Validation of a simplified method for the crashworthiness of offshore wind turbine jackets using finite elements simulations

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Context

- Wind farms
  - More, larger and closer to traffic lanes
- Ships
  - Commercial, passenger and maintenance vessels

Probability of collision ↗

[offshorewindindustry.com]  [ship-technology.com]  [maritimejobs.org]
Context

• Several types of wind turbine supporting structures
  • Monopile
  • Tripod
  • Jacket
  • Floating

• Finite elements: accurate but time demanding

• Need a faster method for pre-design stage
  • Analytical developments → Continuous Elements Method
Deformation modes

Overall motion

Local crushing

Punching

Base of jacket
Analytical developments

• Use of the virtual work principle, in combination with the upper-bound theorem (Jones, 2003)
  \[ F \times \delta = \dot{E}_{int} \]

• Example for local crushing

General algorithm

• Combine all deformation modes

Numerical modelling

- Parameters
  - Dynamics of tower and nacelle
  - Effect of gravity
  - Soil structure interaction
  - Wind, waves, current

  Neglected

- Ship stiffness influence
  - Consider here rigid colliding ships

- Large energy impact
  - Direction of tower collapse


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Finite elements models

Mesh: 10cm
Mesh size

No significant variation for a mesh size < 10cm
Results
Rupture

• Lehmann & Peschmann (2002)
  \[ \varepsilon_f = \varepsilon_g + \varepsilon_e \frac{t}{l_e} \]

• Applicable on zones in tension

• No rupture for \( E_k < 75 \text{ MJ} \)
Validation

![Diagram of a structure with graphs showing the relationship between crushing force and energy vs. displacement.]
Validation

![Diagram of a structure with graphs showing crushing force and energy over displacement. The graphs compare numerical and analytical results.](image-url)
Validation

<table>
<thead>
<tr>
<th>Case</th>
<th>Simul.</th>
<th>Max ship disp. (anal)</th>
<th>Max ship disp. (num)</th>
<th>Disc (%)</th>
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</table>
Conclusions & Perspectives

• Analytical and numerical simulations are described
• Validations show a discrepancy < 10%

Future work
• More investigations for rupture
• Several contact points
• Deformability of the striking ship
• Ship colliding sideways

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