

MIKE 21 Maritime

Frequency Response Calculator

User Guide



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1 About this User Guide

1.1 Purpose

The main purpose of this User Guide is to get you started in the use of the new MIKE 21 Mooring Analysis (MA) modelling system, for analysis of moored vessels (or a floating body in general) subjected to wave, current and wind forcing, whether located in ports, coastal or offshore areas. The effect of breakwaters and other port structures on the wave field is included in the model.

The MIKE 21 MA modelling system consists of two applications in the MIKE 21 Maritime Product Group, which works together in a full work flow:

1. Frequency Response Calculator
2. MIKE 21 MA

This guide will explain how to operate the Frequency Response Calculator (FRC), which is the first application to consider in a mooring analysis work flow.

This User Guide is complemented by the Online Help.

The MIKE 21 MA modelling system, is a further commercialisation and development of the previously released DHI model called DVRS (Dynamic Vessel Response Simulator) as well as the DHI internal tool known as WAMSIM /1/. Therefore reference papers and past studies that refer to DVRS and WAMSIM refer as well to the MIKE 21 MA modelling system as such.

1.2 Assumed User Background

Although the MIKE 21 MA suite of applications have been designed carefully with emphasis on a logical and user-friendly interface, and although the User Guide and Online Help contain modelling procedures and a large amount of reference material, common sense is always needed in any practical application.

In this case, "common sense" means a background in hydrodynamics and flow-structure interaction, which is sufficient for you to be able to check whether the results are reasonable or not. This User Guide is not intended as a substitute for a basic knowledge of the area in which you are working: Mathematical modelling of flow-structure interaction.

It is assumed that you are familiar with the basic elements of MIKE Zero: File types and file editors, the Plot Composer, the MIKE Zero Toolbox, the Data Viewer and the Mesh Generator. An introduction to these can be found in the documentation.



1.3 General Editor Layout

The Frequency Response Calculator (FRC) setup editor consists of three separate panes.

1.3.1 Navigation tree

To the left is a navigation tree, that shows the structure of the model setup file, and is used to navigate through the separate sections of the file. By selecting an item in this tree, the corresponding editor is shown in the central pane of the setup editor.

1.3.2 Editor window

The editor for the selected section is shown in the central pane. The content of this editor is specific for the selected section, and might contain several property pages.

The FRC editor windows offer the user a vessel hull rendering tool, where characteristics like:

- Spatial vessel extent (Length Over All (LOA), beam (B) and height)
- Volume displacement of the vessel/floating body, at a particular draft
- Waterline and deck plane contours in the XY plane

are instantly computed and visualized, in order to grant the user quantitative and visual information of the conditions for the vessel/floating body.

Further options may be available in the context menu depending on the section being edited.

1.3.3 Validation window

The bottom pane of the editor shows possible validation errors, and is dynamically updated to reflect the current status of the setup specifications. By double-clicking on an error in this window, the editor in which this error occurs will be selected.

1.4 Online Help

To access the help associated with a specific dialog page, press the F1-key on the keyboard after opening the editor and activating the specific property page.



2 Introduction

Frequency Response Calculator (FRC) is an independent software application to generate geometric, hydrostatic and computational response data. It can be applied in two ways:

- As the basis for a further time-domain computation of the temporal dynamics of a vessel/floating body exposed to incident environmental forcings (wave, wind, current).
- As an independent stand-alone tool for a specific analysis of for example Response Amplitude Operators (RAO) and added mass for a vessel/floating body of any geometry and loading conditions.

It is the first of these applications, which is the primary intended purpose of the FRC. In such a workflow the user will:

1. Generate the fundamental necessary vessel/floating body data (geometric and frequency response data) with FRC (step 1)
2. Load the generated data into the MIKE 21 Mooring Analysis (MA) editor, which subsequently can compute time-domain results for the vessel/floating body (step 2).

FRC will thus typically be part of a "double team" together with the MIKE 21 MA application.

A further description of how the two applications depend on each other is found in the User Guide for MIKE 21 MA.

2.1 Short Description

FRC offers a graphical environment, where the user on basis of:

- A supplied 3D panelized grid representing the vessel/floating body
- Relevant hydrodynamic characteristics

can set up a model of a static vessel/floating body, with local static conditions.

