State-of-the-art and Development Needs of Simulation Codes for Offshore Wind Turbines

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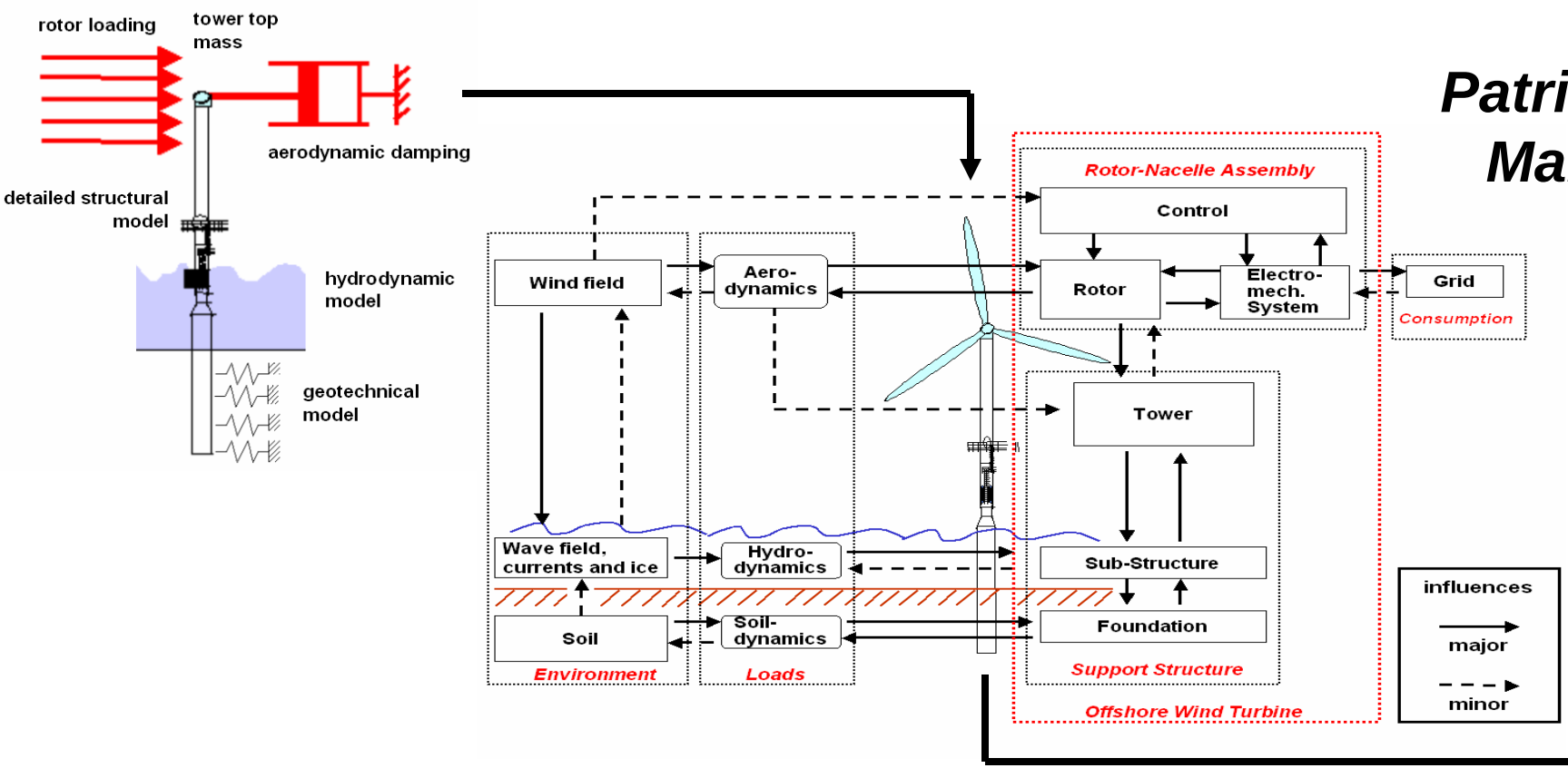

Offshore environment	Bladed	Flex5	HAWC2	FAST	ADAMS/WT & FAST-to-ADAMS	TURBU	PHATAS	ADCoS
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PM - UD - Airy+ -								
CNW- PFT –								ngs)

taking into account diffraction and radiation
6) breaking wave impact
7) MacCamy-Fuchs correction for diffraction
- arbitrary space frame structures, e.g. jackets
MPI - user input of modal properties or system matrices
7) non-linear
AF - apparent fixity length

Codes, codes, codes...

