A numerical study of a catamaran installation vessel for installing offshore wind turbines

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Outline

1. Introduction

2. The catamaran installation concept

3. Numerical simulation

4. Conclusion
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4. Conclusion
Background

Bottom-fixed

Floating

Water depth:

<20m <40m 50-70m >50-100m

GBF
Monopile
Tripod
Jacket
TLP
Semi-sub
Spar

blades
nacelle
tower
TP
Capital expenditure of offshore wind

Installation methods - foundation

Tripod installation using a jack-up vessel
(http://worldmartimenews.com)

Jacket installation using a floating vessel
(https://www.boskalis.com)

Monopile installation
(www.seawayheavylifting.com.cy)
Installation methods - rotor blade

- Bunny ear
  - Vatenfall

- Full rotor
  - Dong Energy

- Single-blade installation
  - Fred Olsen Wind Carrier
Installation methods - full assembly

Saipem 7000
Statoil AS

Novel installation vessel
Ullstein AS
Purpose of numerical simulation

• Design and testing of novel installation methods

• Response-based prediction of limiting operational conditions

• Online decision support for offshore installations
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The catamaran installation concept

L.I. Hatledal et al. (2017)
Challenges of the concept

• Hydrodynamics
  hydrodynamic coupling, sloshing, viscous effect

• Structural dynamics
  coupled motion modes, mechanical coupling

• Automatic control
  station keeping of the vessel, active ballast system
  motion tolerance and control, landing force control
Installation procedure
Monitoring the relative motions

Mating point
Properties of the catamaran

*Catamaran with four wind turbines*

<table>
<thead>
<tr>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length overall (m)</td>
<td>$L_{OA}$</td>
<td>144</td>
</tr>
<tr>
<td>Breath moulded (m)</td>
<td>$B$</td>
<td>60</td>
</tr>
<tr>
<td>Spacing between monohulls at waterline (m)</td>
<td>$L_{hull}$</td>
<td>38</td>
</tr>
<tr>
<td>Draft (m)</td>
<td>$T_c$</td>
<td>8.0</td>
</tr>
<tr>
<td>Displacement mass (tonnes)</td>
<td>$D$</td>
<td>18502.9</td>
</tr>
<tr>
<td>Vertical center of gravity above baseline (m)</td>
<td>$KGC$</td>
<td>28.6</td>
</tr>
<tr>
<td>Transverse metacentric height (m)</td>
<td>$GMT$</td>
<td>66.4</td>
</tr>
</tbody>
</table>
## Properties of the spar

<table>
<thead>
<tr>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter at top (m)</td>
<td>$l_{bd}$</td>
<td>9.5</td>
</tr>
<tr>
<td>Diameter at waterline (m)</td>
<td>$m_{bd}$</td>
<td>14</td>
</tr>
<tr>
<td>Draft (m)</td>
<td>$t_s$</td>
<td>70</td>
</tr>
<tr>
<td>Displacement mass (tonnes)</td>
<td>$D$</td>
<td>11045</td>
</tr>
<tr>
<td>Vertical center of gravity above baseline (m)</td>
<td>$Kg_s$</td>
<td>30</td>
</tr>
<tr>
<td>Vertical fairlead position below waterline (m)</td>
<td>$Z_f$</td>
<td>15</td>
</tr>
<tr>
<td>Body origin in global coordinate system</td>
<td>$(X_s,Y_s,Z_s)$</td>
<td>$(0,0,0)$</td>
</tr>
<tr>
<td>Total length of mooring line (m)</td>
<td>$L_{moor}$</td>
<td>680</td>
</tr>
<tr>
<td>Diameter of upper chain segments (mm)</td>
<td>$D_{up}$</td>
<td>132</td>
</tr>
<tr>
<td>Diameter of lower chain segments (mm)</td>
<td>$D_{low}$</td>
<td>147</td>
</tr>
</tbody>
</table>
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3. Numerical simulation
   Time-domain simulation
   Frequency-domain simulation

4. Conclusion
**Time-domain simulation**

**WADAM**: Hydrodynamic analysis of the two-body system

**HAWC2**: Calculation of the wind forces on the turbine assemblies

**SIMO**: Time-domain coupled analysis
Catamaran with dynamic positioning system; spar with mooring lines; sliding grippers between catamaran and spar
Modelling of the hydrodynamics
Modelling of the sliding grippers
Modelling of the mooring system
Frequency-domain approach

1. Hydrodynamic analysis of the two-body system

2. Short-term motion prediction of the mating point by using Response Amplitude Operators
Magnitude of the pitch RAOs

Spar

Catamaran
Environmental conditions

Hs = 2.0 m  Tp = 6, 8, ..., 12 s  \( \beta = 0, 90 \text{ deg} \)
Results - relative surge motion

Hs=2.0 m, β=0 deg
Results - relative roll motion

Hs=2.0 m, $\beta=90$ deg
Conclusion

• A numerical modelling approach of the catamaran installation concept is introduced.

• Future work is needed for implementing the active heave compensator, dimensioning of the catamaran, active ballast system, etc.
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- Zhen Gao
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