When a full setup has been created, a simulation with the associated engine can be launched, leading to a series of generated results, storing a series of relevant data.

Static spatial data representing the physical system:

- The geometric XYZ data of the full vessel hull
- Vessel statistics of dimensions + volume displacement
- Depth and draft, deck plane values



Computational response data for the vessel/floating body, which is also relevant as input data in a subsequent time-domain computation in MIKE 21 MA:

- Hydrostatic and gravitational restoring matrix (geometrically dependent)
- Radiation potentials (frequency dependent).
- Added mass (frequency dependent)
- Radiation damping (frequency dependent)
- Wave drift forces (frequency dependent)
- Generation of RAOs for the vessel/floating body
- Generation of exciting forces for the vessel/floating body

Some of these data can be of isolated interest to inspect, but the main perspective is that these data are stored into a single binary file (.vre), which is subsequently loaded into the MIKE 21 MA application.

In MIKE 21 MA the data above will be the basis for:

- Defining spatial mooring line setups (relying on spatial vessel hull data above)
- Solving the equations of motion for the vessel/floating body exposed to environmental forcings and mooring line forces, in the time domain (relying on the computational response data above).



3 Reference Manual

The Frequency Response Calculator (FRC) calculates geometric, hydrostatic and computational response data for a vessel.

3.1 Vessel Configuration

The functionality under the tabs allows definition the number of vessels being part of the (.fresponse) setup, the relative positions of the vessels and a plot of the full vessel system in a local XY system.

3.1.1 Configuration tab

On this tab you must specify the vessel configuration. You can Add or Delete as many vessel instances as you need, and supply individual names to each vessel instance.

The 'Go to...' button will take you to the vessel instance GUI where the more detailed characteristic data for each single vessel instance are to be provided.

In the common conditions you are to specify the water depth and density, in the spatial neighbourhood where the system of potentially many vessels is located.

3.1.2 Vessel positions tab

On this tab the relative positions of the vessel instances declared on the Configuration tab, are to be set. Before the Vessel position data can be meaningfully provided, one must in advance have declared data for all vessel instances (see section 3.2 Vessel Instance (*p. 12*) below) - most importantly the vessel grids.

For each vessel instance you have to supply a position consisting of an X and a Y coordinate - which will govern where in the XY system the amidship point of the vessel instance is located. At the moment we only support vessel configurations where the rotation is 0 - e.g. vessels which are lying mutually parallel to each other.

3.1.3 System view tab

The System view tab contains an overall plot of the full vessel configuration, as an XY plot where each vessel is shown.

This plot utilizes the data given for all vessel instances (vessel grid, draft value, deck plane height), as well as the set of vessel positions from the previous Vessel position tab.



In order to control and work more easily with correct relative vessel positioning, this plot offers a select feature (when in select mode) allowing one to interactively click within the deck-plane contour, which makes the position record appear below the plot as an instant tool to swiftly access and alter the position of the selected vessel. A Measure tool is also available in order to assess metric distances in the overall vessel configuration.

3.2 Vessel Instance

The vessel instance GUI covers three tabs: Vessel characteristics, Freedom of motion and Vessel view.

3.2.1 Vessel characteristics

The first data to be provided on the Vessel characteristics GUI is the Vessel grid, which is the three dimensional panellized vessel hull. The intended work flow is that the vessel grid should be selected before you set any of the other properties on vessel characteristics.

After loading the vessel grid you must specify additional parameters to configure the vessel.

Vessel statistics

On basis of the vessel grid and the associated parameters, an automatic computation of some vessel statistics will take place. These include:

- Length Over All (LOA): maximum length of a vessel
- Beam (B): breadth of the vessel
- Maximum height: height of the entire vessel hull (keel to deck plane)
- Submerged volume (\bar{V}): volume of the vessel below the water line due to draft.

Vessel grid

The vessel grid is supported in two different formats: (.grd) which is an **open text format** and (.hull) which is an **encrypted data format**. If supplying a vessel grid in (.grd) format, the delimiters space, comma and tab are supported.

