# Advanced tools for modelling fluid interaction with coastal and marine structures

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## Introduction

Due to the increasing availability of computational resources the Engineering and Research community is gradually moving towards using high fidelity Computational Fluid Dynamics (CFD) models for supporting technical design and specialized analysis. In this context, the CFD Toolkit Proteus is used to perform numerical modelling of physical processes pertaining to wave propagation within coastal and offshore environment and to fluid structure interaction.

## Overview

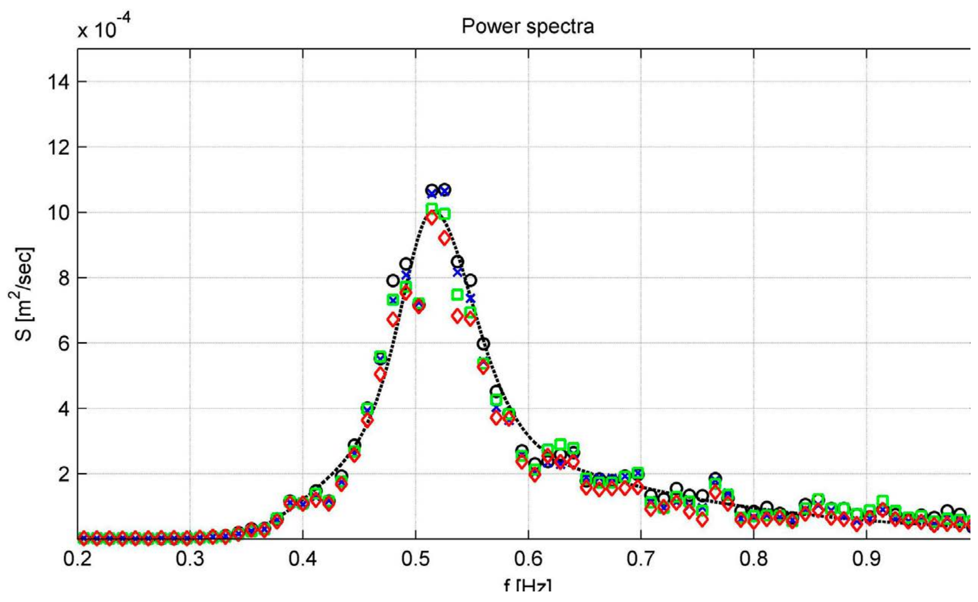
Proteus is a Finite Element Method (FEM) based software originally developed as a computational toolkit for primarily solving generic transport equations. The basic set of the numerical tools is available as an open-source computational methods and simulation toolkit at: https://github.com/erdc/proteus.

In order to demonstrate the models capabilities in terms of simulating and provide a verification and validation platform for modelling air/water flow cases, a repository containing a customizable set up of numerous benchmarks and test cases is available at https://github.com/erdc-cm/air-water-vv.

## Generation of random waves

Random waves are of stochastic nature and therefore statistical and spectral properties such as mean and significant wave height, mean and peak period and spectral distribution shape must be defined to describe the wave field. Among the avail- able spectra that can be used to describe a random wave, the most well-known one is the JONSWAP one. A comparison between an analytical JONSWAP spectrum and the numerical results at different locations in the numerical wave tank is shown below.

