Simulation and Optimization in the wind energy industry

Numerical Simulation & Optimization

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Summary

- Why to use numerical simulations and optimization?
- An overview on CAE applications in wind energy
- Conclusion
Process integrated of product development

Manufacturing

High performance product requirements

Physical prototyping

Concept and design

Optimization

Numerical simulations
Numerical Simulation and optimization process

Numerical simulations allow to check the performance of the product before manufacturing.

New technologies allow to simulate every kind of complex phenomena, included iterations between different field.

Increased computational power of commercial work stations reduce time of simulations.

Optimization process coupled with virtual prototyping increase the product performance minimizing costs.
Advantage gained with process integration

Numerical simulation and optimisation

- Shortened physical prototyping phase
- Deep understanding of product behaviour
- Find the optimum product choosing the best parameter settings
- Automatic update of simulation and optimisation process

- Minimizing cost
- Minimizing time
- Maximizing reliability
- Maximizing performance
ANSYS Offering

- **Multiphysics analysis**
  - structural, thermal, fluid dynamics, electromagnetic, combustion, chemical reactions, phase change etc.

- **Coupled fields**
  - fluid-structure interaction, fluid-thermal, electrostatic-structural, thermal-electric-structural, electromagnetic-thermal-structural etc.

- **Advanced capabilities for simulations**
  - all kinds of structural non-linearities, explicit solution, fluid dynamic turbulence and transient model, electromagnetic low and high frequency, etc.

- **Advanced capabilities to make your life easier**
  - allows the import of all CAD formats, geometry repair, automatic meshing (swept, hex), automatic thin-sweep meshing, scripting language, parameter manager, parallel solver report generator etc.
ModeFrontier Offers

- The Design of Experiments algorithm (DOE) creates an initial population of possible designs.

- ModeFrontier starting from the initial population created with the DOE, explore all the domain of the parameters searching the maximum or minimum of the objective function(s).

- A trade-off curve behavior is typical of problems involving an optimization against conflicting objective, where we don't have an optimal solution, but rather a full set of optimal solutions.

The whole process, from the DOE generation to the Pareto FRONTIER identification is carried out in an efficient and automated fashion by modeFRONTIER.
Simulation and Optimization on Wind energy

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Tower Design

Why to use numerical simulation on tower design process
- Get a deep understanding of the statical and dynamic behaviour of the structure
- Evaluate the interactions between fluid and structure

Goals
- Prevent the shadow effect due to wind change
- To guarantee seismic safety
- Minimizing weight and cost
Generator Design

Why to use numerical simulation on generator design process

- Virtual prototyping of initial candidate designs to determine all the generator characteristics
  - Heat exchange in air passage
  - Open-circuit saturation curve
  - Output voltage signal harmonic distortion

Goals

- Maximizing thermal loads dissipation and minimizing of power losses
- Optimizing the voltage signal
Why use numerical simulation on blade process

- Virtual prototyping of initial candidate designs for reduced wind tunnel and full scale testing
  - Automation of design of experiments/wind conditions of interest
- Pull down the design costs

Goals

- Evaluating and maximizing structural performance
- Evaluating and maximizing blade profile aerodynamic efficiency
- Minimizing weight and cost
- Reducing noise generated by implant
Shaft and Gear Systems

Why use numerical simulation in the shaft and gear system design process?

- Virtual prototyping of initial candidate designs to determine all system characteristics
  - Critical speed
  - Whirl
  - Stability
  - Transient response

Goals

- Optimize rotational stability
- Prevent interface generated by deformation during exercise phases
Offshore Turbines

Why to use numerical simulation to design offshore wind implants

- To properly evaluate the effect of the forces transmitted by the waves, wind and currents on the structures
- To gain a deep understanding of the interaction between fluid and structure
- To design the implant according to international standards

Goals

- Minimize the resistance of underwater structure to the current
- Maximize strength and minimizing weight
- Minimize costs
Why use numerical simulation to evaluate the site location?

- To predict wind behaviour over complex terrains
- To estimate implant power performance over wind change

Goals

- Optimize tower placement
- Minimize the shadow effects for varying wind directions and speeds
Conclusion

- All the different systems of the wind turbine can be deeply analysed using numerical simulations.

- Complex fluid-structure iterations can be evaluated in order to:
  - design blades
  - design wind turbine systems
  - right positioning of the different wind turbine in order to avoid shadow effects

- Computational fluid dynamics simulations allow you to estimate how wind interacts with the location’s orography.

- All the performances of different systems can be optimised so that efficiency of the wind turbine is maximised.

- An optimum location and positioning of different wind turbines can be achieved in order to get the best performance over changing wind conditions.
Demo case

- Purpose of the demo case is to give a general overview to set a simulation on fluid structure interaction using Ansys Workbench R12

- The simulation on interaction between the wind and the turbine is made in order to evaluate the effects of the fluid on the structure.
• **Two way FSI**: The results of structural analysis in the Mechanical application is transferred to the ANSYS CFX analysis as a load. Similarly, the results of the ANSYS CFX analysis are passed back to the Mechanical application analysis as a load. *The analyses will continue until overall equilibrium is reached between the Mechanical application solution and ANSYS CFX solution.* [Ansys Help]
Demo case

- Main page (GUI)
Geometry can be generated in Design Modeler or imported from an external file. Some new features are available in R12.
Demo case

• Mesh

Both structural and fluid mesh can be generated in Design Simulation.

Some new features are available in R12
Demo case

• Setup FSI (2 way)
Demo case

- Setup domains
• Setup interface fluid - structure
Demo case

• Setup boundary conditions
  • Inlet
  • Outlet
  • Ground
  • Side

...after the setup submit the analysis...
Demo case

- Review results.

Several features to post process results are available
  - Vector
  - Contour
  - Streamline
  - Particle track
  - Clip plane
  - Chart
  - ....
Demo case

Conclusion

• The simulation on fluid-structure interaction allowed us to:
  
  ➔ Determine the stress on the tower and blades
  ➔ Analyse the fluid flux to evaluate any shadow effects close to the tower
  ➔ Analyse the fluid flux around the turbine

• Further analysis can be added in order to evaluate:
  
  ➔ The heat exchange between fluids and the turbine
  ➔ A random analysis on tower and blades in order to completely characterize the structural behaviour
Thank You For Your Attention

• Please let us know if you have any questions on specific topics

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