Availability of (.grd) files

A free selection of prepared vessel hull grids in (.grd) format, instantly ready for use, representing these hull classes:

- Bulk Carrier
- Container
- Cruise Ship



- Gas Carrier
- General Cargo
- Tanker

is available as part of the MIKE Zero installation in the folder:

<MIKE installation folder>\MIKE Zero\Templates\Maritime\MooringAnalysis\Vessel Hulls

The individual vessel hulls are documented and visualised in a file 'DHI Vessel Hull Data Sheets, Data Sheets for Different Vessels' which can be accessed from the MIKE 21 Documentation Index.

If you want to generate a vessel hull yourself, then you need to generate a (.grd) format file. It's general structure is as seen in Figure 3.1.

```

1 1=3DHI converted from STL
2 1 0 9.81
3 0 1
4 (2423)
5 184.937 0.447 9.837
6 184.470 0.282 10.582
7 184.806 0.000 10.817
8 185.377 0.000 10.379
9 184.806 0.000 10.817
10 184.470 0.282 10.582
11 184.036 0.423 11.404
12 184.036 -0.000 12.324
13 184.036 0.423 11.404
14 184.470 0.282 10.582
15 184.937 0.447 9.837
16 184.036 0.846 10.484
17 185.034 0.521 15.615
18 184.793 0.436 15.114
19 184.566 0.872 15.214
20 184.702 1.043 15.630
21 184.793 0.436 15.114
22 184.552 0.351 14.614
23 184.431 0.702 14.798
24 184.566 0.872 15.214
  
```

Annotations in the image:

- Number of Vessel Panels. A panel is spanned by a set of 4 adjacent rows**: Points to the value '1' in line 3.
- first value:** refers to whether .grd data is provided symmetric around the x-axis
0: means non-symmetric
1: means symmetric
- second value:** refers to whether .grd data is provided symmetric around the y-axis
0: means non-symmetric
1: means symmetric

Figure 3.1 Vessel grid format

Availability of (.hull) files

In addition to the free vessel grid archive in (.grd) format being part of the MIKE installation, DHI hosts an even more extensive database of vessel hulls in the encrypted (.hull) format, which can be provided upon request. They are documented and visualized in a file 'DHI Vessel Hull Data Sheets, Additional Vessels Data Base' which can also be accessed from the MIKE 21 Documentation Index.

FRC will in the first release only support vessel grid files which are symmetrical around only one axis e.g. either x-axis or y-axis. This means that the vessel grid is assumed to contain a 'half' hull, and that the full representation of the vessel in the processing is obtained by mirroring data around the axis of symmetry.

It is recommended to ensure that the vessel hull has its length direction parallel with the x-axis. Below in Figure 3.2 the assumed content of the panelized vessel grid file is visualized.

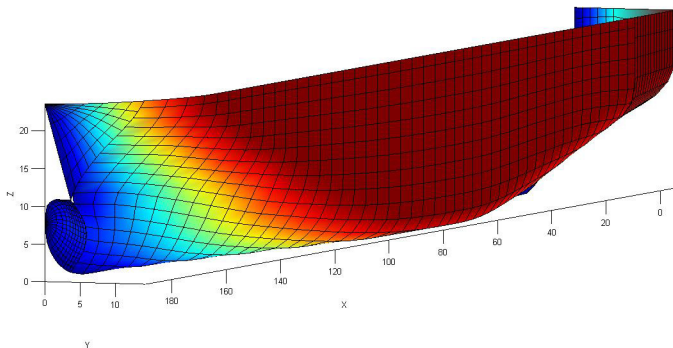


Figure 3.2 Symmetrical vessel hull

Vessel scaling

By default it is assumed that the content in the vessel grid is provided in a 1:1 ratio according to the vessel hulls true spatial extent. But if the vessel hull XYZ values in the vessel grid is up or down scaled to another ratio, the correct scaling factors in all 3 dimensions must be provided. It is recommended to scale the vessel not more than 15% of its original size. The vessel hull values in the further processing, will then be vessel hull values from the vessel grid, multiplied with the scaling factors.

Radii of gyration

Radii of gyration, describing the moment of inertia in terms of a distance between a mass point and each axis, for the vessel must be provided as well.

