FOCUS6

Integrated Modular
Wind Turbine
Design Tool

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What is FOCUS6

- FOCUS6 is an advanced ‘suite’ to design wind turbines and blades
- A set of application modules integrated via a graphical user interface
- Each module has specific functionality eg. ‘Parse blade model’, ‘Generate Load Sets’
- Modules ‘optionally’ purchaseable
FOCUS6 Modules

- Rotor Pre-Design
- Wind Turbine Design
- Structural Blade Modeller (3d)
- Design Optimization
- Wave Loads (Offshore)
- 3e Party Module Integration Tool
- Blade Design FEM *(Q3 2010)*
- Report Generator
FOCUS6 Upcoming Modules

- CAD/CAx Blade Export & Import (2010)
- Noise Emission (2010)
- Cost (2010)
- Earthquake loads (2010)
- Offshore Additions (2011)
FOCUS6 WORLDWIDE

1995: FOCUS4
2004: FOCUS5
2009: FOCUS6
FOCUS6 Improvements from FOCUS5

- FOCUS6 user interface experience
- Multi-user environment
- 3D graphical blade modeller
- Results visualization 2D/3D
Control Design Projects
Control Design Projects

- Richard-WS Turbine and Blade design
- RichardBuis
- DEMO 2MW
- FOCUS5 Import project
Control Design Projects

- Calculations, input data and results
- Parameter categories
- Sets of input data
Control Design Projects
Control Design Projects

Copied data for re-use in other project
Parameters Organized In Categories
Parameters Organized In Categories

- Richard-WS Turbine and Blade design
- Calculation Sets
- Base Parameters
- Resultsets
- Parameters
  - Categories
    - Acoustics
    - Blade hinge
  - Blade profile
    - Parameters
      - Datasets
      - Load Sets
      - Files
      - File Types
      - Blade properties
    - Control
    - Costs

<table>
<thead>
<tr>
<th>name</th>
<th>value</th>
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</thead>
<tbody>
<tr>
<td>Airfoil table</td>
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<tr>
<td>3D correction</td>
<td>ON</td>
</tr>
<tr>
<td>dynamic stall</td>
<td>1</td>
</tr>
</tbody>
</table>
Parameters Organized In Categories

- Acoustics
- Blade hinge
- Blade profile
- Parameters
- Datasets
- Load Sets
- Files

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</tr>
</tbody>
</table>
Parameter Input Wizards
Parameter Input Wizards

- Gear ratio: 139.3110
- Constant loss: 45090.0000 Nm
- Proportional loss: 0.048000 Nm
- Slow shaft inertia: 5.495000E-003 kgm²
- Fast shaft inertia: 5.620000E-002 kgm²
- Shaft stiffness: 3.289999E-009 Nm/rad
- Gearbox inertia: 6.000000E-000 kgm²
- Support stiffness: 1.000000E-012 Nm/rad
- Support damping: 0.0 Nm/(rad/s)
Parameter Input Wizards

Transmission ratio of the gearbox. The value of 'gear_ratio' can be either positive or negative depending on the rotational direction of the generator shaft. 'gear_ratio' is negative if the generator shaft rotates opposite to the rotor shaft. The rotational direction is of importance to solve the correct nacelle and tower moments when speeding-up or down and when yawing.

constant_loss REAL (0.0) [Nm]

The losses in the drive train are described by a linear function of the generator shaft torque. 'constant_loss' is the loss of torque for an unloaded generator expressed at the slow shaft, figure 5. Not used for generator_model 4.
Parameter Input Wizards

Transmission ratio of the gearbox. The value of 'gear_ratio' can be either positive or negative depending on the rotational direction of the generator shaft. 'gear_ratio' is negative if the generator shaft rotates opposite to the rotor shaft. The rotational direction is of importance to solve the correct nacelle and tower moments when speeding-up or -down and when yawing.

