SHIP-MOORINGS

Alkyon's computer model for design and optimisation of moorings in harbours and at sea terminals

1 Introduction

SHIP-MOORINGS is a computer program that simulates the behaviour of a moored ship or a floating moored object under conditions of wind, waves and current.

The program is provided with pre- and post-processing tools. Input is possible both through files as well as interactively on-screen while output can easily be compiled on-screen and presented on paper. Results of simulations can also be animated on screen.

SHIP-MOORINGS has been primarily developed as a design tool for ship-related infrastructure. Such infrastructure is developed with increasingly smaller margins and under increasingly difficult site conditions. Therefore it is important be able to simulate the entire ship operation including arrival, berthing, behaviour at berth and departure. In order to anticipate to these demands we have developed SHIP-MOORINGS as part of the three-dimensional simulation model SHIP. This is an integrated ship-simulation suite which simulates the manoeuvring ship (*SHIP-NAVIGATOR*) as well the moored ship (*SHIP-MOORINGS*).

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.

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.

2 Input

Data for SHIP-MOORINGS may be entered within the interface or with an ASCII editor directly in the input files. The following input files are required:

- Layout drawings to assist input and provide animation of results:
  - berth
  - ship

- Ship data:
  Ships can be selected from a database within the program. One or more ships are included in the delivery and more ships can be obtained when required. 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 force transfer functions, retardation functions; these data have been computed with a 3D-diffraction model.

- Wave data :
  Several main wave systems (each with a different direction) may be input. This allows for simultaneous wave attacks by for instance sea waves, swell waves, free long waves etc. For <u>each</u> main wave system it is possible to:
  - define the character by a JONSWAP spectrum, characterised by significant wave height, peak period and enhancement factor
  - use longcrested or shortcrested (directionally spreaded) waves;
  - define various secondary wave systems, related in phase to the main wave system; this allows for the modelling of reflected and diffracted waves, all originating from the same offshore wave system
  - include the effect of bound long waves
  - include the mean wave drift force

  Additional features allow the wave systems to be defined by multiple JONSWAP spectra, or by a user-defined spectrum, or through pre-processed waveforce time-series. For some wave parameters the wave height may also vary with the water level.

- Other environmental data :
  All these data may vary their magnitude and direction (where applicable) in time and space, they include:
  - wind (time variation allows for modelling of gustiness)
  - current
  - water level

- Mooring data:
  - mooring line layout
  - individual line characteristics
  - fender layout
  - fender force characteristics

Wind and current may vary both spatially as well as in time. Water depth may also vary spatially (the average depth over the ship's length is used in the computation).

Non-linear mooring line and fender force characteristics can be stored in an on-line accessible database for easy access from within the program. Mooring layout and choice of types and size of lines and fenders can be defined from within the interface and is visualised on screen during input to avoid errors.

In case of buoy/catenary mooring systems, their characteristics have to be computed off-line and entered as force-displacement characteristics in the model. At this moment we are working to integrate this in a future release of SHIP-MOORINGS.

3 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, ϕ, θ, ψ) 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.

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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.

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.

4 Output and post-processing

Output is generated in he form of an ASCII file, a binary file and an animation file. The binary files are accessible through the post-processing program PostMoorings.

Through PostMoorings it is possible to present for:
- the six motion components and their derivatives (velocity, acceleration)
- each individual mooring line
- each individual fender
- for any interval of the simulation
- with respect to zero or mean,

the following parameters in tabular form:
- statistical values (minimum, maximum, mean, RMS, $H_{1/3}$, $H_{10\%}$, $H_{5\%}$, etc.)
- spectral values (m0, m2, m4)

The motions, velocities and accelerations are standard presented for the centre of gravity, but may also be computed for any other number of points of interest (e.g. motions of the manifold, accelerations at container lashings etc., ramp velocities).

Besides the tabular form the output is also presented graphically in the form of:
- time series
- spectra
- exceedance curves

Finally from each simulation also an animation file is made. This can be viewed from within the SHIP-MOORINGS interface. It shows the ship from top-view as well as in cross-section with adjacent the quay or jetty. The location of the cross-section and the speed of replay can be changed during the animation.

5 Quality

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 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.