Vertical parameters

The three vertical parameters,

- vertical center of gravity, Z_G : vertical position where the distributed mass of the vessel is centered
- draft: vertical distance between keel and water line
- deck plane height: vertical distance between keel and deck plane

follows a vertical sign convention where positive values means upwards from the keel level of the vessel, see Figure 3.3.



While the draft plays a crucial role in the computation of the frequency response data of the floating vessel, the deck plane height does not play any role: The deck plane height only determines the displayed deck plane contour on the graphical plots of the vessel (red contour), and is only included as a tool allowing inspection of the planar (XY) extent of the vessel at a particular height above the keel, see Figure 3.6.

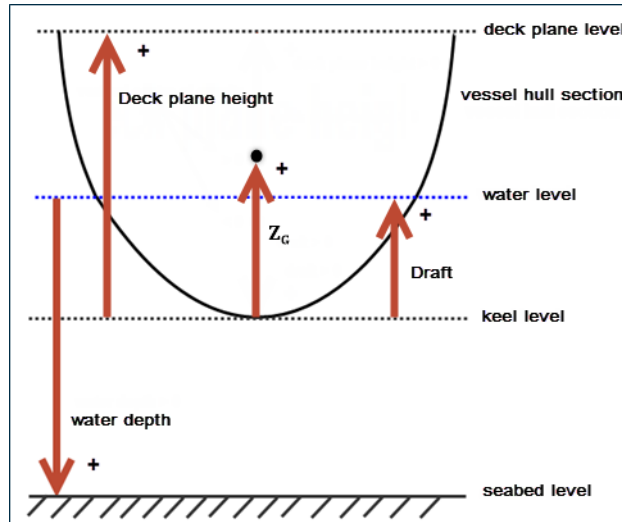


Figure 3.3 Vertical sign convention

3.2.2 Freedom of motion

The Freedom of motion tab allows specification of whether the vessel with the properties given under Vessel characteristics tab is to be modelled as:

- Freely floating (default)
- Locked in all 6 degrees of freedom

Note: at least one vessel in the setup needs to be freely floating.

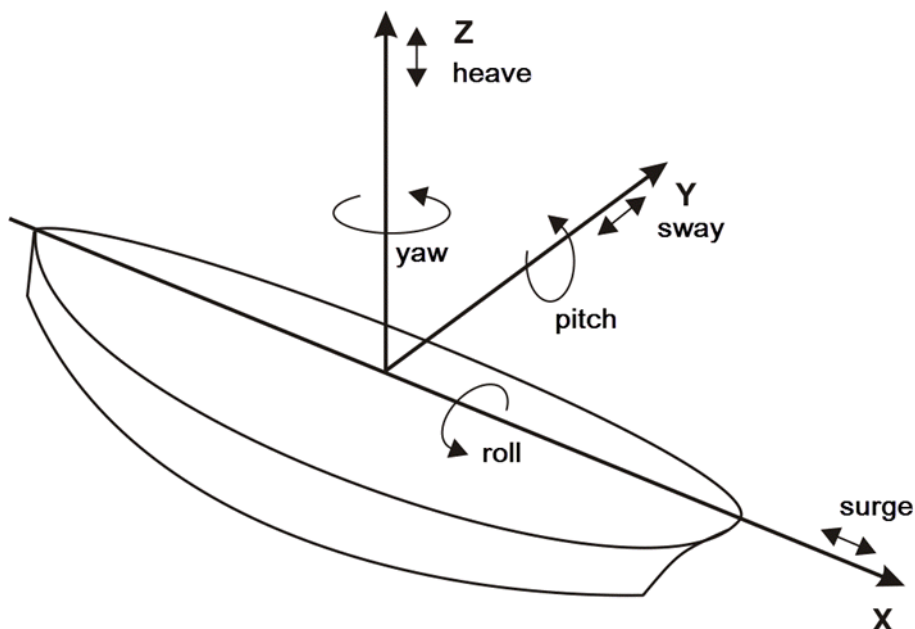


Figure 3.4 Ship motions in six degrees of freedom

3.2.3 Vessel view

Provided a valid vessel grid has been selected on the Vessel characteristics tab, the Vessel view tab will display a spatial 2D plot in the XY plane of the water line contour around the vessel (due to draft), as well as the deck plane contour (due to deck plane height). A definition of the two planes is given in Figure 3.5.

