MIKE
Powered by DHI

MIKE 21 Maritime

MIKE 21 Mooring Analysis

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 MIKE 21 Mooring Analysis (MA) modelling system, for analysis of moored vessels (or a floating body in general) subjected to wave, current and wind forcings, 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 2 applications in the MIKE 21 Maritime Product Group, which supplements each other in a full workflow.

1. Frequency Response Calculator (FRC)
2. MIKE 21 MA

This guide will explain how to operate MIKE 21 MA, which is the final application to consider in a mooring analysis workflow.

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 related to these models refer as such to the MIKE 21 MA modelling system as well.

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 contains 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 MIKE 21 MA 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 MIKE 21 MA editor windows offer the user an overall tool where:

- Several graphical features are available, to visualize the physical system.
- A range of material profiles for mooring line types and fender types can be provided.
- Each vessel can be set up with all relevant Vessel-fixed attributes (winches, fairleads).
- All relevant Port-fixed attributes can be set up (bollards, fairleads).
- The full vessel system including spatial mooring lines can be set up on basis of interactive features, thus connecting the vessel and the port.
- All desired environmental conditions (wave, wind, current) can be included.

This grants the user an easy-to-use graphically based environment, and the possibility for a full quantitative analysis of vessel/floating body motions.

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

MIKE 21 MA is an independent software application for solving the equations of motion for a vessel/floating body exposed to dynamic environmental forcing in the time-domain.

The basis for a MIKE 21 MA simulation, is always the output (.vre) file generated by the associated application Frequency Response Calculator (FRC). The (.vre) file contains the bundled set of various data relevant for a vessel submerged to a certain draft (geometric and frequency response data etc.), all of which is necessary for MIKE 21 MA as input.

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

2.1 Short Description

MIKE 21 MA offers a graphical environment, where the user on basis of:

- A (.dfs2) domain file
- A (.vre) file generated with FRC (representing geometric and response data properties of a vessel)
- A spatial set up of a vessel in a port, which can include mooring lines, fenders and chains
- Wave forcing data
- Wind forcing data
- Current forcing data

can launch a simulation, which leads to a series of dynamic instantaneous results in a time series format (.dfs0) for a specific spatial and environmentally forced set up. The output may contain:

- Vessel motion in all six degrees of freedom of the vessels/floating body's centre of gravity.
- Forces on mooring lines, fenders and chains
- Mooring forces on the vessel/floating body
- Local water elevation adjacent to the vessel
- Diffraction forces on the vessel
- External forces on the vessel (wind, current and drift forces)

3 Vessel Response Simulations

3.1 About Vessel Response Simulations

Movements of moored ships can be caused by various external forces such as winds, waves, currents and passing ships. Ship motions occur in six degrees of freedom, namely three displacements (surge, sway and heave) and three rotations (roll, pitch and yaw). These are shown in Figure 3.1.

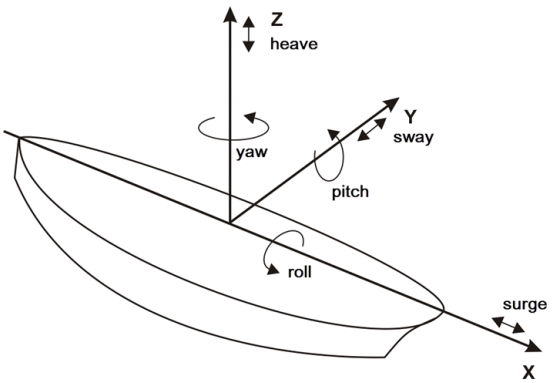


Figure 3.1 Ship motions in six degrees of freedom: displacements (surge, sway, heave) and rotations (roll, pitch, yaw)

When ship motions exceed certain criteria, safe working limits and safe mooring limits will eventually be exceeded. Ultimately, damage to the ship and port installations may occur.

Preventing dangerous conditions at vessel berths (and terminals) and minimising costly downtime requires a detailed description of vessel responses in often complex and energetic environmental conditions. Numerical modelling is a cost effective method of simulating complex wave processes and associated wave forces on moored vessels and ultimately, calculating ship motions of moored vessels at berths and terminals.

Additionally, several mooring configurations can be rapidly tested under a wide range of environmental conditions, ideal for preliminary optimisation of mooring configurations.

This guide provides a brief overview of mooring principles with an introduction to different types of moored vessels likely to be encountered in MIKE 21

MA projects, fundamentals of mooring systems and recommended ship motion criteria for safe working conditions on moored vessels.

3.2 Vessel Types

Various types of vessel and berth configurations may be modelled in MIKE 21 MA. For familiarisation, a brief overview of the common vessel types and characteristics is presented below. The information presented in this section (unless otherwise specified) is derived from /3/.

Fishing vessels

Fishing vessels range from small ships of 10-100 GRT (Gross Register Tonnage) up to large trawlers, liners and net boats of 3,000 GRT. These vessels are mainly moored in their home ports. Fishing vessels are typically moored with polypropylene lines against truck tire fenders or rubber fenders. Cranes, elevators and suction pumps are used for unloading.

Figure 3.2 Fishing vessel
(image source: United States Coast Guard, www.uscg.mil)

Coasters and freighters

Coasters and freighters are ships of less than 10,000 DWT (Deadweight Tonnage) sailing on short sea and domestic routes. These vessels are generally moored with polypropylene lines against rubber fenders. Cargo can be handled by quay cranes or ship's own gear.

Figure 3.3 Freighter (image source: Damen Shipyard, www.damen.com)

Ferries and Ro-Ro vessels

Ferries and Ro-Ro vessels are characterised by loading and unloading operations taking place horizontally via ramps and walkways. Ramps may be shore ramps, bridge ramps (including link span) and ship ramps. The main function of the mooring arrangements for these ships is to reduce the horizontal ship motions as much as possible, in particular at the position of the ramps and walkways. This can sometimes be achieved by tensioning the mooring lines. Ro-Ro vessels have a high windage area and, as a result are highly sensitive to strong winds.

Figure 3.4 Ro-Ro vessel (image source: Fleetmon, www.Fleetmon.com)

General cargo vessels

General cargo vessels range typically from 5,000 to 10,000 DWT and may carry a wide variety of cargo. Ships are most often moored with polypropylene lines, while large vessels are equipped with nylon ropes and/or steel wires. Generally these vessels are moored with 8 to 10 lines.

Figure 3.5 General cargo vessel
(image source: Maritime Connector, www.maritime-connector.com)

Container ships

Container ships are cargo ships that carry all of their load in containers. They are a common means of commercial freight transport. Containers are loaded and unloaded using cranes and ship motions that affect container handling productivity vary with equipment specification, skill of the operator, crane size, distribution and location of the cranes on the ship and landside operations. Ref. /4/ provides a more detailed description of container vessels and the impact of ship motions on container handling productivity.

Dry bulk carriers

Dry bulk carriers have been developed to transport cargoes such as ore, grain, and fertiliser in bulk. Some typical sizes for bulk carriers are the Handy size (30,000 - 40,000 DWT), Panamax size (70,000-80,000 DWT) and CAPE size (120,000 - 150,000 DWT)

Bulk carriers are mainly moored with 8 to 10 lines. Mooring lines are attached to bollards located at the front side of the quay walls.

Figure 3.6 Panamax bulk carrier
(image source: Pacific Carriers Limited, www.pclsg.com)

Oil tankers

Oil tankers are used to transport crude oil and oil products. Oil products are generally transported in tankers under 70,000 DWT, while crude oil is transported in high-capacity tankers up to 420,000 DWT. Tankers are loaded and unloaded through the manifold located in the middle and close to the side of

the ship. A typical berth layout for an oil tanker comprises breasting and mooring dolphins, and a loading platform. Tankers are moored with spring lines, breast lines and (optionally) head and stern lines. The mooring lines for large tankers are in general steel wires and steel wires with nylon tails.

A typical mooring pattern at a tanker terminal is shown in Figure 3.7. This was derived from OCIMF /5/.This document provides much useful information on all aspects of offshore moorings.

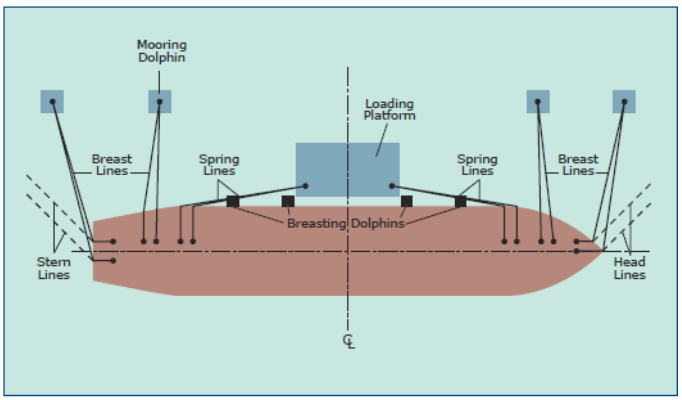


Figure 3.7 Typical tanker mooring (OCIMF /4/)

Berths for large tankers are generally located in deep water at more exposed locations. Due attention should be given to align a berth with the predominant wave and current conditions. Tanker motions may be reduced by pre-tensioning the breast lines in order to maintain sufficient friction between the ship's hull and fenders.

Figure 3.8 Oil tanker (image source: www.shipsandharbours.com)

Gas tankers

Gas tankers may range from refrigerated ships of over 100,000 m^3 for the transportation of liquefied natural gas (LNG) and liquefied petroleum gas (LPG) to small tankers of up to 5,000 m^3 for the shipment of propane, butane and chemical gases in pressure tankers. The berths and mooring arrangements for gas tankers are similar to those of oil tankers. Motions of moored gas tankers are in particular induced by currents and low-frequency wind and wave effects. Wind effects on gas tankers are more important compared to oil tankers because of the higher freeboard and the possible presence of spherical tankers.

The two most common types of gas tankers likely to be encountered in MIKE 21 MA projects are prismatic and spherical tankers. Prismatic (membrane) tankers have a relatively wide base with holding tanks mostly contained below deck level. Spherical (moss) tankers have a relatively narrow base with holding tanks that extend far above the deck. When modelling tankers it is essential to check that the correct vessel hull type is being used.

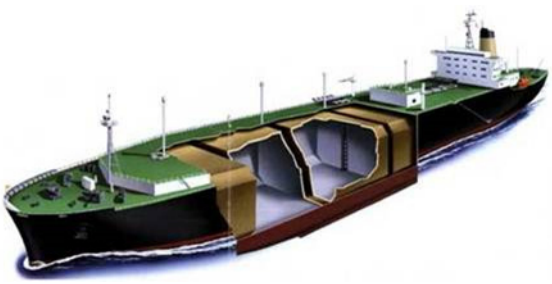


Figure 3.9 Prismatic tanker (image source: www.globalsecurity.org)

Figure 3.10 Spherical tanker (image source: www.gazprom-sh.nl)

3.3 Mooring Configurations

The most common terminals for bulk carriers are jetties and land backed wharves. Offshore moorings for tankers may consist of piers, sea islands, single point moorings (SPM), multibody moorings and floating production, storage and offloading vessels (FPSO).

The mooring arrangements for ships moored at berths and terminals comprise of the following elements:

- Mooring lines connecting ships to berths
- Bollards and storm bitts on shore. Mooring hooks or quick-release mooring hooks on mooring and breasting dolphins
- Fenders between ship and berth
- Mooring winches and bollards on board the ship

There are three main types of mooring lines:

- Spring lines - these are used to reduce the surge motion of a moored vessel. These lines should be as parallel as possible to the ship. (PIANC guidelines /4/ recommend a maximum angle of 10 degrees)
- Breast lines - these are used to reduce sway and yaw motions. These lines should be as perpendicular to the ship as possible and should be connected to the ship's fairleads positioned at the bow and stern
- Head and stern lines - these are used in addition to spring and breast lines to reduce overall ship motions.

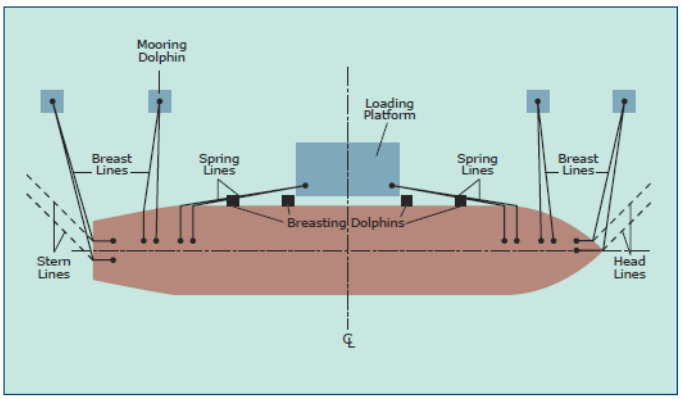


Figure 3.11 Typical mooring line configuration on a tanker (OCIMF /4/)

3.4 Recommended Ship Motion Criteria

PIANC 1995 /3/ recommends the following motion criteria for safe working conditions, as shown in Table 3.1.

Table 3.1 Recommended Motion Criteria for Safe Working Conditions (PIANC /2/)

Ship Type	Cargo Handing Equipment	Surge (m)	Sway (m)	Heave (m)	Roll (°)	Pitch (°)	Yaw (°)
Fishing vessels	Elevator crane	0.15	0.15	0.4	3	3	3
	Lift-on-Lift-off	1.0	1.0				
	Suction pump	2.0	1.0				
Freighters, Coasters	Ship's gear	1.0	1.2	0.6	2	1	1
	Quarry cranes	1.0	1.2	0.8	3	1	2
Ferries, Ro-Ro vessels	Side-ramp[b]	0.6	0.6	0.6	2	1	1
	Dew/storm-ramp	0.8	0.6	0.8	4	1	1
	Linkspan	0.4	0.6	0.8	4	2	3
	Rail ramp	0.1	0.1	0.4	1	1	-
General Cargo	-	2.0	1.5	1.0	5	2	3
Container vessels	100% efficiency	1.0	0.6	0.8	5	2	3
	50% efficiency	2.0	1.2	1.2	6	2	1.5
Bulk Carriers	Cranes	2.0	0.6	0.8	3	1	1
	Elevator/bucket wheel	1.0	0.5	1.0	2	2	2
	Conveyor belt	5.0	2.5				3
Oil Tankers	Loading arms	3.0[c]	3.0				
Gas Tankers	Loading arms	2.0	2.0		2	2	2

Remarks:
a) Motions refer to peak to peak values (except for sway: zero peak)
b) Ramps equipped with rollers
c) For exposed locations 5.0 m (regular loading arms allow large movements)

3.5 MIKE 21 MA Overview

MIKE 21 MA is a product for preparing and executing moored vessel response simulation scenarios, cf. Figure 3.12 for a typical application. The Frequency Response Calculator (FRC) offers a vessel hull rendering tool and provides MIKE 21 MA with the required hydrodynamic, hydrostatic, and inertia coefficients of the vessel.

MIKE 21 MA solves the time-domain equations of motion to obtain the temporal evolution of body motion in six degrees of freedom, due to a specified incident wave field, and mooring arrangement.

MIKE 21 MA delivers highly accurate results, which can easily be interpreted by decision makers. The raw output of the simulations consists of time-series of motions for surge, sway, heave, roll, pitch and yaw of the centre of gravity of the body, as well as forces in the mooring lines and vessel diffraction forces. These can be used to make powerful 3D animations with MIKE Animator Plus, thus illustrating the vessel motions and mooring system performance in the time domain to be used for easy visualisation and presentation.

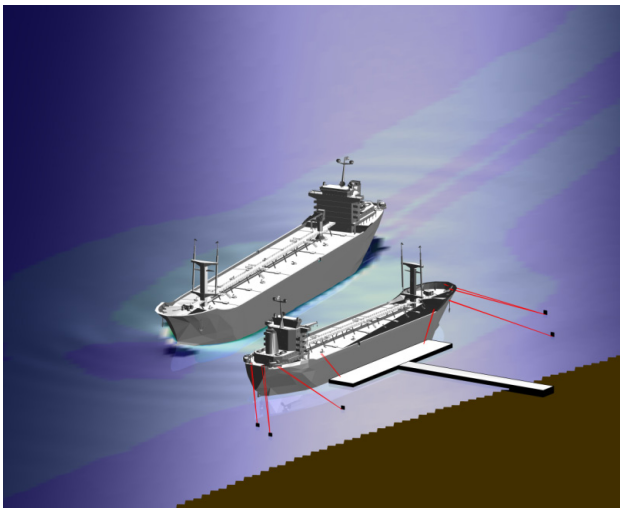


Figure 3.12 Example of MIKE 21 MA application (passing vessel induced wave impact on a moored vessel)

MIKE 21 MA calculates the motion of moored vessels and floating structures in the time domain through an innovative and efficient coupling method.

The full software suite for moored vessel modelling consists of the following:

1. Frequency Response Calculator (FRC) - diffraction/radiation panel program used for calculating the frequency response functions of the floating structures

2. MIKE 21 MA - time-domain floating body engine, which computes the temporal body dynamics on the basis of the obtained frequency response functions (from FRC), moorings and environmental forcings (wave, current and wind data)

4 Examples

One of the best ways of learning how to use a modelling system like the MIKE 21 Maritime Tools is through practice. Therefore examples are included which you can go through yourself and which you can modify, if you like, in order to see what happens if one or the other parameter is changed.

A comprehensive Step-by-Step Training Guide covering examples with the MIKE 21 Maritime Tools is accessible via the MIKE 21 Documentation Index.