Figure 5: Configuration of the drive train model
### Calculation Sets

**Project**: Richard WS Turbine and Blade design

**Name**: Fatigue analysis

**Description**: Post-Process

<table>
<thead>
<tr>
<th>Parameter</th>
<th>start_value</th>
<th>stop_value</th>
<th>steps</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Browse** | **Project** | **Dataset** | **Parameter** | **Table** | **Project File** | **Calculation Set** | **Stop** | **Load Set** | **Results** |
Calculation Sets

- Richard-WS Turbine and Blade design
  - Calculation Sets
    - alt_fem
    - Cross section based buckling
    - deflection line
    - Fatigue analyses
      - Steps
        - 1 FAROB_structural_analysis
      - Runs
      - Datasets
        - default
        - loadcases
Running Calculations

Created empty calculation set
Running Calculations

Add calculation step

Add dataset with input parameters
Running Calculations

Richard-WS Turbine and Blade design
- Calculation Sets
  - alt_fem
  - A new calculation
- Steps
  - 1 FAROB_Parse_Model
    - Runs
    - New Run
    - New Run & Execute
- Cross section based buckling
Running Calculations

**Calculation Form**

- **Run**: A new calculation 15/06/2010 14:38:57
- **Run event**: 1 15/06/2010 14:39:00

Found 1 events for this run:
- Starting run event #1 15/06/2010 14:39:00
- start job A new calculation-1 FARO8_Parse_Model
- createJobLog 14:38:55
- createJobLog 14:38:55
- createJobDataset 14:38:55

[Run] [Stop] [Browse] [Close]
Running Calculations

Date and time of execution:
15/06/2010 14:38:57

Calculation output files:
- blade_geometry.mac
- buffer\ELEMENTS
- buffer\FAROB.pm
- buffer\LINES
- buffer\MATERIAL
- buffer\R0.$SP
Parametric Models

- A set of global parameters defines the turbine model
- Calculation modules (programs) under FOCUS6 can use these parameters
- For "What-If" studies sets of parameters can be defined to override the global parameters without changing the actual model
‘What-if’ Calculation Parameters

![Wind turbine calculation software interface]

- **Name**: Blade identifier
- **Value**: blade2.mw1

Blade identifier
‘What-If’ Calculation Parameters

Create new dataset

Add specific parameters
‘What-If’ Calculation Parameters

Create new dataset

Higher priority dataset overrules lower priority
‘What-If’ Calculation Parameters

Executed new calculation with specific parameters

Calculation results saved separately
Normal Model Parameters

Generic Turbine:
- blade span = 60 m
- blade root = 2 m

Module 1:
- rotor radius = 62 m

Module 2:
- rotor diameter = 124 m

Module 3:
- blade length = 60000 mm
Variable Model Parameters

Generic Turbine
- blade span = \( X \)
- blade root = 2 m

Module 1
- rotor radius = \( X + 2 \) m

Module 2
- rotor diameter = \( 2 \cdot (X + 2) \) m

Module 3
- blade length = 1000 \( \cdot X \) mm
Variable Expansion

- FOCUS6 handles (‘expands’) variables
- Variables are replaced with actual values by FOCUS6
- Calculations modules (programs) do not know about these variables!
- Any custom program can be used!
Multi-User Design Projects

- FOCUS6 organizes projects and data into a shared location
- Multiple users may work on the same project simultaneously!
- All changes by users are tracked
- Calculations can run in parallel on PCs with multi-core processors
  - Other computers in the network can join in for even shorter turnaround times e.g. for load set calculations
3D Graphical Blade Modeller
3D Graphical Blade Modeller

- 3D graphical viewer and editor
- Easily create or edit blade properties
- Representation using 1st degree lines, surfaces, etc
- Direct 3D/2D feedback of changes
Define Shapes
Define Shapes

Points

[0] (1,0)
[1] (0.999, -0.00279)
[2] (0.99, -0.00544)
[3] (0.98, -0.0084)
[4] (0.97, 0.0113)
[5] (0.96, 0.01415)
[6] (0.95, 0.01696)
[7] (0.94, 0.01973)
[8] (0.93, 0.02248)
[9] (0.92, 0.02522)
[10] (0.91, 0.02797)
[11] (0.9, 0.03071)
[12] (0.89, 0.03345)
[13] (0.88, 0.03618)
[14] (0.87, 0.03892)
Define Shapes
Define Blade: Place Shapes
Define Blade: Place Shapes

