4th Wind And Drivetrain Conference

Wind and Drivetrain Update

3DEXPERIENCE®

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DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

Dassault Systèmes Long-term Commitment to Simulation

Agenda

- Applications areas
- Aerodynamics and Hydrodynamics
- Bearings and Gearwheels
- Multi domain Interfaces
- Electromagnetics
- Acoustics
- 3DEXPERIENCE
- Conclusion

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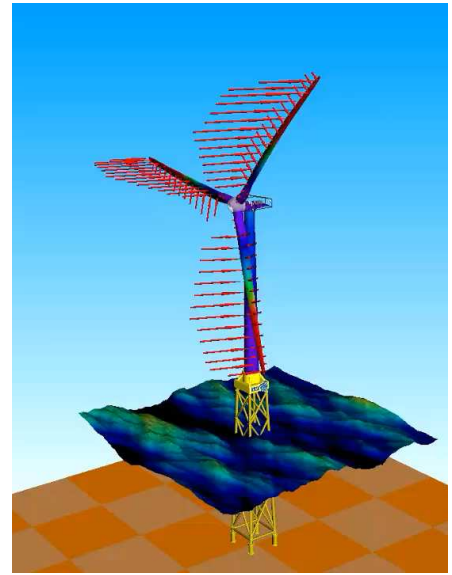

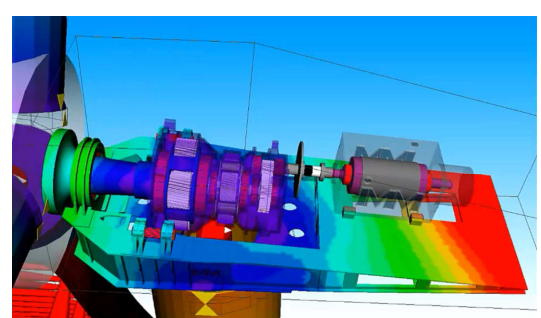

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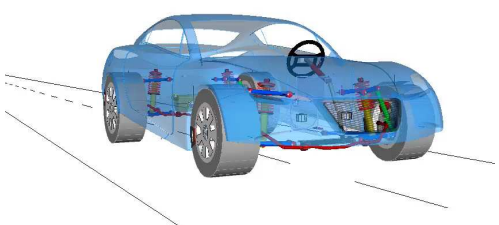
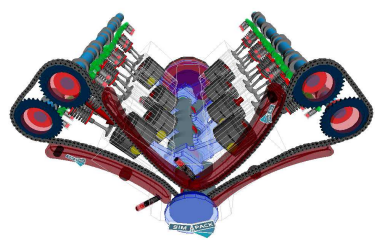
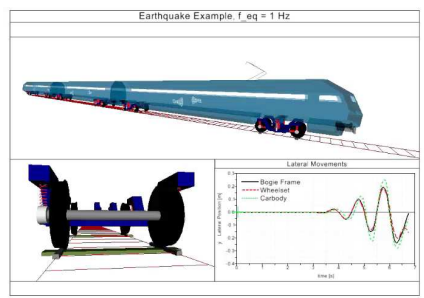
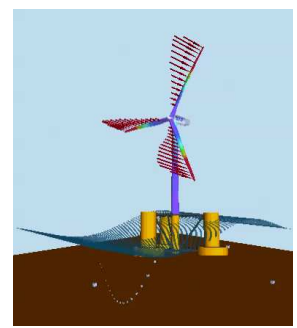
Simpack Application Sectors

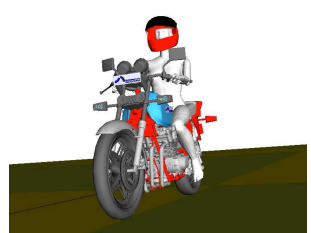
Simpack is used to **predict** and **optimize motion and loading** of any mechanical and mechatronic systems, even up into the **acoustic range**.

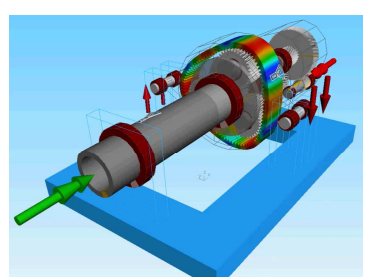






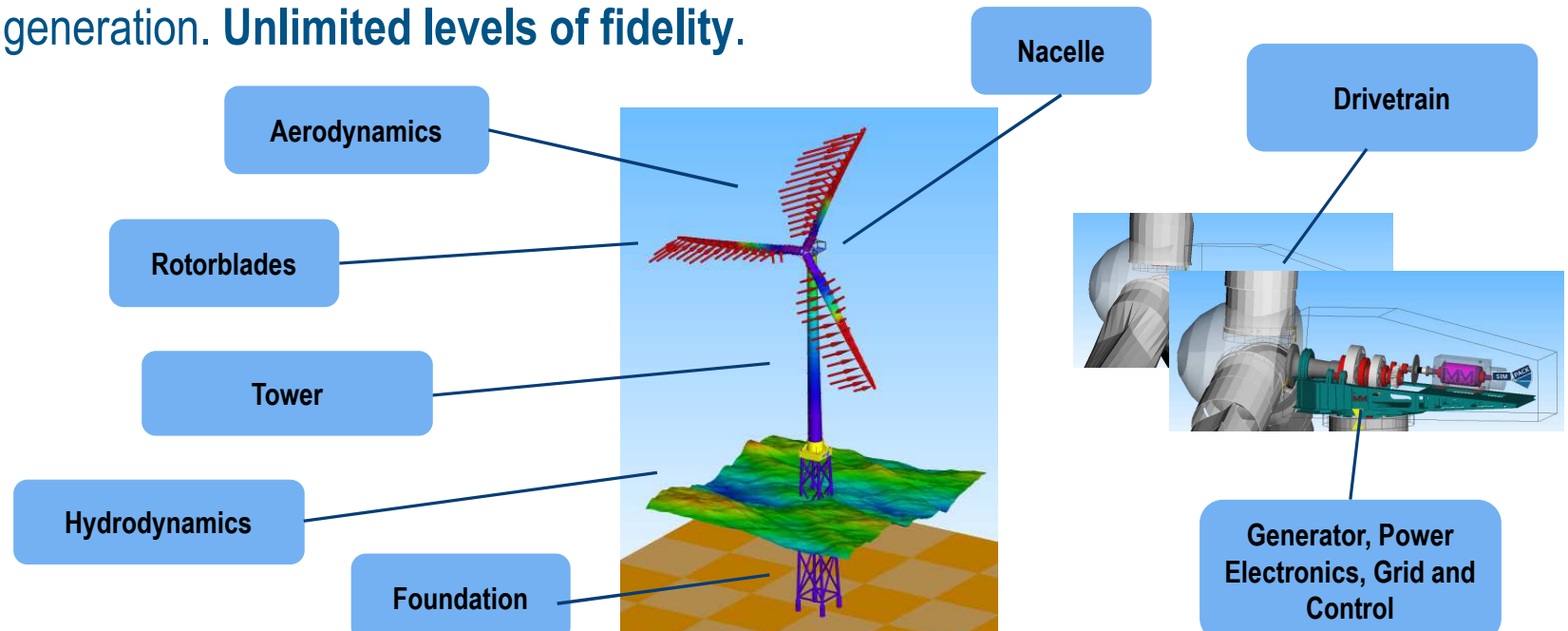






Simpack: Scalable Simulation for Wind Turbines

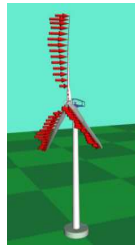
Complete turbines with/and sub-systems can be simulated for dynamic analysis and load generation. **Unlimited levels of fidelity**.

