



Document title	Article 002: Seakeeping and workability
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Abstract

Knowledge about wave induced loads and motions of ships and offshore structures is important both in design and operational studies. Offshore vessel assets are often deployed in harsh weather conditions that cause uncertainty in design and operational decision making. The vessel hydrodynamics deliverables are part of the mooring, transport & installation analysis, but can also be carried out as a separately. In this article, frequency domain seakeeping calculations and workability analysis of ships in waves are further explained. The result of such a study are linear calculated ship motions, velocity, accelerations, and relative wave elevation of a sailing ship in waves. Once the ship motions in 6 degrees of freedom are calculated, the equations of motions in any arbitrary point are solved for a unitary wave. With these results the overall ship behavior can be analyzed and ship appendages such as rudder, propellor, bilge keels or stabilizing fins can be further optimized. Without proper evaluation, important aspects in planning or operation might be overlooked. For the readability of this report, the underlying theory is omitted.

1. Seakeeping calculations

1.1. Methodology

According to the linearized theory in seakeeping calculations, the response to a regular wave will have the same frequency, but a different amplitude and phase shift. This theory is generally applicable when the wave steepness is small, i.e., the waves are far from breaking. Linear theory means that the wave induced motion and load amplitudes are linearly proportional to the wave amplitude.

The amplitudes and phase shift are calculated by the numerical model in the CoG for different frequencies and wave directions. Once the motions have been solved in the CoG, the harmonic (absolute) vertical displacement in a point $P(x_b, y_b, z_b)$ on the ship-bound axes system are calculated by standard ship hydromechanics theory (this is further omitted for the readability of this report, but available upon request).

The methodology of obtaining vessel responses is as follows:

1. Seakeeping calculations are performed with a numerical model for the design vessel(s) in the considered loading condition(s) and stability parameters. Viscous damping is typically included in the model as standard linear diffraction theory neglects the effect is viscous damping, therefore overestimating the roll motions.



There are different ways to calculate the damping, such as calculating this damping from appendages or by Ikeda damping. The results of the seakeeping calculations are databases containing:

- a. Natural periods of the vertical modes (heave, roll and pitch). These natural periods can be used to estimate potential resonance behavior in waves.
- b. RAOs of vertical motions evaluated at specific points.

These databases can be created for different wave angle of attacks, vessel speeds, and water depths.

2. Operability calculations are performed by further postprocessing. This postprocessing uses the RAO databases and transforms it into response spectra using a numerical wave spectrum. From the response spectra, the statistical factors 'zero-upcrossing period' T_2 and 'significant amplitude of vertical motion, velocity and acceleration in one or more points can be evaluated. These statistical parameters consist of coupled heave/roll/pitch motions (depending on the location of the point).

The seakeeping calculations are performed for different wave heights/periods, wave directions and (optionally) directional spreading parameters. The latter is also important to consider, as swell waves generally lead to larger vessel motions: the energy density is more narrowly distributed around the wave peak period. If this peak period is closer to the natural frequency of the mode (heave, roll or pitch), this will result in larger responses that need to be considered in the design.

If many design scenarios are to be considered, it might be easier to precompute results within the expected boundaries and perform interpolation or lookup for the actual design condition (wave height, period, direction).

3. The statistical parameters from the operability calculations are then used to obtain expected maximum vertical motions by multiplying the significant amplitude with a safety factor. This safety factor should consider the design intend and typically includes total duration in which the operation is planned and statistical quantities such as upcrossing periods or risk related factors.
4. Results can then be used to evaluate responses against criteria (for example Motion Sickness Indicators, or available channel depth) to obtain operability and workability assessments. Additionally, by combining results with environmental statistical data, downtime can be obtained. Downtime is defined as the % of time in which operations cannot be carried out as one or more criteria are exceeded.



1.2. Test case

In Figure 1-1 the vertical significant amplitudes evaluated at keel points are plotted for a large bulk carrier with known dimensions, loading condition and stability parameters for a unitary wave. The angle shows the wave angle of attack and the radius shows the wave period [s].