The specification files for the examples are included with the installation of MIKE Zero in the folder 'MIKE_21\Maritime\MooringAnalysis':

- The example in folder '.\0D Wave forcing' is a simple domain-independent example relying on 0D (time series) wave forcing used on a vessel in a user defined local domain.
  This example is described in sections below as well as in the Step-by-Step Training Guide.
- The example in folder '.\2D Wave forcing' is more advanced and representative of a real-life mooring study and shows the combined usage of Frequency Response Calculator (FRC) and MIKE 21 MA, when the vessel is positioned in a geographic based domain and the moored vessel is affected by a drawdown wave induced by a passing vessel (two-dimensional (2D) wave).
  This example is described in the Step-by-Step Training Guide
- The example in folder '.\Simple Port' is a simple example using 2D wave forcings within a simple artificial port. The purpose is to show that the input wave data can origin from various models.
  This example is described in the sections below.
- The example in folder '.\Multivessel' demonstrates how to setup a simulation where two adjacent vessels are moored to each other.
  This example is described in the Step-by-Step Training Guide.
- The examples in folder '.\AutoMoor Mooring' demonstrates how to setup a Trelleborg AutoMoor automatic or a DynaMoor mooring unit.
  These examples are described in the Step-by-Step Training Guide.

Note: If you have executed previous models from MIKE Zero project mode, where the output data is going to be used as input data in a subsequent MIKE 21 MA execution, please be aware that all the result files will be gathered in a common Result folder next to the (.mzp) file.
This means that if you are running the examples within a MIKE Zero project mode, then the paths to these files need to be updated, as the default state of the examples are based on non-project mode, where all output data is stored in a Result Files folder next to each individual Setup file.

The first of these examples showcase the combined usage of FRC and MIKE 21 MA in order to perform a simple mooring analysis and is presented in short form in the following sections.

4.1 Simple Wave Forcing on a Vessel

4.1.1 Purpose of the example

This example demonstrates the work flow for a mooring analysis investigation using the MIKE 21 Maritime tools. The example calculates vessel motions in six degrees of freedom of a moored tanker under a time series (0D) of incident wave conditions. The waves are described by 0D wave forcing, which represents a horizontal water surface in the entire domain that moves vertically with time.

The numerical computations are typically divided into three parts:

- Obtain frequency response for vessel under given conditions
- Find an initial vessel displacement leading to a uniform (pre-set) tension distribution among all mooring lines.
- Simulate the final displacement in time

The details of the input data are described in the MIKE 21 Mooring Analysis Step-by-step training guide, see MIKE 21 Documentation Index.

The outline of the vessel and defined mooring lines once the model is setup will be as shown in Figure 4.1.

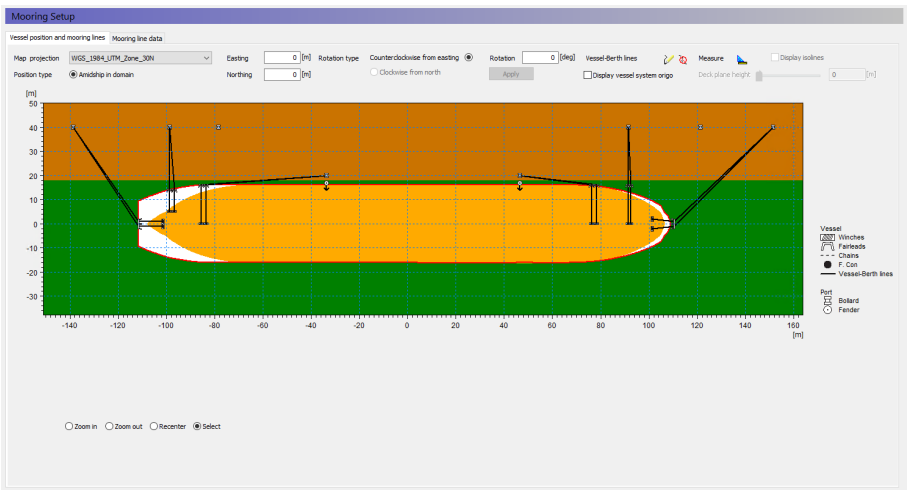


Figure 4.1 Outline of vessel located at port with specified mooring lines

4.1.2 Applying Frequency Response Calculator

The first step in any mooring analysis is to obtain frequency response data for the vessel in question. This is done by using the FRC where you specify the characteristics of the vessel and common conditions for mooring.

For this example the setup is saved in the file 'Frequency Response setup.fresponse'.

Vessel configuration

The vessel layout is specified by a vessel grid file (.grd). A grd file is an ascii file that contains the node positions for all elements describing the vessel outline. The vessel is described by the file 'tanker.grd'. A graphical overview illustrates the horizontal outline of the vessel as shown in Figure 4.2. The user may change the height of the deck plane by using the slider or by providing a specific value in metres. When activating the "Display isolines" checkbox, the deck plane is removed and the view on the vessel's z contour lines is provided for a better impression of the vessel shape.

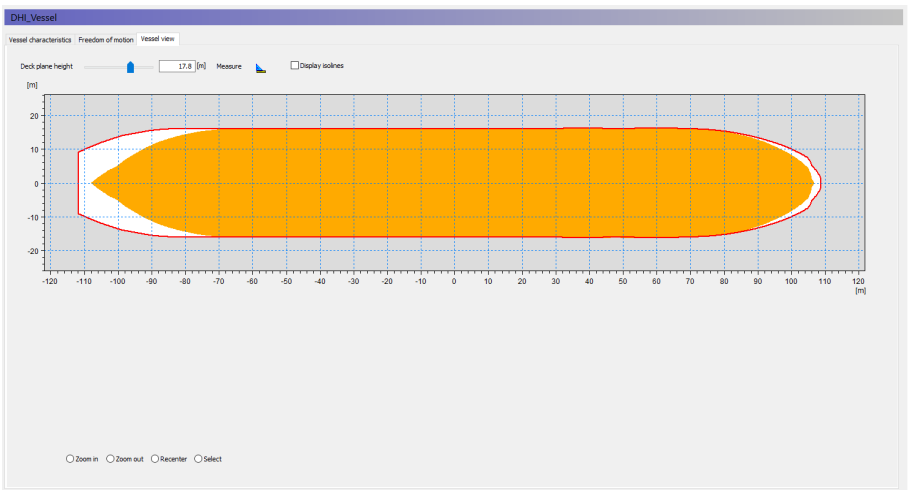


Figure 4.2 Outline of vessel
A bold line defines the outer outline of deck plane. The filled colour within defines the horizontal cross-section of the vessel at the water line

When the vessel grid is loaded, the remaining parameters on the Vessel Characteristics tab will be automatically updated with some default values derived from the vessel hull itself.

Computational settings

This setup use the default settings, i.e. “M21 Mooring Analysis compatible mode”, using 256 frequencies.

Wave drift forces

This setup exclude 2nd order wave drift forces

Outputs

All relevant output are per default included.

Note that the Vessel Response output file (.vre) is a binary file and this will be the basis for the subsequent mooring analysis simulations.

The FRC simulation will take some time depending on how complex the vessel is defined. The simulation for this example will take about 1 hour on a 4 core PC.

4.1.3 Setting up MIKE 21 MA for convergence mode

Next step is to setup a model describing the vessel and how it is moored to the port.

When adding mooring lines to the model they will each influence the position of the ship. Hence an initial simulation is required to find the initial vessel displacement under constant (or low-frequency) governing conditions, leading to a uniform (pre-set) tension distribution among all mooring lines (described later in this section).

The various inputs required for such a simulation are described below. The actual setup for the convergence calculations is saved in the file 'Mooring Setup.m21ma'.

Domain

Precise domain files displaying the exact positions of berths and breakwater structures are essential when utilizing 2D environmental forcings in a mooring study, but for 0D wave data a local domain file with enough spatial extent to surround the full mooring system will be sufficient.

It is not necessary for the domain file to hold any bathymetry values as they are not relevant for this simple type of setup, but they can be included to add to the illustrative layout in the editor, which can easily be exported by right-clicking on the illustration for reporting. In this example the domain extent is as illustrated in Figure 4.1.

Time

The simulation time is specified by a start time, time step and number of time steps.

This example setup is set to simulate wave disturbance during more than one hour.

Simulation mode

Initially the simulation setup is set to run in Convergence mode in order to attempt to find the initial vessel displacement under governing constant or low-frequency conditions, leading to a uniform (pre-set) tension distribution among all mooring lines.

The result from this mode is entered into the final computation as initial vessel displacement to ensure a subsequent stable time-domain analysis.

Material profiles

It is necessary to define the properties of each type of line, fender or chain and bollard that is used for the mooring. This entails e.g. total breaking strength for a line or friction coefficients for a fender or a vertical line angle, at which the line is expected to slip off the bollard, as well as force increment curves for the given types for fenders and lines specified in (.dfs0) files.

Both a nylon rope and a steel wire are included in this model setup to hold the ship in position along with fenders and bollards.

Vessels

The vessel characteristics defines the given vessel instance and are defined independently from the mooring setup.

First the vessel response file generated from the previously executed FRC setup is included. Next additional vessel parameters such as loading conditions and vessel class is specified. Finally, the position of fairleads, winches and chains on the vessel must be defined. The positions are given in a ship-coordinate system. A graphical overview illustrates the defined positions, as shown in Figure 4.3. Similar to FRC, the user may change the deckplane height and display the vertical isolines of the vessel hull.

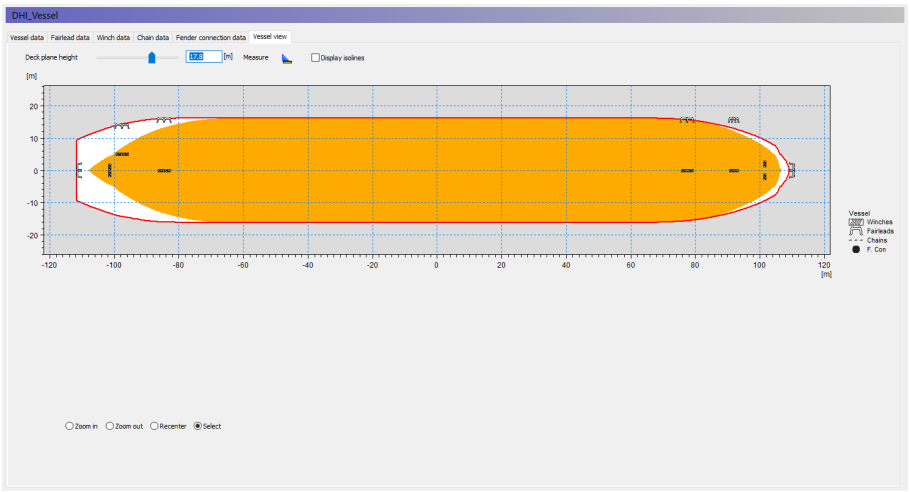


Figure 4.3 Vessel view after fairlead and winch positions have been specified

Port data

Similar to the spatial attributes for the vessel, it is necessary to define the position and characteristics of bollards and fenders in the port. The coordinates are related to a map projection. Similar to the vessel, a graphical overview illustrates where the full set of bollards and fenders are positioned in the domain.

Mooring setup

The mooring setup is where you specify where the ship is located and oriented in the port layout and how the ship is constrained in the port using mooring lines.

A mooring line is created by connecting a winch over a fairlead with a bollard. Each mooring line can be drawn/defined interactively in the graphics interface, but it is also possible to define the mooring line data in the table manually. Besides the connectivity information, the pre-tension needs to be specified for each line in this table.

The mooring line data for the present example is illustrated in the graphical overview as shown in Figure 4.1.

Environmental conditions

The environmental conditions represent the physical conditions and forcings that applies in the domain where the vessel is located.

This example is only considering the forcings from simpe 0D wave data. As the convergence mode run does not consider the influence of wave data, no forces are included here.

Convergence parameters

The convergence parameters control the iteration. In the present example the values have been defined to obtain a more accurate solution than obtained by default parameters.

Vessel displacements

The vessel displacements can be considered an initial condition. When executing the first convergence simulation the vessel displacement will typically start from zero.

Convergence output

The convergence process in the simulation can be reviewed by inspecting various output dfs0 files.

After specifying all the input, ensure that all the data in the (.m21ma) setup are saved and run the simulation to obtain the initial vessel displacement for the final mooring analysis. The resulting vessel displacement is saved in the last time step of the Vessel motion file.

4.1.4 Setting up MIKE 21 MA for final mode

Having calculated the initial vessel displacement, we can move on with the final time-domain computation.

Normally the initial task is to save the setup file used for convergence calculations under a new file name, e.g. ‘Final mooring setup.m21ma’ as it is the case here. Then only a few editions are necessary in order to calculate the final resulting vessel displacements in time. All variables besides the below mentioned are kept as in the preceding convergence simulation.

Simulation mode

The simulation mode must be changed to 'Final Computation Mode'.

Environmental Conditions

The environmental conditions are the same as for the convergence run apart from the wave forcings in the Waves dialog (these can only be applied when in 'Final Computation mode')

In this example the wave field is constant in domain but varying in time (i.e. same surface level variations over the domain) and defined by a dfs0 file. The wave direction is assumed to be 120° true north in the entire simulation period. The applied surface elevation is shown in Figure 4.4.

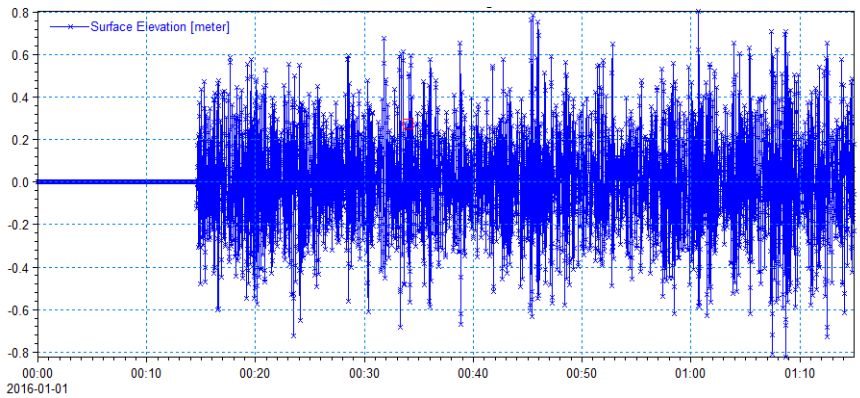


Figure 4.4 Water surface elevation time series with a zero warmup period

Vessel Displacements

The convergence simulation saved the vessel displacement in a default output file. By using the same setup file as a template for the present setup file you should by now see an enabled Load button in the dialog.

Click on this button to populate the six initial vessel displacement fields (surge, sway, heave, roll, pitch and yaw) from the output file we previously produced from the convergence mode execution.

This action ensures the final time-domain computation starts from a vessel state where the pre-tension settings are reflected sufficiently by the vessel's position.

Final output

The resulting vessel motion and other output parameters are saved in pre-defined dfs0 files. Here all output files except 'External forces' and 'Chain forces' are included.

These small changes complete the final mooring setup and you are ready to simulate the final vessel motion. This simulation will be fast and produces the relevant output files for the time-domain analysis.

4.1.5 Inspect and present results

After running the simulation the various results can be evaluated and presented by various tools within MIKE Zero.

- Operability summaries for lines and fenders are given at the end of the log file. They disclose if the critical load for an individual line or fender is exceeded or if a line snaps.
- Data statistics tools can be used to assess e.g. the maximum movements of the vessel.
- Plot composer can plot e.g. the resulting vessel motions in time, see Figure 4.5.
- MIKE Animator Plus can be used to animate the mooring movements in a three-dimensional (3D) environment using a 3D ship model as representative for the vessel. An example is shown in Figure 4.6.