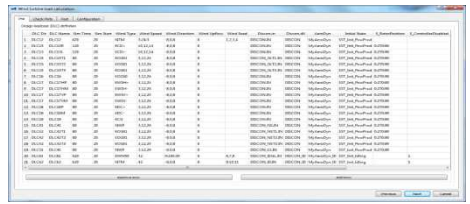


Simpack Wind

Applications

- Load Calculations
  - Any wind turbine model, any level of detail
  - Template Scripts and example model
- Drivetrain Resonance Analysis (GL 2010)
- Components and Systems
  - Design, analysis, comprehension and optimization
- Extreme events
- Stress and Durability
- Acoustics
- Test-rigs, Turbine assembly, …





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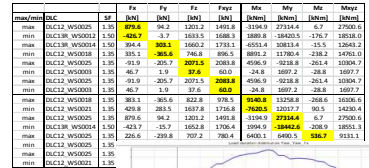
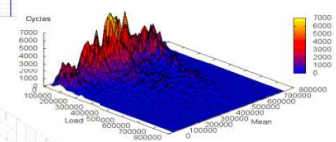
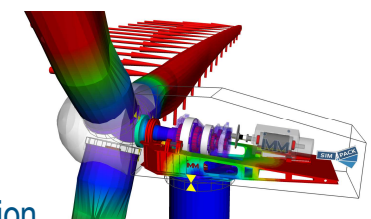
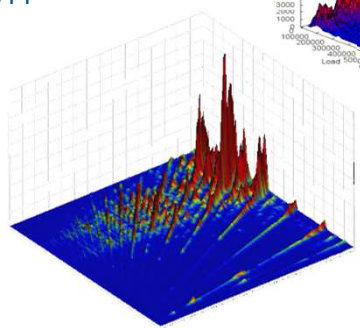
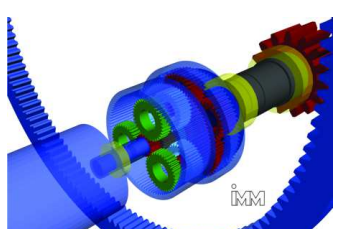
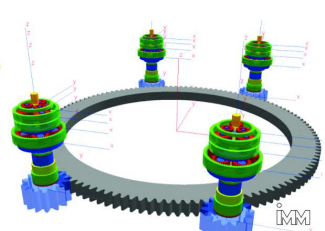


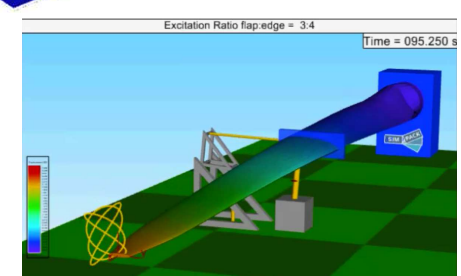








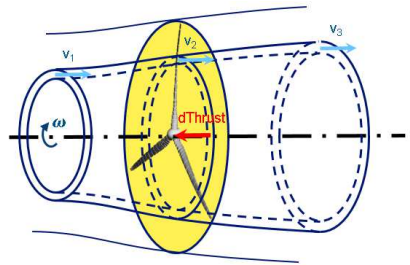


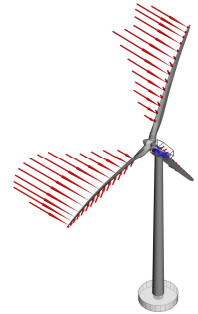


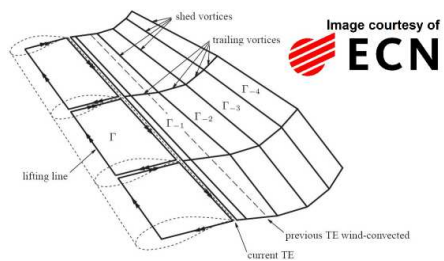
Aerodynamics

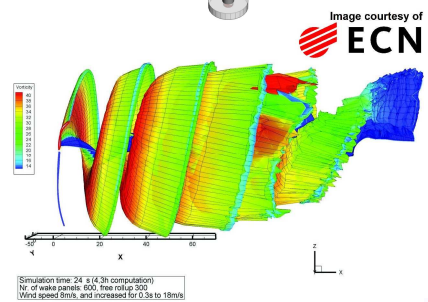
Methods

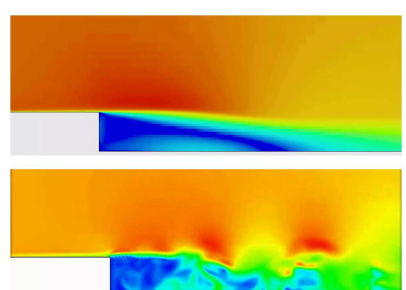
- Blade Element Momentum (BEM)
  - AeroDyn from NREL
  - AeroModule from ECN
  - Flex5 (customer implementation)
- Free Vortex Wake
  - AeroModule from ECN
  - S4 from DLR (customer implementation)
- CFD (Navier Stokes, Lattice Boltzmann)
  - Abaqus, XFlow, Exa PowerFLOW, 3DEXPERIENCE
  - Customer implementations

