The 39^{th} International Workshop on Water Waves and Floating Bodies, 14-17 April 2024, St Andrews, Scotland

Experiments and computations of a floating cylinder

Atle Jensen[a], **Thierry Coupez**[b]
a. Department of Mathematics, University of Oslo, Norway
b. FL / CEMEF / Mines-ParisTech, Sophia-Antipolis, France
Email: atlej@math.uio.no

Introduction

Polar regions, and the Arctic in particular, have become the focus of increased research in the last 10 years. Changes in the climate alongside technological developments are creating new opportunities in these regions for human activities, including sustainable development of resource-based industries, fishing, tourism, and faster shipping routes between Europe and Asia. A more profound scientific comprehension of the Arctic environment is crucial for enhancing our ability to predict sea ice hazards associated with human activities. This, in turn, will naturally contribute to increased value in polar regions, promoting safety and environmental sustainability.

This study originated within the research project; "Dynamics of floating ice (DOFI)", which delved into topics related to waves and ice (see e.g. Løken et al. (2022), Løken et al. (2021) and Sutherland et al. (2019)). Our approach was twofold: firstly, to identify methods for assessing the stability of icebergs, and secondly, to enhance our understanding of the coupling between wind, currents, waves, and iceberg drift, with the aim of improving predictions of iceberg trajectories.

Numerical simulations were executed on complex geometries floating in a wavy environment. However, these results indicated the need for benchmarking on a simpler problem. Similar issues have been explored in previous studies, such as Itō (1977) and Kramer et al. (2021).

Dynamics of a floating cylinder

The first step in comprehending this complex phenomenon involves conducting experiments using simple geometries. Idealized experiments were carried out in a small tank at the Hydrodynamics Laboratory at UiO, where a cylinder with a diameter of $58.8mm$, length of $243mm$ and mass of $621gr$ was utilized. The cylinder is mounted horizontally, with rods connected to air bearings to induce vertical, frictionless motion. Oscillations are measured with a laser leveling instrument with an accuracy down to μm.

In addition to laboratory experiments, Computational Fluid Dynamics (CFD) simulations of floating cylinders were performed. CFD was conducted using finite element methods and adaptive meshing, representing the cutting edge of numerical methods. The mixed velocity pressure solver is using unstructured (simplex elements) and is stabilized by a residual based Variational multiscale method (VMS). Adaptive remeshing are driven by a metric (anisotropic mesh adaptation, Coupez (2011), Coupez & Hachem (2013)) calculated a posteriori by an error estimate accounting for the dynamics both of two fluids (air/water) and the solid, within a monolithic formulation of the incompressible Navier-Stokes equation (Coupez et al. (2015), Hachem et al. (2015)). The solid dynamics are predicted by a penalty method of the deformation in the fluid equations and post-corrected by a rigid motion. The interfaces (liquid/gas/solid) are all tracked by a convected level set method (Ville et al. (2011)). The mesh adaptation enables to avoid any mixture at the interfaces (the formulation is fully Eulerian) without any observed spurious added mass effects. 2D simulations have been run on a laptop, accuracy of the 3D simulations (running on supercomputer, Digonnet et al. (2019)) are still under investigation. Several cases were run and the cylinder was initialized in two different positions; falling and submerged. In the falling case, lower part of the cylinder touched the free surface, and for the submerged case, the upper part was aligned with the free surface. After the release, the damping of the cylinder where measured.