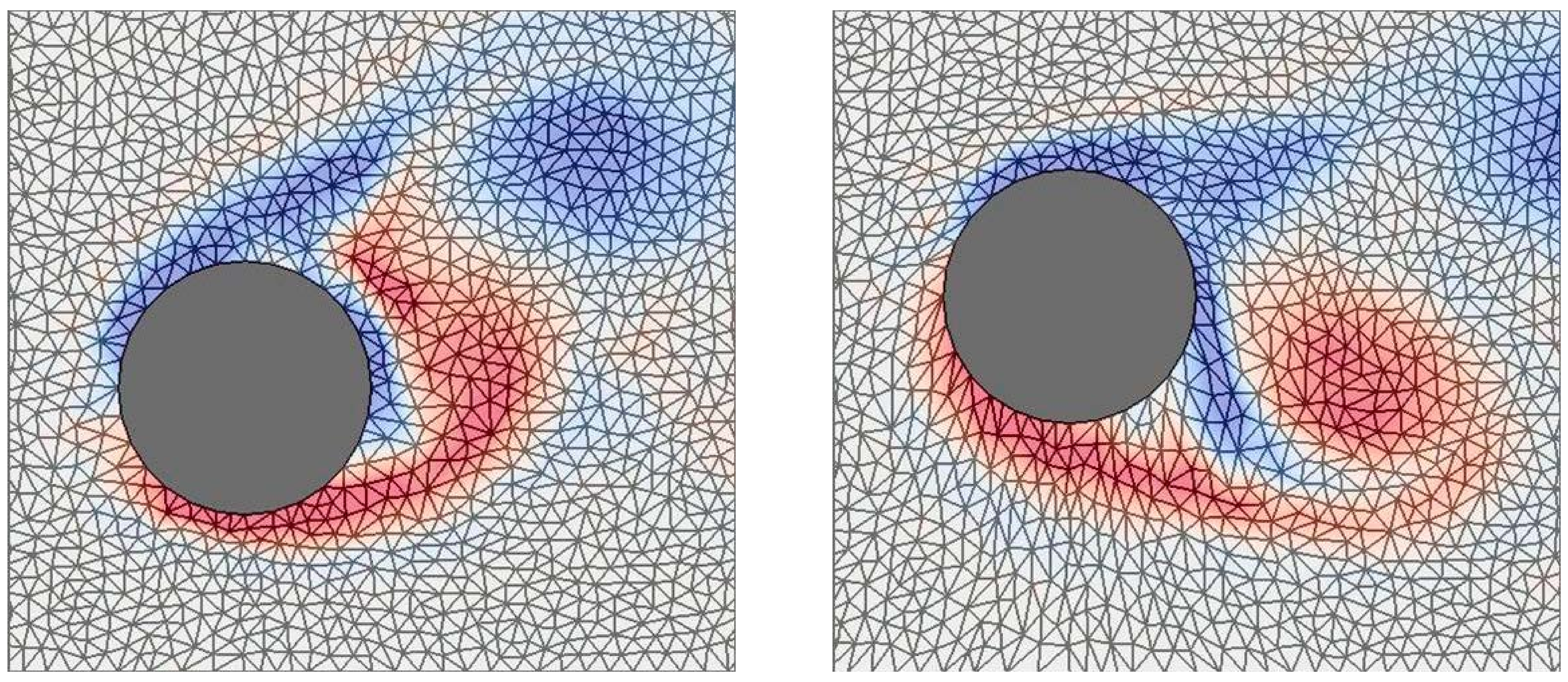
In Proteus, a novel reconstruction methodology based on signal processing using windows is introduced rather than directly processing the time series of free surface elevation. The method is used for pre-processing a free surface elevation time series and generating the wave field using a reduced number of frequencies. The wave field is introduced in the numerical tank following the relaxation zone method. The method allows reflected waves to be absorbed in both the offshore and the landwards boundary. More details on [1].




Wave spectra in the numerical wave tank (coloured symbols), compared against the JONSWAP distribution.

## Fluid-structure interaction

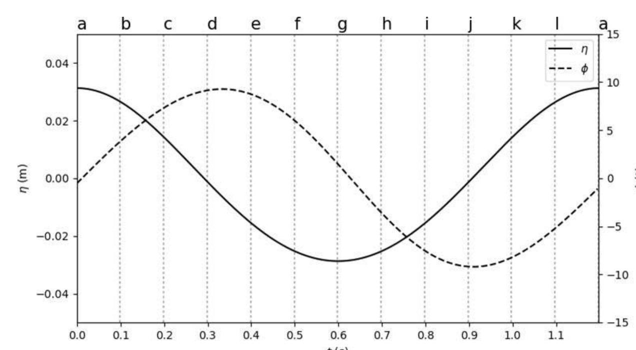
Fluid-Structure Interaction (FSI) is achieved in a partitioned manner, where the multi-body dynamics is computed with the help of another open source tool (Project Chrono [2]). An Arbitrary Lagrangian Eulerian (ALE) technique is used for moving the mesh with the structures, by solving the equation of linear elastostatics in the fluid domain.