Parameter V = 1200 mm
Define Materials

Material name: UD

Material type: orthotropic

S-N Line: GL2003

Properties:
- Density: unknown
- Orthotropic:
- Isotropic:
- Core:
- E_modulus: 8000
- nu_12: 0.25
- G_12: 0
- G_23: 0
- G_31: 0
- FiberAngle: 0
- E-Modulus (obsolete): 0
- G-Modulus (obsolete): 0
- Poisson ratio (obsolete): 0

Fatigue analysis:
- Constants
- K
- S-N line name: GL2003

Appearance:
- Color: 255, 0, 255
- Failure data:
Define Materials

Material type:
- orthotropic
- isotropic
- core
- 8000
- 0.25

S-N Line:
- GL2003

Fatigue analysis:
- G-Modulus (obsolete)
- Poisson ratio (obsolete)
- Constants
- K
- S-N line name
**Define Materials**

<table>
<thead>
<tr>
<th>General</th>
<th>GL2003</th>
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<tbody>
<tr>
<td>Name</td>
<td>GL2003</td>
</tr>
<tr>
<td>Description</td>
<td>test</td>
</tr>
<tr>
<td>S-N line branches</td>
<td></td>
</tr>
<tr>
<td>Branch</td>
<td>SLOPE</td>
</tr>
<tr>
<td>History</td>
<td>08/06/2010 14:55:57</td>
</tr>
<tr>
<td>Change Log</td>
<td>richard row(4)</td>
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<tr>
<td>Misc</td>
<td>SNLine_lines</td>
</tr>
<tr>
<td>Constants</td>
<td>False</td>
</tr>
<tr>
<td>Debug</td>
<td>False</td>
</tr>
<tr>
<td>REDUCTION NEN2063</td>
<td>False</td>
</tr>
</tbody>
</table>

Goodman diagram fatigue formulation
Define Material Boundary Lines
Define Material Boundary Lines
Place ‘Sections’ of Material
Place ‘Sections’ of Material

- **General**
  - **MaterialName**: UD
  - **SectionType**: SKIN
- **Appearance**
  - **DisplayColor**: Light Blue
  - **Visible**: False
  - **History**
    - **Change Log**: 09/07/2009
  - **Misc**
    - **Line1**: SPARF-
    - **Line2**: SPARF-
    - **Offset**: no offset
- **Points**
  - **[0]**
    - **Change Log**: (V+2000, 1)
  - **[1]**
    - **Change Log**: (V+3900, 50)
- **Thickness**
  - **Z position**: V+2000
  - **(2)**
    - **Change Log**: V+3900 (RADIUS, 5)
    - **Thickness**: 5
    - **Z position**: RADIUS
Place ‘Sections’ of Material

- Material Name: UD
- Section Type: SKIN
- Display Color: Light Blue
- Visible: False
- Change Log: 09/07/2001
- Line 1: SPAR
- Line 2: SPARA
- Offset: no offset
- Change Log: (V+2000, 1)
- Thickness: 1
- Z Position: V+2000
- Change Log: (V+3900, 50)
- Thickness: 50
- Z Position: V+3900
- Change Log: (RADIUS, 5)
- Thickness: 5
- Z Position: RADIUS
Place ‘Sections’ of Material
Verify Parsed Blade Model
Verify Parsed Blade Model

element_thickness

70.0

53.3

36.6
Verify Parsed Blade Model

- TRIAX 4.83422-4.82679 (mm)
- FOAM 19.0053-18.9608 (mm)
- TRIAX 4.86346-4.85627 (mm)
- COATING 0.1-0.1 (mm)
Verify Parsed Blade Model

Blade mass distribution per material
3D visualization of analysis results

- Strain based analysis results
  - Overall minimum / maximum normal and shear strains for a full load set
  - Static reserve factors per material
    - Compression
    - Tension
    - Shear

- Fatigue analysis results (fatigue reserve factors)
3D interactive view

Maximum normal strain plot

Similar plot to show fatigue reserve factors
3D interactive view

Maximum normal strain plot

Similar plot to show fatigue reserve factors
Visualization of data and results

PV curve

Airfoil data

Max normal strain
Comparing Calculation Results
Comparing Calculation Results

- Turbine 2MW
  - Calculation Sets
    - Aerodynamic analysis
    - annual energy capture
    - Beam frequencies
    - pv curve
    - pv curve close frequencies
    - pv curve no generator damping
    - pv curve peak shaved
## Comparing Calculation Results