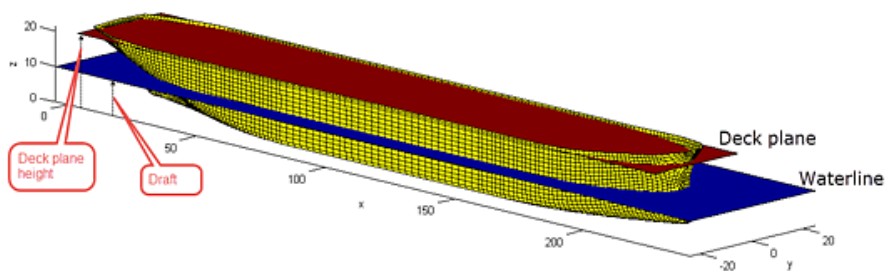


Figure 3.5 Definition of waterline and deck plane contour

The purpose of the plot under Vessel view is to give an insight into what the spatial picture looks like, where these two contours are relative to each other, as shown in Figure 3.6.

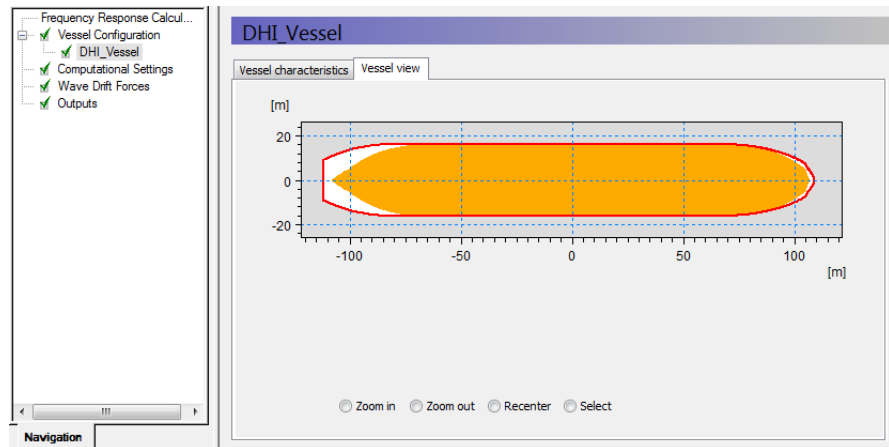


Figure 3.6 Displaying vessel
 Red polygon: Deck plane contour as defined by the deck plane height.
 Filled polygon: Submerged contour as defined by the draft.

The origo in this contour plot will by default be positioned at the amidship point of the vessel.

Just like the Vessel statistics values on the Vessel characteristics tab, the contour plot will respond to changes in draft (water line contour will be updated) and deck plane height (deck plane contour will be updated) as well as the scaling parameters (both contours will be updated). The user can assess if it looks meaningful, and change the draft and deck plane height, if assessed needed.

NOTE:

Advanced interactive features like **Pan** and **Mouse Wheel based zoom**, are available for the most flexible work flow, e.g. when certain details are to be looked up and inspected. These two features become active when you click on the plot and hold down the shift key on the keyboard.

3.3 Computational Settings

Here you specify the Simulation mode:

- M21 Mooring Analysis compatible mode
- User defined mode

M21 Mooring Analysis compatible mode

This is the default simulation mode. This mode should be used if the overall aim is to proceed with a vessel motion analysis in the time-domain, with MIKE 21 MA. Execution in this mode will create a (.vre) output file bundling all relevant geometric and frequency response output data, which is later to be loaded into MIKE 21 MA for further processing. Due to compatibility requirements the only freedom you have in this mode, is to decide the number of fre-

quencies to be solved for, either 256 or 512. Notice that when running the FRC simulation in this mode two extra frequencies (zero and infinity) are always implicitly included, meaning that an additional 2 frequencies are taken into account. The frequency range, and the directional range are pre-defined in this mode.

User defined mode

This mode is used if you want to perform independent analyses with FRC, e.g. analyze RAOs. RAOs help determining the vessel's response subject to recurring load cycles, e.g. waves. In this mode, FRC can be used to investigate the vessel's response for a particular number of specified frequencies, in a certain frequency range, in a certain directional range. Figure 3.7 depicts the horizontal directional sign convention in FRC, which is similar to the OCIMF Guidelines /4/. Execution in this mode won't generate a (.vre) file which can be used as a basis for further time-domain behaviour of a vessel.

