

Integrated Automated Optimization of Offshore Wind Turbine and Support Structure

EERA DeepWind 2015

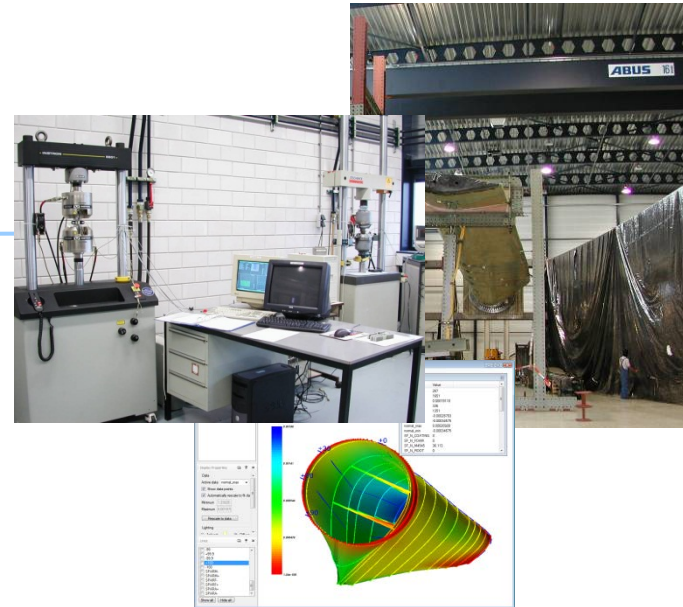
12th Deep Sea Offshore Wind R&D Conference

February 4-6, 2015, Trondheim

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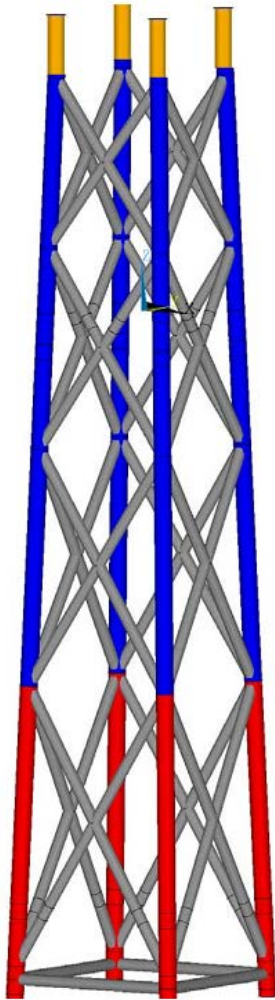
Introduction

Far and Large Offshore wind

FLOW consortium, 13 companies

XEMC Darwind XD115 5MW

ECN controllers, OC4 jacket



Integrated Design Optimization

The screenshot shows the FOCUS6 software interface. The top menu bar includes File, Edit, Definition, Calculation, Post Process, Tools, and Help. The left sidebar displays a project tree with 'Projects' containing 'Tjeerd - XD 115 - SSM - Offshore' and 'Tjeerd - XD 115 - SSM - on OC4 jacket'. Under 'Calculation Sets', '0 Optimization' is selected, showing a list of steps: 1a Model building, 2 1b Model simulation, 3 1c Tower buckling check, 4 1d Member check, 5 1e Joint check, and 6 OptiHat. The main panel shows the 'Info' tab for a 'Calculation Set'. The 'Project' is 'Tjeerd - XD 115 - SSM - on OC4 jacket' and the 'Name' is 'Optimization'. There are checkboxes for 'Post Process' (unchecked) and 'Optimize' (checked), and a dropdown for 'Order calculation by' set to 'STEP'. The 'Description' field is empty. Below this is a table for optimization parameters and constraints:

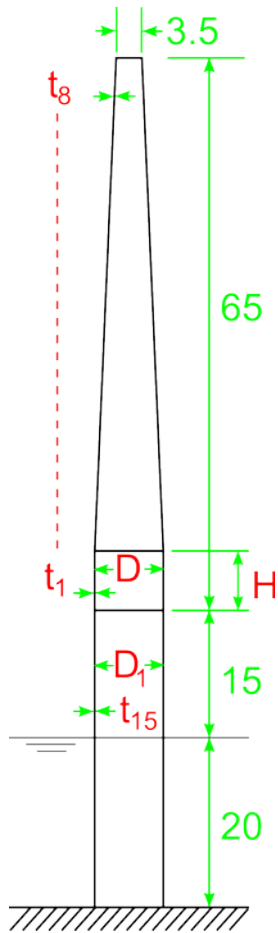
vector_order	parameter	constraint_order	parameter	constraint_type
9	user_paramet...		user_paramet...	GREATER
10	user_paramet...	2	user_paramet...	SMALLER
11	user_paramet...		user_paramet...	SMALLER

