HYDRODYNAMICS OF FLOATING OFFSHORE WIND TURBINES

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1. INTRODUCTION

Floating offshore wind turbines (FOWT) provide a viable energy source for near-shore deep water sites, however a lack of research on the floating body problem is evident. The present research involves numerical simulations of cylinders of different dimensions, resembling a spar-buoy type FOWT, using the open-source software OpenFOAM in order to determine which physical processes must be incorporated in order to adequately design a floating turbine.

2. NUMERICAL SET-UP

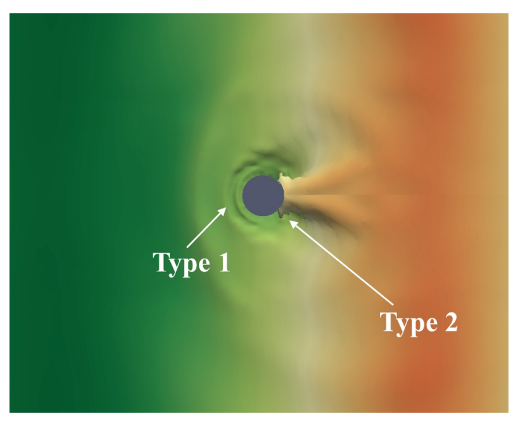
Numerical simulations were decomposed into the two parts of the floating body problem:

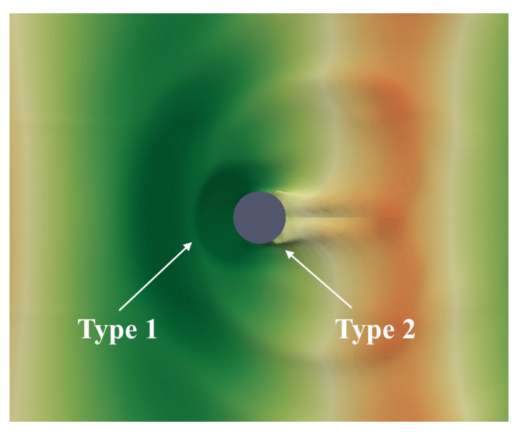
- Part A – The excitation problem: Simulations of fixed cylinders in incident regular waves using the waveFoam library
- Part B – The radiation problem: Simulations of prescribed heave and surge motions of cylinders using the interDyMFoam library

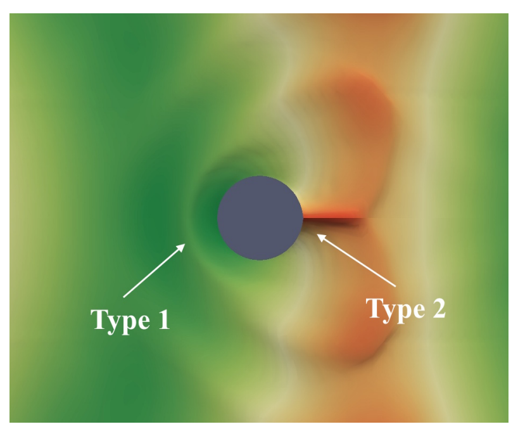
Part A Set-Up	**Part B Set-Up**
Incident wave conditions • Wave height H = 0.15 m • Wave period T = 1 s • Water depth d = 1 m • Wave theory: Stokes 5th	Prescribed motion conditions • Amplitude of oscillations A = 0.075 m • Period of oscillations T = 1 s • Degrees of freedom: surge and heave separately
Cylinder diameters • $D_1 = 0.09$ m • $D_2 = 0.20$ m • $D_3 = 0.30$ m	Cylinder diameters • $D_1 = 0.09$ m • $D_2 = 0.20$ m • $D_3 = 0.30$ m
Cylinder drafts • Bottom-mounted cylinder • 80 %, 60 %, 40 % and 20 % draft	Cylinder drafts • 60 % and 40 % draft