More than 7 different aero-elastic codes for simulation of offshore wind turbines (OWT) exists!

Capable of modelling different types of support structures.

Is everything fine then?

Contents

Status & Needs for design and simulation of OWT

- Environmental conditions
- Load Modelling
- Structural Dynamics
- Verification
- Design Approach
- Design Process

Conclusions

Environmental Conditions

environmental conditions
- met-ocean
- soil

Large uncertainties & site specific variability of environmental conditions!

environmental conditions → simulation codes → fatigue, etc

garbage in? garbage out?

Better understanding of physics & improved site specific representation of environmental processes needed!

- representation of stochastic nature of environmental parameters
- correlation of environmental parameters (e.g. wind-waves, scouring)
- reliable met-ocean database

Chance: Hindcasting, FINO research platform?!

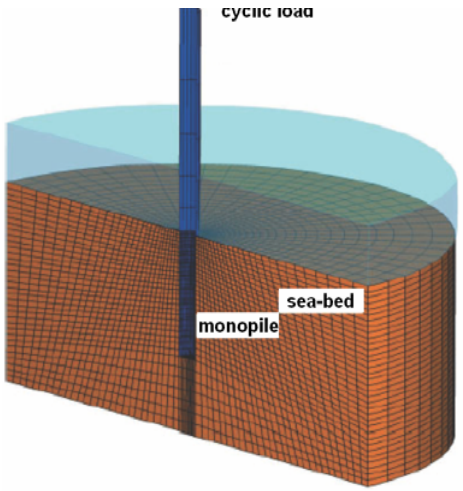
Load Modelling i): Hydrodynamics & Aerodynamics

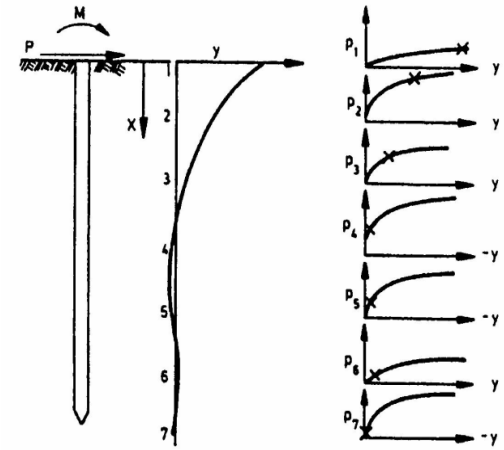
Status	Needs
• Aerodynamics & aero-elastic models based on megawat-class wind turbines	• Improvements for very large wind turbines
• Morison equation for wave loading	• Diffraction effects (for large monopile structures and floating structures)
• None- breaking waves or simplified models	• Modelling of breaking waves (if relevant)
• Linear, stochastic waves	• Non-linear, stochastic waves (if relevant)
• Long-crested waves	• Short-crestness of waves

Load Modelling ii): Soil

A first step?!

Derivation of improved engineering models from scientific models needed!





[Grabe, Mahutka, Dührkop]

Structural Dynamics

Modal approach is a very popular solution to deal with structural dynamics
- Allows for fast calculations due to large reduction of DoFs.
- Shows good applicability for structures of the monopile type with linearized foundation models

Difficulties connected with modal approach
-> space-frame support structures (convergence of member forces)
-> assessment of non-linearities, e.g. soil-structure interactions & plasticity

Modelling of dynamics for floating structures shows different requirements!

- rigid body motion

- mooring dynamics

- multi floating units

Verification

Status:

Limited verification of codes

- mainly company internal (e.g. Utgrunden)
- EU-Project OWTES (Blyth Harbour)
- Vindeby & Middelgrunden (wake measurements)

Ongoing:

- Measurements: FINO I, Arklow, Horns Rev
- IEA WindAnnex 23, Subtask 2 :Offshore Code Comparison Colaboration (OC^3)

Design Approach & Safety Concept

Deterministic design approach is current practise, e.g. 50 years environmental conditions.

-> Safe designs by partial safety factors & conservative load cases to cover uncertainties in the design parameters.