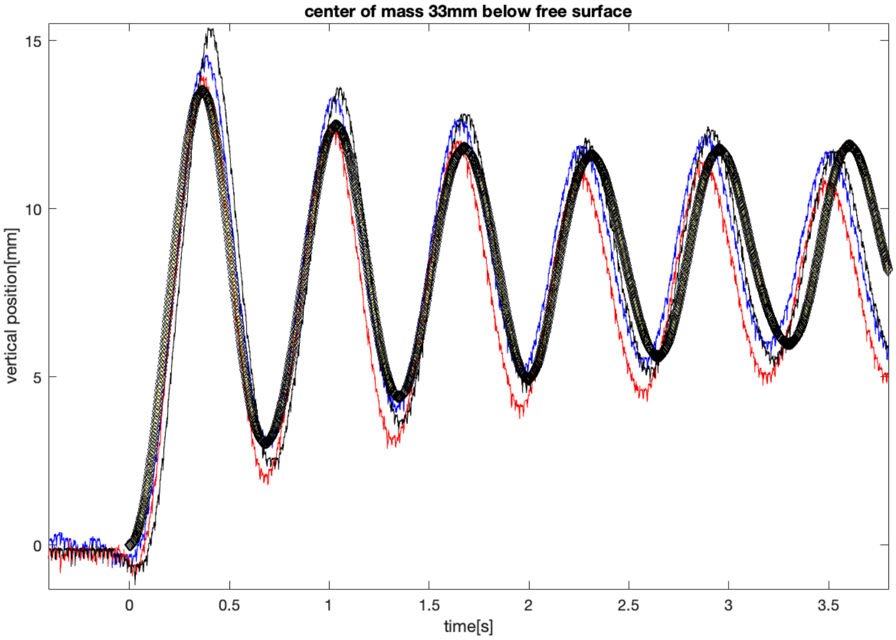

Figure 1: Release of submerged cylinder. A first comparison between experiments and numerical simulations. Black symbols: simulation. Coloured lines: experiments.

Figure 1 displays results from a 2D simulation alongside experimental data for the submerged case, demonstrating a favorable comparison. Nonetheless, it is worth noting that the vertical oscillations are highly sensitive to the initial position and the geometry of the submerged cylinder.

References

Coupez, T. (2011), ‘Metric construction by length distribution tensor and edge based error for anisotropic adaptive meshing’, *Journal of computational physics* **230**(7), 2391–2405.

Coupez, T. & Hachem, E. (2013), ‘Solution of high-reynolds incompressible flow with stabilized finite element and adaptive anisotropic meshing’, *Computer methods in applied mechanics and engineering* **267**, 65–85.

Coupez, T., Silva, L. & Hachem, E. (2015), ‘Implicit boundary and adaptive anisotropic meshing’, *New challenges in grid generation and adaptivity for scientific computing* pp. 1–18.

Digonnet, H., Coupez, T., Laure, P. & Silva, L. (2019), ‘Massively parallel anisotropic mesh adaptation’, *The International Journal of High Performance Computing Applications* **33**(1), 3–24.

Hachem, E., Feghali, S., Coupez, T. & Codina, R. (2015), ‘A three-field stabilized finite element method for fluid-structure interaction: elastic solid and rigid body limit’, *International Journal for Numerical Methods in Engineering* **104**(7), 566–584.

Itō, S. (1977), Study of the transient heave oscillation of a floating cylinder., PhD thesis, Massachusetts Institute of Technology.

Kramer, M. B., Andersen, J., Thomas, S., Bendixen, F. B., Bingham, H., Read, R., Holk, N., Ransley, E., Brown, S., Yu, Y.-H. et al. (2021), ‘Highly accurate experimental heave decay tests with a floating sphere: A public benchmark dataset for model validation of fluid–structure interaction’, *Energies* **14**(2), 269.

Løken, T. K., Marchenko, A., Ellevold, T. J., Rabault, J. & Jensen, A. (2022), ‘Experiments on turbulence from colliding ice floes’, *Physics of Fluids* **34**(6).

Løken, T. K., Marchenko, A., Rabault, J., Gundersen, O. & Jensen, A. (2021), Iceberg stability during towing in a wave field, *in* ‘Proceedings-International Conference on Port and Ocean Engineering under Arctic Conditions’, Port and Ocean Engineering under Arctic Conditions.

Sutherland, G., Rabault, J., Christensen, K. H. & Jensen, A. (2019), ‘A two layer model for wave dissipation in sea ice’, *Applied Ocean Research* **88**, 111–118.

Ville, L., Silva, L. & Coupez, T. (2011), ‘Convected level set method for the numerical simulation of fluid buckling’, *International Journal for numerical methods in fluids* **66**(3), 324–344.