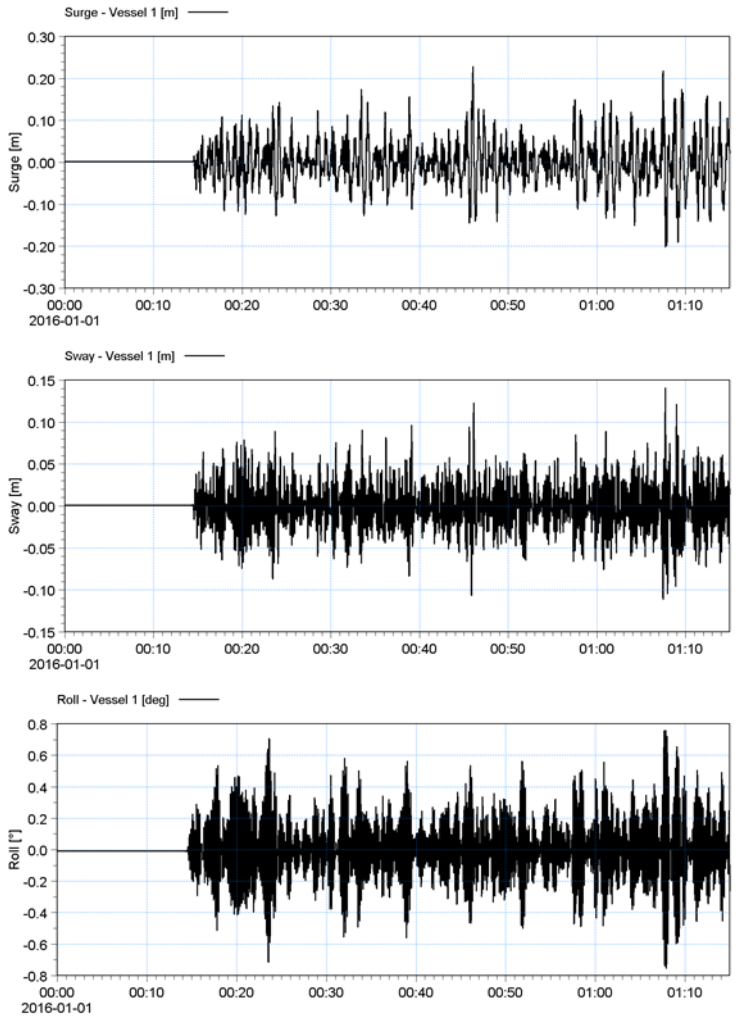


Figure 4.5 Time series of vessel motions (surge, sway and roll)

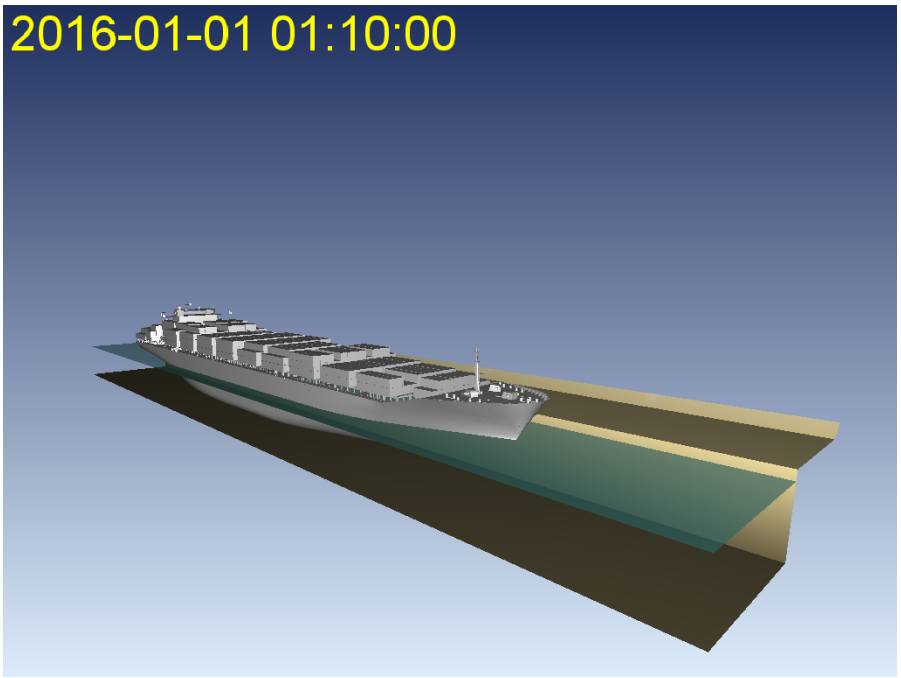


Figure 4.6 Screendump from MIKE Animator Plus.
By using a representative vessel to reflect the simulated movements in six degrees of freedom it is possible to create an illustrative animation.

4.2 Simple Port

4.2.1 Purpose of the example

This example illustrate the movements of a moored vessel system within a simple artificial port where the harbour area is partly sheltered by incoming waves, see Figure 4.1. The purpose is to show that the input wave data can origin from various other models.

The example simulates the vessel motions in six degrees of freedom of a moored tanker influenced by a time series (0D) of incident wave conditions (representing a horizontal water surface in the entire domain that moves vertically with time) as well as influenced by 2D wave fields, calculated by MIKE 21 BW and MIKE 3 Wave Model FM, respectively.
The overall wave conditions are based on irregular JONSWAP waves coming from south, with H_s=1m and T_p = 10s.

The numerical computations are typically divided into three parts:

1. Frequency response computation: Obtain frequency response for the vessel under the given conditions
2. Convergence computation: Find an initial vessel displacement fulfilling the pre-set uniform tension distribution among all mooring lines.
3. Final computation: Simulate the vessel motion dynamics in time, on basis of the obtained initial vessed displacement

The work in part 1 and part 2 only relates to the core mooring setup definitions, and is thus independent of the availability of pre-generated wave data.

The layout has been defined such that the coordinates of the vessel and defined mooring lines once the model is setup is the same as in the setup for the 0D example. Also the various inputs required for these simulations are similar to those for the 0D Wave Forcing example, apart from the main domain data and the wave input. Hence the calculated frequency response data and the initial displacement values will be similar.

For details on how to setup the models please see section 4.1.

4.2.2 Setting up MIKE 21 MA for convergence mode

After generating the frequency response file for the vessel system (.vre) the next step is to setup a model describing the vessel and how it is moored to the port.

The various inputs required for this simulation is the same as for the 0D Wave Forcing example, apart from the main domain. Precise domain files displaying the exact positions of berths and breakwater structures are essential when utilizing 2D environmental forcings in a mooring study. In this example the domain bathymetry is saved in the file ‘Domain_SimplePort.dfs2’. The actual setup for the convergence calculations is saved in the file 'Mooring Setup Simple Port.m21ma'.

The mooring setup will be as shown in Figure 4.1.

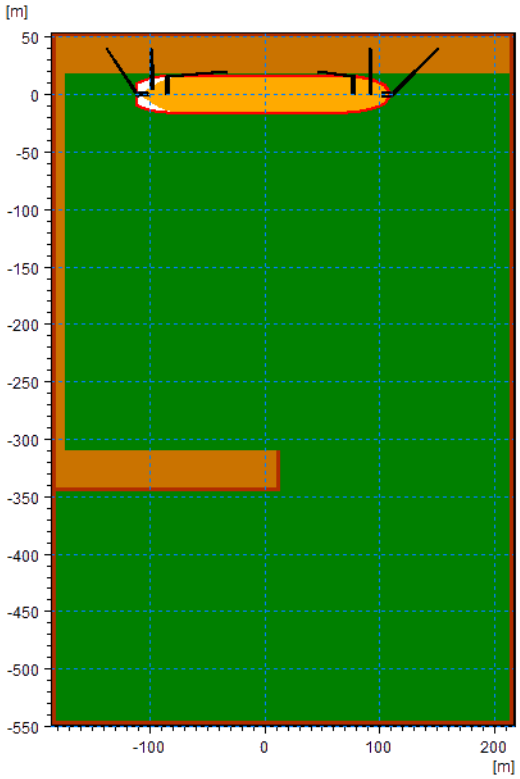


Figure 4.7 Outline of vessel located at port with specified mooring lines

4.2.3 Setting up MIKE 21 MA for final computation mode

Having calculated the initial vessel displacement from running the convergence mode simulation, we can move on with the final time-domain computation.

This example contains three cases, each with different wave data

a. 0D wave data similar to the 0D Wave data example
b. 2D Wave field calculated by MIKE 21 BW
(Note: creation of the wave field requires a license to MIKE 21 BW)
c. 2D Wave field calculated by MIKE 3 Wave Model FM
(Note: creation of the wave field requires a license to MIKE 3 Wave FM)

Case A: 0D wave data

The setup file used for convergence calculations should have the vessel displacement loaded in on the Vessel Displacements dialog, and afterwards be saved as ‘Final Mooring Setup - A.m21ma’.

The simulation mode is changed to 'Final Computation Mode' and the vessel displacement is as found from the convergence simulation.

The environmental conditions are the same as for the convergence run apart from the wave forcings in the Waves dialog.

In this example the wave field is constant in domain but varying in time (i.e. same surface level variations over the domain) and defined by a dfs0 file named ‘Waves_A.dfs0’. The wave direction is assumed to be 180° true north in the entire simulation period. The applied surface elevation has been calculated using the MIKE 21 Toolbox tool ‘Random Wave Generation’ and is shown in Figure 4.4.

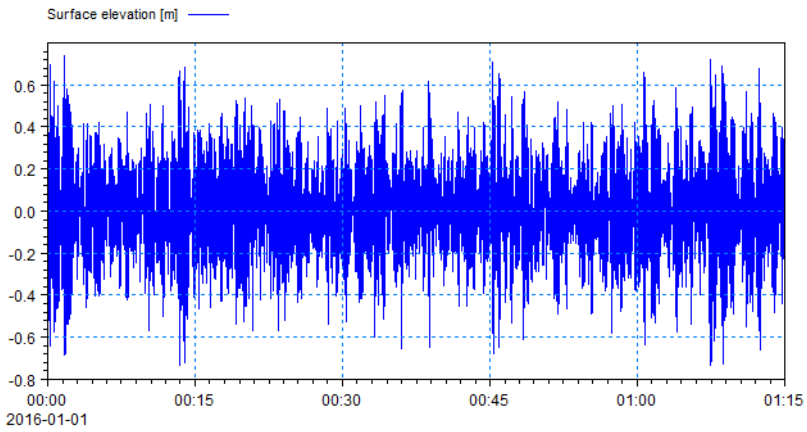


Figure 4.8 Water surface elevation time series for Case A

Case B: 2D wave data calculated by MIKE 21 BW

The setup file used for convergence calculations should have the vessel displacement loaded in on the Vessel Displacements dialog, and afterwards be saved as ‘Final Mooring Setup - B.m21ma’.

The simulation mode is changed to 'Final Computation Mode' and the vessel displacement is as found from the convergence simulation.

The environmental conditions are the same as for the convergence run apart from the wave forcings in the Waves dialog.

In this example the wave field is varying in both time and domain. The input wave field, named ‘Waves_B.dfs2’, is derived by the MIKE 21 Boussinesq Wave model (MIKE 21 BW) using the setup file ‘GenerateWaveField_B.bw’. The input required for this simulation is supplied with this example. The wave boundary is based on the wave data from Case A, assuming the wave direction to be 180° true north in the entire simulation period. An example of the wave output is shown in Figure 4.9.

NOTE: It requires a license for MIKE 21 BW to simulate the wave field.

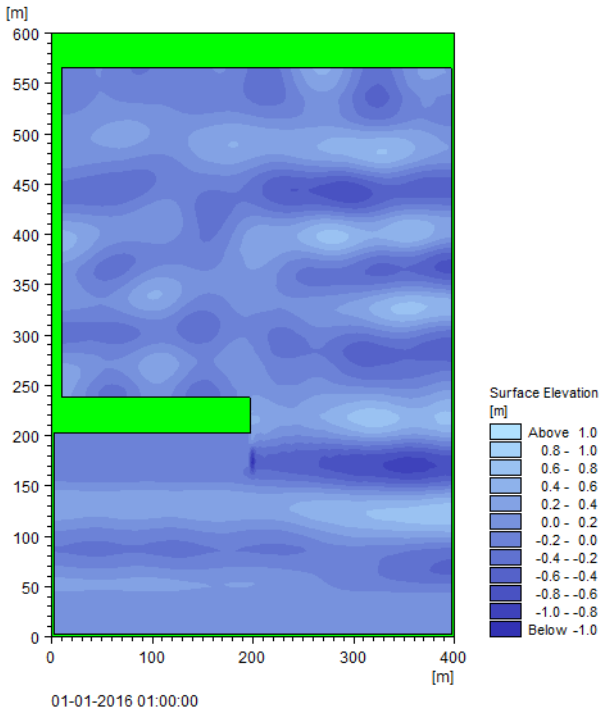


Figure 4.9 Instant surface level one hour into the MIKE 21 BW simulation

Case C: 2D wave data calculated by MIKE 3 Wave Model FM

The setup file used for convergence calculations should have the vessel displacement loaded in on the Vessel Displacements dialog, and afterwards be saved as ‘Final Mooring Setup - C.m21ma’.

The simulation mode is changed to 'Final Computation Mode' and the vessel displacement is as found from the convergence simulation.

The environmental conditions are the same as for the convergence run apart from the wave forcings in the Waves dialog.

In this example the wave field is varying in both time and domain. The input wave field, named ‘Waves_C.dfs2’, is derived by the MIKE 3 Wave Model FM (MIKE 3 Wave FM) using the setup file ‘GenerateWaveField_C.m3wfm’. The input required for this simulation is supplied with this example. The wave conditions at the boundary are similar to the ones for Case B. An example of the wave output is shown in Figure 4.10.

The resulting wave field seems very similar to the one derived from the MIKE 21 BW simulation in the previous section.

NOTE: It requires a license for MIKE 3 Wave Model FM to simulate the wave field.

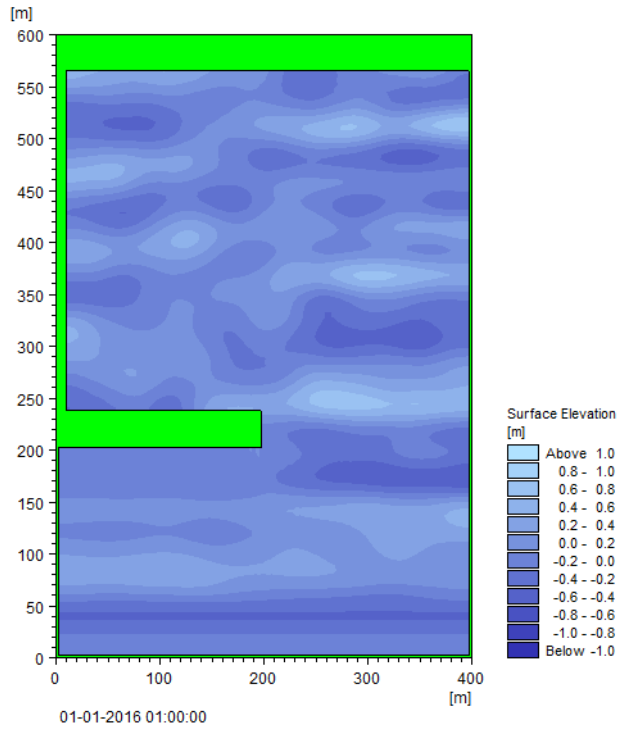


Figure 4.10 Instant surface level one hour into the MIKE 3 Wave FM simulation

4.2.4 Result visualisation

After running the simulations the various results can be evaluated and presented by various tools within MIKE Zero and MIKE Animator Plus.

The three cases can provide results as described in the following.

Case A: 0D wave data

The output file data is processed for presentation in MIKE Animator Plus in similar way as described in section 4.1.4.

An example of the required input file 'DHI_Vessel_motions_MAPlus.dfs0' is included with the installation along with the MIKE Animator Setup file 'Vessel_Motions_A.lyt' and the object file 'Container.3ds'.

From the log-file and the output of line forces it can be seen, that many of the mooring lines 'snaps' early in the simulation, allowing for the vessel to float more freely in the port.

Figure 4.11 shows the initial and resulting position of the vessel as presented in MIKE Animator Plus.

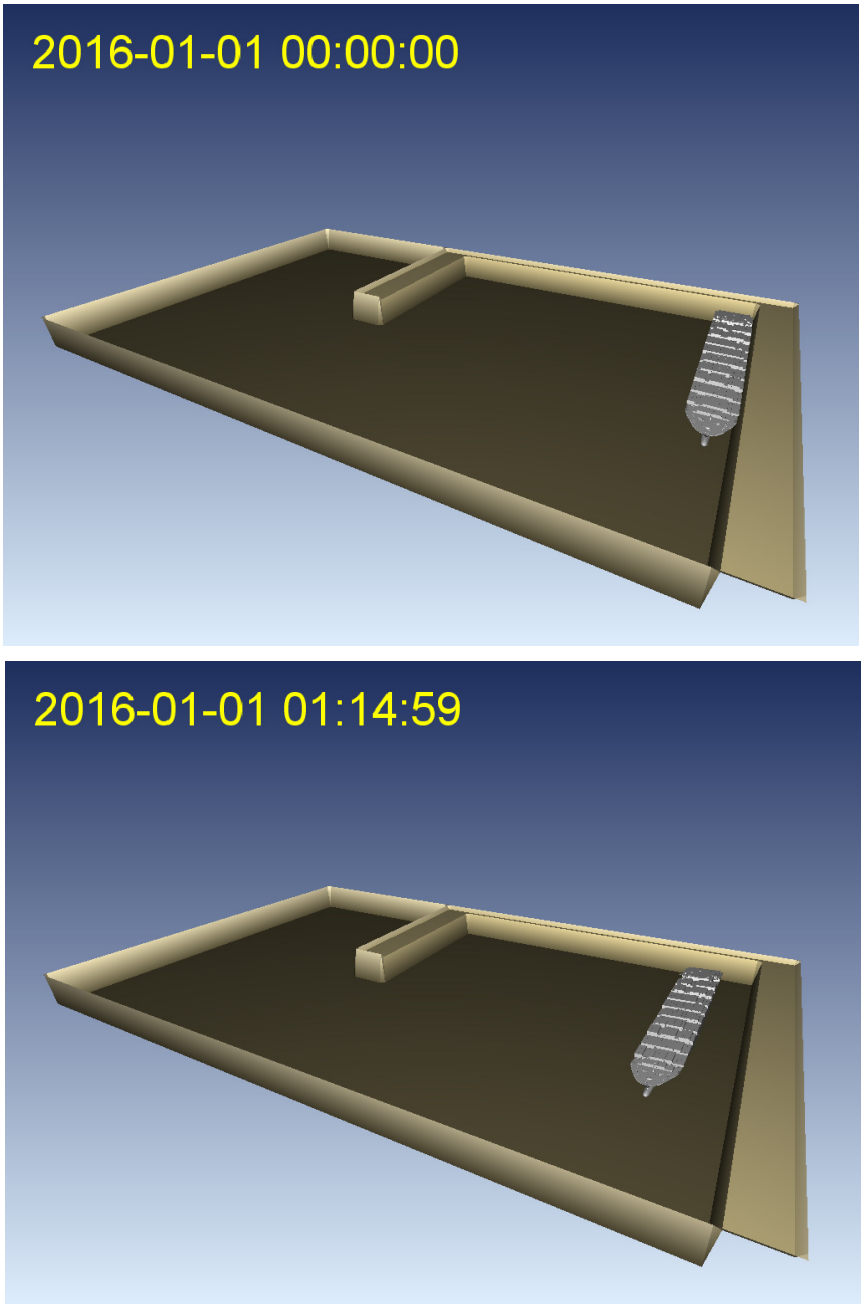


Figure 4.11 Screendumps from MIKE Animator Plus using representative vessel. Upper: Initial position, Lower: Position at end of simulation

It can be noticed that even if the wave height and wave period of the 0D wave data are similar to the wave impact in the first example in section 4.1, the change in incoming wave angle have a large impact on the applied forcing on the mooring lines.

