

Development

Given the high level of demands on a specialised consultant, we view the development of our software-tools in general and of SHIP in particular as a continuous process. Where possible, we directly implement experience and specific know-how gained during our many projects.

SHIP-MOORINGS has been developed by a team of engineers in the field of ship hydrodynamics, flow and wave hydrodynamics, applied mathematics and system developers. This team has in-depth expertise and experience both in the moored ship field as well as in the design of complex software systems. The team has previous working experience at Delft Hydraulics (including the three former section heads of Harbours, Ship Hydrodynamics and Waves and Currents), the Maritime Research Institute Netherlands (MARIN), The Netherlands Organisation of Applied Scientific Research (TNO) and The National Aerospace Laboratory (NLR). As a team and as individuals they have developed several simulation models, including new or further developments of ship-simulation software for TNO, the Netherlands Royal Navy, Delft Hydraulics and IHC.

SHIP-MOORINGS has been programmed by a group of programmers under the supervision of an experienced software system developer. The latter has previously also been responsible for the software design and implementation of complex refraction-diffraction models, of a 3-D finite-element model for the computation of hydrodynamic forces on floating bodies and of a Navier-Stokes model for simulating breaking waves on coastal defences. He also participated in the EU projects ESPRIT and REDO, designed a Kalman graphical model for the Dutch Government and carried out software design projects for the EU-projects PACE and SAFE.

For Alkyon Hydraulic Consultancy & Research bv, developing and maintaining at a state-of-the-art level for the software-package SHIP-MOORINGS, is an essential task in order to be able to supply high-level specialist advice in the area of water-related infrastructure and management.

The program SHIP has been obtained by the Netherlands Ministry of Transport and Public Works for national projects as well as by the Civil Engineering Faculty of the Delft University of Technology for educational goals.

SHIP-MOORINGS has been designed such that common restriction of mooring models do not apply any more. In such it is a state-of-the-art model that can be used to determine the correct moored ship behaviour even at locations where there is so much wave action that the ship motion are no longer "small" (as normally assumed in traditional moored ship models).

The program has been verified by carrying out extensive basic-simulations for all degrees of freedom and types of mooring systems and by comparison with scale model simulations. More information regarding the verification can be found in the report: "Ship-Moorings, validation document", which can be send to you on your request.

For harbours, marine terminals, floating terminals and offshore structures, optimising the mooring system is important for improving safety and minimising downtime.

Moored objects are subject to external forces in the form of wind, waves, current and interaction effects from passing ships. These forces may have various impacts, including:

- hampering the cargo handling operations due to large motions (downtime)
- damaging the moorings due to large loads and endangering ship's crew and terminal personnel

Optimising the mooring system is a cost-effective measure to reduce these negative impacts. In order to do this, a thorough knowledge and efficient tools in the field of moored ship dynamics are required.

For the assessment of the downtime and the optimisation of mooring systems Alkyon has available the moored ship computer simulation program SHIP-MOORINGS. This is a tool capable of simulating the behaviour of a ship moored to fixed structures (quays, jetties) as well as floating structures (single point or spread mooring systems).

The program is provided with integrated pre- and post-processing tools. Input is possible both through files as well as interactive on-screen while output can be compiled on-screen or presented on paper; also ship motions are animated directly on screen.



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SHIP-MOORINGS

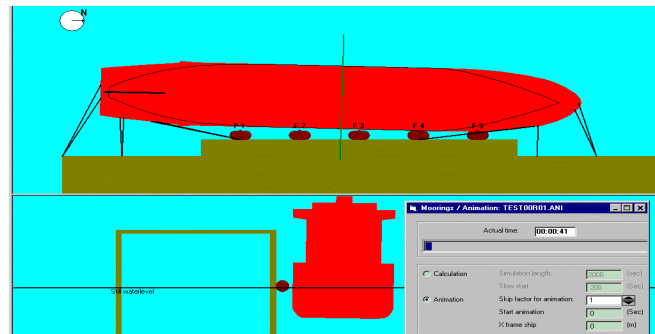
Alkyon's mathematical model SHIP

SHIP-MOORINGS is part of the nautical SHIP suite of programs developed by Alkyon. The programs may be used either integrated or in a stand-alone fashion.

SHIP models:

- the simulation of the manoeuvring of a sailing vessel;
- the horizontal and vertical motions of a vessel sailing in waves;
- motions and mooring forces of a vessel moored to a jetty, quay, SPM or spread mooring system.

In these simulations the effects of in time and space varying wind, waves, currents and water depths can be considered. The influence of rudder(s), propeller(s), bow and stern thrusters, tugs, mooring lines and fenders are also included.