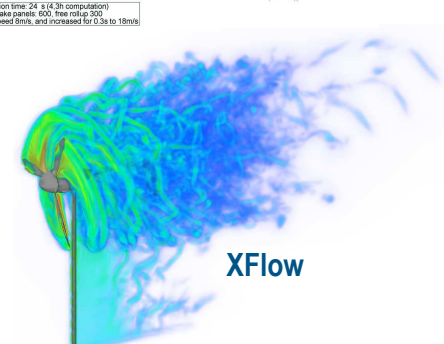








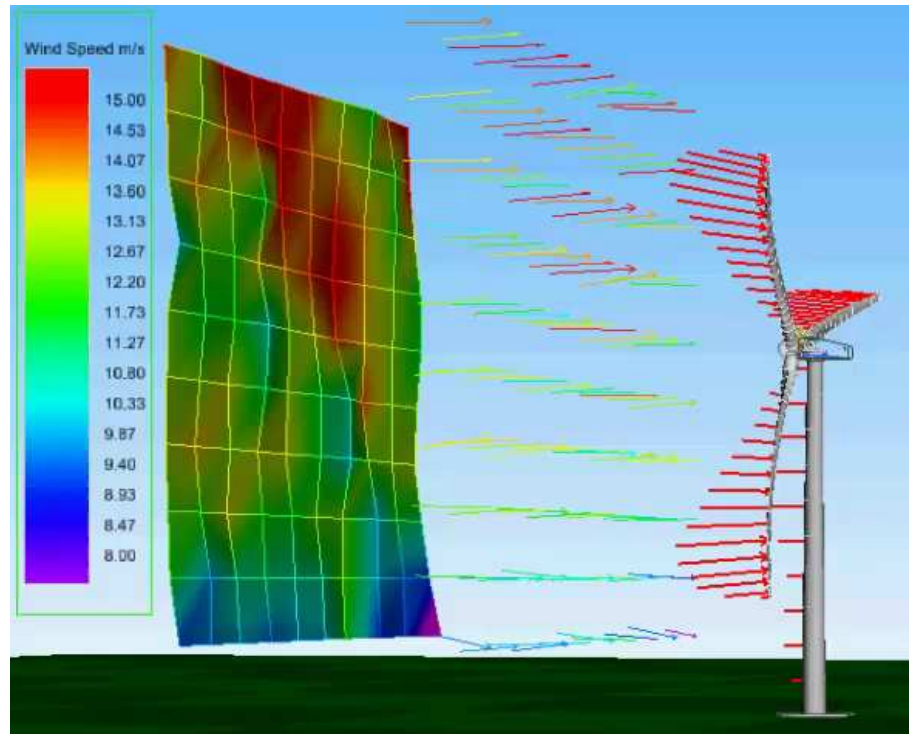




NREL AeroDyn v15

Major Improvements

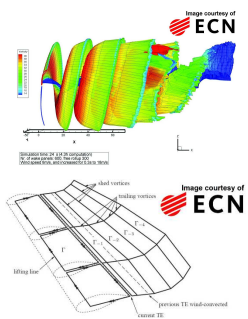
- Aerodynamic loads on the tower
- Wind field graphical representation
- Aerodynamically different rotorblades
- Map meshing between structural and aerodynamic mesh

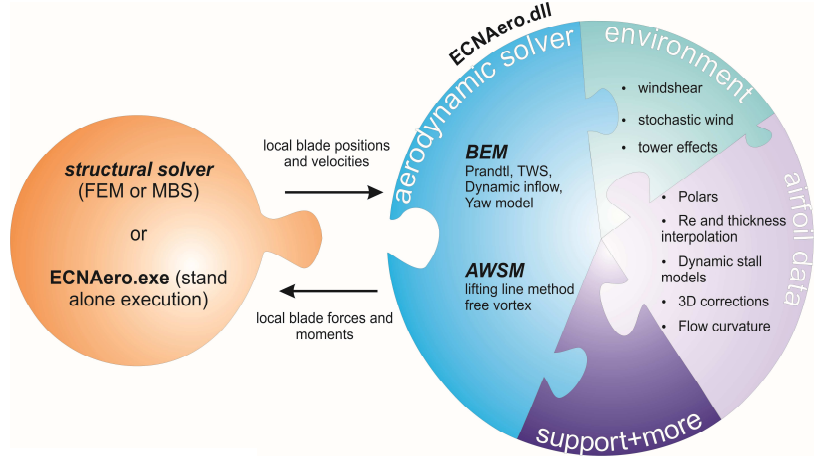


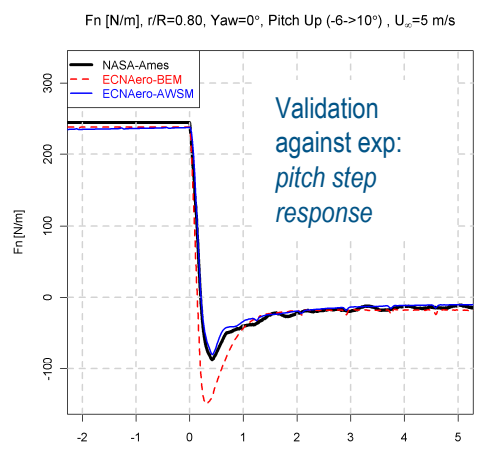
ECN Aero-Module

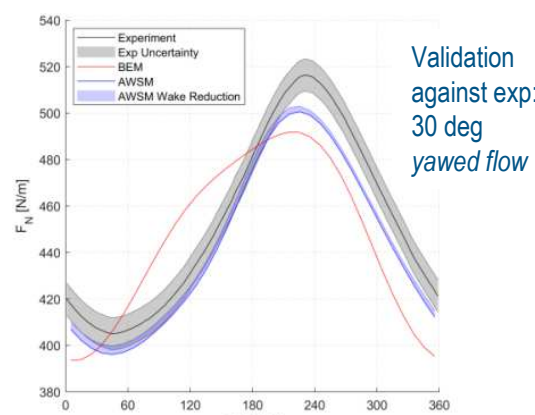
Wind Loading

- Two levels of fidelity, same input
  - Blade Element Momentum method (BEM) + engineering methods
  - Lifting line free vortex wake method (AWSM)
- Based on and validation
  - Many years of research and industrial projects
- Standard Simpack interface





