The effects of using multi-parameter wave criteria for accessing wind turbines in strategic maintenance and logistics models for offshore wind farms

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Outline

"The effects of using multi-parameter wave criteria for accessing wind turbines in strategic maintenance and logistics models for offshore wind farms"

• Motivation – accessibility
• Multi-parameter wave criteria
• The effects in a strategic maintenance and logistics models
• Conclusions
Motivation – accessibility
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Traditional access criterion: Limiting significant wave height (Hs)
Low limiting Hs → low accessibility → low availability of the wind turbines
Motivation – accessibility

Traditional access criterion: Limiting significant wave height (Hs)
Low limiting Hs $\rightarrow$ low accessibility $\rightarrow$ low availability of the wind turbines

Strategic maintenance and logistics models as decision support tools:
- Wants to know what vessels to use
- Wants to use vessels with high accessibility
- Needs to know the value of the limiting Hs
Is a single limiting Hs good enough?

Other weather parameters:
- Wave period
- Relative wave heading
- Current
- Wind speed
- Wind direction
- Visibility
- Swell
- ...

Is a single limiting Hs good enough?
Methodology of the work

1. Numerical analysis to calculate multi-parameter wave criteria (including also wave heading and peak wave period)
2. Estimate possible corresponding measures of a single limiting $H_s$
3. Compare multi-parameter and single-parameter wave criteria for a simulation model
   - NOWIcob: Simulates maintenance activities and related logistics to estimate O&M costs and analyse O&M strategies
4. Compare multi-parameter and single-parameter wave criteria for an optimisation model
   - Finds the optimal vessel fleet size and mix, minimizing O&M costs
Objective of the work

What question are we asking?

• *Not* how a given vessel performs in absolute terms
• *Not* how the performance of a given vessel compares with the numbers stated for its limiting significant wave height
• *But* what are the effects of using multi-parameter vs single-parameter wave criteria in strategic maintenance and logistics models
  • How can modelling approaches be compared?
  • Does it matter which approach one uses?
  • Is there any added value of more complex modelling?
Numerical analysis to calculate wave criteria

- Crew transfer vessel with bow fender
- Wave conditions:
  - Significant wave height
  - Peak wave period
  - Relative wave heading
- Also modelled: Motion-compensated gangway
Multi-parameter wave criteria
Corresponding single-parameter wave criteria

Possible measures of a single limiting significant wave height:

a) Weighted average
b) Most probable wave conditions
c) Most typical wave conditions
d) Equal average accessibility
e) Most restrictive/limiting value
Corresponding single-parameter wave criteria
Corresponding single-parameter wave criteria

Possible measures of a single limiting significant wave height:

a) Weighted average
b) Most probable wave conditions
c) Most typical wave conditions
d) Equal average accessibility
e) Most restrictive/limiting value
Corresponding single-parameter wave criteria

Possible measures of a single limiting significant wave height:

a) Weighted average 1.513 m
b) Most probable wave conditions 1.11 m
c) Most typical wave conditions 1.030 m
d) Equal average accessibility 1.160 m
e) Most restrictive/limiting value 0.82 m
Reference case for simulation and optimisation models

- Weather time series with wind speed, peak wave period, wave heading and relative wave height
- Wind farm with 80 turbines 50 km from onshore maintenance base
- Corresponding single-parameter wave criteria
- Vessel fleet fixed to 3 crew transfer vessels for simulation model
- Optimisation model finds the optimal vessel fleet
Comparison for the simulation model – availability
Comparison for the simulation model – availability
Comparison for the simulation model – availability
Comparison for the simulation model – availability

![Graph showing time-based availability vs. Hs (m)](image_url)
Comparison for the simulation model – availability

![Graph showing time-based availability (%) versus $H_s (m)$, with three marked points: (a), (b), and (c). The graph compares single-parameter wave criteria and multi-parameter wave criteria.](image-url)
Comparison for the simulation model – availability
Comparison for the simulation model – availability
Corresponding single-parameter wave criteria

Possible measures of a single limiting significant wave height:

a) Weighted average 1.513 m
b) Most probable wave conditions 1.11 m
c) Most typical wave conditions 1.030 m
d) Equal average accessibility 1.160 m
e) Most restrictive/limiting value 0.82 m
Corresponding single-parameter wave criteria

Possible measures of a single limiting significant wave height:

a) Weighted average 1.5 m
b) Most probable wave conditions 1.1 m
c) Most typical wave conditions 1.0 m
d) Equal average accessibility 1.2 m
e) Most restrictive/limiting value 0.8 m
Comparison for the simulation model – availability
Comparison for the simulation model – O&M costs
Comparison for the optimisation model
Conclusions

• Demonstrated how one may use multi-parameter weather criteria in comparing vessel concepts with strategic maintenance and logistics models
• The difference between multi-parameter and single-parameter wave criteria may be relatively small
• This requires that the single limiting Hs is chosen carefully
• Information from multi-parameter wave criteria and wave conditions useful

• If a single limiting Hs can be used to represent the wave criteria, how is it found?
• Would a single limiting Hs apply for all locations?
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