Case B: 2D wave data calculated by MIKE 21 BW

The Time Series plot object in Plot Composer can plot e.g. the resulting vessel motions and line forcings in time.

From the log-file and the output of line forces it can be seen, that mooring lines 1 to 4 lines ‘snaps’ during the simulation. The remaining mooring lines keeps the vessel to moored to the pier, however one can see that after the snap of the lines the front of the vessel sways away from the pier.

This is illustrated in Figure 4.12.

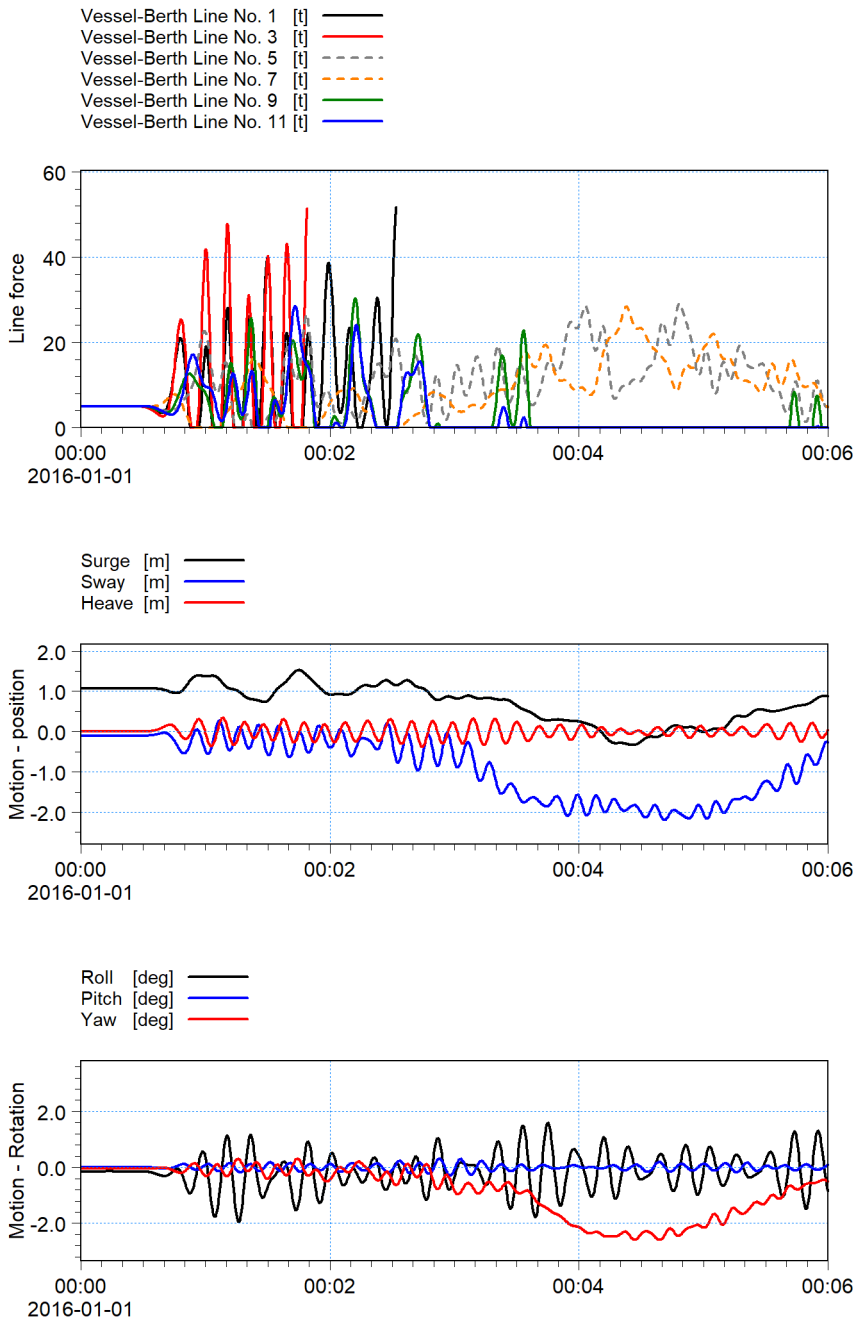


Figure 4.12 Time series of results at the start of the simulation.
Upper: line forcings for mooring lines 1, 3, 5, 7, 9 and 11
Middle: mooring position of vessel (surge, sway and heave)
Lower: rotation of vessel (roll, pitch and yaw)

Case C: 2D wave data calculated by MIKE 3 Wave Model FM

From the log-file and the output of line forces it can be seen, that mooring lines 1 to 4 lines ‘snaps’ during the simulation. However the lines fails at a later time step than compared to Case B, i.e. 13 and 46 minutes after start, respectively.

It is possible to illustrate the horizontal movements of the vessel in the domain by using the Profile series functionality in the Result Viewer.

When inserting a profiles series file (.dfs1) in the Results Viewer, one can select that the location of the line series is to be defined by geographical coordinates derived by temporally varying item values in the file. By creating a line series file with 2 grid points, and only specify values in one grid point, it is possible to illustrate one point feature that moves and rotates. If the point symbol type is defined as an enhanced meta-file (.emf) that illustrates the vessel outline, it is possible to illustrate the resulting horizontal movements as an animation.

An example of the required input file ‘ResultViewer_VesselMotion.dfs1’ is included with the installation along with the Result Viewer setup file ‘Vessel_Motions_C.rev’ and the enhanced meta file ‘Tanker.emf’ representing the outline of the applied vessel.

Figure 4.13 shows a snapshot of the vessel position as presented in Result Viewer.

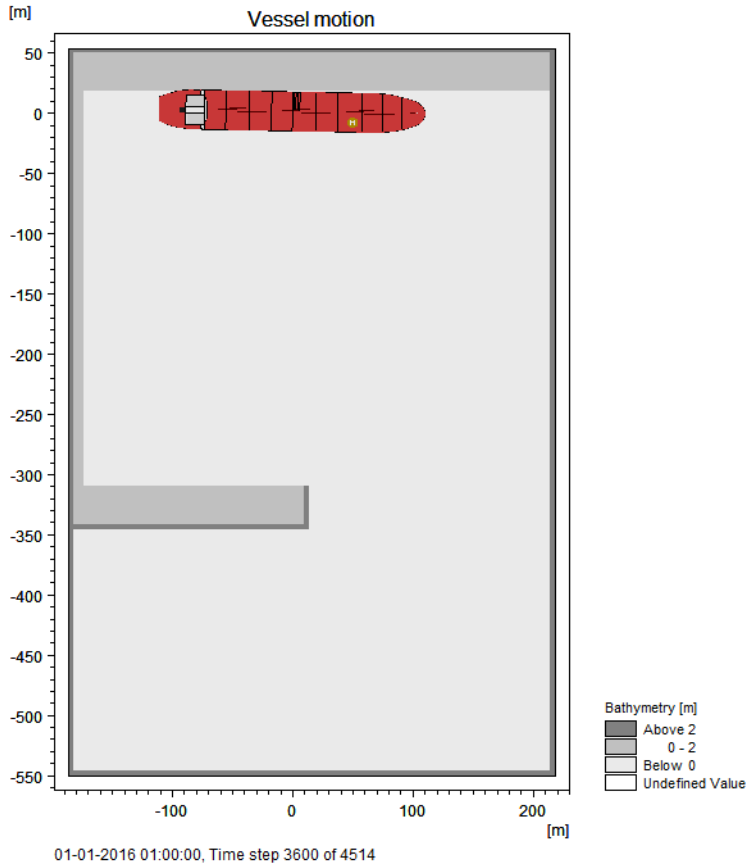


Figure 4.13 Snapshot from Result Viewer using profile series data and enhanced meta file to illustrate vessel movements in time.

5 Reference guide

The MIKE 21 Mooring Analysis (MA) model calculates the response of vessels subject to external forcings such as waves, currents and winds while considering the mooring setup.

5.1 Domain

On this dialog you must specify the Domain under consideration (Berth layout). The required input file is a Bathymetry file of (.dfs2) format. Geographic based map projections where the domain resolution is in degrees are not supported for the domain file or an extracted area from the entire bathymetry, which corresponds to size and position of two-dimensional (2D) forcing files (see Section 5.9).

If using MIKE 21 BW or MIKE 21 Flow Model (both structured grid models) for modelling of wave generated flux, you should use the Bathymetry file from these setups as domain file.

If using MIKE 21 Flow Model FM with a mesh file bathymetry (un-structured grid model) for modelling of wave generated flux, you will have to map the resulting (.dfsu) file into the (.dfs2) format with sufficient resolution.

The geographical information from the (.dfs2) domain file will be fully interpreted and utilized in both the editor and the computational engine, so it is important that you ensure the geographical information of the (.dfs2) grid is meaningfully declared, relative to the utilized map projection.

Once the file is loaded you will see the domain in the projection plane associated with the domain file.

By default the plot extent is set to Automatic, which means that the plot extent will fit the spatial extent of the domain file. But the plot extent can be user defined by setting the plot extent to custom, and changing the values of (Min Easting, Min Northing) and (Max Easting, Max Northing). Increasing the plot extent can be necessary if certain mooring attributes (Bollards and Fenders) are located outside the domain.

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.

5.2 Time

The period to be covered by the simulation is specified on this dialog. You can specify the simulation period in two ways

- No. of time steps, time step interval and simulation start date
- Time step interval, simulation start date and simulation end date

The simulation always starts with time step number 0 and the simulation start-date is the historical data and time corresponding to time step 0. When "No. of time steps, step interval and simulation start date" is selected the simulation end date is presented for reference. When "time step interval, simulation start date and simulation end date" is selected the number of time steps is calculated as the smallest integer (a whole number), which is larger than the duration time divided by the time step interval, and the simulation end data is corrected accordingly.

The number of time steps to be included for warm-up and warm-down of the applied environmental conditions is also to be set.

5.3 Simulation mode

MIKE 21 MA offers two different simulation modes:

- Convergence mode
- Final computation mode

5.3.1 Convergence mode

In practice, to ensure an even (or otherwise pre-set) load distribution amongst the mooring lines, the tension in the mooring lines is in reality manually adjusted by winching in the ropes until the vessel is idle and equal tension exists in all mooring lines.

In MIKE 21 MA this is obtained numerically by running the simulation in convergence mode. When this mode is enabled a stop criteria based simulation is launched, which only takes mooring line impact, and the wind, current and drift forcings (e.g. low frequency forcings) into account.

In convergence mode it is not possible to include wave forcings (high frequency forcing).

When convergence mode is enabled, the dialog Convergence Parameters will be specifically available, where the stop criterias for this simulation mode is to be specified.

Note: If a convergence mode run is not executed prior to the final time-domain computation (final computation mode), the mooring system can cause the vessel to move. This will change the tension in each mooring line. For unbalanced mooring systems, the vessel response can be so significant that tension in some lines disappear completely. The subsequent vessel response in an incident wave/current/wind field will be significantly different to

specified design conditions and will most often be regarded as a serious flaw in the model setup.

5.3.2 Final computation mode

Assuming you have successfully completed the simulation in convergence mode and loaded the resulting vessel displacement, you should continue switching to the Final computation mode.

The following additional dialog is specific for the final computation mode:

- Waves

This enables you to specify high frequency Wave forcings.

Note: If the aim of a particular vessel motion study is to investigate a range of scenarios with different conditions, it is not needed to re-run the convergence mode for each scenario.

In such a study a convergence run only needs to be executed for the first scenario. The resulting vessel displacement can then subsequently be re-used in all the remaining scenarios. In practice you'd just need to copy the (.m21ma) setup with final computation mode enabled and correctly set vessel displacement, as many times as you have scenarios, and just update the wave data in each setup.

5.4 Material Profiles

Here you can specify the material characteristics of the different mooring lines, fenders, chains, bollards, AutoMoors, DynaMoors and port fairleads involved in the spatial setup.

A comprehensive selection of mooring line stiffness curves and fender compression curves is available as part of the MIKE Zero installation in the following folders:

<MIKE installation folder>\MIKE Zero\Templates\Maritime\MooringAnalysis\Material Profiles\Line Profiles

<MIKE installation folder>\MIKE Zero\Templates\Maritime\MooringAnalysis\Material Profiles\Fender Profiles

<MIKE installation folder>\MIKE Zero\Templates\Maritime\MooringAnalysis\Material Profiles\AutoMoor Profiles

The (.dfs0) curves for line stiffness and fender compression can be copied and used instantly as part of a mooring analysis.

The mooring line stiffness curves have been digitized from OCIMF guidelines /5/ and the fender compression curves are obtained from Trelleborg manuals or ShibataFenderTeam /6/.

AutoMoor T40 unit, and DynaMoor properties are provided by Trelleborg Marine and Infrastructure.

5.4.1 Line profiles

This dialog allows you to declare a number of material mooring line profiles. By clicking 'Go to ..' you will be taken to the specific Line instance, where the specific mooring line data must be declared.

Line instance

In the line instance dialog you specify the following properties:

- Total breaking strength
- Failure load
- Linear damping coefficient
- Quadratic damping coefficient
- the material profile of the line as a dfs0 file

When preparing your own material profile files, the (.dfs0) file must have Axis Type as Relative Item Axis, and the data should consist of (x-axis) strain/elongation in [percent] and (y-axis) relative force increment in [percent], see Figure 5.1.

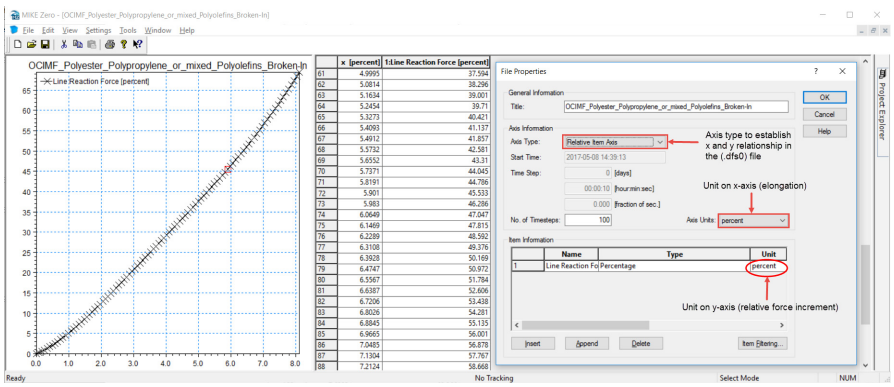


Figure 5.1 Example of Line response curve

The full set of data will characterize a certain material line profile, e.g.: steel wire, polyamide. During simulation the engine will rely on linear interpolation between the given points in the (.dfs0) file in order to retrieve the relevant line data from this curve.

The failure load will be used as part of an operability summary in the (.log) file, and represents the critical load for the line material (as a percentage of the total breaking strength). The default failure load is 50% of the total breaking strength.

The damping coefficients can be applied for the purpose of calibration.

Mooring line types

The main category of mooring lines include:

- Natural fibre lines - Traditional mooring lines manufactured from manila, sisal etc. These lines are relatively cheap, easy to handle (when dry) but have a moderate resistance against abrasion. They have a relatively low load/diameter ratio and cannot easily absorb peak loads.

- Synthetic fibre lines - manufactured from nylon, polypropylene, terylene, etc. Compared to natural fibres, these lines have a high load/diameter ratio, are relatively light and easier to maintain. The elongation of synthetic lines is relatively large and strength characteristics can be affected in case of high temperature (e.g. caused by friction)

- Steel wires - Steel wires are stiff, have a high load/diameter ratio and low elongation proportional to the line reaction force. However, they are difficult to handle and are not suitable under dynamic conditions. High line forces occur for small ship displacements and they have a high potential for breakage.

- Combi lines - Combination of steel wires and synthetic tails and are particularly useful for mooring tankers. These lines have good shock absorption. Tails in most cases should be no longer than 10m. MIKE 21 MA is able to simulate combi lines.

Figure 5.2 presents commonly used load-extension curves /5/.

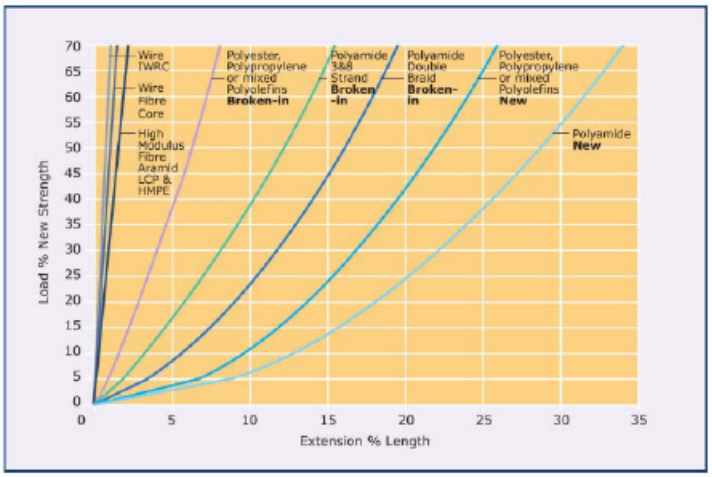


Figure 5.2 Load-Extension characteristics of wire and fibre ropes (OCIMF /4/)

5.4.2 Fender profiles

This dialog allows you to declare a number of material fender profiles. By clicking 'Go to ..' you will be taken to the specific Fender instance, where the specific fender data must be declared.