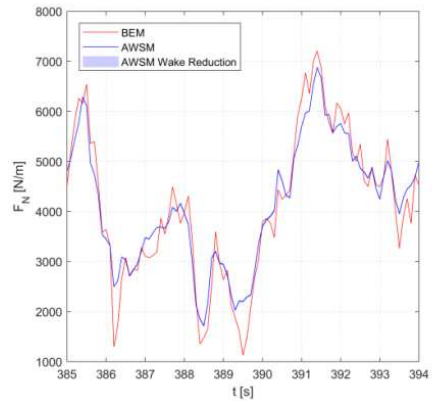


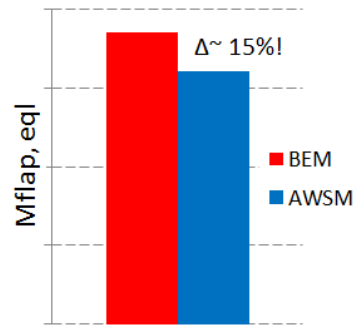


ECN Aero-Module

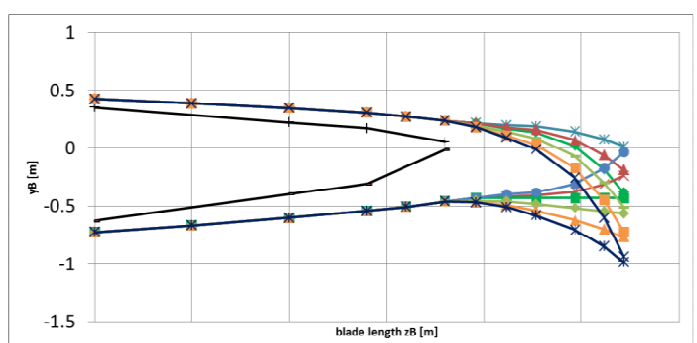
Added Value

- Flexible switch for required balance between accuracy and computation time (different methods, same input)
- AWSM, better prediction of unsteady aerodynamics
  - Non-uniform inflow (e.g. turbulence, shear)
  - Aero-elastic instabilities (e.g. flutter)
  - Dynamic inflow (e.g. pitch step, IPC)
  - Yawed flow
- AWSM intrinsically includes
  - Tip effect
  - Curved blade axis (sweep, winglet)
  - Radial interaction

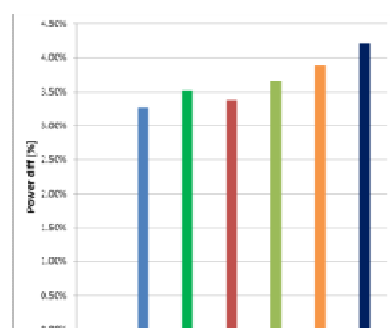




Blade Root Loading



Blade Shapes



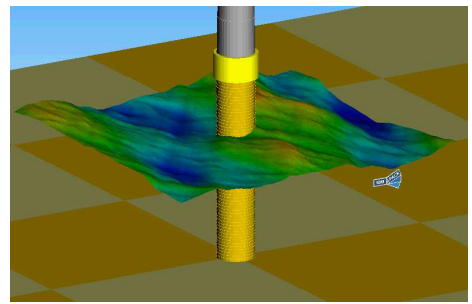
Power Performances

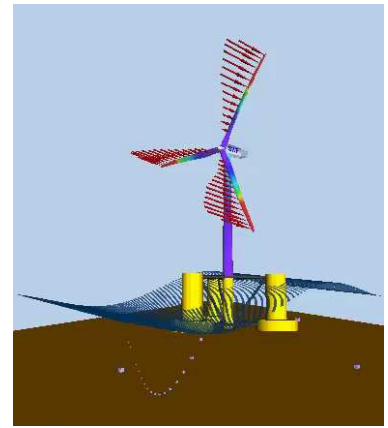
https://www.ecn.nl/docs/library/report/2012/m12003.pdf
http://iopscience.iop.org/article/10.1088/1742-6596/753/2/022030

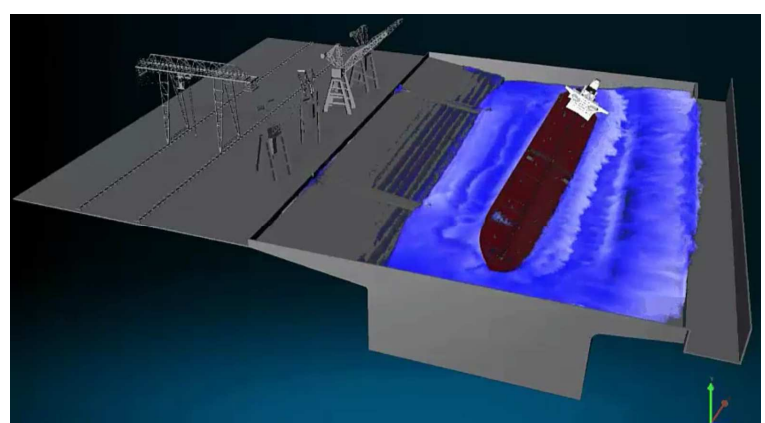
Hydrodynamics

Methods

- Morrison Equations (HydroDyn)
  - Slender cylinders
  - Offshore fixed and floating structures
- Linear hydrodynamics (HydroDyn)
  - hydrostatic, waves/currents, added mass, radiation/diffraction
- CFD
  - Detailed Loading
  - Extreme events
  - Turbine shadowing
  - Optimization



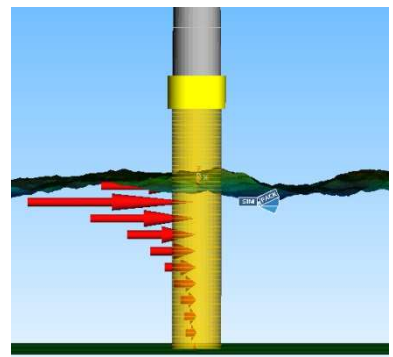


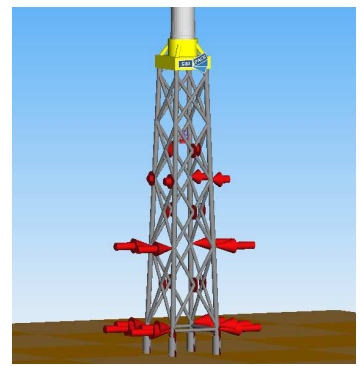


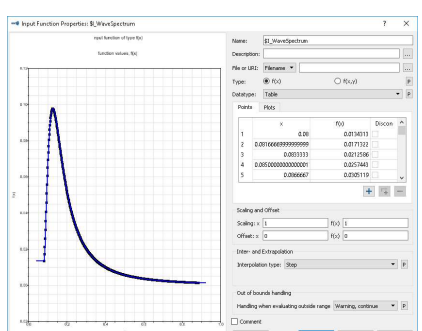
HydroDyn (in Simpack)

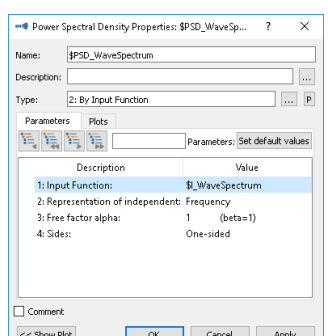
Major Improvements

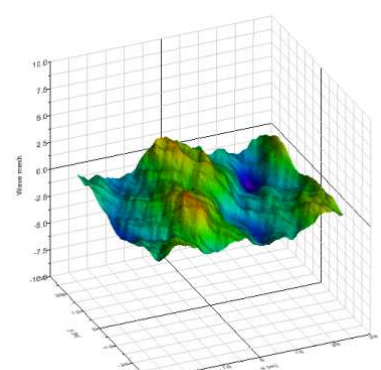
- Linearization
  - Including added mass from surrounding water
- User Defined Wave Spectrum via PSD
  - Input function → PSD → HydroDyn