Below the table, the 'Optimizer target' is 'user_parameters support_structure_mass' and the 'Optimization method' is 'POWELL'. A 'Delete Row' button is visible at the bottom left of the table area.

Geometry parameters
Controller selection
Simulation
Tower performance:
● Objective value
● Constraints
Optimization: Powell's Cobyla

MJR Finished

Parametrization



Tower wall thickness

Tower base diameter

Tower base height

Monopile diameter

Monopile thickness

Controller selection, simulation

Controller selection

- 4 pre-built ECN controller dlls
- Selection based on stiffness

Simulation

- Reduced support structure model based on FE
- Simplified geometry for hydrodynamic loads
- PHATAS

Simulation

Phatas Baseline Extremes

- Steps
- Results
- Runs
- Datasets
- Load Cases
- Result Sets

Phatas Baseline Fatigue

- Steps
- Results
- Runs
- Datasets
- Load Cases
 - 11320
 - 11321
 - 11340
 - 11341
 - 11360
 - 11361
 - 11380
 - 11381
 - 12040
 - 12041
 - 12042
 - 12043

name	description	loadset
13081	DLC1.3 ETM, Normal operation with positive misalignment.	7 Full set LCPrep Offs
13083	DLC1.3 ETM, Normal operation with negative misalignment.	7 Full set LCPrep Offs
13085	DLC1.3 ETM, Normal operation without misalignment.	7 Full set LCPrep Offs
13090	DLC1.3 ETM, Normal operation with negative misalignment.	7 Full set LCPrep Offs
13091	DLC1.3 ETM, Normal operation with positive misalignment.	7 Full set LCPrep Offs
13092	DLC1.3 ETM, Normal operation without misalignment.	7 Full set LCPrep Offs
13093	DLC1.3 ETM, Normal operation with negative misalignment.	7 Full set LCPrep Offs
13094	DLC1.3 ETM, Normal operation with positive misalignment.	7 Full set LCPrep Offs
13095	DLC1.3 ETM, Normal operation without misalignment.	7 Full set LCPrep Offs
13100	DLC1.3 ETM, Normal operation with negative misalignment.	7 Full set LCPrep Offs
13101	DLC1.3 ETM, Normal operation with positive misalignment.	7 Full set LCPrep Offs
13102	DLC1.3 ETM, Normal operation without misalignment.	7 Full set LCPrep Offs

MJR Finished

Computationally expensive

Baseline calculation

- 1562 Extreme load cases
- 446 Fatigue load cases

Reference set for

- 3 Extreme load cases
- 16 Fatigue load cases

Objective and Constraints

Support structure mass

Monopile:

- Frequency of 1st mode of the tower
- Buckling
- Fatigue damage

OC 4 Jacket:

- Frequency of 1st mode of the tower

Joints

- Extreme loads
- Fatigue

Members

- Stress
- Buckling

Joint evaluation

CIDECT design guides

International Committee for the Development and Study of Tubular Structures

Criteria (among others)

- Circular Hollow Sections (CHS) chord punching strength, chord plastification
- Hot spot stress method



