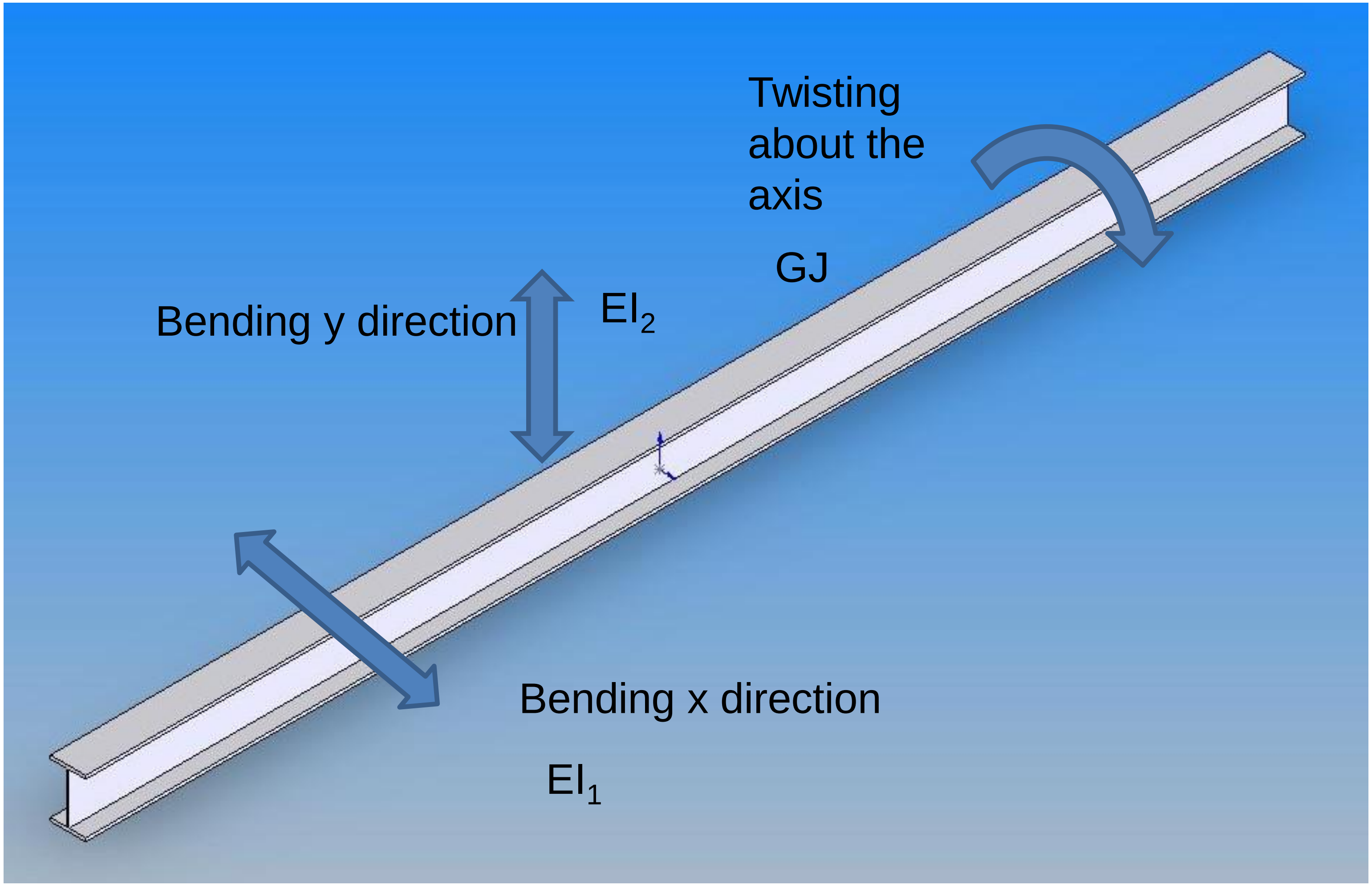
Goals of Phase 2

- Create a dynamic model that links the STFC-RAL blade model to the Aerodynamic code in development at Imperial College
  - Study the affect of blade deflection on wake
  - Model the affect of gust loads
  - Optimise placement of turbines for maximum efficiency
  - Investigate use of moveable aerodynamic surfaces
- Include a representation of a generator

Supergen Phase 2 Model

- Use a simpler model
  - less computationally expensive
  - easier to couple with the aerodynamic model
  - but behave in a similar way to the phase 1 blade.
- This can be done by using beam elements with mechanical properties derived from the phase 1 model.