Fender instance

In the fender instance dialog you specify the following properties:

- Max reaction force
- Max deflection
- Failure deflection
- Fender friction coefficient
- Linear damping coefficient
- Thickness
- the material property of the fender as a dfs0 file

The Fender thickness defines the distance between the attachment and activation point of the physical fender - see the figure below:

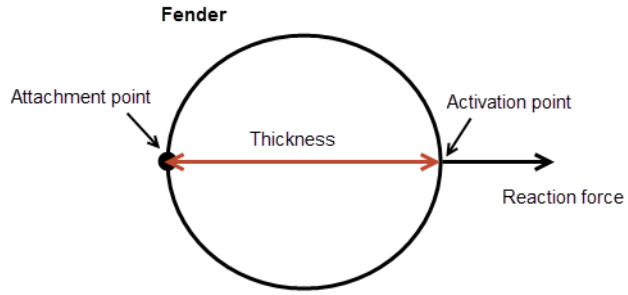


Figure 5.3 Definition of fender thickness

In M21 MA all Fenders are visualized as a circular symbol, so all spatial fenders will be plotted with a diameter corresponding to the thickness of the fender profile associated with the spatial fender (applies for both Port fenders and Vessel-Vessel Fenders).

The maximum reaction force and maximum deflection are fender specific and depend on the fender type and material, such as rubber composition. The working curve of a fender shows the ratios of fender reaction force to the fender deflection, both given in % from the maximum reaction force and the maximum deflection. Figure 5.4 shows the reaction over the deflection for a number of fender types /6/.

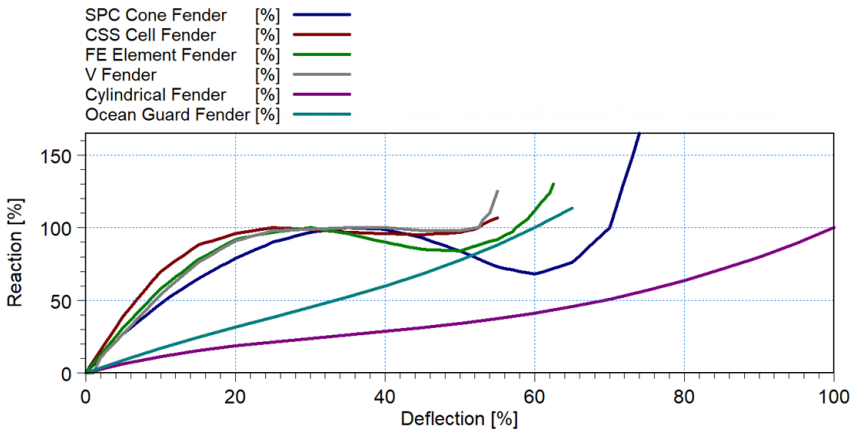


Figure 5.4 Fender deflection reaction curves for Shibata fenders /5/

The Fender shear modulus changes considerably with the temperature. Therefore, temperature correction factors should be applied to the maximum

reaction force /7/. Table 5.1 and Figure 5.5 show examples of the temperature correction factors from /5/.

Table 5.1 Temperature correction factors /5/

Temperature (°C)	Rubber fenders (-)
-30	1.559
-20	1.375
-10	1.182
0	1.083
10	1.034
20	1.000
30	0.976
40	0.945
50	0.918
60	0.917

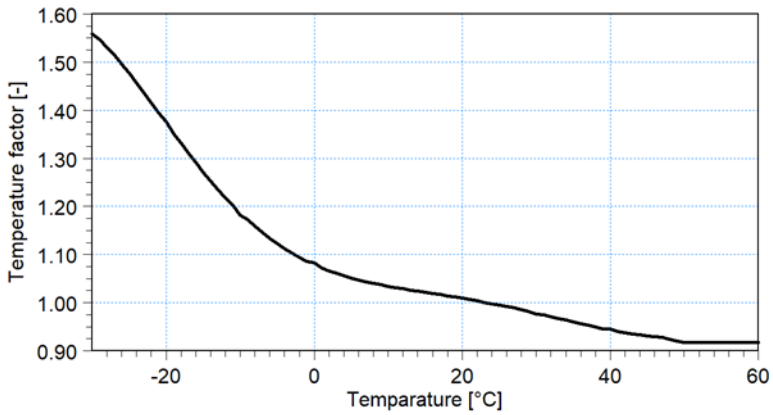


Figure 5.5 Temperature correction factors for ShibataFenderTeam rubber fenders

When preparing your own material profiles, the (.dfs0) file must have Axis Type as Relative Item Axis, and the data should consist of (x-axis) compression in [percent] and (y-axis) relative force increment in [percent].

This full set of data will characterize a certain fender type (rubber, foam, …). The engine will rely on linear interpolation in order to retrieve the relevant fender data from this curve at run-time.

The failure deflection will be used as part of an operability summary in the (.log) file., and represents the critical compression for the fender (as a per-

centage of the max deflection). The default failure deflection is 100% of the maximum reaction force.

Note: The most common types of fenders encountered in moored vessel assessments are cell and pneumatic fenders.

The line and fender response curves can usually be digitized directly from the manufacturer catalogue. Where unavailable, mooring line information can often be obtained from /5/.

5.4.3 Chain profiles

This dialog allows you to declare a number of material chain profiles. By clicking 'Go to ..' you will be taken to the specific Chain instance, where the specific chain data must be declared.

Chain instance

In the chain instance dialog you specify the following properties:

- Max tension
- Failure load
- Submerged mass
- Quadratic damping coefficient

Unlike lines and fenders, the chain profile does not require a (.dfs0) file characteristic to be specified. The full chain type is only characterised by the four scalar values above.

The failure load will be used as part of an operability summary in the (.log) file, and represents the critical load for the chain (as percentage of Max tension). The default failure load is 85% of the maximum tension.

5.4.4 Bollard profiles

This dialog allows you to declare a number of bollard profiles. By clicking 'Go to..' you will be taken to the specific Bollard instance, where the specific bollard data must be declared.

Bollard instance

In the bollard instance dialog you may include criteria by activating the corresponding check box, which will be checked during the simulation. When included, you must specify the following properties:

- Max. horizontal bollard pull force
- Max. vertical bollard pull force

- Max. total pull force
- Max. vertical line angle
- Failure load

Unlike lines and fenders, the bollard profile does not require a (.dfs0) file to be specified.

5.4.5 AutoMoor profiles

The Trelleborg AutoMoor system is a passive automated vacuum mooring system that maintains vessel mooring through the use of spring dampening. The passive system is engaged at the position of vessel berthing and extended/retracted if loads exceed rated limits.

MIKE 21 MA includes properties for the AutoMoor T40 unit variant.

This dialog allows you to declare a number of AutoMoor profiles. By clicking 'Go to..' you will be taken to the specific AutoMoor instance, where the specific AutoMoor data must be declared.

AutoMoor instance

In the AutoMoor instance dialog you must specify the following properties:

- Maximum force (%), a percentage of teh AutoMoor strength
- The AutoMoor data file

5.4.6 DynaMoor and port fairlead profiles

A Trelleborg DynaMoor (DM) is a controllable moving hook on the berth connected to the end of a berth-vessel line. The application of DynaMoor is to maintain a minimum tension force of F_{min} and to cap the maximum line force at F_{max}. A fixed berth-based fairlead leads the line connected to the DynaMoor. This fairlead is referred to as "Port_fairlead". In some designs the Port_fairlead forms part of the DynaMoor unit, whereas in others it can be separated. Therefore, to make a generic model, two devices are defined, DynaMoor and Port_fairlead.

This dialog allows you to declare a number of DynaMoor profiles. By clicking 'Go to..' you will be taken to the specific DynaMoor instance, where the specific DynaMoor data must be declared.

DynaMoor instance

In the DynaMoor instance dialog you must specify the following properties:

- Total breaking strength

- Min. DynaMoor tension force
- Max. DynaMoor tension force
- Min. DynaMoor displacement
- Max. DynaMoor displacement
- Failure displacement load

Port_Fairlead instance

In the Port_Fairlead instance dialog you must specify the following properties:

- Max. horizontal Port_Fairlead pull force
- Max. vertical Port_Fairlead pull force
- Max. total pull force
- Max. vertical line angle
- Failure load

5.5 Vessels

In the vessels dialog you are to select the (.vre) file, which is the main output file produced by the Frequency Response Calculator (FRC).

When loading the (.vre) file the editor will instantly retrieve the number of vessels and their names, as well as the full geometric data for all vessels in the full vessel system.

The number of vessels will be represented as individual records in a grid, where the 'Go to ..' button will take you to the corresponding vessel instance.

Depending on the vessel setup in the FRC, the radiation damping output from the FRC can potentially contain some freak values at certain frequencies. This can be problematic, since this output is provided as input to MIKE 21 MA. For setups considering only one vessel the FRC remedies this by applying automatic filtering. However, for multi-vessel setups it is difficult to predict the location of these freak values. Therefore, the vessels dialog offers the possibility to filter for irregular frequencies. This is done by specifying one or more frequency ranges (bands) for which the filtering should be applied. If specifying more than one frequency band to filter for, the individual bands are not allowed to be overlapping.

Please, be careful to only filter the regions where irregular frequencies occur. If the filter range is too large, energy will be removed from frequencies believed to be correct.

5.5.1 Vessel data

The Vessel instance GUI is divided into six different tabs:

- Vessel data
- Fairlead data
- Winch data
- Chain data
- Fender connection data
- Vessel view

Vessel data

On this tab you specify:

- Longitudinal area (wind)
- Transverse area (wind)
- Length between perpendiculars (LPP)
- Loading conditions
- Vessel class

There are eight different vessel classes to choose from:

1. User defined
2. Bulk Carrier
3. VLCC Cylindrical
4. VLCC Conventional (default)
5. Container
6. General Cargo
7. Gas Carrier Prismatic
8. Gas Carrier Spherical

Please refer to Section 3.2 Vessel Types *(p. 14)* for a description of these vessel classes. The choice of vessel class will determine which current and wind drag curve data that will be used in the computations. If selecting Vessel class as user defined, you must provide your own wind and current drag curves. First item in a wind drag curve file must be the angle, and the remaining items must consist of 2 series of drag coefficients (CX,CY,CN) (eg. 7 items in total). First item in a current drag curve file must be the angle, and the remaining items must consist of an even series of drag coefficients (CX,CY,CN) (eg. the number of drag coefficients in the file must be even and dividable by 3). For the other vessel classes (non-user defined) the applied

drag curve data is predefined as part of the MIKE installation and not visible to the user and will be automatically loaded in by the engine and used when executing the simulation.

The Loading condition is a value between 0 and 100 and is used for weighting the wind drag coefficients between ballast and ladden condition.

For summary the vertical parameters will be displayed again.

Fairlead data

On this tab you are to specify the XYZ coordinates of the full set of fairleads on the vessel instance in question.

'Vessel origo at' will determine the reference point on the vessel with respect to which the XY values are to be provided. The Z coordinates are to be provided positive upwards from the keel of the vessel for fairleads.
The XYZ data for fairleads can be inserted record-by- record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.
The symbol orientation for fairleads can be controlled by the value for 'Symbol orient' (0° in the ship coordinate system by default). This symbol orientation has no computational impact, it is only for making the illustration more realistic.

Winch data

On this tab you are to specify the XYZ coordinates of the full set of winches on the vessel instance in question.

'Vessel origo at' will determine the reference point on the vessel with respect to which the XY values are to be provided. The Z coordinates are to be provided positive upwards from the keel of the vessel for winches.
The XYZ data for winches can be inserted record-by- record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.
The symbol orientation for winches can be controlled by the value for 'Symbol orient' (0° in the ship coordinate system by default). This symbol orientation has no computational impact, it is only for making the illustration more realistic.

Chain data

On this tab you are to specify the XYZ coordinates of the full set of chains on the vessel instance in question.

'Vessel origo at' will determine the reference point on the vessel with respect to which the XY values are to be provided. The Z coordinate for chains are with respect to the water line.
The XYZ data for chains can be inserted record-by- record, but can also be

imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.
If importing from an (.xyz) file to populate chain data, a special rule applies, as the (.xyz) file must contain a total of 6 columns, giving data to the six fields: X (from), Y (from), Z (from), X (to), Y (to) and Z (to) - 'from' meaning start point of the chain, and 'to' meaning end point of the chain.

For a chain you must furthermore choose a value for Horizontal force, as well as selecting a previously declared chain material profile, among the full set of earlier declared chain profiles, to be associated with the spatial chain.

Fender connection data

On this tab you are to specify the XYZ coordinates of the full set of fender connections on the vessel instance in question.

'Vessel origo at' will determine the reference point on the vessel with respect to which the XY values are to be provided. The Z coordinates are to be provided positive upwards from the keel of the vessel for Fender connections. The XYZ data for Fender connections can be inserted record-by- record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

A Fender connection is a point on the vessel hull to which one can attach Fenders.

Vessel view

On this tab you can see the full set of declared vessel-fixed Fairleads, Winches, Chains and Fender connections plotted on top of the vessel contours for deck plane height (editable) and water line (fixed at this stage). The deck plane height does not play any computational role in MIKE 21 MA. The deck plane height only determines the displayed deck plane contour on the graphical plots of the vessel (red polygon). The deck plane height is thus a tool for graphical inspection of the vessels extent in the x-y plane at a particular height above the keel. This is particularly useful when positioning fairleads.

This plot offers an interactive feature, allowing you to select (by choosing the select mode radio button) on any given Fairlead, Winch, Chain or Fender connection in order to (if needed) change a property of the given attribute. The table record for the selected attribute will then be displayed in the lower part of the dialog, and you can then edit the property of the selected attribute.

Note: Advanced interactive features like **Pan** and **Mouse Wheel based zoom**, are available for the most flexible work flow. The features can be utilized during any graphical activity, e.g. selection of attributes or when certain details are to be looked up and inspected. These two features becomes active when you click on the plot and hold down the shift key on the keyboard.

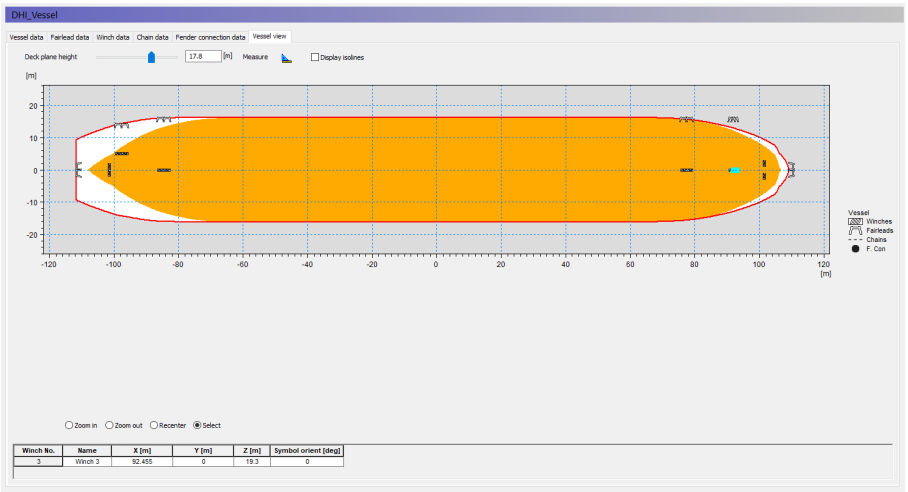


Figure 5.6 Example of vessel view

5.6 Vessel-Vessel Data

This dialog is conditionally visible. This means it is only visible if the number of vessels from the (.vre) file is > 1 (e.g. a multi-vessel case).

So when loading in the (.vre) file on the Vessels GUI (see section 5.5 Vessels *(p. 53)*) this dialog will either show or not show depending on whether the above criteria is met.

The functionality on this dialog is distributed over 3 tabs:

- System view
- Vessel-Vessel Fenders data
- Vessel-Vessel Lines data

The functionality on these 3 tabs are described in the following.

System view

This tab will show the full system of vessels in their relative positioning in an XY coordinate system. The various vessels positions in the XY plot are directly taken from the (.vre) file, which inherits these positions from the previous workflow in Frequency Response Calculator. This plot is basically similar to the plot in the System view tab in the Frequency Response Calculator - with the exception that at this stage various vessel-fixed attributes (fairleads, winches, chains, fender connections) have potentially been defined on the various vessels and these symbols are now visible. So at this stage the vessel system has still not been positioned in the domain, but all relevant vessel-fixed attributes have been declared on all vessels.

The aim on the Vessel-Vessel data GUI is to allow specification of:

- Vessel-Vessel Fenders
- Vessel-Vessel Lines

The functionality of the icons for insertion and deletion of fenders and lines are described section 5.6.3.

5.6.1 Vessel-Vessel Fenders

A vessel-vessel fender is a fender which is attached to a particular vessel at a fender connection, and which exerts a reaction force towards a neighboring vessel at the fender activation point. The symbol used for vessel-vessel fenders helps the user in this understanding see definition of the vessel-vessel fender symbol properties in Figure 5.7 below.