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 can be used to determine the correct moored ship behaviour even at locations where there is so much wave actions that the ship motion are no longer "small" (as is normally assumed in traditional moored ship models). Special features allowing this are:

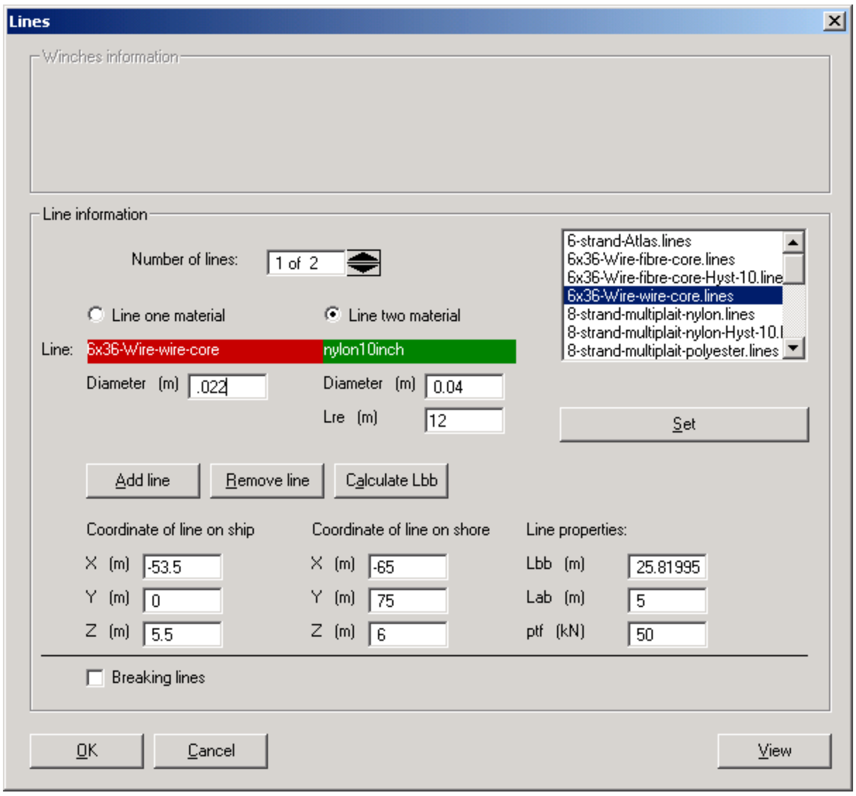
- the forces on the ship are dependent on the actual ship's location and orientation (commonly moored ship models assume the motions of the ship to be small and keep the relative direction of external forces constant)
- fender forces are applied at the correct point-of-contact in the three-dimensional 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 the program allows for the application of special fender constructions and winch layouts
- 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 as well 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

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.

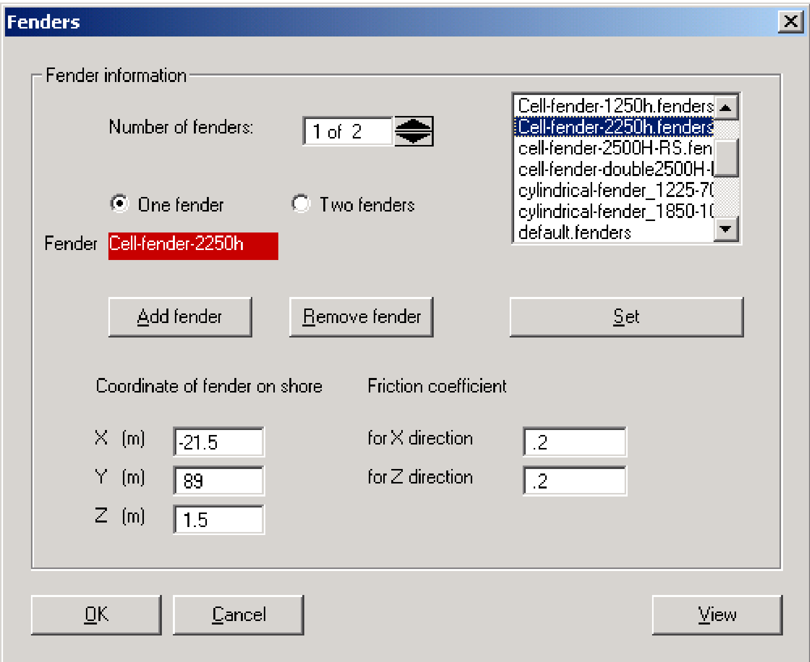
The program has been verified by carrying out extensive basic-simulations for all degrees of freedom and types of mooring systems and by comparison with scale model simulations. Presently many simulations have been carried out with SHIP-MOORINGS using many mooring systems and for many environmental conditions.