But: conservative safety reserves are expensive!

Probabilistic approach:
more rationale consideration of uncertainties and response variability,
e.g. load extrapolation techniques as discussed for IEC 61400-3s

->optimizing designs and costs for certain risk levels

Design Process i): Design Optimisation Problem

Increasing number of design parameters:

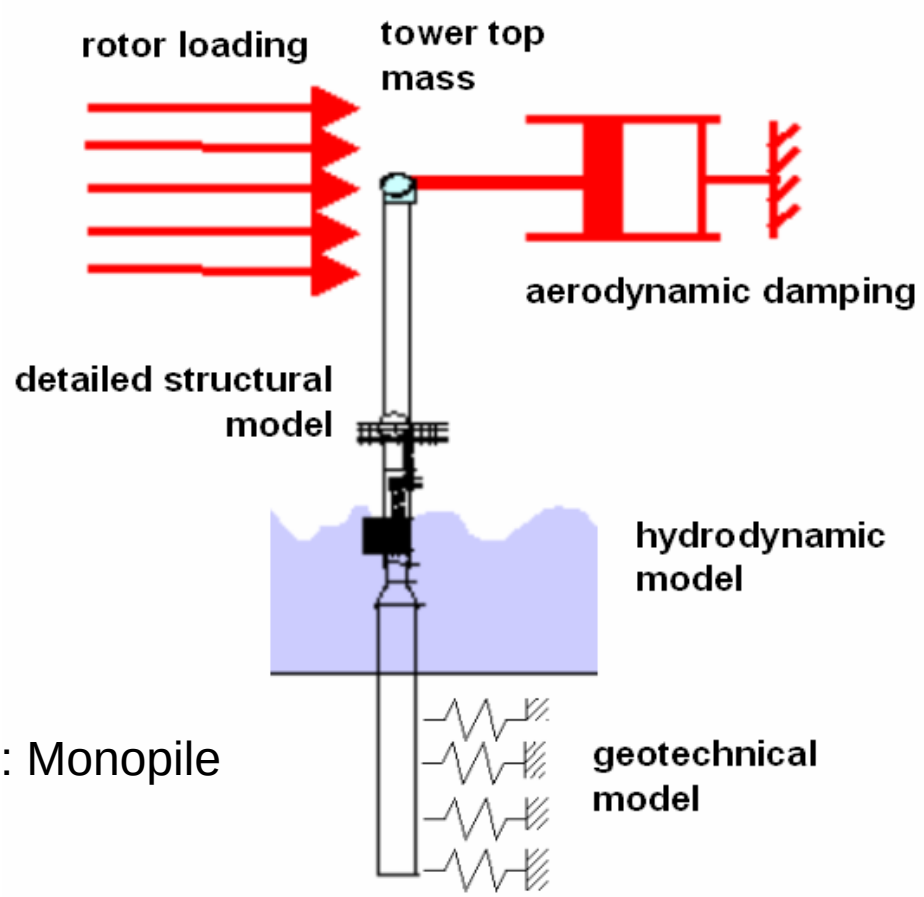
- **less engineering experience**
- **fast & simple preliminary design tools**
- **generic design algorithms**

Monopile	Tripod, Quadpod...	Jacket
~8 design parameter	~17 design parameter	~ 49 – 85 design parameter

Design Process ii): Preliminary Design Tools

Fast and approximative

-> insight, parameter studies, design iterations and preliminary draft



Example: Monopile

Design Process iii): Design Phases & Tools

design phase ↓ / structure type / design process	first generation (monopile, GBS)	second generation (jackets & tripods..)	floating types
preliminary design	integrated models (Flex5, Bladed, etc.) ↔ component models preliminary design toos (if available)	simple preliminary design tools (superimposed)	
detailed design	integrated models ↔ component models	integrated models ↔ component models	

Current design practise

Proposed future design process

Conclusions

Status:

- Various aero-elastic simulation codes for Offshore Wind Turbines
- Under development: space-frame support structures & more flexible designing
- Code development pushed by industry

Needs:

- Environmental parameters
- Scientific improvement of certain engineering models
- Verification of latest code developments
  -> code comparison
  -> against measurements
- Utilization of remaining optimisation potentials
  -> probabilistic approaches
  -> sophisticated design process with complementary design tools