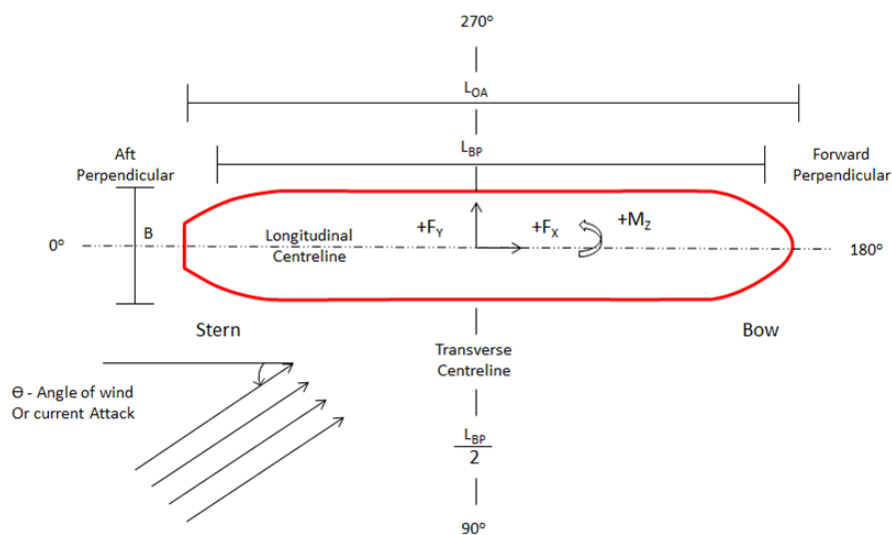


Figure 3.7 The FRC directional range sign convention (same as OCIMF guidelines /4/)

3.4 Wave Drift Forces

Here you can specify whether you want to include the physical phenomenon of 2nd order wave drift forces. The 2nd order wave drift forces are based on the Newman's approximation /3/ which is only valid in deep water.

NOTE:

Including wave drift forces will lead to a more time consuming overall FRC simulation (20-30 % extra for typical applications). The wave drift forces are negligible at high wave periods. So an example where it is not recommended to include wave drift forces is for a passing vessel scenario, where you just



have one high period wave. It should thus always be assessed whether it is required to include wave drift forces.

3.5 Outputs

The selection of potential output files includes:

- Vessel response
- Added mass
- Damping
- Drift forces
- Response amplitude operator
- Exciting forces

3.5.1 Vessel response

This is a special file of type (.vre) which stores a lot of different bundled output data (geometric and frequency response data). When generated, this file is binary and cannot be inspected for content with any MIKE related editor. The only application of this file is that it is the input file in order to use MIKE 21 MA for time-domain analysis of the defined vessel when exposed to environmental forcing and moored. This file is only possible to generate if Simulation mode is set to M21 Mooring Analysis compatible mode, in the Computational Settings section.

3.5.2 Added mass

This dfs0 file contains the added mass response for each degree of freedom as a function of wave frequency. The added mass is contained in a 6x6 matrix for each wave frequency and can be described as an inertia added to the system due to an acceleration of the vessel. Table 3.1 describes the item names in the added mass dfs0 file. In Table 3.1 the columns are the responses and the rows are the motions in each degree of freedom (see Figure 3.8). So position (3,2) is the heave added mass due to a sway motion.

Table 3.1 Added mass item definition

| | | Motions | | | | | |
|--|--|---------|------|-------|------|-------|-----|
| | | Surge | Sway | Heave | Roll | Pitch | Yaw |
| | | | | | | | |

Table 3.1 Added mass item definition

| | | | | | | | |
|-----------|-------|-----|-----|-----|-----|-----|-----|
| Responses | Surge | 1,1 | 1,2 | 1,3 | 1,4 | 1,5 | 1,6 |
| | Sway | 2,1 | 2,2 | 2,3 | 2,4 | 2,5 | 2,6 |
| | Heave | 3,1 | 3,2 | 3,3 | 3,4 | 3,5 | 3,6 |
| | Roll | 4,1 | 4,2 | 4,3 | 4,4 | 4,5 | 4,6 |
| | Pitch | 5,1 | 5,2 | 5,3 | 5,4 | 5,5 | 5,6 |
| | Yaw | 6,1 | 6,2 | 6,3 | 6,4 | 6,5 | 6,6 |