Special features

SHIP-MOORINGS has been designed in a way that it is also possible to design a safe berth at mooring locations where the environmental conditions are harsh. Special features allowing this are:

- The forces on the ship are dependent on the actual ship's location and orientation (commonly moored ship models assume the motions of the ship to be small and keep the relative direction of external forces constant).
- Fender forces are applied at the correct point-of-contact in the three-dimensional space (commonly this is not the case, see above).
- Forces also depend on the slowly varying ship motions themselves.
- Motions, velocities and accelerations are computed and analysed for any location on the ship.
- The program produces an animation of the ship motion, which is especially important for analysing the behaviour of vessels moored to SPM-like terminals.
- Multiple wave components (as present in harbours or with swell and wind waves) can be applied as well as so-called "long" waves, which the model computes.
- Directional wave spreading can be applied on both short and long waves.

- "Special" forces can be applied in the form of time series, like for instance passing ship forces.
- All parameters (wind, waves, current, water level and special forces) may vary in time and place.

Computations

The ship motions at berth are computed in the time domain. The set-up of the system is such that there is no limitation for large horizontal motions. The ship may travel any horizontal distance or change any magnitude of heading.

SHIP-MOORINGS solves the impulse response function for ship motions in the time domain as derived by Cummins (1962). The equation describes the motion of the ship in 6 degrees of freedom ($x, y, z, \phi, \theta, \psi$) in the time domain. The hydrodynamic response characteristics of the ship are based on 3-D diffraction theory in the frequency domain. The transfer into the time domain is according to Oortmerssen (1976). The low frequency second order wave exciting forces on shallow water are modelled according to Pinkster (1980).^{references}

External forces include wave exciting forces, hydrodynamic reaction forces, hydrostatic reaction forces, hydrodynamic viscous forces, wind forces, current forces and mooring forces.

Wave exciting forces include irregular first order waves, second order (bound) long waves which are very important for large vessels and mean wave drift forces, important for ships moored at buoys.

Coefficients for the higher frequency hydrodynamic reaction are applied using retardation functions as described by Cummins. These enable the associated forces to be computed in terms of the motions of each mode up to that moment.

The motion computations are carried out for the ship's centre of gravity. Motions at other locations are computed in the post-processor assuming that the ship is a rigid body.

references

Cummins, W.E., 1962; *The impulse response function and ship motions*; Symposium on ship theory, Institut für Schiffbau der Universität Hamburg, Hamburg, Germany, 25-27 January 1962:

Oortmerssen, G. van, 1976; *The motions of a moored ship in waves*; Thesis; Delft University of Technology, June 1976.

Pinkster, J.A., 1980; *Low frequency second order wave exciting forces on floating structures*, Thesis; Delft University of Technology, October 1980.

Input Data:

Ship data

Ships can be selected from a database within the program. The ships characteristics include:

- 3D form description for ship-fender interaction
- hydrostatic and mass/inertia properties
- static flow force coefficients (function of angle of attack)
- dynamic flow force coefficients (rotational, damping)
- wind force coefficients (function of angle of attack)
- ship dynamic characteristics added mass, wave transfer functions, retardation functions; these data have been computed with a 3D-diffraction model.

Environmental data

- Bottom schematisation – Water depths in a user defined rectangular grid.
- Current (including dynamic effects) – U- and V-components of the current velocity in a user defined rectangular grid.
- Wind (including gusts) – U- and V-components of the wind speed in a user defined rectangular grid.
- Wave parameters – Spectral parameters, wave direction and significant wave height for multiple wave systems.

Mooring data

- Location of fenders.
- Location of mooring.
- Fender characteristics – Type of fender.
- Non-linear mooring line characteristics – Line type, material, pretension, diameter of line, length of line.

Output

Printed output

- Ship's motions in six degrees of freedom.
- Ship' velocities (u, v and r).
- Wind forces.
- Wave forces.

Post-processing data

- Motions in six degrees of freedom at each desired location on the ship.
- Velocities and accelerations at each desired location on the ship.
- Line forces.
- Line extensions.
- Fender forces.
- Fender deflection.
- Spectral analysis of motions, velocities and accelerations.
- Spectral analysis of line forces and fender forces.

- Exceedance distributions of motions, velocities and accelerations.
- Exceedance distributions of line forces and fender forces.

Animation data

- Ship motions - x-y motion and y-z motion at each desired cross-section.

Simulation process:

Integration module based on Gear's BDF method with:

- Good solutions for stiff systems.
- Self-computing time step – The time step is computed such that the required error level is achieved. This way, results are obtained with a minimum of computational effort.
- Solving of the system of equations each time step.
- Error analysis each time step.

Time varying conditions for:

- Wind-, Wave- and current conditions.
- Water depth (Tide simulation).

Each time step evaluation of:

- Environmental conditions, dependant on the ship's actual position.
- External forces like line forces, fender forces, wave forces, wind forces.

Generating output data at fixed time intervals