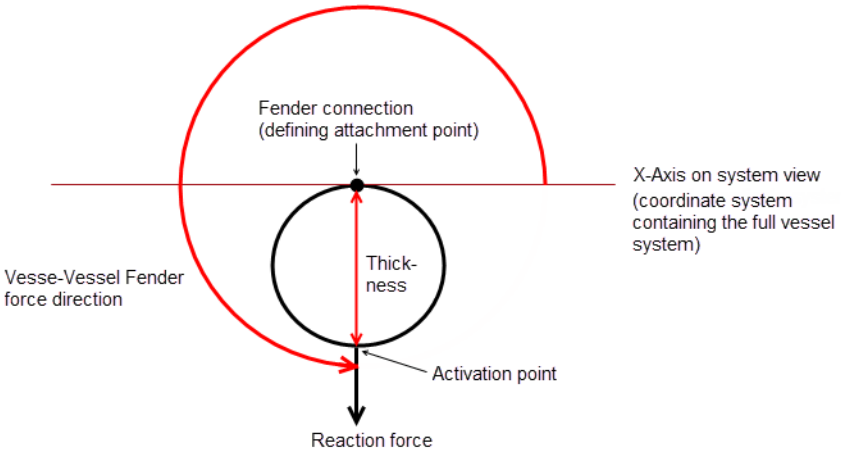


Figure 5.7 Definition of Vessel-Vessel fender symbol properties

Explanation of the properties of a Vessel-Vessel Fender.
The Vessel-Vessel Fender symbol will rotate around the fender connection according to the angle given as the force direction. The vessel-vessel fender symbol has a reaction force arrow symbol attached, in order to make it instantly apparent in which direction the fender affects a neighboring vessel, at the activation point. The actual diameter of the (circular) fender symbol is controlled by the thickness value - which comes from the associated fender material profile. Hence if you switch fender material profile, the fender symbol will be re-scaled to the new thickness value.

5.6.2 Vessel-Vessel Lines

A Vessel-Vessel line is a mooring line which simply connects 2 mutual vessels with one another. It originates in a winch on one vessel and terminates in another winch on another vessel, via fairlead connections. In this sense vessel-vessel lines are domain-independent and thus only depends on the relative positions between vessels.

The System view tab offers interactive tools for declaration of:

- Vessel-Vessel Fenders
- Vessel-Vessel Lines

Proper definition of vessel-vessel fenders and lines concludes the workflow on the Vessel-Vessel Data dialog.

5.6.3 Insertion and deletion of lines and fenders

Vessel-Vessel Fender insertion/deletion functionality

Insert Vessel-Vessel Fender icon: works by enabling this mode, and subsequently left-clicking in spatial vicinity of a Fender connection symbol on a vessel.
Insertion impact on graphics side: Puts/Creates a Vessel-Vessel Fender symbol next to the Fender connection.
Insertion impact on table side (Vessel-Vessel fender data): Inserts a new record into the Vessel-Vessel Fender table according to these default rules:

Name: "V-V Fender X" - X being the running number

Vessel (connected): The vessel to which the fender connection (on which you clicked) belongs

Fender connection: The fender connection (on which you clicked)

Vessel (affected): The vessel which the vessel-vessel fender affects (at fenders activation point). By default the GUI will try populating this as the vessel (among full set, minus vessel (connected)) which has it's amidship point located closest to the fender connection. It is particularly important to verify whether this setting is correct.

Force dir.:
If y-coordinate (on local vessel) of Fender connection > 0.0 = 90.0 [deg]
If y-coordinate (on local vessel) of Fender connection < 0.0 = 270.0 [deg]
This flat rule implies that the force direction of a vessel-vessel fender by default points outwards. It is however always relevant to assess for yourself whether the fender force direction is as it should be.

Fender profile: By default it will always be the first fender profile (if any) which this value will be populated with by doing interactive vessel-vessel fender insertion. The desired fender profile must always be selected.

Delete Vessel-Vessel Fender icon: - works by enabling this mode, and subsequently left-clicking in vicinity of an existing Vessel-Vessel Fender symbol.
Insertion impact on graphics side: Removes the Vessel-Vessel Fender symbol in which vicinity you have clicked.
Insertion impact on table side (Vessel-Vessel fender data): Removes the given table record corresponding to the Vessel-Vessel Fender number you have clicked.

Vessel-Vessel Line insertion/deletion functionality

Insert Vessel-Vessel Line icon: - works by enabling this mode, and subsequently dragging the vessel-vessel line according to these 4 steps:

1. Initiate in any Winch (could be at any vessel, call it start vessel)
2. Connect to a Fairlead (MUST be located at start vessel - eg. at same vessel where you previously initiated the line in a winch)
3. Connect to any Fairlead (could be at any vessel, call it end vessel)
4. Terminate in a Winch (MUST be located at end vessel - eg. same vessel as where you previously connected to the fairlead)

Insertion impact on graphics side: Draws a Vessel-Vessel Line which connects between the involved 4 attributes, ultimately connecting a start vessel, and an end vessel with each other.
I*nsertion impact on table side (Vessel-Vessel line data)*: Inserts a new record into the Vessel-Vessel Line table.

Delete Vessel-Vessel Line icon: - works by enabling this mode, and subsequently clicking on an existing Vessel-Vessel Line (any of the 3 segments which spans a V-V Line should obey this deletion)

Deletion impact on graphics side: Removes the Vessel-Vessel Line visualization on which you clicked.
Deletion impact on table side (Vessel-Vessel line data): Removes the Vessel-Vessel Line record, corresponding to the Vessel-Vessel Line number of the line you clicked.

5.7 Port data

The Port data GUI covers six tabs:.

- Bollard data
- Port fender data
- AutoMoor data

- DynaMoor data
- Port_Fairlead data
- Port view

On these tabs you are to provide the data for port-fixed attributes relevant for a mooring arrangement: bollards and port-fixed fenders, Dynamoors, Port_-Fairleads and AutoMoor units.

5.7.1 Bollard data

On this dialog you are to provide the data for bollards.

The horizontal coordinates for bollards are to be provided in (Easting, Northing) or (Longitude, Latitude) dependent on the choice of map projection. If the domain file has projection Local coordinates, you will be forced to provide all horizontal positions with respect to this projection. The vertical coordinate is positive upwards from the water level.

The XYZ data for bollards and fenders can be inserted record-by-record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

For each bollard, you have to select a bollard profile (previously defined in the Material Profiles instances).

5.7.2 Port fender data

The horizontal coordinates for Port fenders are to be provided in (Easting, Northing) or (Longitude, Latitude) dependent on the choice of map projection. If the domain file has projection Local coordinates, you will be forced to provide all horizontal positions with respect to this projection. The vertical coordinate is positive upwards from the water level.

The XYZ data for Port fenders can be inserted record-by-record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

For each Port fender you furthermore have to provide a direction in which the fender force works, as well as associating the spatial fender with one of the earlier declared fender material profiles.

The fender force must point towards a vessel and it's direction is defined as counter-clockwise positive from Easting axis (going to), see Figure 5.8.

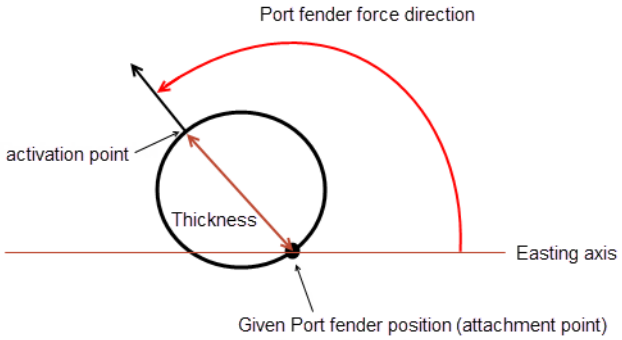


Figure 5.8 Full definition of port fender properties. A supporting arrow at the Port fender symbol boundary points towards the given force direction, making this direction instantly apparent. The thickness from the fender profile governs the Port fender symbol diameter.

The symbol orientation for bollards can be controlled by the value for 'Symbol orient' (90° by default for bollards and 0° by default for fenders). The port coordinate system is in the Domain dialog - see page 43. These symbol orientations have no computational impact, it is only for making the illustration more realistic (symbol orientation relative to the domain). Furthermore, you need to select a fender profile from the previously defined Material Profile instance and select the affected vessel.

5.7.3 AutoMoor data

On this dialog you are to provide the data for AutoMoor units.

The horizontal coordinates for AutoMoor units are to be provided in (Easting, Northing) or (Longitude, Latitude) dependent on the choice of map projection. If the domain file has projection Local coordinates, you will be forced to provide all horizontal positions with respect to this projection. The vertical coordinate is positive upwards from the water level. The direction (deg) is usually defined as the direction of the nearest fender. This is because AutoMoor units and fenders work together to control the vessel motion.

The XYZ data for AutoMoor units can be inserted record-by-record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

For each AutoMoor unit, you must select an AutoMoor profile (previously defined in the Material Profiles instances).

5.7.4 DynaMoor data

The horizontal coordinates for DynaMoor are to be provided in (Easting, Northing) or (Longitude, Latitude) dependent on the choice of map projection. If the domain file has projection Local coordinates, you will be forced to provide all horizontal positions with respect to this projection. The vertical coordinate is positive upwards from the water level.

The XYZ data for DynaMoor can be inserted record-by-record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

For each DynaMoor you furthermore have to select a DynaMoor profile.

5.7.5 Port_Fairlead data

On this dialog you are to provide the data for Port_Fairleads.

The horizontal coordinates for Port_Fairleads are to be provided in (Easting, Northing) or (Longitude, Latitude) dependent on the choice of map projection. If the domain file has projection Local coordinates, you will be forced to provide all horizontal positions with respect to this projection. The vertical coordinate is positive upwards from the water level.

The XYZ data for Port_Fairleads can be inserted record-by-record, but can also be imported from an (.xyz) file, where the following delimiter choices are supported: space, comma and tab.

For each Port_Fairleads, you have to select a Port_Fairleads profile (previously defined in the Material Profiles instances).

5.7.6 Port view

On this tab you can see the full set of specified port-fixed bollards, fenders, AutoMoors, DynaMoors and Port_Fairlead units plotted on top of the (.dfs2) domain file as provided on the Domain dialog, as shown in Figure 5.9.

If bollards and port fenders are declared, for example, but you cannot see them on the Port view tab, it is likely because there is a mismatch between the horizontal coordinates for the Port Fenders and Bollards, relative to the geographical information in and the extent of the domain file. As a user you must be cautious about consistency in horizontal coordinates and projections.

To see the full set of bollards, fenders, AutoMoors, DynaMoors and Port_Fairleads units you might also need to increase the plot extent. This is controlled on the Domain dialog.

This plot offers an interactive feature, allowing you to select (by clicking) on any given bollard or fender. The table record for the selected attribute will

then be displayed in the lower part of the dialog, and you can then edit the property of the selected attribute.

Note: Advanced interactive features like **Pan** and **Mouse Wheel based zoom**, are available for the most flexible work flow. The features can be utilized during any graphical activity, e.g. selection of attributes or 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.

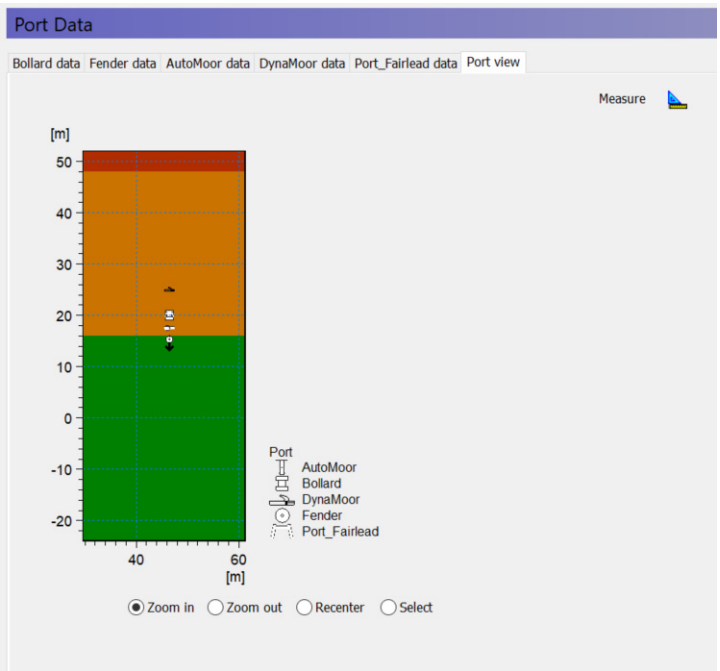


Figure 5.9 Example of port view

5.8 Mooring setup

The Mooring setup dialog is the main dialog in MIKE 21 MA, as this is where the spatial mooring system is to be set up, which includes insertion of the full vessel system into the domain and definition of the mooring lines. This dialog is divided into two tabs.

- Vessel position and mooring lines
- Mooring line data

5.8.1 Vessel position and mooring lines

On this tab you will see the domain as a background layer with the earlier declared bollards and fenders. The toolbar grants you the necessary functionality to insert the vessel into the domain as desired.

Position vessel

The vessel position is provided according to a given Map projection. The following rules apply:

- If: projection of the domain file equals Local coordinates
  Then: you must to provide the vessel position with respect to Local coordinates
- If: projection of the domain file does not equal local coordinates
  Then: you can specify the vessel position with respect to any Map projection, except Local coordinates

The position type is always 'Vessel system origo in domain'. It means that you insert the full system of vessels (consisting of 1 or multiple vessels) into the domain, by inserting the (0,0) reference point into the domain. The vessels positions relative to (0,0) were defined from the workflow in Frequency Response Calculator and is available in the (.vre) file.

Rotation type reflects how the vessel rotation is to be interpreted. For the moment we only support 'Counter clockwise from Easting', meaning this is the convention for a positive rotation value. It is the X-axis of the relative vessel system which is rotated (and implicitly all vessels) according to this rotational definition.

When clicking Apply, the specified state for vessel system position and rotation will be effectuated. If editing the latest specified state for position and rotation, the Apply button will be active again (indicating that a new state has been declared).

When finished positioning the vessel system, you should see all involved vessels meaningfully positioned somewhere in the Domain/Berth layout. An example view is given in Figure 5.10 for a vessel system consisting of a single vessel.

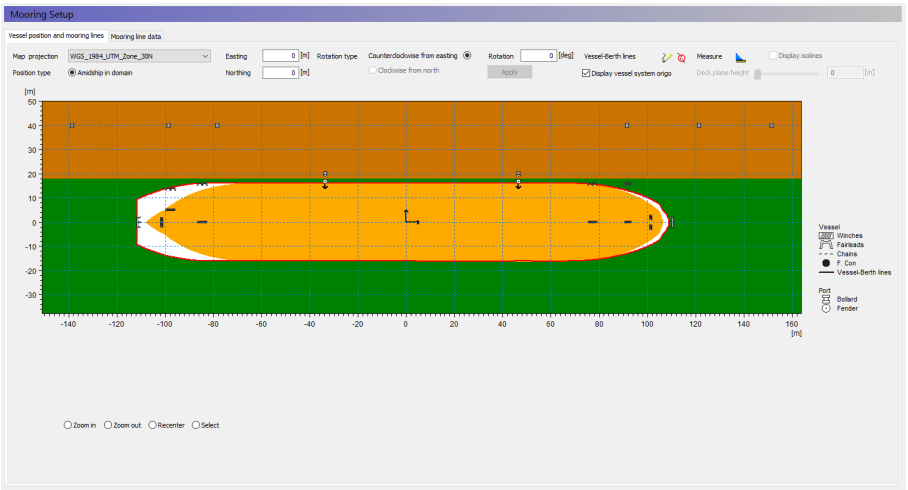


Figure 5.10 Example of vessel position with defined spatial characteristics

Insert mooring lines

When the vessel system position in the domain is considered acceptable, the mooring line arrangement is ready to be declared.

Two icons exist for the insertion and deletion of Vessel-Berth lines:

- Insert line
- Delete line

A single Vessel-Berth line can be inserted by doing these steps:

1. Click the **insert line** icon
2. Initiate the line by clicking any given **winch** on any vessel
3. Move the cursor to any given **fairlead** on the same vessel as the winch selected in step 2, and click on the fairlead
4. Continue moving the cursor to a berth-based connection. The connection can be done to a bollard or to a DynaMoor.
5. Finalize the mooring line by clicking on the bollard or DynaMoor

If lines are specified incorrectly, they can be deleted at any time by clicking the delete line icon and subsequently clicking on the graphical symbol representing the full vessel-berth line. Figure 5.11 and Figure 5.12 show an example for inserting mooring lines.

This plot offers an interactive feature, allowing you to select (by clicking) on any given Vessel-Berth Line. The data record for the selected line will then be displayed in the lower part of the dialog, and you can then edit the property of

the selected line. This functionality is useful when you need to set the correct line and tail profile, and line pretension and tail length for each spatial line.

Note: Advanced interactive features like **Pan** and **Mouse Wheel based zoom**, are available for the most flexible work flow. The features can be utilized during any graphical activity: vessel-berth line insertion/deletion, selection of attributes or 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.