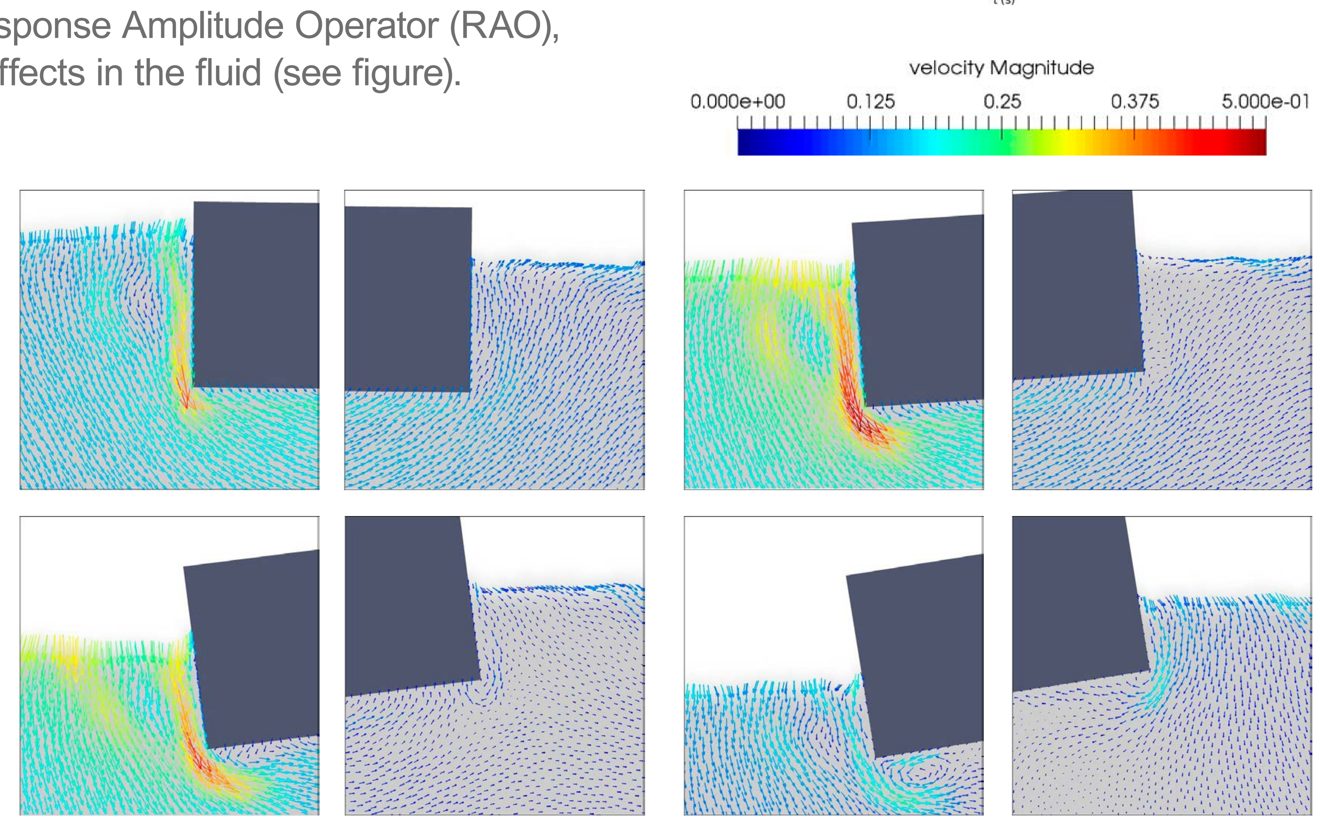


Mesh motion for fluid-structure interaction problems.