Typical beam analysis

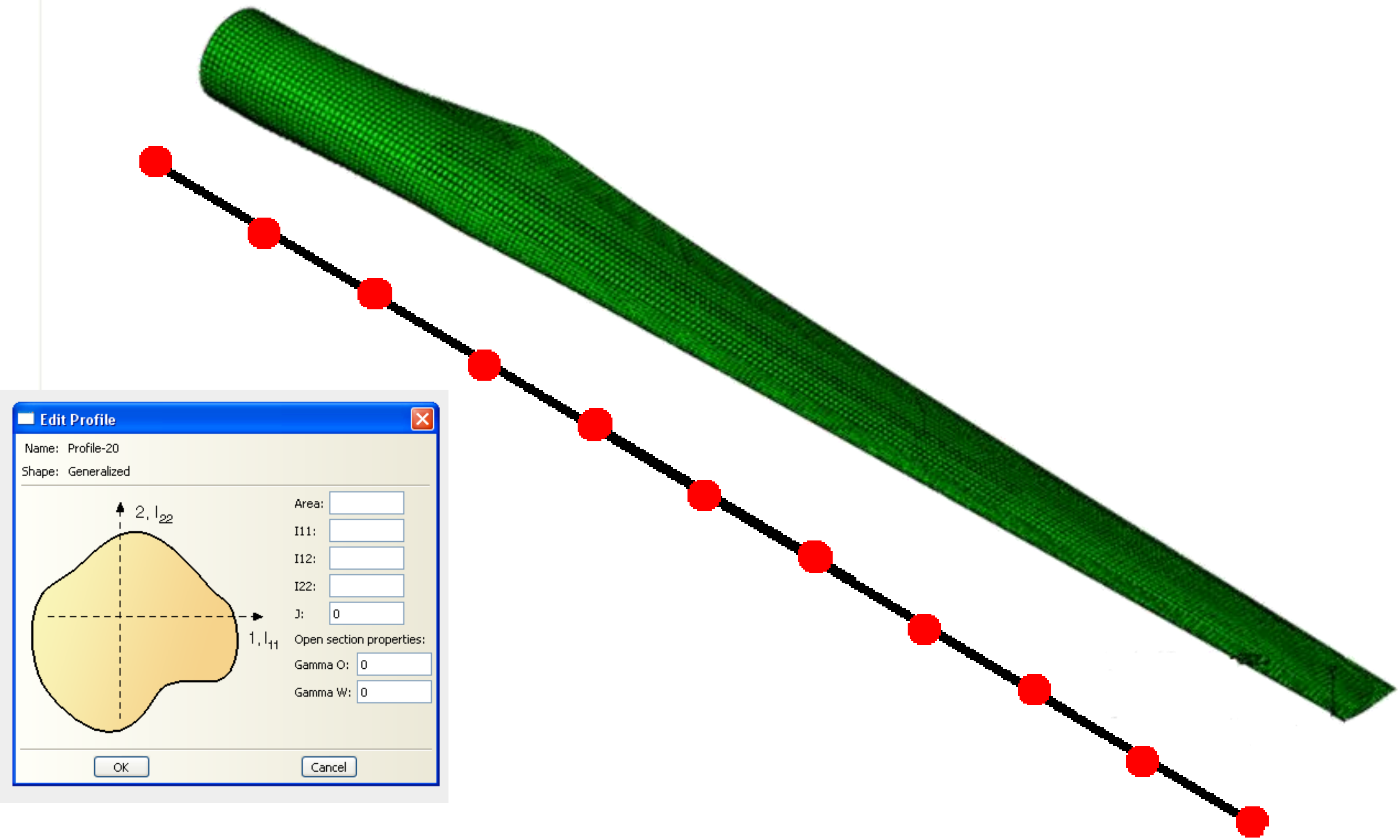


Material Properties

In order to model a turbine blade using beam elements we need:

- Bending stiffness EI_1 (edge) & EI_2 (flap)
- Torsional Rigidity (GJ)
- Inertia (For the rotational dynamics)
- These values are calculated using the Phase 1 model

Supergen Phase 2 Model



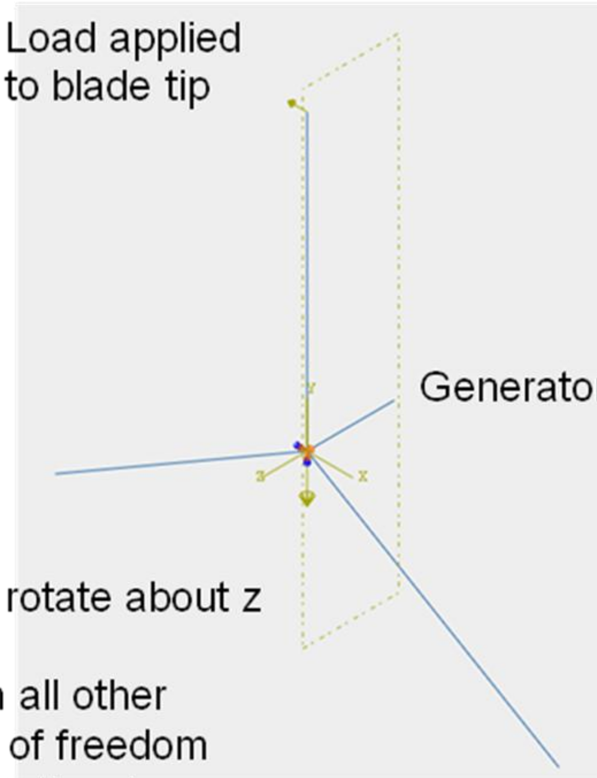
Coupling the Aerodynamic and the Structural codes

- Need to pass information between the two codes mid run
  - Aerodynamic code needs the edgewise and flapwise deflection, angle of twist and angular velocity
  - The Abaqus structural code needs the edgewise and flapwise force.
- So far the challenge is to get the forces back into Abaqus during a solution.

Coupling the Aerodynamic and the Structural codes

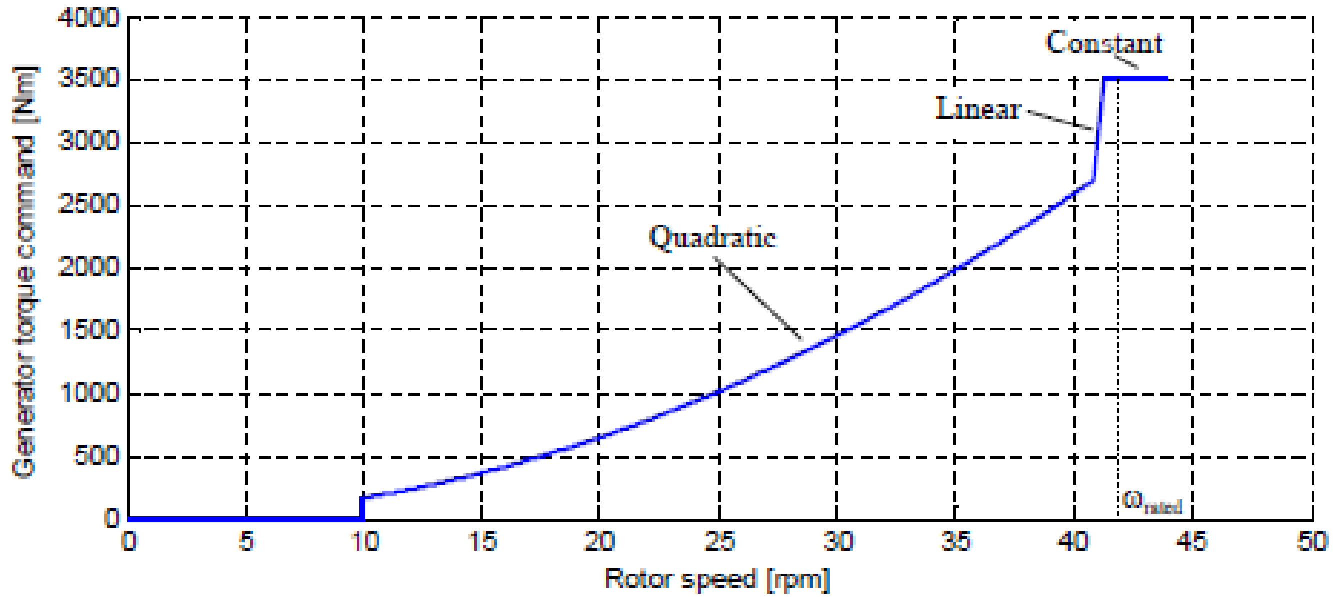
- In order to input/output data from Abaqus during a solution Fortran subroutines are being investigated
- Abaqus supplies a set of subroutines that fulfil various tasks.
  - Unfortunately none cover the input/output requirements of this model
  - But using a combination of two subroutines it is believed to be possible.
    - Still to be demonstrated!