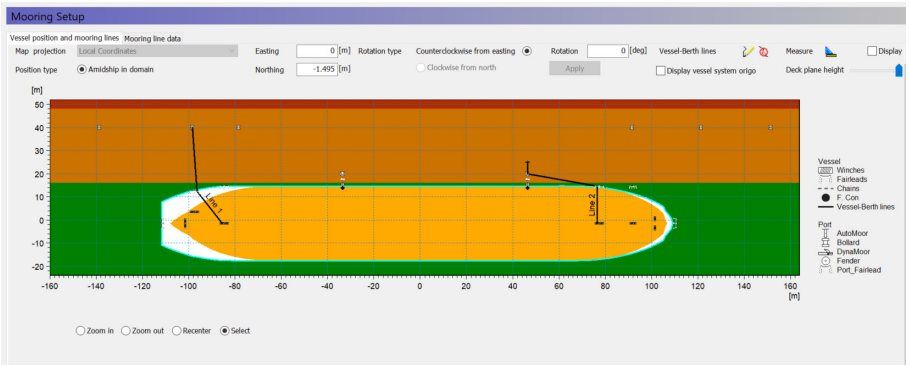
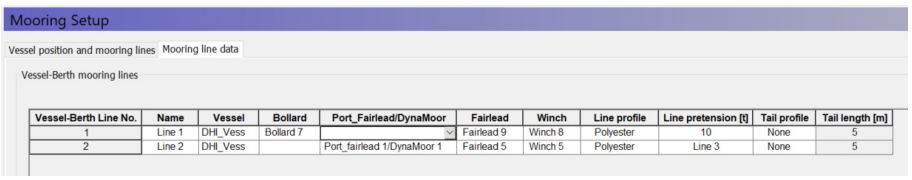


Figure 5.11 Example of inserting mooring lines



Vessel-Berth Line No.	Name	Vessel	Bollard	Port_Fairlead/DynaMoor	Fairlead	Winch	Line profile	Line pretension [t]	Tail profile	Tail length [m]
1	Line 1	DHI_Vess	Bollard 7		Fairlead 9	Winch 8	Polyester	10	None	5
2	Line 2	DHI_Vess		Port_fairlead 1/DynaMoor 1	Fairlead 5	Winch 5	Polyester	Line 3	None	5

Figure 5.12 Example of mooring lines table

5.8.2 Mooring line data

On this tab you can see the full set of data representing all declared Vessel-Berth mooring lines.

Every time you insert Vessel-Berth lines interactively, a record is appended into the Vessel-Berth Mooring Lines table.

When inserting mooring lines interactively, the line profile will by default be the first line material profile. The line pretension will per default be 10 tons and there will by default not be a tail profile. Changes to this must be made in either the full Vessel-Berth Mooring lines table or by selecting and editing each line data record individually on the vessel position and mooring lines tab.

Alternatively, you can also specify the full set of Vessel-Berth Mooring lines manually record-by-record directly from the Vessel-Berth lines table, and go see the consequence on the graphical plot on the Vessel position and mooring lines tab. But the easiest way to define mooring lines is to define them interactively one by one, and subsequently edit their properties individually by selecting them and afterwards edit them.

Note: The tail lines should always be more elastic than the mooring line. Tails are added to the end of mooring lines to increase the overall elasticity of the mooring system.

5.9 Environmental conditions

The environmental conditions represent the physical conditions and forcings which apply in the domain where the vessel is located.

5.9.1 Physical parameters

Here you can specify the values of densities and kinematic viscosities of water and air, using other than their default values, if needed.

5.9.2 Drift forces

It is only possible to include Drift Forces, if 2nd order wave drift force data exists in the (.vre) file (e.g. if this phenomenon was included in the previously executed FRC simulation). Otherwise the 'Include wave drift forces' checkbox is disabled. Since drift forces rely on wave data, inclusion of drift forces will require you to specify wave data.

The calculation of drift forces in FRC relies on the assumption that the entire system can be viewed as one entity. For multiple vessels, this is only valid if the motions of the vessels are closely linked, as, for example, for two vessels that are moored tightly together. If the assumption is not valid, then drift forces should not be included.

5.9.3 Waves

The first order wave forcing conditions applying in the domain can be specified on the Wave dialog.

In **Final computation mode** (see Section 5.3.2), the first order wave forcing will be taken fully into account in the wave pressure computation on the vessel hull. This should only be done when an initial vessel displacement has been achieved in advance, from running a previous simulation in convergence mode.

In **Convergence mode** (see Section 5.3.1), the first order wave forcing will be ignored in the wave pressure computation on the vessel hull. In Convergence mode the first order wave forcing can only be provided if including drift forces, and the first order wave forcing data will for this mode only be applied implicitly as part of the 2nd order drift forces computation.

By default the wave data is set to be included in the warm up and warm down durations as specified on the Time dialog.

The first order wave forcing is specified in one of the following ways:

- Wave file
- Wave parameters

For some computations, the wave data is needed in the frequency domain and the data is transferred between the time domain and the frequency domain using the methods FFT (Fast Fourier Transform) and IFFT (Inverse Fast Fourier Transform). When the computations rely on a Fourier transform of wave data, the user can control the minimum number of time steps from the wave file that should be used for the FFT/IFFT. The number of time steps must be a power of two, i.e., 2^N, and the user selects the power N. The FFT size should be chosen so it represents the minimum number of time steps from the wave file that properly dissolve the waves.

Wave file

Two formats for waves are supported:

- Varying in time, constant in domain
- Varying in time and domain

Regardless of which wave format is used, there is an option for specifying the minimum number of time steps for FFT.

If 2nd order wave drift forces are available and included, and the wave file format is specified as 'Varying in time and domain', you must also provide the Mean wave direction.

Wave file format

Varying in time, constant in domain:
When this format is selected, a time series (.dfs0) wave file is expected temporally, covering the simulation period.

The number of wave conditions must be specified and for each wave condition the waves are specified by a constant main wave direction and a time varying surface elevation. For example, you can choose to have two, when distinguishing between wind-induced waves and swell waves. The input dfs0 file must contain two items for each wave condition (main wave direction and

surface elevation). The value for the wave direction for each wave item pair must be constant throughout the time series.

The meteorological convention is used for the wave direction. The Meteorological convention relates the wave direction to North and express the wave direction as 'coming from' in a clockwise direction relative to North. Waves travelling from North to South have therefore a direction of 0 degrees. This is shown in Figure 1.17:

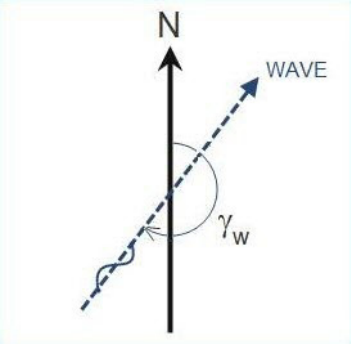


Figure 5.13 Definition of the wave angle convention

Varying in time and domain:

When this format is selected, a grid series (.dfs2) file is expected, covering the simulation period, and matching the domain extent in number of cells horizontally and vertically.

For this format you must provide three items, which should represent a pure wave induced flux field:

- Total water depth H
- P-flux
- Q-flux

This file must come from a pre-executed MIKE 21 model, e.g. MIKE 21 BW, MIKE 21 Flow Model or MIKE 21 Flow Model FM.

If using MIKE 21 BW or MIKE 21 Flow Model (structured grid flow models):

> Then the wave input file is already in (.dfs2) format, and can be used instantly here.

If using MIKE 21 Flow Model FM (un-structured grid flow model):

> Then the wave data will be in (.dfsu) file format, so you must convert it to (.dfs2) format (using the MIKE Zero Toolbox) and very importantly ensure that this resulting (H,P,Q) (.dfs2) file matches the utilized (.dfs2) domain file in horizontal and vertical cell extent.

For a (.dfs2) wave file, there are associated frequency limits. By default the frequency band is [0, 0.5] hertz, which is the frequency band of induced flux due to wave motion.

FFT size

The minimum FFT size (2^N) set in the Wave GUI plays a crucial role in relation to how the M21 MA engine processes the wave data. There are several computations that involves a Fourier transformation of the wave data.

The wave data is the foundation for the computation of the diffraction forces the vessel hull is exposed to due to the wave induced pressure. When the wave format is specified as varying in time and domain, the diffraction forces are calculated in the frequency domain. Therefore, the wave time series is Fourier transformed into the frequency domain to perform the calculations. After the diffraction forces have been calculated in the frequency domain, they are converted to the time domain using IFFT. See Figure 5.14 for an illustration.

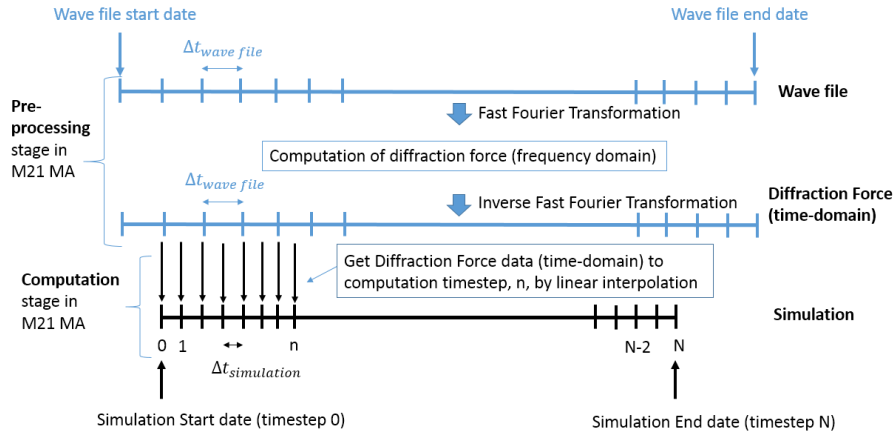


Figure 5.14 Description of interpolation process

When drift forces are included, they are also computed in the frequency domain. A similar approach to the one described for diffraction above is used and, again, this requires conversion of the wave data to the frequency domain.

When the wave format is varying in time, constant in domain, the wave data is also Fourier transformed to shift the wave data spatially to the centre of gravity for each vessel.

In signal processing terms, the wave file represents the available full sample (of wave steps), which the FFT can resolve into a discrete spectrum of frequency bins. The more points (wave steps) included in the FFT, the more frequency bins will be available to identify the frequency spectrum of the sample.

The precision/quality of the wave forcing computation on the vessel hull (diffraction force), will thus strongly depend on how many wave steps are included in the FFT. Therefore, the user can set a minimum requirement for the number of time steps that should be used for FFT.

The time steps of wave data that is used for FFT is determined based on several requirements. The wave file provided must fulfill the following conditions.

- The time interval must cover the simulation period
- The number of time steps must be larger than or equal to than Min. FFT Size

In addition to these, the wave data to use for FFT/FFT must also fulfill a third condition:

- The number of time steps must be a power of 2

To fulfill all three conditions might require more time steps than is provided in the wave file, in which case the data is zero-padded up to the nearest power of 2.

How to set the Min. FFT Size (2^N) will depend on the individual case. The wave data should contain sufficiently many steps to resolve the waves full frequency content by FFT/IFFT and in general it is recommended to use at least 4096 for Min FFT Size. There are two cases, which are presented in the following.

Case 1: Simulation period and wave file period are identical or almost identical

Given that the wave file contains sufficiently many steps to resolve the waves full frequency content by FFT/IFFT (general recommendation of minimum wave steps is 4096), then the Min. FFT Size (2^N) will not play a role here.

Because the simulation and the wave covers the same time axis extent, the engine will use a sufficient amount of wave steps for FFT/IFFT (regardless of how they're identified), hence the diffraction forces used in the simulation will be computed as precise as possible. This case is illustrated in Figure 5.15.

Figure 5.15 Illustration of interpolation for Case 1

Recommendation: no attention needs to be paid to the Min. FFT Size (2^N).

Case 2: Short simulation with long wave file period

It is in cases like these where the Min. FFT Size (2^N) will be **most relevant to apply**.

Here the simulation duration is small, but in order to produce diffraction force data for the simulation timesteps of sufficient quality (include enough steps for FFT/IFFT), many more wave steps than what just covers the simulation period is needed to be processed.

Here a sufficiently high Min. FFT Size (2^N) will help ensure that enough wave steps will be processed in FFT/IFFT for the diffraction forces to be computed with appropriate accuracy. This case is illustrated in Figure 5.16.

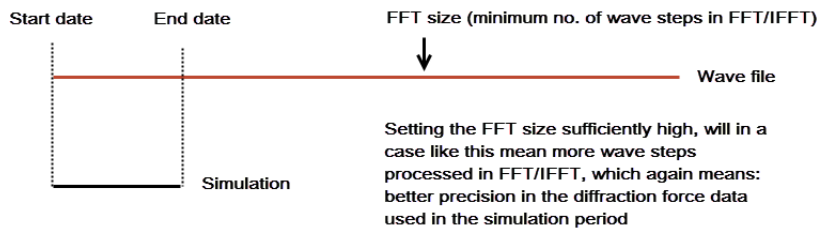


Figure 5.16 Illustration of interpolation for Case 2

Recommendation: In order for the FFT to capture enough of the waves frequency content, it must be assessed if enough wave steps cover the simulation period. If this is not the case, then the Min. FFT Size (2^N) should be increased to a value assessed to be high enough to capture enough frequency content (the general recommendation of minimum number of wave steps is 4096).

Wave parameters

One or more wave conditions must be specified in the grid, and for each wave condition a set of wave parameters is specified.

Each wave condition can be specified in two different ways

- Regular wave parameters
- Irregular wave parameters

If 2nd order wave drift forces are available and included, then a FFT size must be specified.

FFT size

When a wave is specified through wave parameters, there is an option to control the FFT size and this serves the same purpose as when a wave is given in a file.

The wave parameters entered in the dialog for each wave is used to generate a time series of wave data. The computation of drift forces is performed in the frequency domain and this requires the wave data to be Fourier transformed. The accuracy of the FFT method can be controlled by setting the minimum number of time steps that should be used for FFT. In general, it is recommended to use at least 4096 for Min FFT Size.

Regular wave parameters

You have to select a theory from among the three different theories available

- Stokes 1st order
- Stokes 5th order
- Stream function

For the Stokes theory, you have to specify the wave conditions through

- Height, H
- Period, T
- Direction, θ

where θ is the meteorological direction of the wave as specified in Convention of angles.

For the Stream function theory, you have to specify if the wave condition should be defined by the wave period or wave length and through

- Height, H
- Period, T
- Length, L
- Direction, θ
- Number of components

You need to specify if the meteorological or scientific convention is used for defining the wave direction (see Convention of angles).

The number of components refers to the number of Fourier components used in the wave generation (see Fenton (1988) /2/).

Irregular wave parameters

For this type of waves you have to specify both a frequency spectrum and a main wave direction for the unidirectional wave.

You can choose among the following frequency spectra, where you have to specify the listed parameters

- Pierson-Moskowitz
  - Significant wave height, H_{mo}
  - Peak wave period, T_p
- JONSWAP
  - Significant wave height, H_{mo}
  - Peak wave period, T_p
  - Non-dimensional peak shape parameter, gamma
  - Spectral width parameter, alpha
  - Spectral width parameter, beta
- TMA
  - Significant wave height, H_{mo}
  - Peak wave period, T_p
  - Non-dimensional peak shape parameter, gamma
  - Spectral width parameter, alpha
  - Spectral width parameter, beta

Furthermore, you have to specify the minimum and maximum cut-off frequency for the frequency spectrum, and the number of Fourier components. The specification for the frequency discretization determines the Repetition period for the generated wave input.

You also have to specify the initial random number (seed) used in the wave generation calculations. The seed is used for the calculation of the random phases in the Fourier description, and for the calculation of the random wave directions. Thus, you can reproduce the random computations by specifying the same seed.

Finally, you have the option to rescale the truncated spectrum as described in Rescale truncated spectrum.

You need to specify if the meteorological or scientific convention is used for defining the wave direction (see Convention of angles).

Convention of angles

The direction convention for the waves can be one of the following angle conventions

- Meteorological
- Scientific

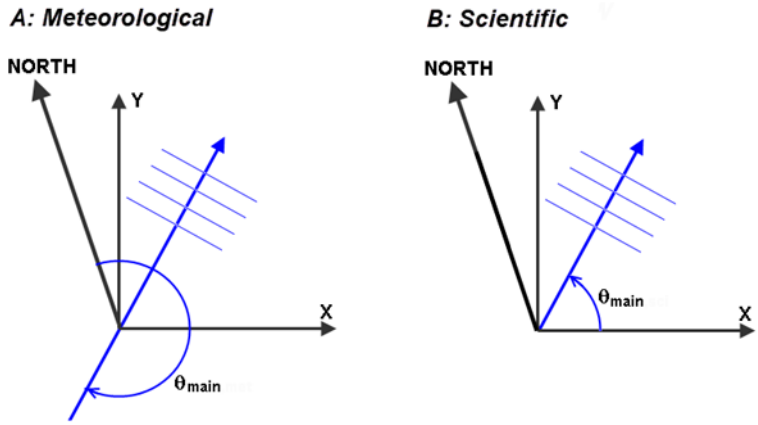


Figure 5.17 Definition of the two types of wave angle conventions

The Meteorological convention relates the wave direction to North and express the wave direction as 'coming from' in a clockwise direction relative to North. Waves travelling from North to South have therefore a direction of 0 degrees. This is shown to the left in Figure 5.17.

The Scientific convention relates the wave direction to the general (or global) x-axis of your mesh file and express the direction the waves are going towards. This is shown to the right in Figure 5.17.

The default angle convention is the meteorological convention.

Repetition period

The repetition period is determined as $1/\Delta f$, where Δf is the frequency interval of the discrete frequency spectrum. The frequency interval is calculated as

$$\Delta f = \frac{f_{max} - f_{min}}{n - 1} \tag{5.1}$$

Here f_{max} is the specified maximum frequency, f_{min} is the minimum frequency and n is the number of components.

Rescale truncated spectrum

As the low frequency part ($f < f_{min}$) and the high frequency part ($f > f_{max}$) of the original spectrum is removed, the resulting integral parameters such as the significant wave height and mean wave periods are altered relative to the input specifications.

If you would like to maintain the significant wave height as specified, then you can choose to re-scale the spectrum. Thus, the total energy in the truncated spectrum is the same as in the original specified spectrum, see Figure 5.18.