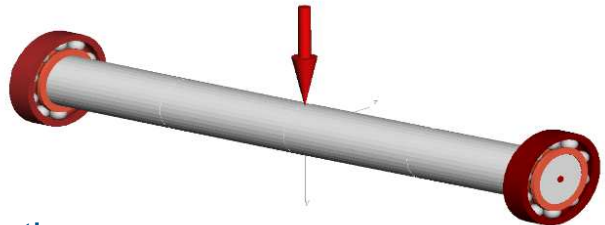


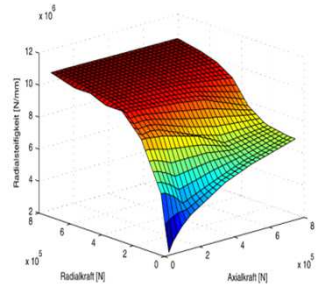


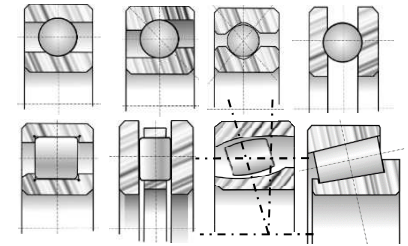




Bearings

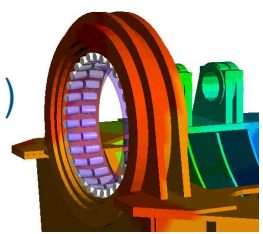




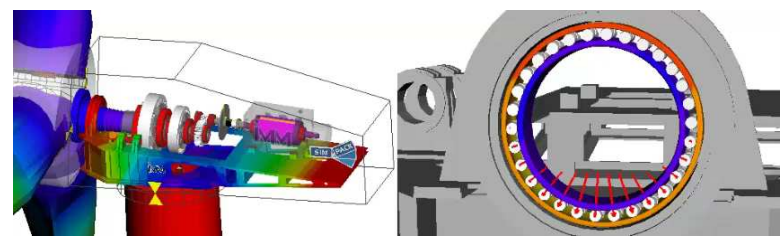


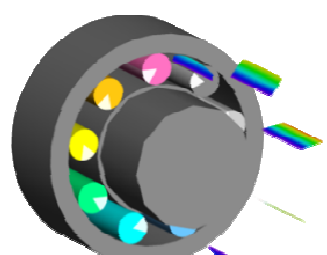
Rolling Bearings

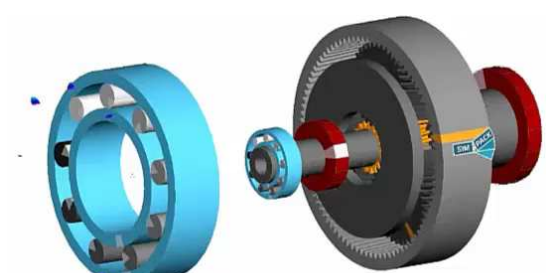
- 3D Contact Description
  - Based on inner bearing geometry
  - Analytical force description (ISO 16281)
  - Non-linear stiffness and cross-coupling
  - Flexible bearing rings
- Full Body Model
  - Full geometrical and inertial description
  - Advanced output values (e.g. surface stress)



Spherical bearing



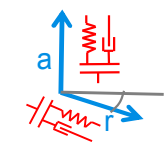


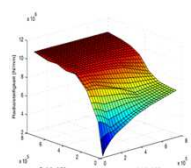


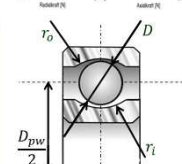
Rolling Bearings – Functionality Overview

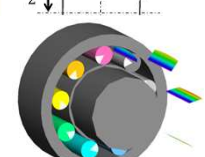
Element	Characteristics	Use
1D Spring-Damper (FE 6, 43, 185)	• Non-linear 1D stiffness • Clearance definition	• Bearing of rigid shafts with linear angular velocity or load • Simplified NVH driveline analysis
3D Stiffness Matrix (FE 41, Bearinx ®)	• Linear 3D stiffness • Cross-coupled forces/torques • All displacements considered	• Bearing of flexible shafts with increasing loads • NVH without bearing excitations
3D Contact Description (FE 88)	• Non-linear 3D stiffness • Cross-coupled forces/torques • Cage rotation & flexible bearings	• Flexible bearing of flexible shafts with dynamic loads • NVH incl. bearing excitations
Full Body Model (FE 198)	• Full description of all bearing components and contacts	• Detailed bearing analysis (e.g. normal stress and cage interaction)

Level of Detail





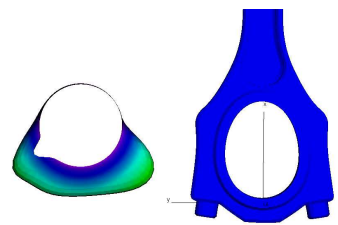


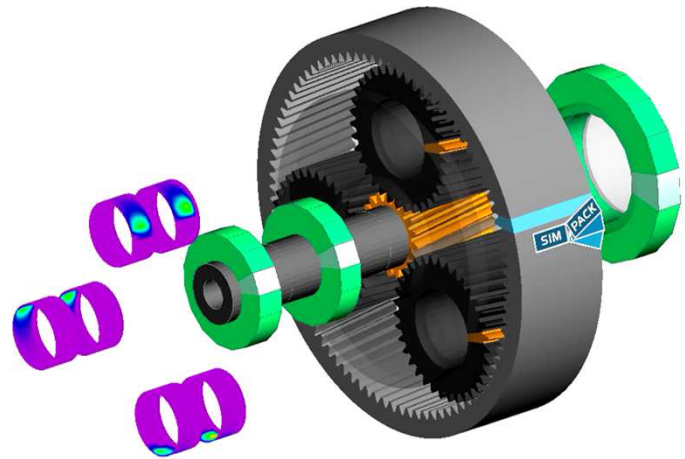


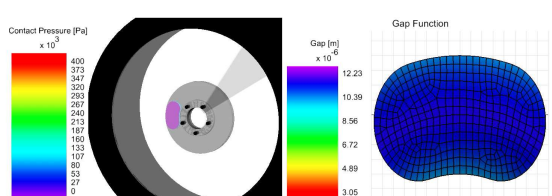
Bearings

Journal Bearings

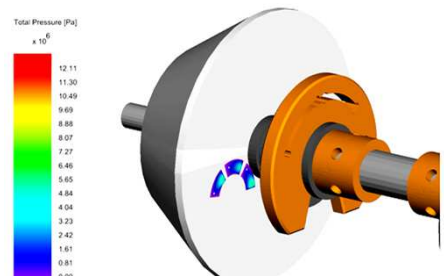
- Easy setup
- Cylindrical or planar bearings
- Analytical HD, online HD or one- / double-sided EHD
- Fluid flow coupling of bearings
- Transient oil temperature by a global thermal balancing
- Wear calculation