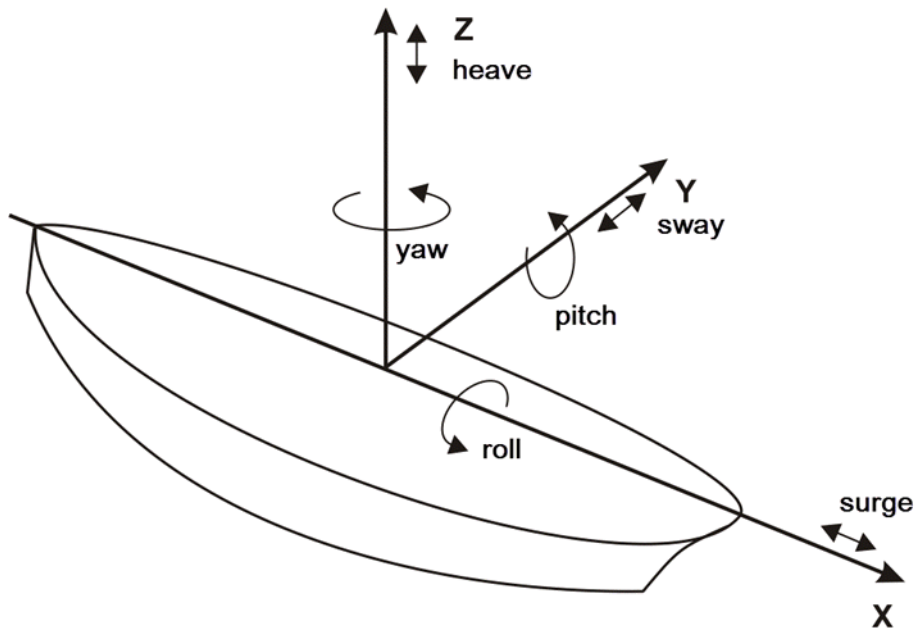


Figure 3.8 Ship motions in six degrees of freedom

3.5.3 Damping

This dfs0 file contains the radiation damping of the vessel and is in the same format as the added mass (see section 3.5.2). Radiation damping describes the energy lost in the vessel as it creates waves through motion.

3.5.4 Drift forces

This dfs0 file contains the second order drift surge and sway forces and yaw moments for each frequency and direction specified. The second order drift forces are calculated based on Newman's Approximation [3]. This output file can only be generated if wave drift forces are included.



3.5.5 Response amplitude operator

This output file is specific for each vessel instance.

The dfs0 file contains the amplitude and phase data of the response amplitude operator (RAO) for each frequency and direction specified. The RAO is a transfer function that can be used to determine the effect that a sea state will have upon the motion of a vessel.

A separate file can be generated for each vessel in the simulation.

3.5.6 Exciting forces

This output file is specific for each vessel instance.

The dfs0 file contains the amplitude and phase data of the exciting forces and moments for each frequency and direction specified. The exciting force is the first order wave force on the vessel and is calculated using the Haskind relation (see e.g. /2/). The exciting force describes the combination of the incident wave forces from a harmonic wave and the diffraction force due to the vessel on the undisturbed wave field.

A separate file can be generated for each vessel in the simulation.





4 References

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- /2/ Wehausen, J.V. and Laitone, E.V. (1960): "Surface Waves in Fluid Dynamics III", in Handbuch der Physik 9, Eds: S. Fluegge and C. Truesdell, pp 446-778, Springer Verlag
- /3/ Newman, J.N. (1974) "Second-Order, Slowly Varying Forces on Vessels in Irregular Waves", Proc., Int. Symp. On Dynamics of Marine Vehicles and Structures in Waves, London, UK
- /4/ OCIMF (2008). "Mooring Equipment Guidelines", 3rd edition, With-erby Seamanship International, Livingston, UK





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