The Optimisation and Analysis of SPAR Sub-Structures for 15MW Turbines

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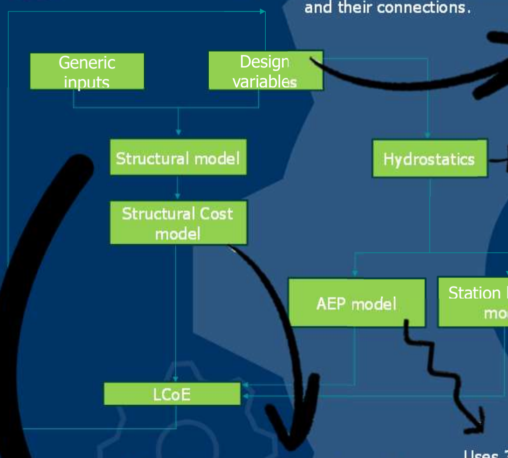
Motivation

- The cost related to floating offshore wind is expected to double, with the floating support structure accounting for 30% of the CapEx [1].
- Introducing optimisation for floating offshore wind sub-structures, has the potential to help aid cost reduction and explore non-traditional shapes.
- Currently, the majority of sub-structure optimisations consider the mass of the platform and a £/kg value to determine the cost, meaning the non-traditional shapes are favourable due to lower mass [2].
- This work aims to consider a more complex cost model which considers manufacturing to understand if there truly is a benefit in exploring non-traditional geometries.

Methodology

This model considers a number of sub-models which allows an equivalent LCoE to be found, the flow chart shows these sub-models and their connections.



Design variables are used to describe the geometry of the platform.

Hydrostatics are calculated to find the ballast required, centre of buoyancy (CoB), gravity (CoG) and the static pitch angle.

This model finds the appropriate mooring line thickness, length, and stiffness, and the anchor type, and size, ensuring the most cost-effective solution is implemented.

A detailed cost model is implemented considering the material (KFM), forming (KF0), welding (KF1-3), assembly (KF4), and painting (KFP) cost of the complete structure including stiffeners.

Uses 30 years worth of wind data to fit a Weibull curve which is combined with the turbine power curve and static angle to find the Annual Energy Production (AEP)

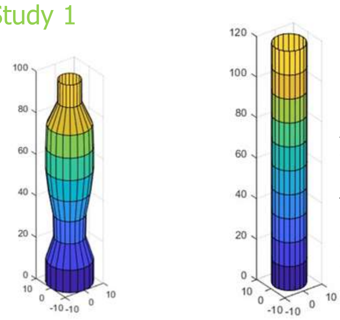
The structural model uses DNV-GL rules to determine the required thickness of the shell and the minimum size of the stiffeners to keep cost to a minimum.

Optimisation Inputs

Algorithm:	Pattern search with multi-start	
Objective:	Minimise cost	
Design variables:	Draught, Length, Radius vector, and Fairlead location	
Constraints:	Study 1	Study 2
	Draught < Length-Freeboard	Draught < Length
	Final radius = Tower radius	Final radius = Tower radius
	Ballast Mass > 0	Ballast Mass > 0
	Pitch angle < 5°	Pitch angle < Maximum angle

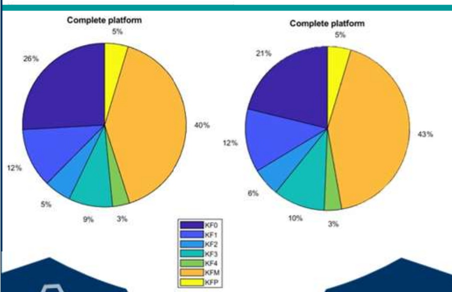
Results

Study 1



A constraint considering a 15m freeboard was used for this study.

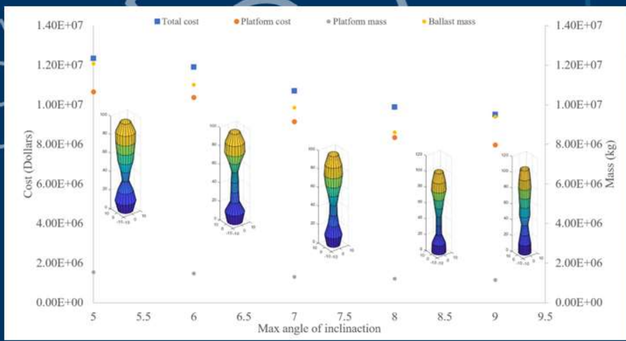
This shows the difference in complexity of the geometries along with the cost breakdown in percentages.



Study 2

The purpose of this study was to determine the effects on relaxing the maximum allowable pitch angle.

The diagram shows the geometry becoming more pinched and the cost increasing with a reducing allowable pitch angle.



Study 1

The following table highlights which aspects have increased and decreased for the two geometries

	Radius	Length	No. of segments	Surface Area	Number of stiffeners	Total cost	Weld cost	Forming cost	Paint cost	Material cost
	↓	↑	↑	↑	↑	↓	↑	↓	↑	↑
	↑	↓	↓	↓	↓	↑	↓	↑	↓	↓

Study 2

- As the maximum pitch angle decreases the lower section of the SPAR radii is increased, increasing the mass, and lowering the COG. This creates a greater distance between the COG and COB which improves the stability.
- Considering the AEP to find an equivalent LCoE still leads to a 30% difference in cost, the difference in angle is so small it is negligible.
- Carrying out more research on the maximum allowable angle in terms of fatigue life and Operations and Maintenance would determine if it is feasible to relax the angle to aid cost reduction.

Conclusion

- Overall, considering manufacturing costs there is no benefit in using non-traditional geometries.
- More work to determine what the maximum allowable pitch angle is could reduce the cost dramatically.

References

[1] Maienza, C., Avossa, A.M., Ricciardelli, F., Coiro, D., Troise, G. and Georgakis, C.T., 2020. A life cycle cost model for floating offshore wind farms. *Applied Energy*, *266*, p.114716.

[2] Sykes, V., Collu, M. and Coraddu, A., 2023. A review and analysis of optimisation techniques applied to floating offshore wind platforms. *Ocean Engineering*, *285*, p.115247.

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