Modelling of the Viscous Loads on a Semi-Submersible Floating Support Structure Using a Viscous-Flow Solver and Morison Formulation Combined with a Potential-Flow Solver

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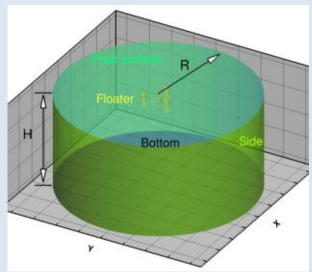
What is the problem?

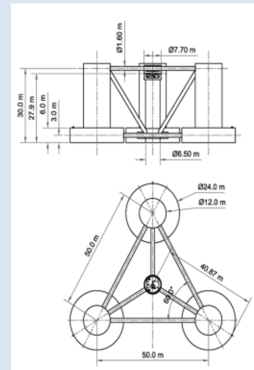
Introduction

Potential-flow (PF) codes are suitable for computing the motions and loads on the floating support structure of floating wind turbines.
However, there are limits of PF codes e.g. for severe sea-states or when the structure is equipped with damping plates. A common practice to overcome this problem is to include viscous loads by a Morison-like approach that uses a constant drag coefficient (C_D) on each structural element. Comparison of the results using standard C_D with model tests of the OC5 DeepCwind semi-submersible showed significant differences of the motion responses when excited at lower frequencies. Wrong viscous loads are suspected to cause this discrepancy. Reynolds-Averaged Navier-Stokes (RANS) based codes are expected to provide a better estimation of the drag coefficients and viscous loads.
The **objective** of this study: A better comparison of the numerical results using a combined "potential-flow and Morison drag" solver with model test data of the OC5 semi-submersible.

Investigated model

Decay tests of the DeepCwind model at 1/50th scale





What is the idea and what are the tools?

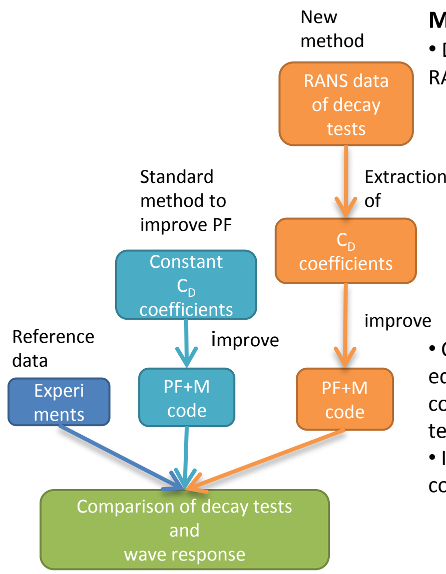
Numerical tools

- Viscous flow simulations
  - ReFRESCO (uRANS CFD code): http://www.refresco.org/
  - Structural equation of motion to solve: $\mathbf{M}\ddot{\mathbf{x}}(t)+\mathbf{C}\dot{\mathbf{x}}+\mathbf{K}\mathbf{x}=\mathbf{F}_H$, ***M***-mass matrix, **C**-damping matrix, **K**-stiffness matrix
- Combined Morison equation and potential flow simulations (PF+M):
  - WavEC's FF2W [1]
  - Combines potential flow theory and the use of Morison-like drag members
  - Rigid body motion for 6dof as follows:

$$\mathbf{M}\ddot{\mathbf{x}}(t)+\mathbf{F}_{rad}(t)+\mathbf{F}_{hs}(t)=\mathbf{F}_{exc}(t)-\mathbf{F}_{drag}(t)+\mathbf{F}_{ext}(t)$$

  - Morison-like drag force to each virtual member:

$$\mathbf{f}_{drag}=\frac{1}{2}\rho C_{d,n}DL\left(\left(\mathbf{V}_{elmt,n}-\mathbf{V}_{fluid,n}\right)\cdot\mathbf{n}\left|\left(\left(\mathbf{V}_{elmt,n}-\mathbf{V}_{fluid,n}\right)\cdot\mathbf{n}\right)\right.\right)\mathbf{n}$$
$$+\frac{1}{2}\rho C_{d,t}DL\left(\left(\mathbf{V}_{elmt,t}-\mathbf{V}_{fluid,t}\right)\cdot\mathbf{t}\left|\left(\left(\mathbf{V}_{elmt,t}-\mathbf{V}_{fluid,t}\right)\cdot\mathbf{t}\right)\right.\right)\mathbf{t}$$



Methodology

- Determine the drag coefficients from RANS:
  - Minimize ε^2 between measured and predicted forces [2]:

$$\varepsilon^2=\frac{1}{I}\sum_{i=1}^{I}\left(F_{mi}-F_{pi}\right)^2$$

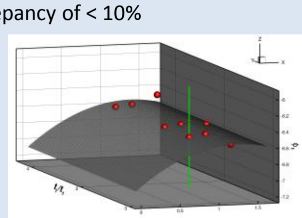
  - F_m from CFD, F_p from Morison
  - Data groups of similar velocity to account for Reynolds dependency
- Comparison with combined Morison equation and potential flow solver using constant drag coefficients and with model tests
- Investigation of the abilities of RANS compared to potential flow, i.e.:

$$F_{\text{CFDw/o}}=F_{ref,vis}$$
$$F_{\text{CFDw/}}=F_{ref,vis}+F_{ref,rad}$$
$$F_{pot,rad}=F_{\text{CFDw/}}-F_{\text{CFDw/o}}=?$$

What is done and what needs to be done?

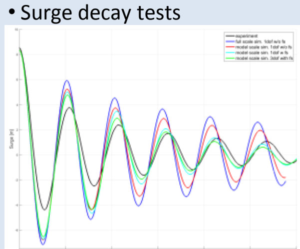
Numerical sensitivity

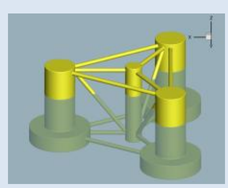
9 RANS computations to estimate the descretization uncertainty: 3 grids with 3 time steps
Using Eca's approach [3] leads to a discrepancy of < 10%



Preliminary CFD results

- Surge decay tests





- CFD simulations with and without free surface
- CFD simulations at full and at model scale
- CFD simulations with 1dof and 3dof

Ongoing investigations

- Determination of CD coefficients
- Abilities of RANS compared to PF
- Comparison of decay tests

References:

[1] Alves, M. 2012. *Numerical simulation of dynamics of point absorber wave energy converters using frequency and time domain approaches.* PhD thesis at Universidade Tecnica de Lisboa
[2] Dean, R.G., Aagaard, P.M. 1970. *Wave Forces, Data Analysis and Engineering Calculation Method.* Journal of Petrol. Technol.
[3] Eca, L., Hoekstra, M. 2014. *A procedure for the estimation of the numerical uncertainty of CFD calculations based on grid refinement studies.* Journal of Computational Physics, 262:104-130

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