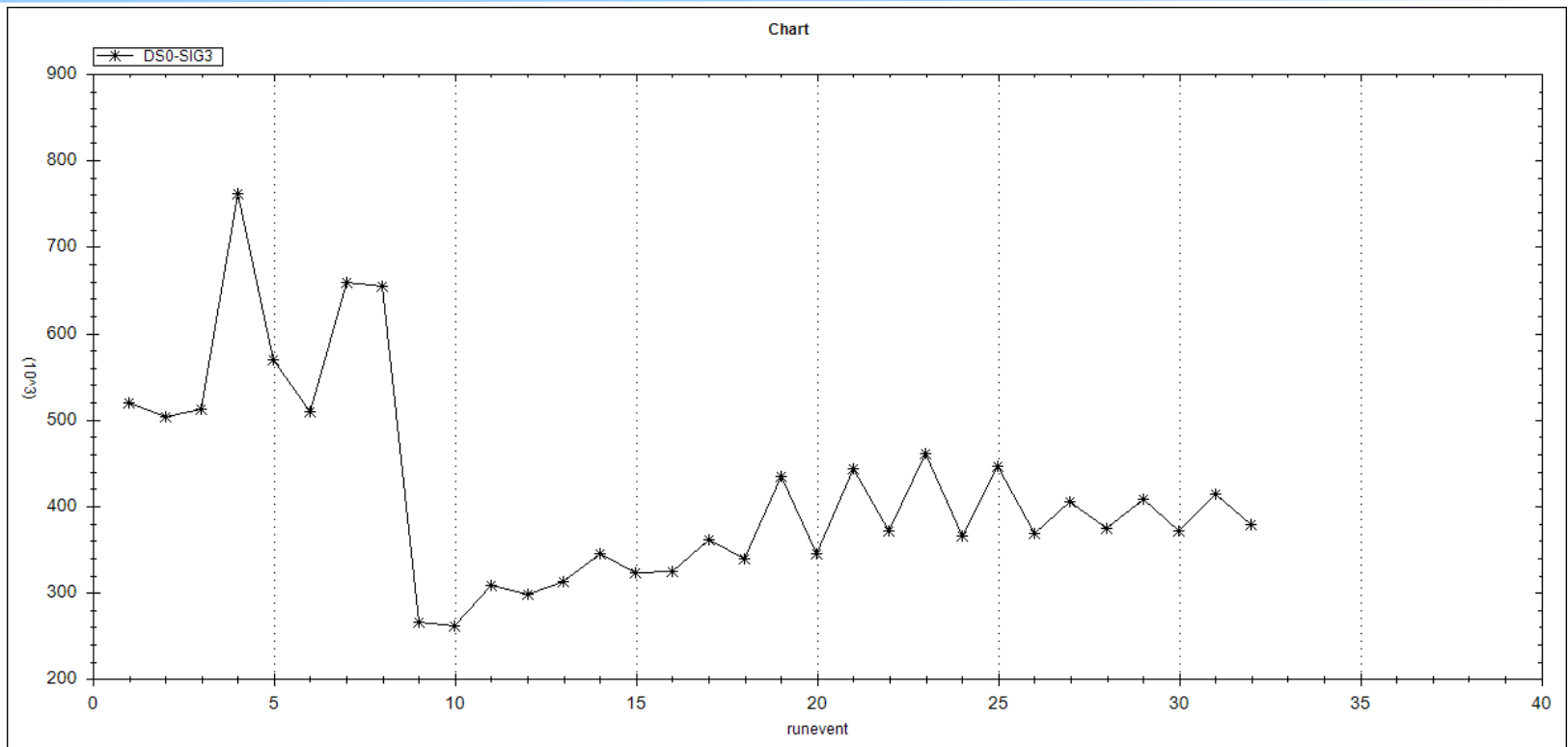
Cobyla

Constrained Optimization BY Linear Approximation

- 0-th order method
- Trust regions (Simplex)
 - Minimizes max. Constraint violation value
 - Uses step remainder to improve objective value
- Initial stepsize, final step size