Brake

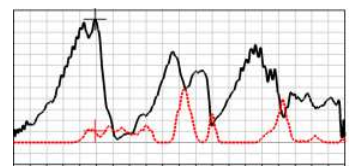


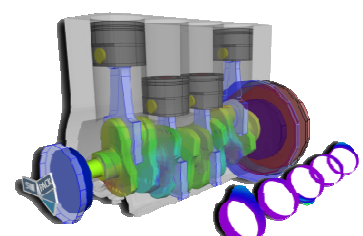
Thrust Bearing

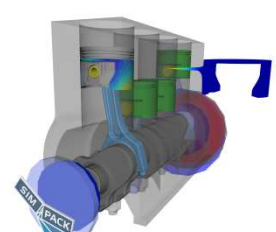
Journal Bearings – Functionality Overview

Element	Characteristics	Use
Approximating Hydrodynamics (FA)	• Analytical approach • All forces/torques • Mixed friction	• Fast cylindrical bearing with friction torque • Durability calculations of holistic models
Hydrodynamics (HD) or Rigid dry contact	• Online solution • All forces/torques/ friction regimes • Lokal design elements	• Geometry optimization (crowning, grooves etc.) • Oil flow analysis
Elasto-Hydrodynamics (EHD) or Rigid elastic contact	• HD / Rigid dry contact + • local deformations on one or both bodies	• Friction and wear analysis • Micro geometry optimization

Level of Detail

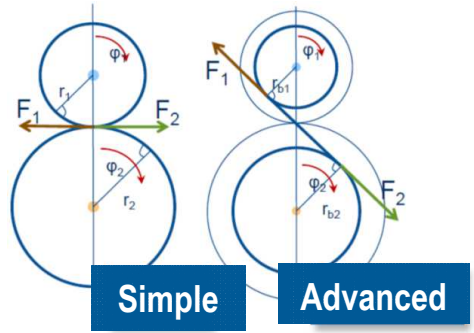


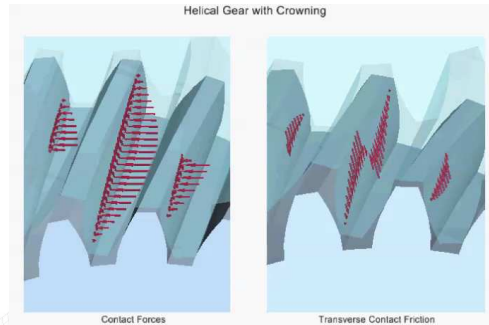


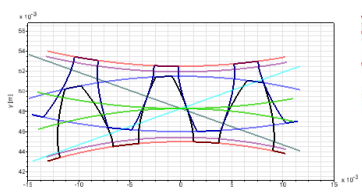


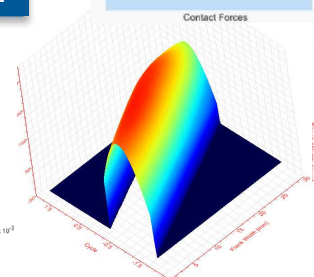
Gear Wheels

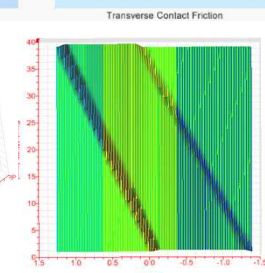
- Basic Gear Pair
  - No meshing excitations
  - Recommended for linearization tasks
- Gear Pair 225
  - Meshing excitations
  - Profile and flank micro geometry
  - Pre Plots: check plot, load intensity, mesh contouring
- Gear Pair 225 with Flexible Bodies
- Non-standard gear profiles

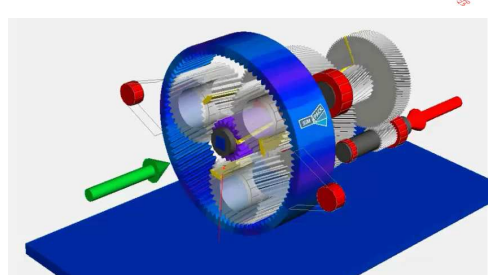


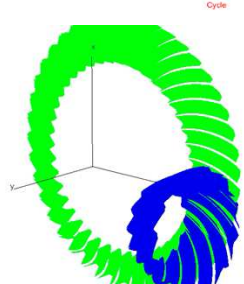








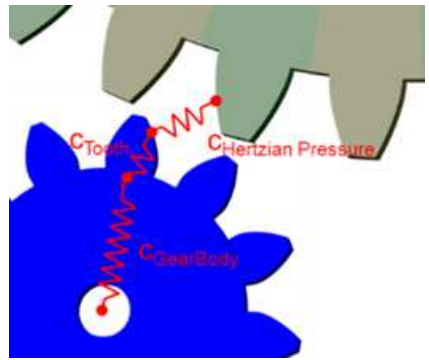


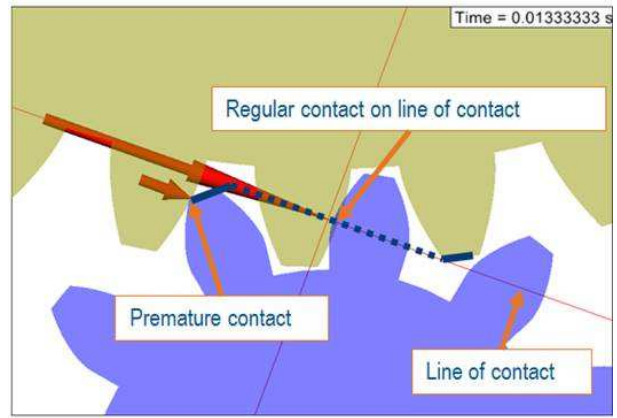


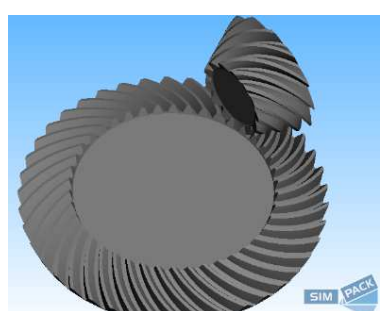
Gear Wheels

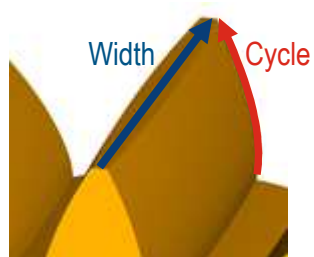
Major Improvements GP 225

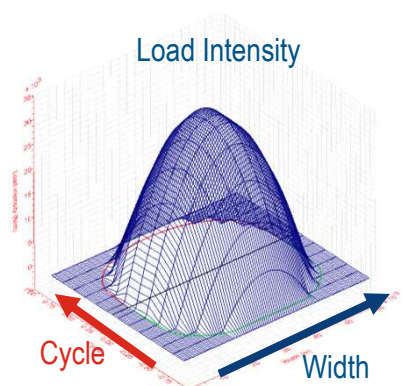
- Weber Banaschek
  - Clear separation of stiffnesses (body, tooth and contact)
  - Recommended for use with flexible gears and ring gears
- Extended tip contact
- Hypoid gear (according to ISO 23509)
- Contact pattern plot







