Dassault Systèmes Long-term Commitment to Simulation
Agenda

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

- **Aerodynamics**
- **Rotorblades**
- **Tower**
- **Hydrodynamics**
- **Foundation**
- **Nacelle**
- **Drivetrain**
- **Generator, Power Electronics, Grid and Control**
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, …
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 rotor blades
- 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

Validation against exp: 30 deg yawed flow
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

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)
## Rolling Bearings – Functionality Overview

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

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<th>Element</th>
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</table>
| **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 |
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 based wind turbine simulation process:
Strong multi physics integration, multi scale and data management requirements:
Multiphysics & Science

Our Technology

Vision

Structures  Thermal  Fluids  Electromagnetics  Controls  Geophysics  Biological  Chemical...

Functional

Logical

Physical (Macroscale Continuum)

Material Sciences

Physical (Microscale and Below Non-Continuum)
3DEXPERIENCE | A new way to simulate

New ways to engineer Product, Nature & Life

ALL PHYSICS, ALL SCALES
“Confidence to simulate everything”

New shifts in engineering efficiency

ENGINEERING EFFICIENCY
“Allow engineers to be engineers”

New ways to power innovation

ENABLE INNOVATION
“Science-driven smart innovation process”

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