Examples of input SHIP-MOORINGS

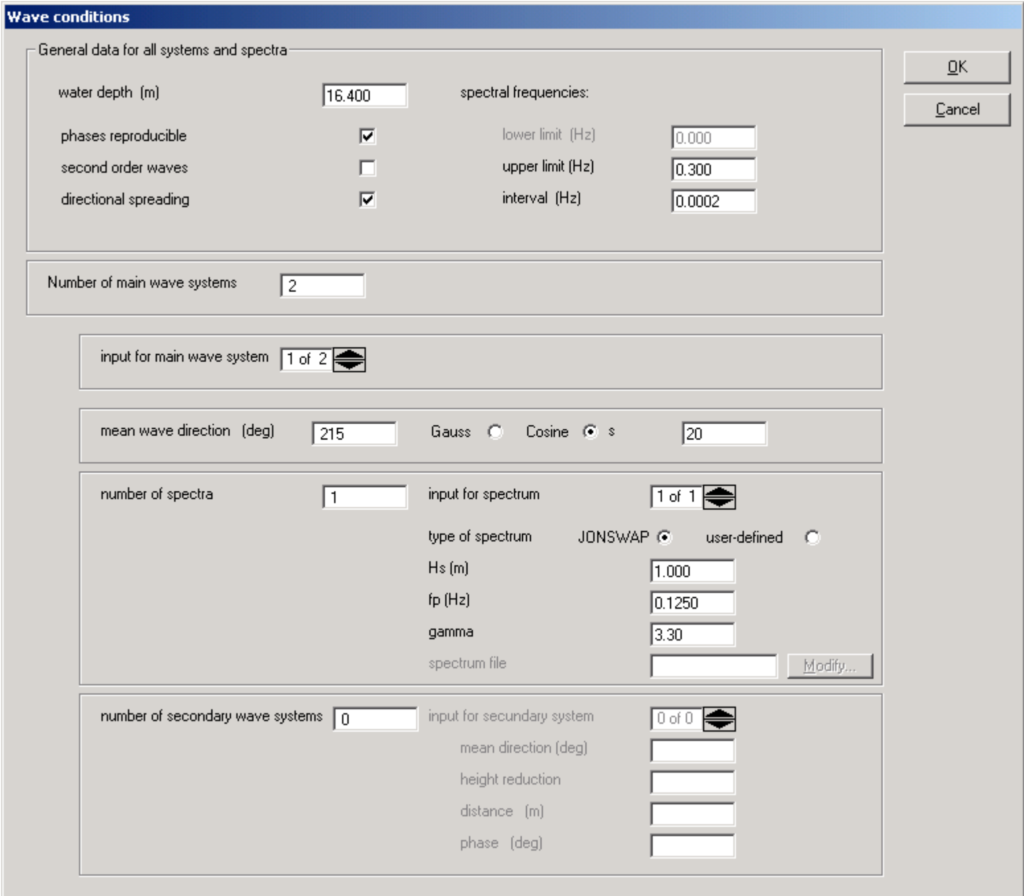
- Definition of Mooring lines



- Definition of fenders

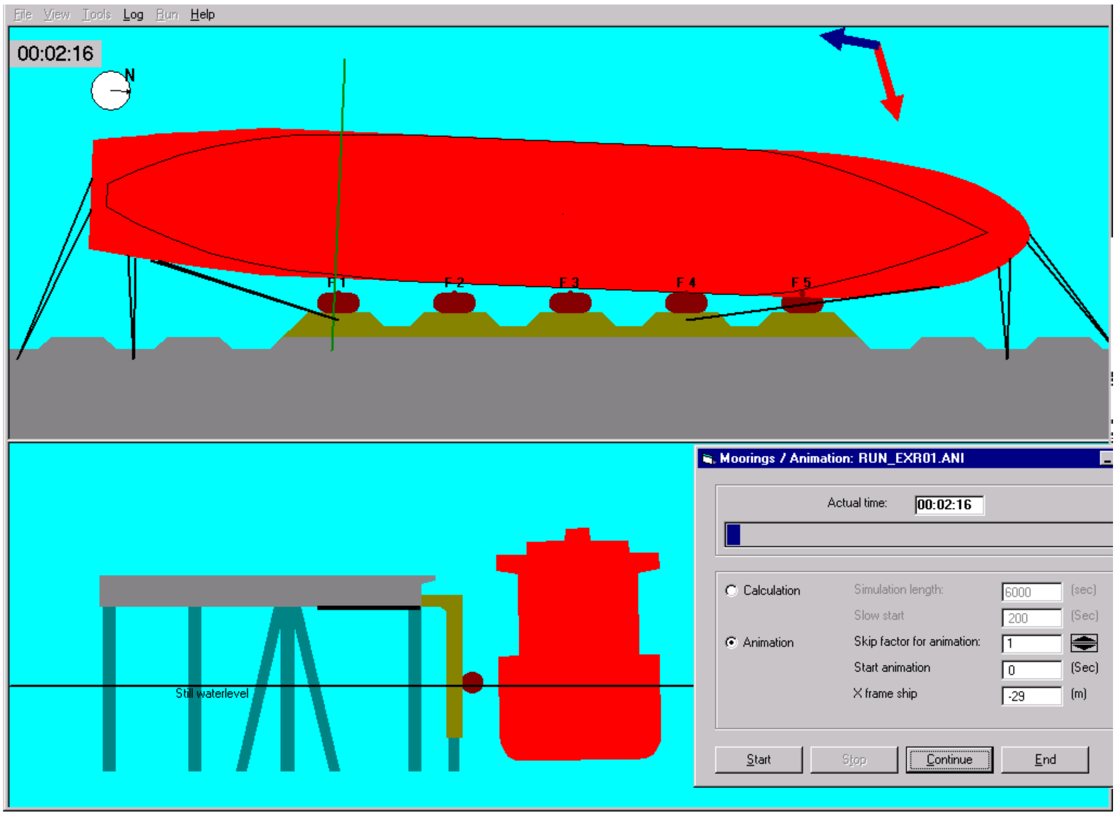


- Definition of waves



Examples of results

- Animation of motions



- Printed Output

```
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File  Edit  Format  Help
        Navigator Version: 5.0.3         ALKYON Hydraulic Consultancy & Research

 Date:   4- 9-2003
 Time: 12:33:42

Run identification : R01

     FILENAMES
Ship        : T:\ship\v5.03\Maritime\default.dsf
Tug         : R:\R1201\test\v5.03\Moorings\run03\tug.par
Current     : R:\R1201\test\v5.03\Moorings\run03\current.par
Wind        : R:\R1201\test\v5.03\Moorings\run03\wind.par
Waves       :
Swell       :
Depth       : R:\R1201\test\v5.03\Moorings\run03\bottom.par

   time          x          y          z          phi        theta        psi           u       
    (s)        (m)        (m)        (m)        (deg)        (deg)       (deg)      (Knots)     (Knot
 200.00       0.96      98.43      -1.22      0.31325     -0.00768    89.26184    -0.04798     0.119
 200.80       0.94      98.48      -1.22      0.36884      0.12257    89.38220    -0.03994     0.099