WMC: Relative scaling of design variables by design interval

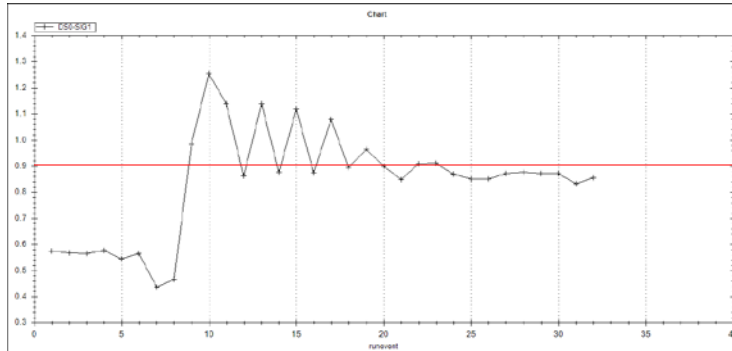
Results - mass



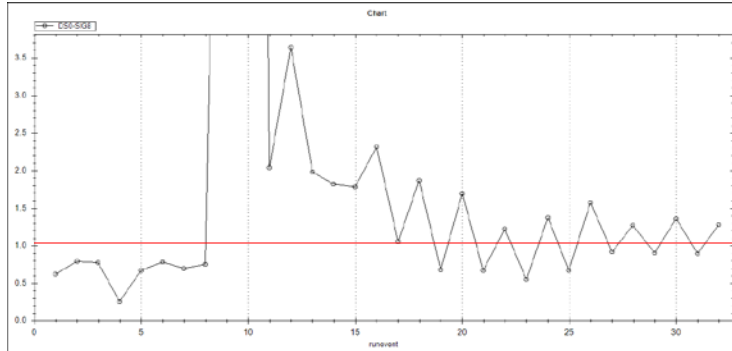
Support structure mass: 520 ton to 413 ton

Results - constraints

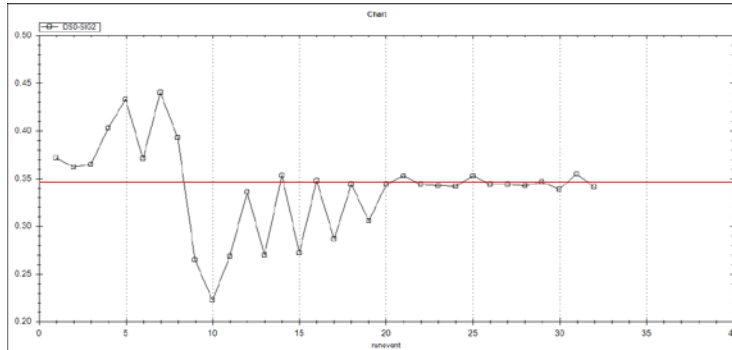
Damage < 0.9



Buckling < 1



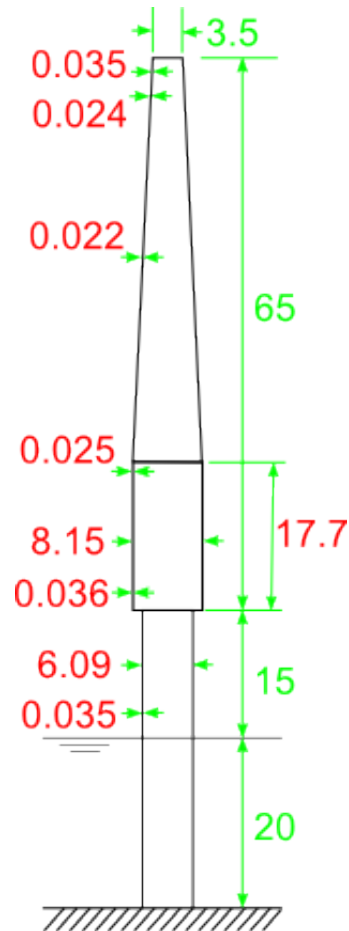
**Tower frequency
1st mode > 0.345**



Results - geometry

Mushroom shape

Design values not at bounds of design interval



Jacket structure

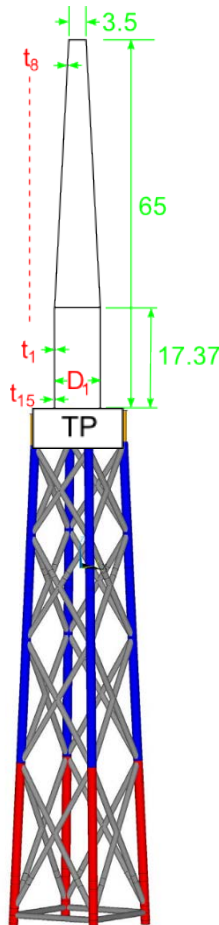
OC4 jacket

Darwind XD 115 5MW WT

ECN controllers

Parametrization:

- Tower base diameter
- Tower wall thicknesses
- Chord diameter and wall thicknesses
- Brace diameter and wall thickness



Jacket results

One iteration of the optimization loop done

Joint analysis performed

Member analysis performed

Work in progress...

Conclusions

- **Integrated Optimization demonstrated using a monopile support structure**
- **Performed evaluation of jacket supported WT**
- **Looking forward to jacket optimization**

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