Generator Response



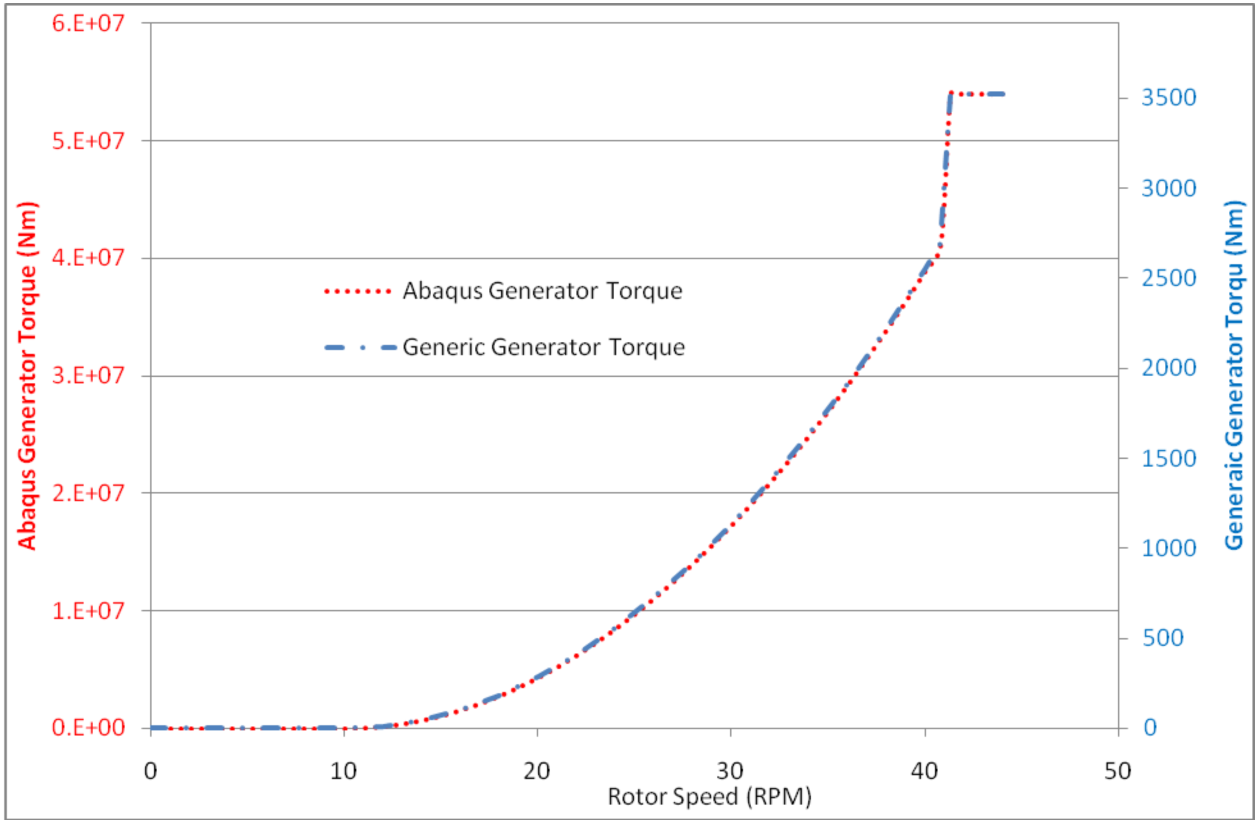
Hub-
- Free to rotate about z axis
- Fixed in all other degrees of freedom
- Hub Rotational Velocity used as a sensor