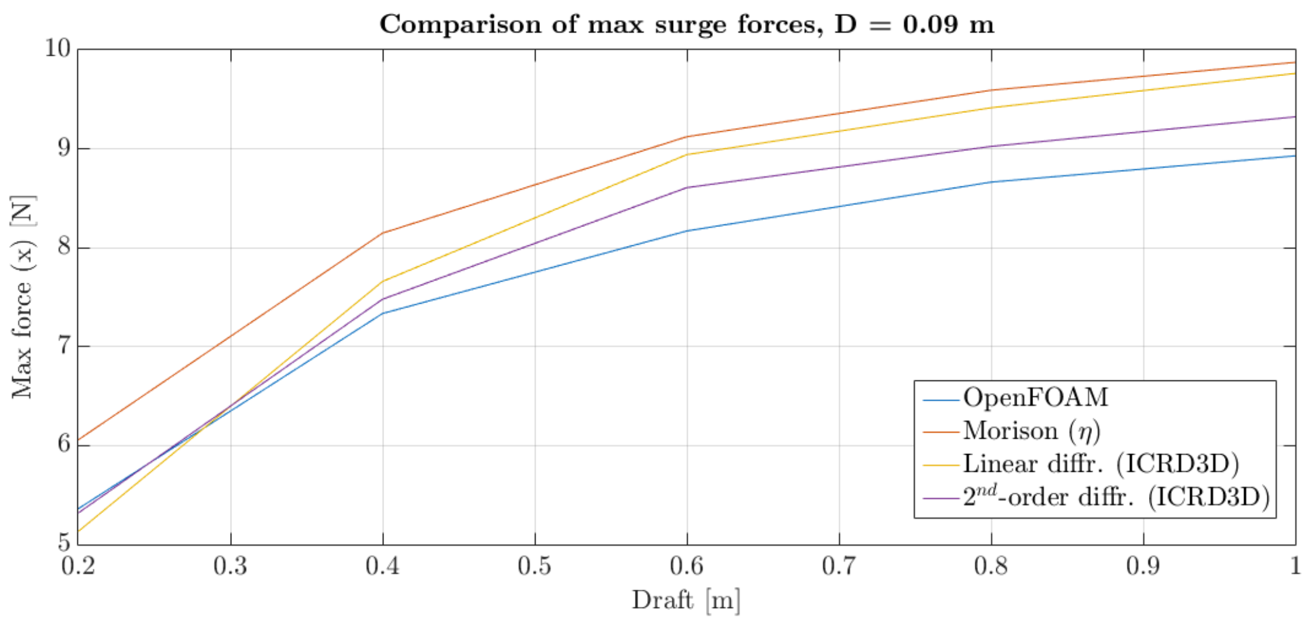
3. PART A – Fixed cylinder in incident regular waves

