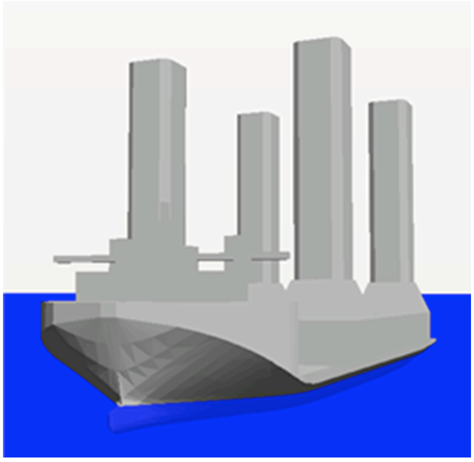
Efficient computation of slamming loads through zonal modeling



HMC
Almere based HMC is a maritime consultancy company offering services ranging from strength and stability calculations on vessels or maritime structures, to calculating the hydrodynamic and mechanical loads acting on a vessel during a voyage and determining the requirements for the loads in terms of sea-fastening and supporting structures. To this end HMC have developed a set of simulation tools aimed at safe seagoing transport and safety of offshore constructions.

Zonal modeling: coupling global and local models
Application of multiphase flow models to analyze the hydrodynamic loads on ships and offshore structures is very computationally intensive. In those cases where these loads only need to be determined on a small part of the structure and the accuracy requirements on the solution can be relaxed, so called *zonal modeling* techniques can be applied: A simplified *global* model for the analysis of the flow around the complete structure is coupled to a high-accuracy *local* model for part of the structure. This type of technique is applied in many fields of aero- and hydrodynamics, and many shapes and forms. An example is given in [1], where a global model based on potential flow is applied to describe the flow around a heaving and pitching hull and coupled to a local model based on the incompressible Navier-Stokes equations to describe the flow around the bow section of the hull to compute the loads induced by the impact of waves on the ship's deck.

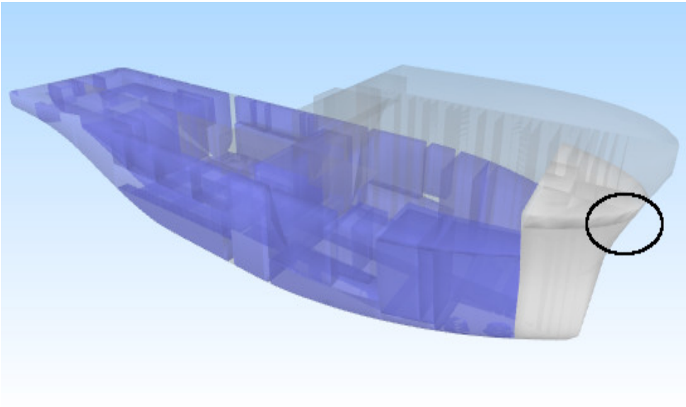


Illustration 1: Slamming induces very large hydrodynamic loads on the indicated areas of the bow of the ship.

Slamming loads
HMC developed the tool CPC3.0 to compute the loads based on a 6-degree of freedom rigid body dynamical model of a vessel. The momentary orientation and draught of the ship, including the dynamics of any partially filled tanks inside the hull, are used to compute the model excitation. Experience has shown that discarding the coupling between the flow and the ship dynamics leads to a sufficiently accurate model to predict the long-term effect of the hydrodynamic loads on the lifetime expectancy of the ship.
However, the current model does not include the effect of *slamming* induced loads. *Slamming* is the impact of the hull of a ship onto the sea surface. It is mainly observed while sailing in waves, when the bow rises from the water and subsequently impacts on it. In addition, on vessels containing sponsoons slamming of waves against these sponsoons occurs. Slamming induces extremely high loads on ship structures. This will significantly decrease the lifetime of this part of the vessel. Slamming typically occurs at a number of locations along the vessel, including the areas indicated in Illustration 1, showing models of vessels analyzed with the CPC3.0 algorithm.

Modeling slamming loads through zonal modeling
In the proposed project *the potential of including the effect of slamming induced loads in the CPC3.0 algorithm through zonal modeling* will be investigated.
A local model based on the assumptions of incompressible, immiscible two-phase flow will be solved in a small region surrounding the forward section of the hull. Appropriate boundary conditions for this flow domain have to be formulated that allow for a momentum and kinetic energy conserving coupling with the mechanical model of the complete ship. In turn the contribution of the slamming loads has to be taken into account in the dynamics of the ship, i.e. a two-way coupling between both models has to be achieved.

Outline of the project
The project will consist of three phases:
1. A literature studies on the current status of zonal modeling, in particular in the context of multiphase flow models for ship hydrodynamics.
2. The realization of a *proof of concept* algorithm, were the accuracy of the approach is assessed for a very simple geometry.
3. The realization of the coupling with CPC3.0.

The literature studies will allow the student to obtain more insight in current zonal modeling techniques, two-phase flow modeling in general and the physics of slamming.
In the second phase the slamming loads on an elliptical object (two spatial dimensions) and an ellipsoid (three spatial dimensions) are computed with and without the zonal modeling techniques. The global model can be realized as a simple, separate algorithm in MATLAB or Python. Different strategies to exchange information between both models can be studied as well as the effect of different coupling strategies on the accuracy and efficiency of the algorithm.
If time allows, the final coupled algorithm will be realized in the last phase of the project.

References
[1] Kleefsman, K. M. T., Loots, G. E., Veldman, A. E. P., Buchner, B., Bunnik, T. & Falkenberg, E. (2005). The numerical simulation of green water loading including vessel motions and the incoming wave field, *Proc. 24th Int. Conf. Offsh. Mech. Art. Eng (3)* pp. 981-992.

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