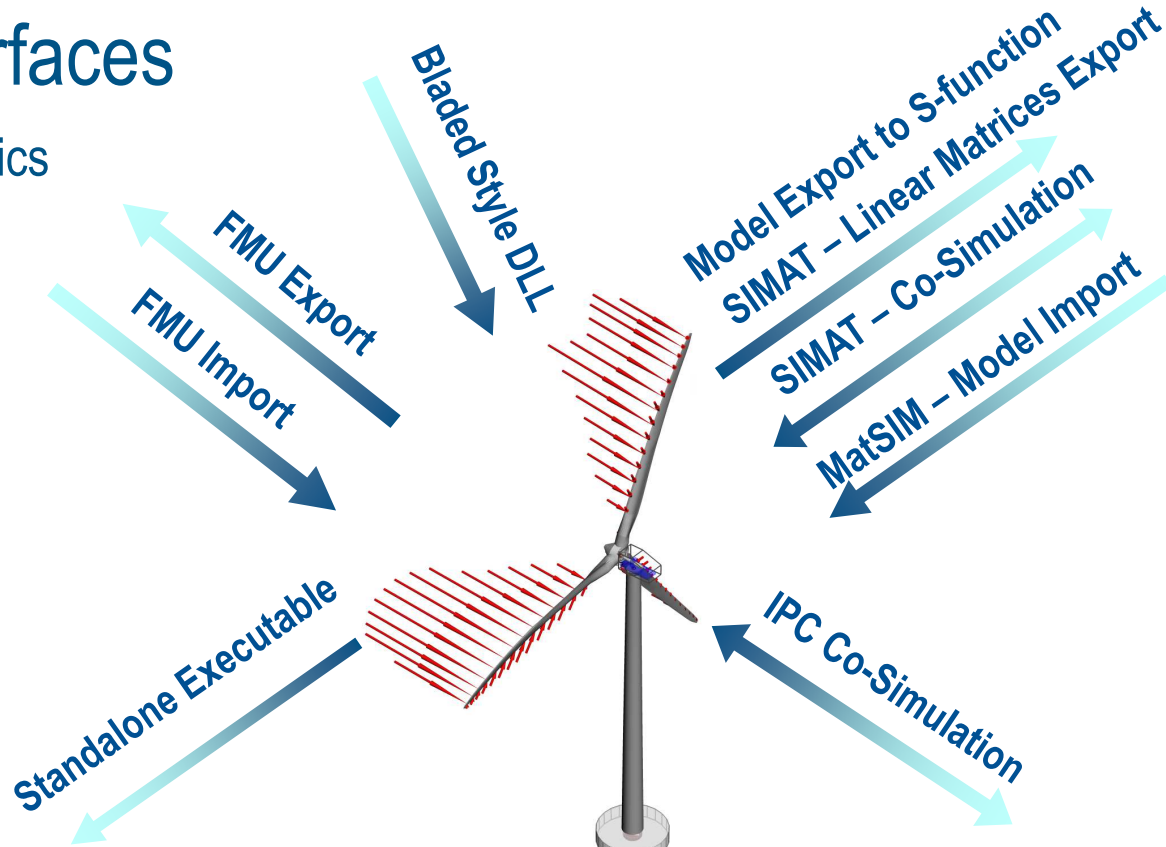




Multi Domain interfaces

Control, Electronics, Hydraulics

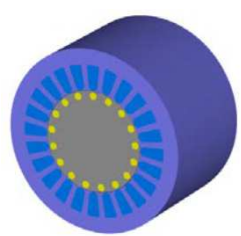
- Simpack Control Module
- Wind Turbine Control Interface
  - **Bladed 4.2** format DLL interface
- Mathworks Interfaces
  - MATLAB® release **R2016b/R2017a**
- FMI (e.g. with Dymola)
  - FMI 1.0 and **FMI 2.0**
- IPC Co-simulation
- User Routines

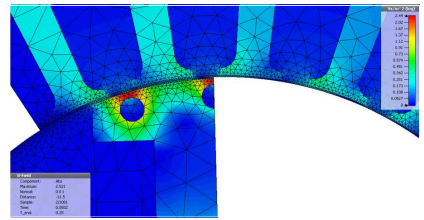


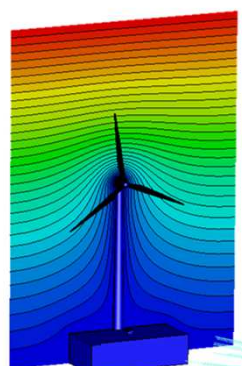
Electromagnetics

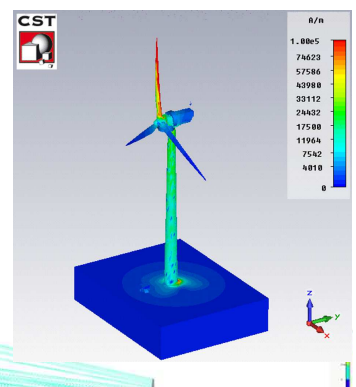
CST

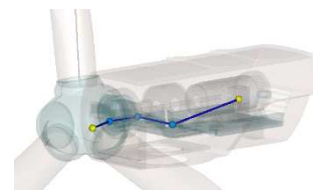
- Generators, Motors
  - Excitation for dynamic analysis
  - Stator and rotor optimization
- Lightning Strike
  - Attachment area prediction
  - Currents on wind turbine and in cabling
- Radar
  - Reflection of signals from rotor
- Antenna Placement

