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| Document title | Article 006: Parametric Identification of Radiation-Force Models of Ships using MSS toolbox. |
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Abstract

3D potential theory programs are available to compute hydrodynamic forces. For a finite set of frequencies, frequency dependent added mass and damping can be calculated. In this article it is explained how the quality of the radiation forces (added mass and damping) are judged by means of parametric identification. This might be required in case of complex geometries or when additional processing needs to be performed. This is done with the use of the publicly available Marine Systems Simulator (MSS) toolbox. MSS is a MATLAB library for marine systems control design.

# 1. Identification of radiation forces

For this example, a 3D mesh representation is created for a tanker type vessel as shown in Figure 1-1. The design loading condition is considered to obtain the required draught (only the underwater part is needed in a linear diffraction calculation). The vessel has around 5,000 panels with a length of 1.5m.

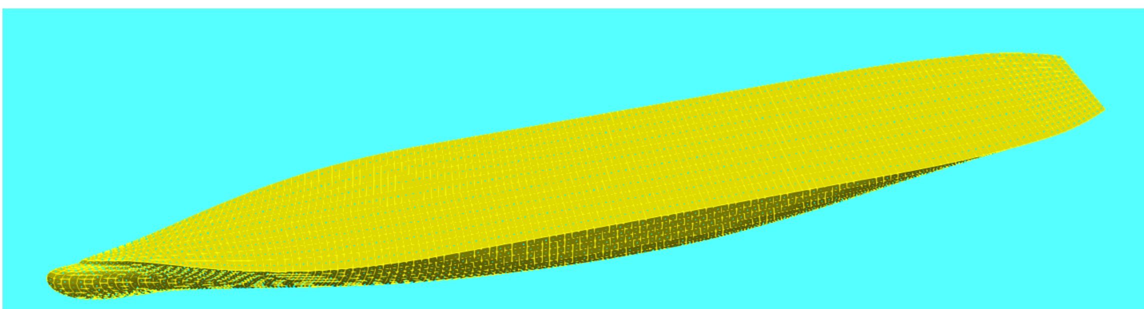

**Figure 1-1: 3D vessel geometry**

For this known vessel geometry, frequency dependent radiation forces are calculated as shown in Figure 1-2 using a hydrodynamic code for frequencies from 0.05 rad/s with steps of 0.05 rad/s to 2.00 rad/s.

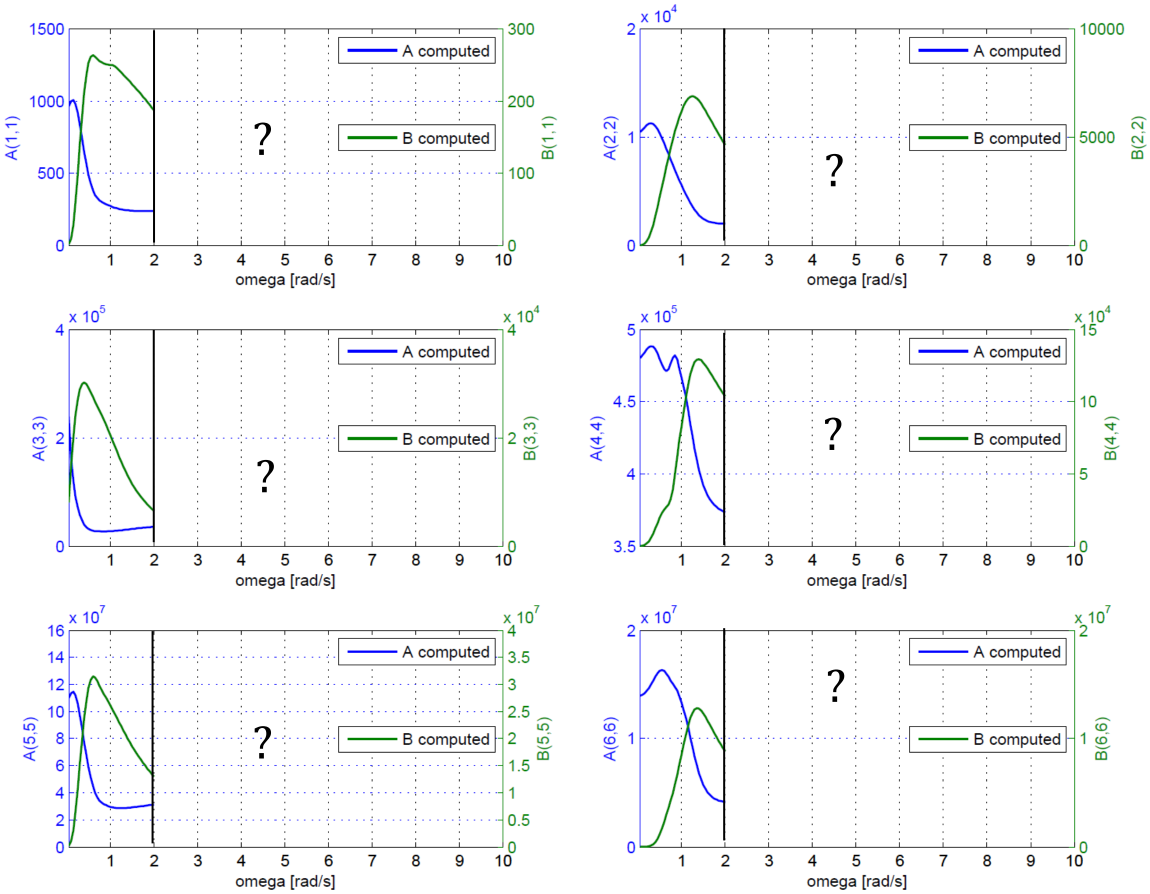


**Figure 1-2: Calculated radiation forces from linear diffraction software for specified vessel mesh**

The maximum frequency for which it is recommended to obtain results is typically a trade-off between accuracy and computational effort. As a general rule of thumb, 7 panels over the wave length are recommended. When applying more panels, further refinement is needed, which also increases the computational effort. The relation between number of panels and set of equations to be solved is quadratic. It is important to sample enough frequencies such that the system can be represented by its frequency response function.