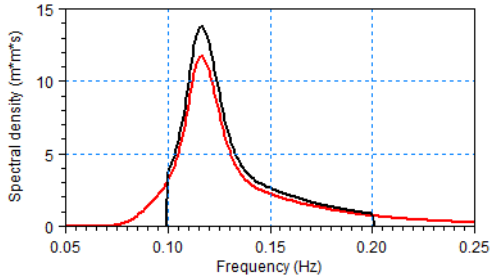


Figure 5.18 Example of the original and rescaled, truncated spectrum. The spectrum is a standard JONSWAP spectrum (i.e. having the shape parameters s_a= 0.07, s_b= 0.09, and g= 3.3). H_{m0}= 2.65 m and T_p= 8.6 s. The minimum and maximum cut-off frequency is 0.1 Hz and 0.2 Hz, respectively.

5.9.4 Current

By default the current data is set to be included in the warm up and warm down durations as specified on the Time dialog.

When a current field is included, it can be provided in 2 ways:

- Speed and direction
- (u,v) components

If providing the current field as Speed and direction, the direction is interpreted as clockwise positive from true north (going to) as seen in Figure 5.19.

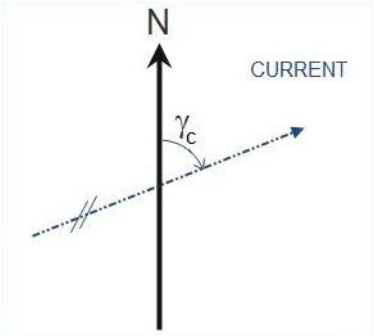


Figure 5.19 Interpretation of directional current data

If providing the current as (u,v) components, the components are interpreted as being with respect to the x and y axes of the domain file. This means you might have to ensure the directions of the components match the grid orientation, dependent on the source used for current data.

Regardless of how the current field is given, these formats are supported:

- Constant in time and domain
- Varying in time, constant in domain (.dfs0) (time series)
- Varying in time and domain (.dfs2) (current field)

At the bottom of the Current dialog, you are to enter drag coefficients for Rear and Front of each vessel, if specifying the current field in (.dfs2) format.

The Drag coefficients are dependent on the Water depth/Draft ratio, and the recommended values are as shown in Table 5.2.

Table 5.2 Recommended drag coefficients

Water depth / Draft	Rear Drag Coefficient	Front Drag Coefficient
1.1	2.25	2
1.3	1.8	1.6
3	1.5	1.1
4.4	1.4	0.9

5.9.5 Wind

By default the wind data is set to be included in the warm up and warm down durations as specified on the Time dialog.

When a wind field is provided it can be given in two ways:

- Speed and direction
- x and y components

If providing the wind field as Speed and direction, the direction is interpreted as clockwise positive from true north (coming from) as seen in Figure 5.20.

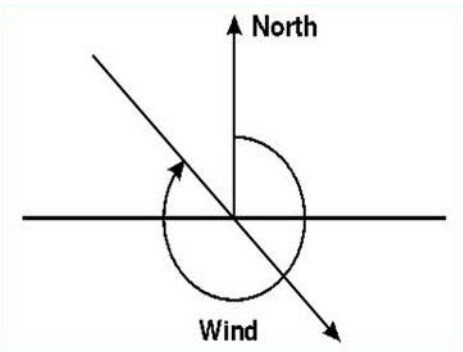


Figure 5.20 Interpretation of directional wind data

If providing the wind as x and y components, the components are interpreted as being with respect to the x and y axes of the domain file. This means you might have to ensure that the directions of the components match the grid orientation, dependent on the source used for wind data.

Regardless of how the wind field is given, these formats are supported:

- Constant in time and domain
- Varying in time, constant in domain (.dfs0)
- Varying in time and domain (.dfs2)

5.10 Convergence Parameters

This dialog is only available in Convergence mode, as specified on the Simulation mode dialog, see Section 5.3.

These parameters defines the conditions in a convergence mode execution:

Max no. iterations is by default set to 100, and this value represents the upper limit of iterations used in a convergence mode simulation.
Each iteration in convergence mode consists of running the simulation with the specified number of time steps and mooring and environmental forcing conditions (wave forcing excluded). Each iteration leads to a new vessel displacement for each vessel, which is then input in the next iteration. This iterative procedure will stop when line convergence is reached.

Line convergence threshold is by default 2.5%, and represents the global stop criteria for the convergence mode simulation:

If

$$100 \cdot \left(\frac{\text{line tension}_i - \text{line pretension}}{\text{line tension}_i} \right) \leq \text{line convergence threshold, for all lines} \quad (5.2)$$

then the convergence simulation will stop at iteration *i*. The above stop criteria applies for all types of mooring lines involved, both vessel-berth lines and vessel-vessel lines.

5.11 Vessel displacements

On this dialog you must supply the initial vessel displacement of the vessels. The vessel displacements can be considered an initial condition. When executing the first convergence simulation, then the vessel displacements will start from zero.

Any initial values for Surge, Sway, Heave, Roll, Pitch and Yaw can be specified, but the idea is that this data should come from the results of a previous Convergence mode execution.

If a convergence mode simulation stops due to successful convergence at some iteration, then the Vessel motion files from the convergence mode execution at the last iteration will contain these six initial vessel displacement values for every vessel being part of the setup.

If vessel motion files exists from a convergence mode execution, the Load button will be active and if clicked it will transfer the data from the last iteration of the vessel motion files into the table.

It may take more than one convergence simulation to actually obtain convergence. In such cases previous convergence vessel displacements can be loaded, so that the next convergence simulation builds on top of previous convergence results instead of starting from zero displacements.

5.12 Outputs

Two classes of outputs can be generated by MIKE 21 MA dependent on the Simulation mode:

- Convergence output
- Final output

If running the final simulation you must load in the final vessel displacement from the convergence results.

5.13 Convergence output

On this dialog you see all the output files specific for the Convergence mode simulation.

These files are all (.dfs0) files with a Relative Item axis. The x-axis will contain integers corresponding to elapsed iterations, and the y-axis will contain the item data.

It is not possible in advance to tell how many iteration steps the convergence output files will contain. If convergence is never reached, the files will contain the maximum number of iterations (see Section 5.10), whereas if convergence does set in, then output files will contain steps up to the iteration step at the point of convergence.

5.13.1 Global files

Line pre-tension deviation:

This is the file which reflects the success of the convergence iteration process. This file contains an item for every specified spatial mooring line, and all these items will at each iteration contain data values representing the percentage deviation between the dynamically computed line tension (at the iteration) and the line pre-tension. If a convergence is successful, then this file will at the last iteration step contain values, which are all smaller or equal the Line convergence threshold on the Convergence parameters dialog, see Section 5.10.

This output file can only be included if mooring lines are defined (see Section 5.8.1).

Line forces:

This file contains an item for every specified spatial mooring line, showing the dynamic computed line force of each iteration.

This output file can only be included if lines are defined (see Section 5.8.1).

Fender forces:

This file contains an item for every specified spatial fender, showing the dynamic computed fender force as a function of the iteration number.

This output file can only be included if there are fenders defined (see Section 5.7).

Bollard forces

This file contains three items for every specified bollard, showing the horizontal and vertical components and the total bollard force over time.

This output file can only be included if there are bollards defined (see section 5.7).

AutoMoor forces

This file contains four items for every specified AutoMoor unit, showing the component forces in X, Y and Z direction and the total bollard force over time.

This output file can only be included if there are AutoMoor units defined (see section 5.7).

AutoMoor XYZ

This file contains six items for every specified AutoMoor unit, showing the displacements X, Y, Z, L, horizontal angle and vertical angle of each AutoMoor unit. Here, Y is the AutoMoor length in the initial AutoMoor direction, X and Z are the deviations from the initial direction on horizontal and vertical planes respectively, horizontal angle is ATAN(X/Y), vertical angle is ATAN(Z/Y), and L is the total length of the AutoMoor.

This output file can only be included if there are AutoMoor units defined (see section 5.7).

DynaMoor forces

This file contains four items for every specified DynaMoor unit, showing the component forces in X, Y and Z direction and the total bollard force over time.

This output file can only be included if there are DynaMoor units defined (see section 5.7).

DynaMoor XYZ

This file contains one item for every specified DynaMoor unit, showing the displacement of each DynaMoor unit.

This output file can only be included if there are DynaMoors units defined (see section 5.7).

Port_Fairlead forces

This file contains three items for every specified port_fairlead, showing the horizontal and vertical components and the total port_fairlead force over time.

This output file can only be included if there are port_fairleads defined (see section 5.7).

Radiation damping

This file contains the radiation damping of the vessel(s) for each frequency. The number of items in the file is equal to the number of degrees of freedom in the system squared. Radiation damping describes the energy lost in a vessel as it creates waves through motion.

This output file can only be included if the filter for irregular frequencies is enabled (see section 5.5).

5.13.2 Vessel specific files

Vessel motion:

This file contains 6 items for the six degrees of freedom for each vessel. The last iteration step in this file contains (if convergence is reached) the most important result of the convergence mode execution: the initial vessel displacement leading to a (sufficiently) even tension distribution among all the mooring lines.

It is this result which is important to get transferred to the initial vessel displacement dialog, when continuing with the Final time-domain simulation.

This output file can always be included.

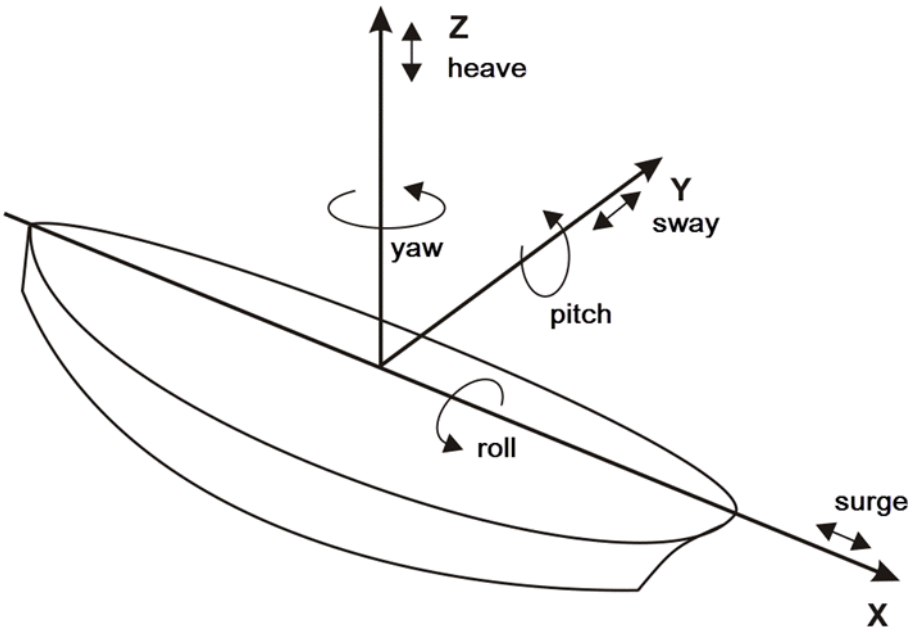


Figure 5.21 Ship motions in 6 degrees of freedom.
Displacements (surge, sway, heave). Rotations (roll, pitch, yaw)

Mooring force on vessel:

This file contains 6 items (3 force items, 3 direction items) representing the force from mooring system on the vessel for each iteration.

This output file can only be included if there are mooring lines, fenders, bollards or chains defined (see Sections 5.5.1, 5.7.2,5.7.1 and 5.8.1, respectively).

Total force on vessel:

For every vessel this file will contain 6 items (3 force items, 3 moment items) due to all forces applied to the vessel.

External forces:

For every external forcing applied (wind, current and 2nd order drift forces) this file will contain 6 items (3 force items, 3 direction items), thus representing the force from each external forcing on the vessel.

This output file can only be included if a current or a wind field or drift forces are included.

Surface elevation:

This file contains the surface elevation at the vessels midpoint for each time step.

This output file can only be included if a wave field is specified.

Diffraction force:

This file contains 6 items (3 force items, 3 direction items) representing the diffraction force on the vessel for each time step.

This output file can only be included if a wave field is specified.

Chain forces:

This file will contain as many items as there are chains declared. The files display the chain force for each.

This output file can only be included if there are chains defined (see Section 5.5.1).

5.14 Final output

On this dialog you see all the output files specific for Final computation mode simulation.

These files are all (.dfs0) files with an Equidistant Calendar Axis. The x-axis will contain the time line extent as specified on the Time dialog, and the y-axis will contain the item data (see Section 5.2).

5.14.1 Global files

Line positions

These files contain three items for the start and end point of each mooring line: their x, y and z coordinates. One file per line is created.

Line forces:

This file contains an item for every specified mooring line, showing the dynamically computed line force at each time step.

This output file can only be included if number of mooring lines > 0.

Fender forces:

This file contains an item for every specified spatial fender, showing the dynamic computed fender force as a function of time.

This output file can only be included if fenders are defined (see Section 5.7.2).

Bollard forces

This file contains three items for each specified bollard, showing the dynamically computed horizontal and vertical component and the total bollard force (see section 5.7.1).

This output file can only be included if there are bollards defined.

AutoMoor forces

This file contains four items for every specified AutoMoor unit, showing the component forces in X, Y and Z direction and the total bollard force over time.

This output file can only be included if there are AutoMoor units defined (see section 5.7).

AutoMoor XYZ

This file contains six items for every specified AutoMoor unit, showing the displacements X, Y, Z, L, horizontal angle and vertical angle of each AutoMoor unit. Here, Y is the AutoMoor length in the initial AutoMoor direction, X and Z are the deviations from the initial direction on horizontal and vertical planes respectively, horizontal angle is ATAN(X/Y), vertical angle is ATAN(Z/Y), and L is the total length of the AutoMoor.

This output file can only be included if there are AutoMoor units defined (see section 5.7).

DynaMoor forces

This file contains four items for every specified DynaMoor unit, showing the component forces in X, Y and Z direction and the total bollard force over time.

This output file can only be included if there are DynaMoor units defined (see section 5.7).

DynaMoor XYZ

This file contains one item for every specified DynaMoor unit, showing the displacement of each DynaMoor unit.

This output file can only be included if there are DynaMoors units defined (see section 5.7).

Port_Fairlead forces

This file contains three items for every specified port_fairlead, showing the horizontal and vertical components and the total port_fairlead force over time.

This output file can only be included if there are port_fairleads defined (see section 5.7).

Radiation damping

This file contains the radiation damping of the vessel(s) for each frequency. The number of items in the file is equal to the number of degrees of freedom in the system squared. Radiation damping describes the energy lost in a vessel as it creates waves through motion.

This output file can only be included if the filter for irregular frequencies is enabled (see section 5.5).

Vessel motion type:

One can choose between 2 possible vessel motion types (this setting will apply for all vessel motion output files - see Section 5.14.2):

- **Relative to displaced position**
  This setting will generate the vessel motions relative to the displaced position of each vessel.

  Initial values in the vessel motion output will with this setting always be: (surge, sway, heave, roll, pitch, yaw) = (0, 0, 0, 0, 0, 0) for each vessel.

- **Relative to initial vessel insertion point**
  This setting will generate the vessel motions relative to original insertion point of each vessel (implicitly this is governed by where you insert the origo of the vessel system in the domain - see Section 5.8.1).

  Initial values in the vessel motion output will with this setting always be:

(surge, sway, heave, roll, pitch, yaw) = the applied vessel displacement for each individual vessel.

5.14.2 Vessel specific files

Vessel motion:

This file contains 6 items for the six degrees of freedom for each vessel, as a function of time.

This output file can always be included.

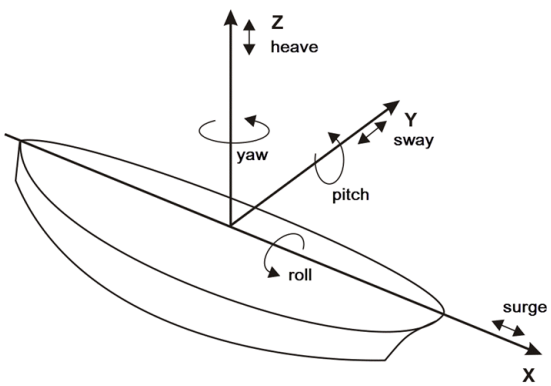


Figure 5.22 Ship motions in 6 degrees of freedom.
Displacements (surge, sway, heave). Rotations (roll, pitch, yaw)

Mooring force on vessel:

This file contains 6 items (3 force items, 3 direction items) representing the force from mooring system on the vessel for each time step.

This output file can only be included if mooring lines, fenders, bollards or chains are defined (see Sections 5.5.1, 5.7.2, 5.7.1 and 5.8.1, respectively).

Total force on vessel:

For every vessel this file will contain 6 items (3 force items in x, y and z directions, and 3 moment items around those axes) due to all forces applied to the vessel.

External forces:

For every external forcing applied (wind, current and 2nd order drift forces) this file will contain 6 items (3 force items, 3 direction items), thus representing the force from each external forcing on the vessel for each time step.

This output file can only be included if a current or wind or drift forces are included.

Surface elevation:

This file contains the surface elevation at the vessels midpoint for each time step.

This output file can only be included if a wave field is specified.

Diffraction force:

This file contains 6 items (3 force items, 3 direction items) representing the diffraction force on the vessel for each time step.

This output file can only be included if a wave field is specified.

Chain forces:

This file will contain as many items as there are chains declared. The file displays the chain force evolution for each time step.

This output can only be include if chains are defined (see Section 5.5.1).

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