## Floating structures

Floating structures require a robust mesh deformation technique as their displacement is usually larger than for coastal defenses under typical conditions. Comparison between experimental results from [3] and numerical results from [4] of a floating body rolling under wave loads show good agreement over the range of frequency tested in terms of Response Amplitude Operator (RAO), capturing nonlinear effects in the fluid (see figure).

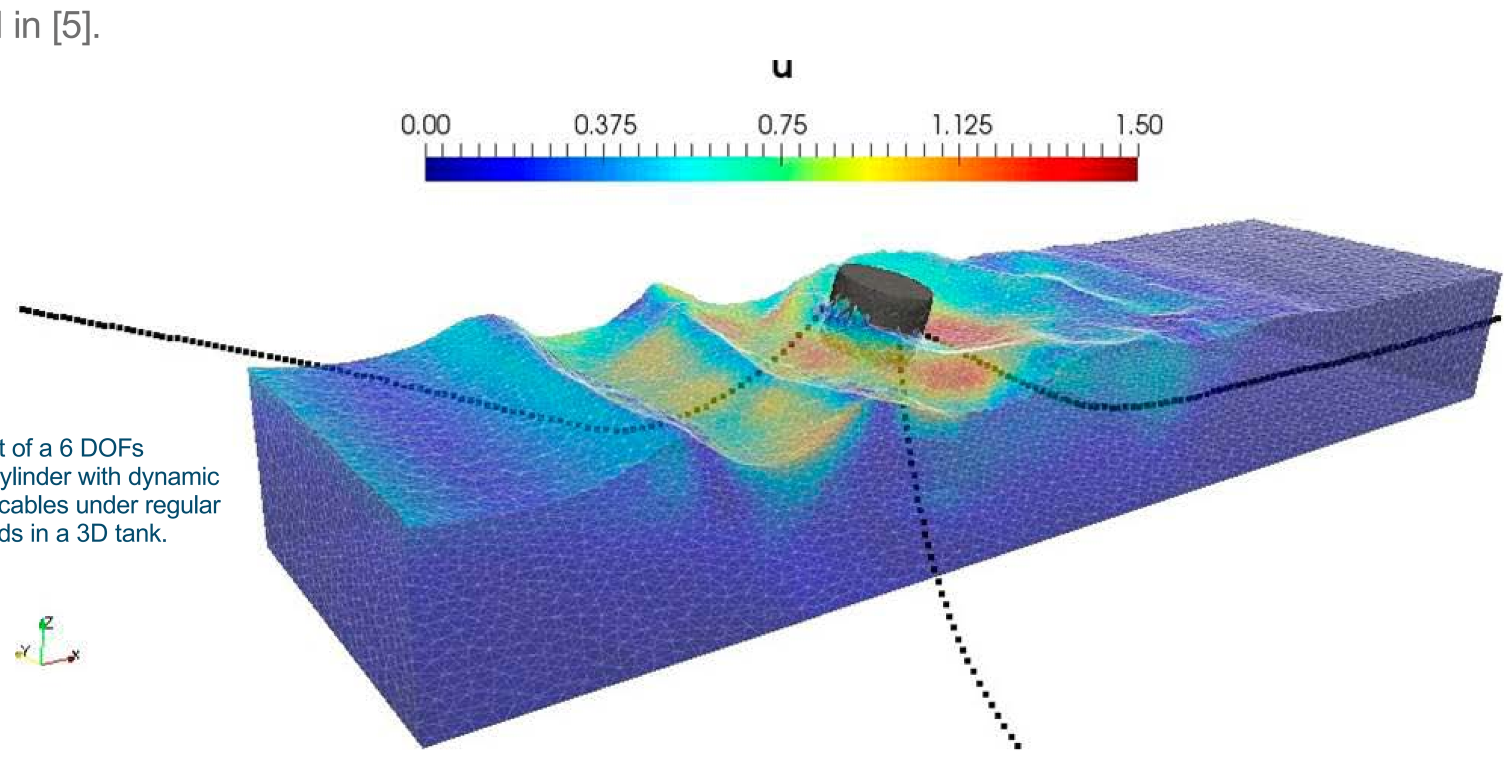



Snapshots for roll motion of floating body under wave loads, (a) to (d), showing fluid velocity magnitude and vortices forming around corners.