### Chart Wizard

**Select Loadcases JOBOUT**

In the table below, please select the loadcases:

<table>
<thead>
<tr>
<th>loadcase</th>
<th>program</th>
<th>calculation</th>
<th>run_date</th>
<th>order_no</th>
<th>event_date</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>Aerodynamic analysis</td>
<td>2010/06/08 11:30:12</td>
<td>1</td>
<td>2010/06/03 11:30:13</td>
<td>No loadcase</td>
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<tr>
<td>None</td>
<td>BLADMODE</td>
<td>Aerodynamic analysis</td>
<td>2010/06/08 10:25:27</td>
<td>1</td>
<td>2010/06/08 10:25:28</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE Annual energy capture</td>
<td>annual energy capture</td>
<td>2010/06/09 11:57:04</td>
<td>1</td>
<td>2010/06/09 11:59:47</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>Beam frequencies</td>
<td>2010/06/07 15:05:07</td>
<td>1</td>
<td>2010/06/07 15:05:08</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>Beam frequencies</td>
<td>2010/06/07 15:03:40</td>
<td>1</td>
<td>2010/06/07 15:03:41</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>Beam frequencies</td>
<td>2010/06/07 14:51:22</td>
<td>1</td>
<td>2010/06/07 14:51:23</td>
<td>No loadcase</td>
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<tr>
<td>None</td>
<td>BLADMODE</td>
<td>pv curve</td>
<td>2010/06/09 11:31:16</td>
<td>1</td>
<td>2010/06/09 11:31:17</td>
<td>No loadcase</td>
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<tr>
<td>None</td>
<td>BLADMODE</td>
<td>pv curve close frequencies</td>
<td>2010/06/09 14:16:05</td>
<td>1</td>
<td>2010/06/09 14:16:06</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>pv curve no generator damping</td>
<td>2010/06/09 14:02:13</td>
<td>1</td>
<td>2010/06/09 14:02:14</td>
<td>No loadcase</td>
</tr>
<tr>
<td>None</td>
<td>BLADMODE</td>
<td>pv curve peak shaved</td>
<td>2010/06/09 12:42:04</td>
<td>1</td>
<td>2010/06/09 12:42:05</td>
<td>No loadcase</td>
</tr>
</tbody>
</table>

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**Tu Delft**

Wind turbine Materials and Constructions
Comparing Calculation Results

Chart Wizard
Select X and Y-axis

X-axis: v_wind

Y-axis: dax_aero
    - v_wind
    - speed
    - cp_aero
    - c_axial
    - gen_power
    - dax_aero
    - Mz_pitch
    - pitch
    - u_x_tip
    - v_y_tip
    - f_z_tip

Buttons: Cancel, Back, Next, Finish
Comparing Calculation Results

PV table dax_aero

(Axial aerodynamic thrust force on the rotor)

![Graph showing PV table dax_aero](chart.png)

- 2010-06-09 12:42:04
- 2010-06-09 11:31:16

![Graph showing v_wind vs. (10^3)](chart.png)

- 0 to 30
- 0 to 300
- (10^3)
- v_wind
Plotting (GL) Loadcase Results

Extreme operating gust (50 years at rated wind)

(2) Wind speed hub [m/s]
Plotting (GL) Loadcase Results

Extreme operating gust (50 years at rated wind)

(104) Blade 1: Pitch angle. [deg] at 0 m
Plotting (GL) Loadcase Results

Extreme operating gust (50 years at rated wind)

(5) Generator shaft power [W]
Plotting (GL) Loadcase Results

Extreme operating gust (50 years at rated wind)

(150) Blade 1: Resultant moment in the blade [Nm] at 0 m
Plotting (GL) Loadcase Results

Extreme operating gust (50 years at rated wind)

(54) Axial (compressive) force on the drive train (non-rot). [N] at 0 m

(10^3)
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Or mail

info@wmc.eu