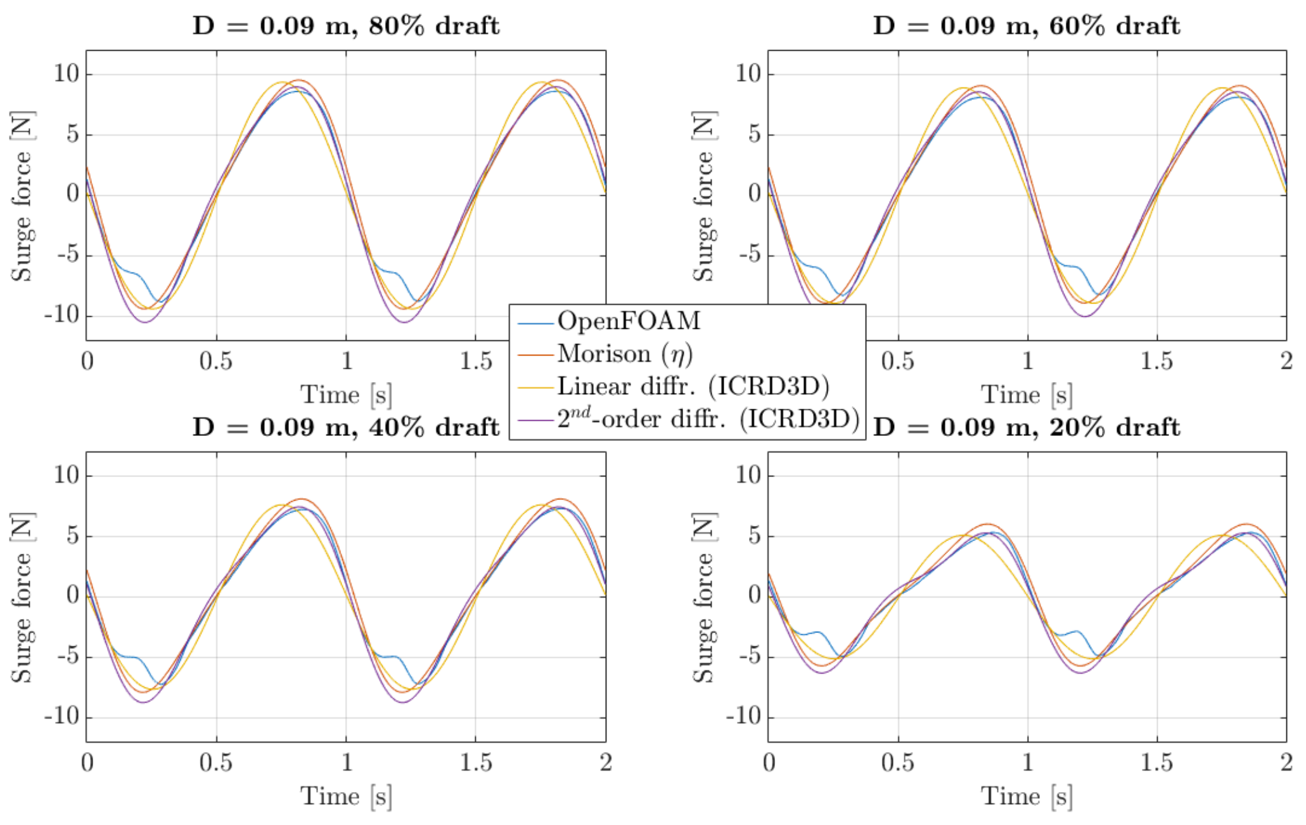
A pronounced secondary loading cycle for surge forcing due to Type 1 and 2 scattering (Sheikh, 2004; Masterton, 2007) was found, in particular for the smaller diameter cylinder. Numerical results for loading were compared to analytical expressions for forcing using Morison's equation and linear and second-order diffraction using the in-house radiation-diffraction code ICRD3D (Bruggemann, 2015).











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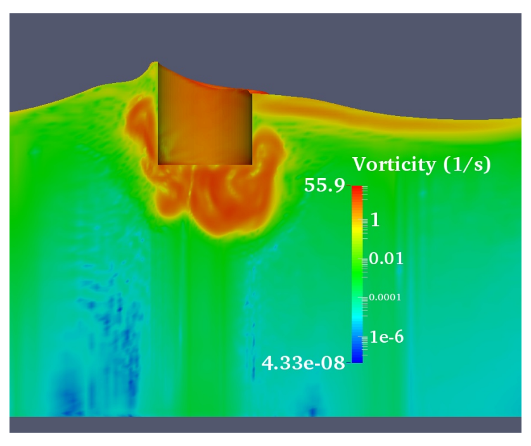