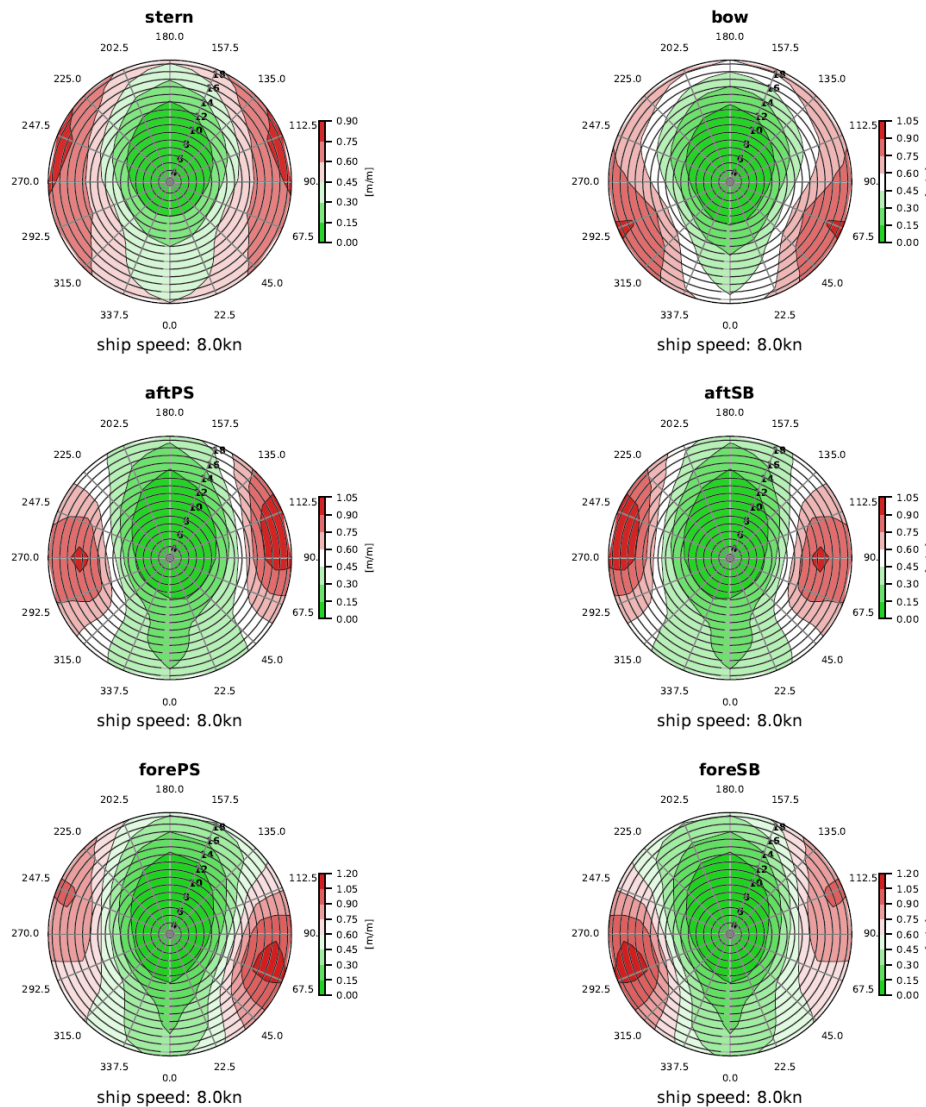


Figure 1-1: Vertical motions evaluated at keelpoints

These polar plots show which keel point are prone to dynamic amplification. A point located at the portside/starboard is prone to rolling motion when the wave period is close to the roll natural period. For a point located at portside, beam-on portside waves cause the largest motions. For a point located at starboard, beam-on starboard waves cause largest motions. A point located at bow/stern experiences largest vertical motions when the wave period is close to the natural pitch periods. Results can be used for further evaluation or optimization and design in the mentioned services and deliverables.