For the calculated set of frequencies, we want to obtain the full parametric model, without running excessive amount of calculations or further refinement of the mesh. For this we use the MSS toolbox (Perez & Fossen, 2013). The MSS toolbox for recovering the radiation forces consist of the following steps:

- For a finite set of frequencies the calculated frequency dependent radiation forces (added mass and damping) from the 3D potential theory program are used.
- The frequency-domain representation of the retardation functions is obtained from these radiation forces by known relations that follow from Fourier transform properties.

- A least square (LS) fit is done on the complex frequency response. A set of constraints is enforced on the solution method to make sure the result is stable. First the lowest order polynomial is fitted (to avoid over-fitting). The LS-problem is non-linear in the parameters and can be solved with Gaussian-Newton methods.
- An error function is evaluated to obtain the difference between the fit and the original sampled data points. If the error is too large, the fit improved by fitting higher order polynomials through the sampled data points. If the error is acceptable, the complex frequency response is considered to be fully recovered.
- The added mass and damping can then be constructed from the real and imaginary parts of this estimate.

The result of this method is shown in Figure 1-3

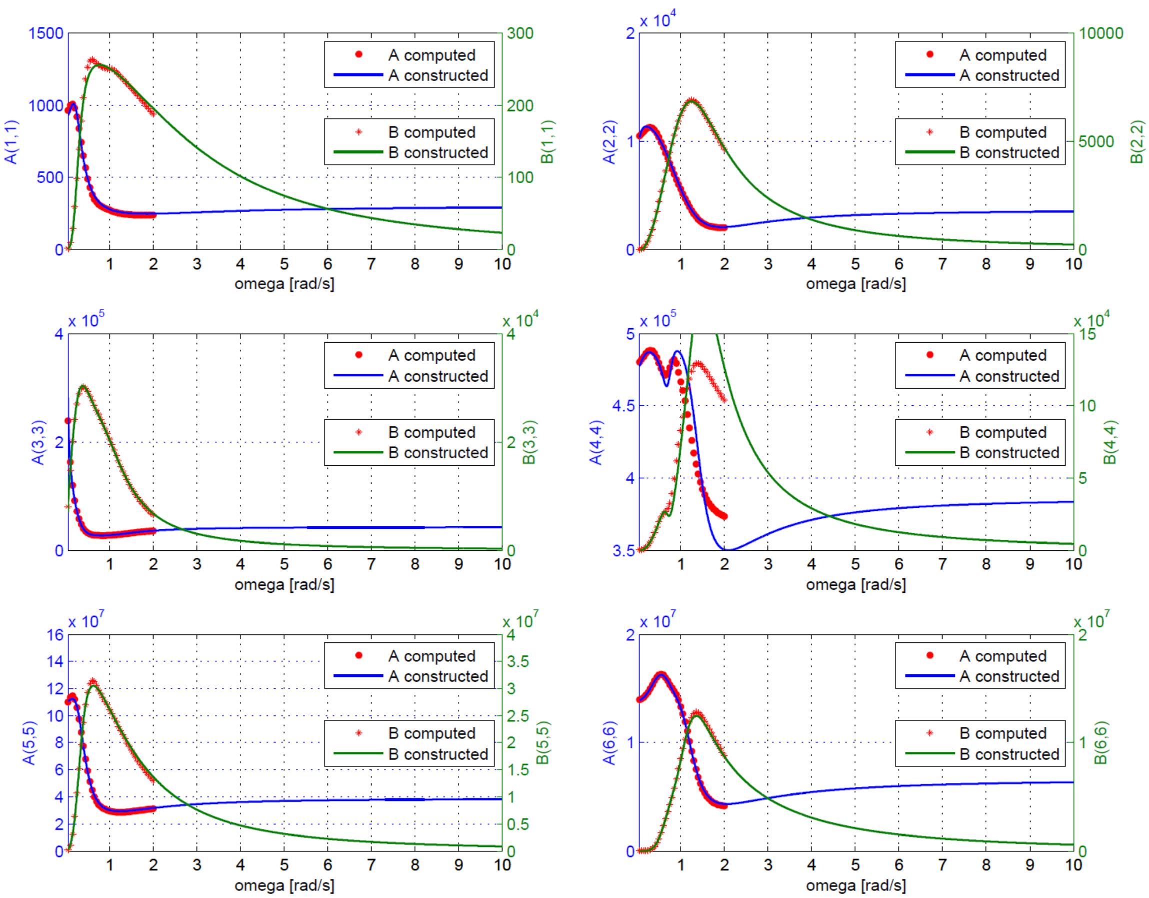


**Figure 1-3: Reconstructing radiation forces (main diagonal is shown only)**

*(the fitting in roll-roll can be improved as some overshoot occurs)*

The main purpose of doing this is to check the quality of added mass and damping for further analysis in mooring assessments: the infinite frequency added mass should be a positive definite near the asymptotic value (here taken at 10 rad/s). The potential damping should go to zero as no energy can be generated (passivity).