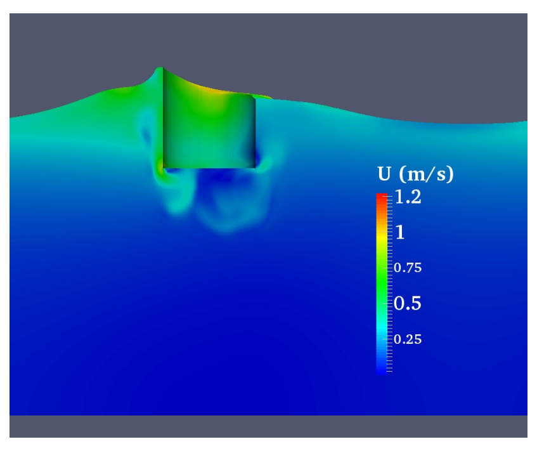

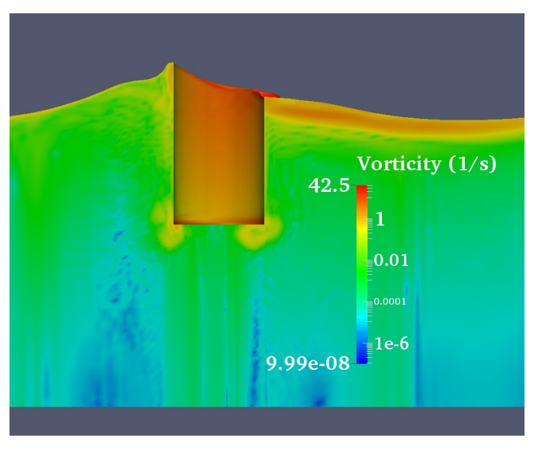

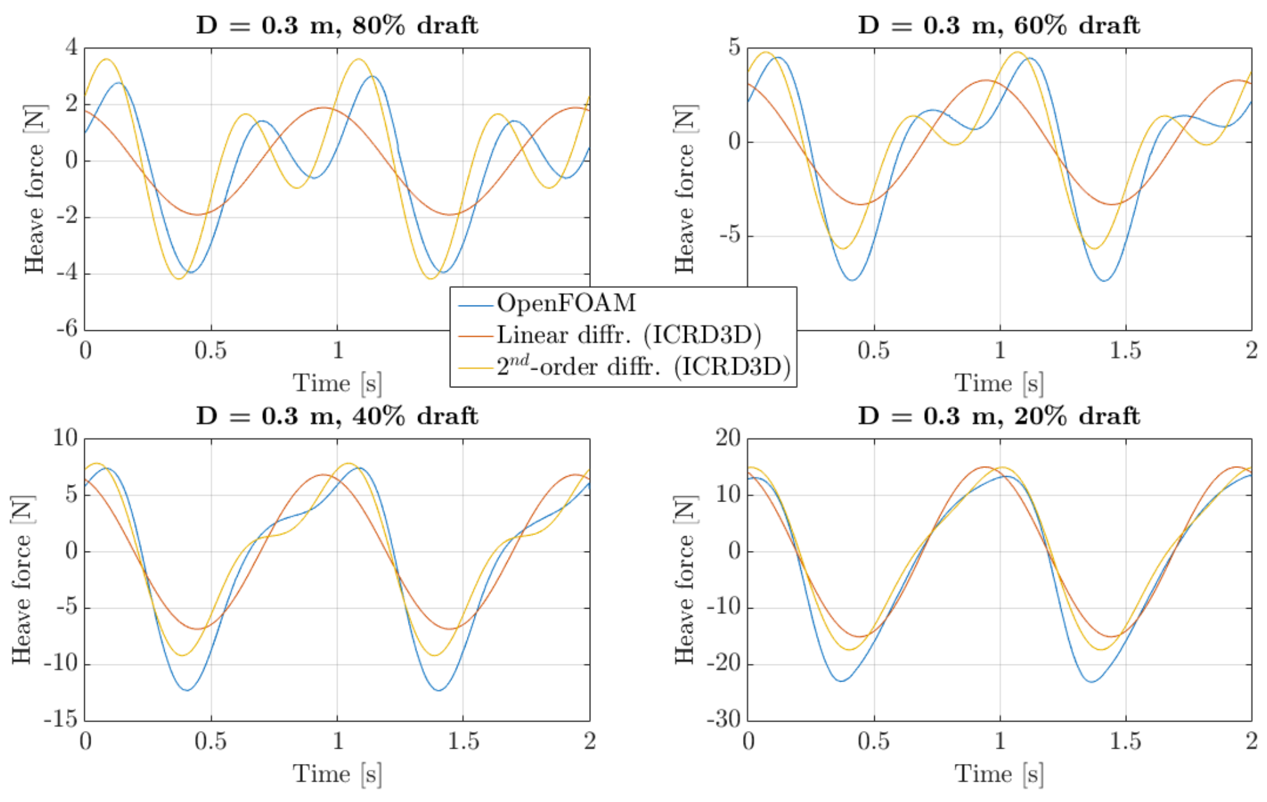

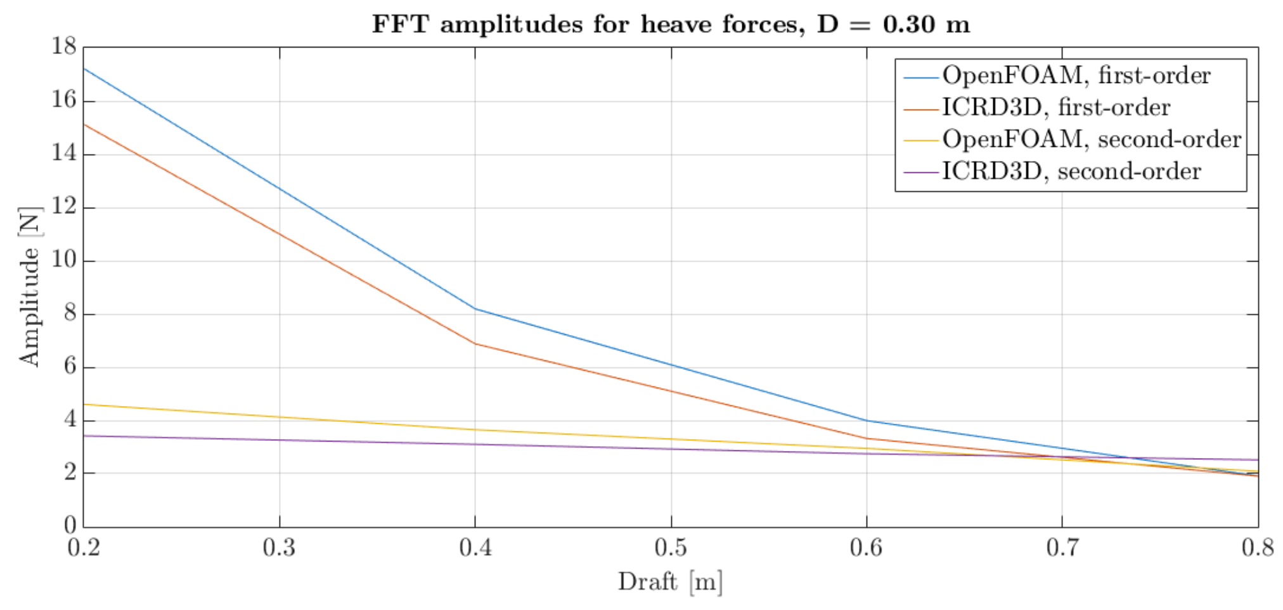

Agreement between second-order diffraction predictions and numerical results for surge forcing improved with increasing cylinder diameters and decreasing cylinder draft. This demonstrates that second-order diffraction effects are more pronounced for greater cylinder dimensions, but also that higher-order potentials are more significant at greater depths. This was confirmed when investigating heave forces underneath the cylinder, where second-order effects were most pronounced for greater drafts. Discrepancies between analytical and numerical results may arise due to higher-order forcing and viscous effects underneath the cylinder.

4. PART B – Prescribed motion in still water

Prescribed surge motions in still water were found to give rise to Type 1 and 2 scattering similar to that found in Part A. Magnitudes of forcing for both surge and heave were comparable to that found in Part A, though an increase was found for the greater diameter, greater draft cylinders. Agreement with linear radiation from ICRD3D was good for heave forcing and poor for surge forcing, demonstrating the effect of nonlinear scattering and possibly viscous damping in the latter case.

Dimensions	**Maximum surge force (N)**		**Maximum heave force (N)**	
	Part A	Part B	Part A	Part B
D_1, 60 % draft	8.2	10.7	0.4	0.7
D_1, 40 % draft	7.3	7.7	0.9	0.9
D_2, 60 % draft	39.5	57.2	1.8	9.0
D_2, 40 % draft	34.9	37.5	3.7	10.0
D_3, 60 % draft	80.8	115.7	4.5	27.9
D_3, 40 % draft	70.5	82.1	7.5	34.8

5. CONCLUSIONS

It was found that the effect of nonlinear forcing on the loading cycle is most significant for the smaller diameter cylinders. Second-order diffraction predicts results more accurately for greater diameters and lower drafts, as higher-order potentials are more significant at greater depths. Both second-order diffraction and higher-order effects due to nonlinear scattering must be taken into account in order to accurately predict hydrodynamic loads. Furthermore, response forces and the effects of viscous damping must be incorporated.

REFERENCES

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