## Moored structures

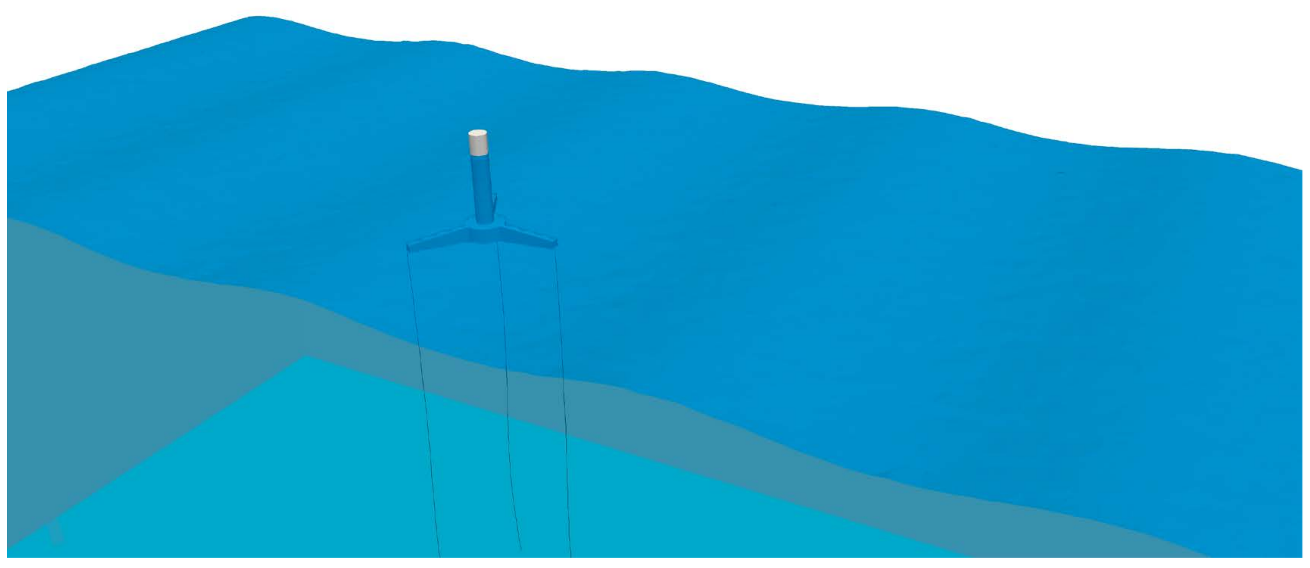
Mooring dynamics can be used to constrain floating structures using FEA with beam theory. The figure shows a snapshot of 6 DOFs cylinder anchored with 3 catenary cables. In these simulations, bending of the cable, as well as drag and added-mass effects on the cable due to the fluid and their effect on the floating structure are taken into account. More details about the implementation can be found in [5].




Snapshot of a 6 DOFs floating cylinder with dynamic mooring cables under regular wave loads in a 3D tank.

## Further work

The aim of the project is to develop robust computational tools for performance assessment of realistic floating structures under extreme environmental conditions. Simulation of a Tension Length Platform (TLP) with associated mooring configuration is currently underway. We will use the toolkit to test various mooring arrangements and look at nonlinear response of mooring lines, associated with extreme loading events.



Snapshot of a 6 DOF TLP cylinder with dynamic mooring (in progress) in a 3D numerical tank.

## References

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[3] Kwang Hyo Jung, Kuang-an Chang, and Hyo Jae Jo. Viscous Effect on the Roll Motion of a Rectangular Structure. Journal of engineering mechanics, 132(2):190–200, 2006.

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