Generic Generator Response



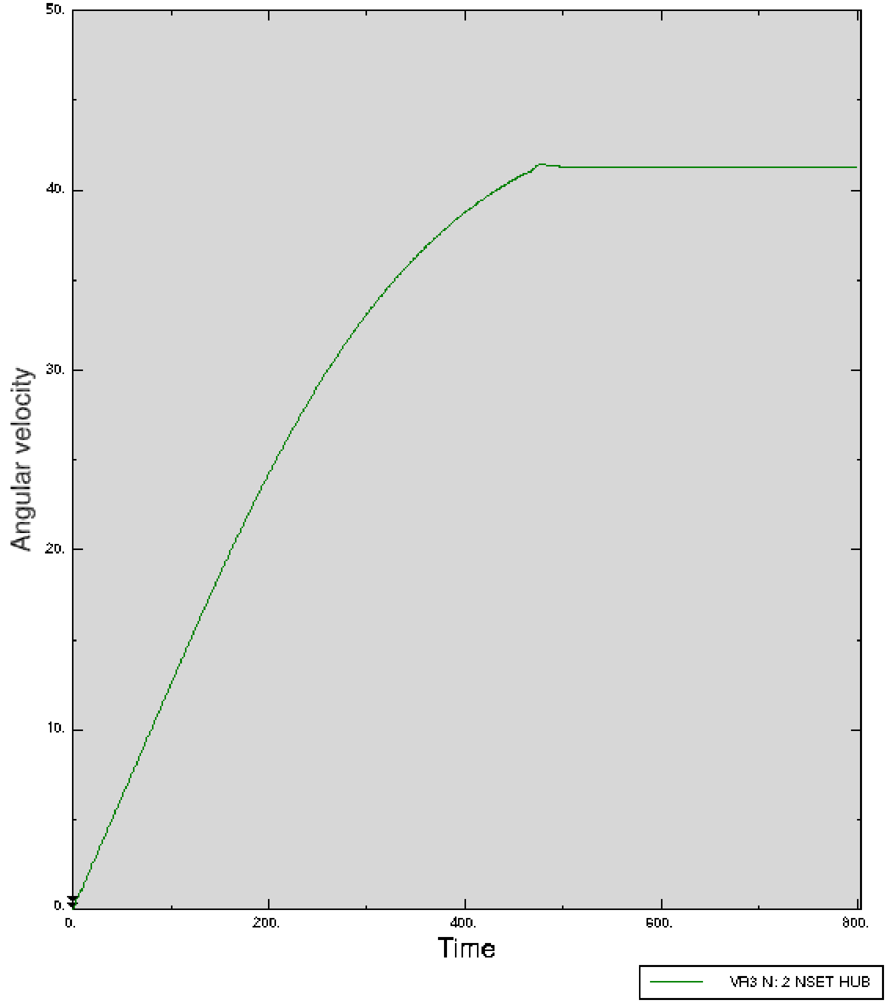
This Generator is designed to keep the turbine tip speed velocity at it's optimum value for a given wind speed.
Between 0 and 10 rpm the generator provides 0Nm torque, to allow the rotor to increase in velocity,
between 10rpm and 40.8rpm (98% rated), there is a quadratic torque response.
Between 98% & 99% of the rated rpm the torque response is linear,
and over 99% of rated rpm the maximum torque supplied by this generator is 3524Nm.

Exaggerated Generator response



In order to get the turbine up to speed quickly I scaled up the force on the tip and the generator response. Although the values used are higher, they follow the same pattern.

Velocity Output from the Hub node



Summary

- Created a simplified version of Phase 1 beam model for dynamic studies
- Still need to couple aerodynamic code to structural code
  - Fortran sub routines look viable but need to be demonstrated
- Incorporated a generic generator response