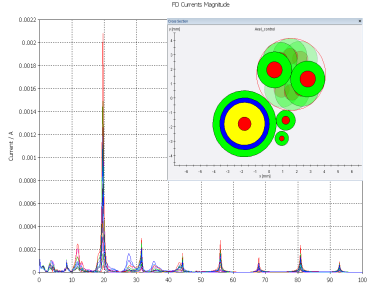


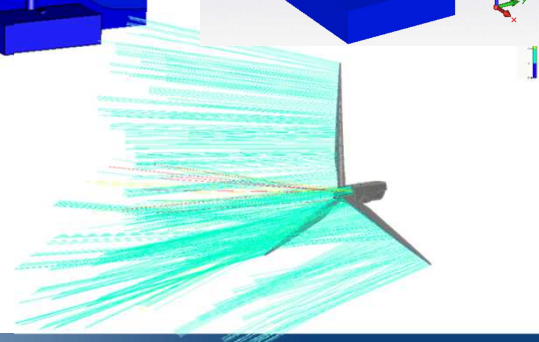








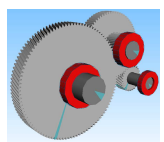




Acoustics

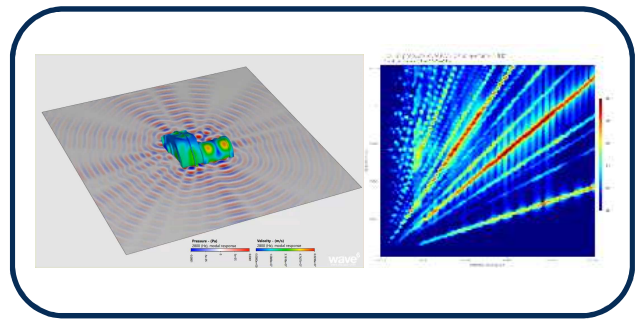
wave6

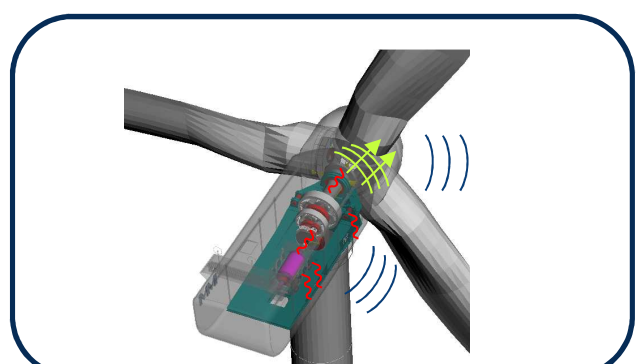
- wave6 exploits results from Simpack and calculates noise and vibration levels
- Straightforward process
  - ▷ Propagation of the vibrations
  - ▷ Attenuation by absorbing materials
  - ▷ Noise radiation



MBS model

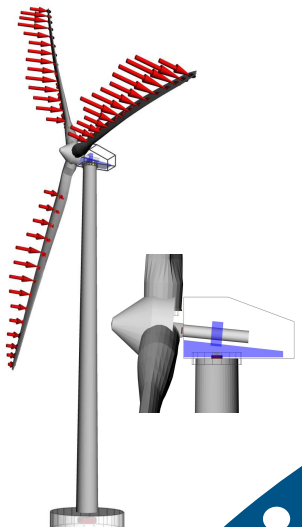
FEM structure

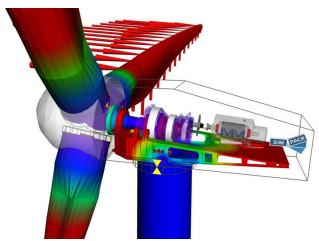


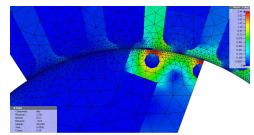


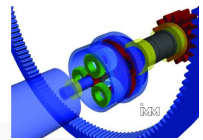
MBS based wind turbine simulation process:

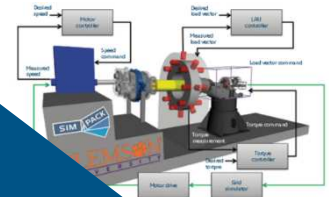
Strong multi physics integration, multi scale and data management requirements:











MBS (Simpack)

Extended System Analysis

Component Analysis Optimization

Extreme Loads Drivetrain Certification*

Load Calculations Certification*

Control (Dymola)

CAD (CATIA) (SolidWorks)

FEM (Abaqus)

Durability (fe-safe)

Optimization (Isight) (Tosca)

Acoustics (wave6) (XFlow)

Electro-Magnetics (CST)

Electrics Hydraulics (Dymola)

CFD (XFlow) (Abaqus)

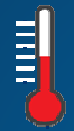
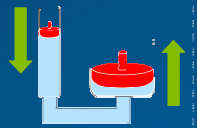
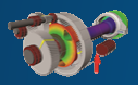
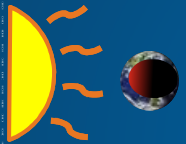
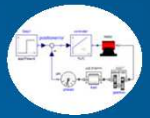
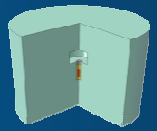
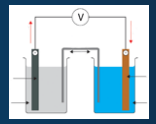
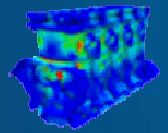
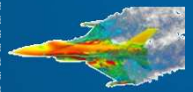
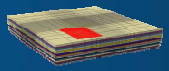
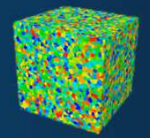
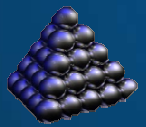
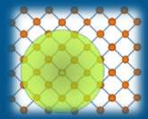
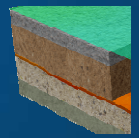
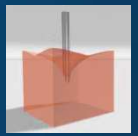
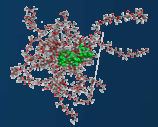
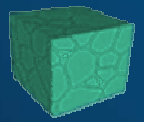
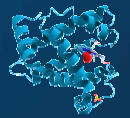
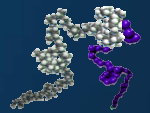
*Basis for Certification Process

Our Technology
Vision

Multiphysics & Science

3DEXPERIENCE

Multiscale

	Structures	Thermal	Fluids	Electromagnetics	Controls	Geophysics	Biological	Chemical ⋯
Functional								
Logical								
Physical (Macroscale Continuum)								
Material Sciences								
Physical (Microscale and Below Non-Continuum)								

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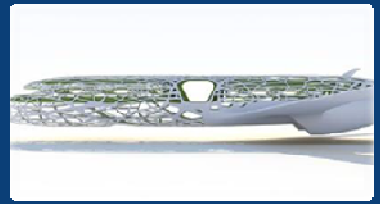
3DEXPERIENCE | *A new way to simulate*

New ways to engineer Product, Nature & Life

ALL PHYSICS, ALL SCALES

"*Confidence to simulate everything*"

New ways to power innovation



ENABLE INNOVATION

"*Science-driven smart innovation process*"

New shifts in engineering efficiency

ENGINEERING EFFICIENCY

"*Allow engineers to be engineers*"

New connections across the eco-system

EXTENDED ECO-SYSTEM

"*Connected and empowered workforce*"

Conclusion

- Simulation of any wind turbine type, any level of fidelity
- Components, test-rigs and systems
- One model database
  - Design Load Cases
  - Optimization
  - Stress, durability
  - Acoustics
  - …
- 3DEXPERIENCE