 201.60       0.93      98.51      -1.22      0.36911      0.23945    89.48331    -0.00886     0.072
 202.40       0.94      98.53      -1.23      0.33429      0.28510    89.52740     0.03340     0.020
 203.20       0.96      98.53      -1.24      0.29893      0.21406    89.50525     0.06912    -0.046
 204.00       0.99      98.50      -1.25      0.27854      0.02807    89.44009     0.08293    -0.112
 204.80       1.02      98.44      -1.27      0.26147     -0.21024    89.37296     0.06648    -0.165
 205.60       1.04      98.36      -1.29      0.21944     -0.40080    89.34684     0.02113    -0.192
 206.40       1.04      98.29      -1.33      0.12471     -0.45351    89.39494    -0.04037    -0.177
 207.20       1.01      98.22      -1.37     -0.02818     -0.33314    89.52818    -0.09637    -0.121
 208.00       0.97      98.19      -1.40     -0.20441     -0.07755    89.72577    -0.12478    -0.042
 208.80       0.92      98.19      -1.41     -0.33231      0.21741    89.93934    -0.11336     0.033
 209.60       0.88      98.21      -1.37     -0.33374      0.43711    90.11253    -0.06591     0.088
 210.40       0.86      98.25      -1.29     -0.16857      0.49522    90.20644    -0.00055     0.109
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```
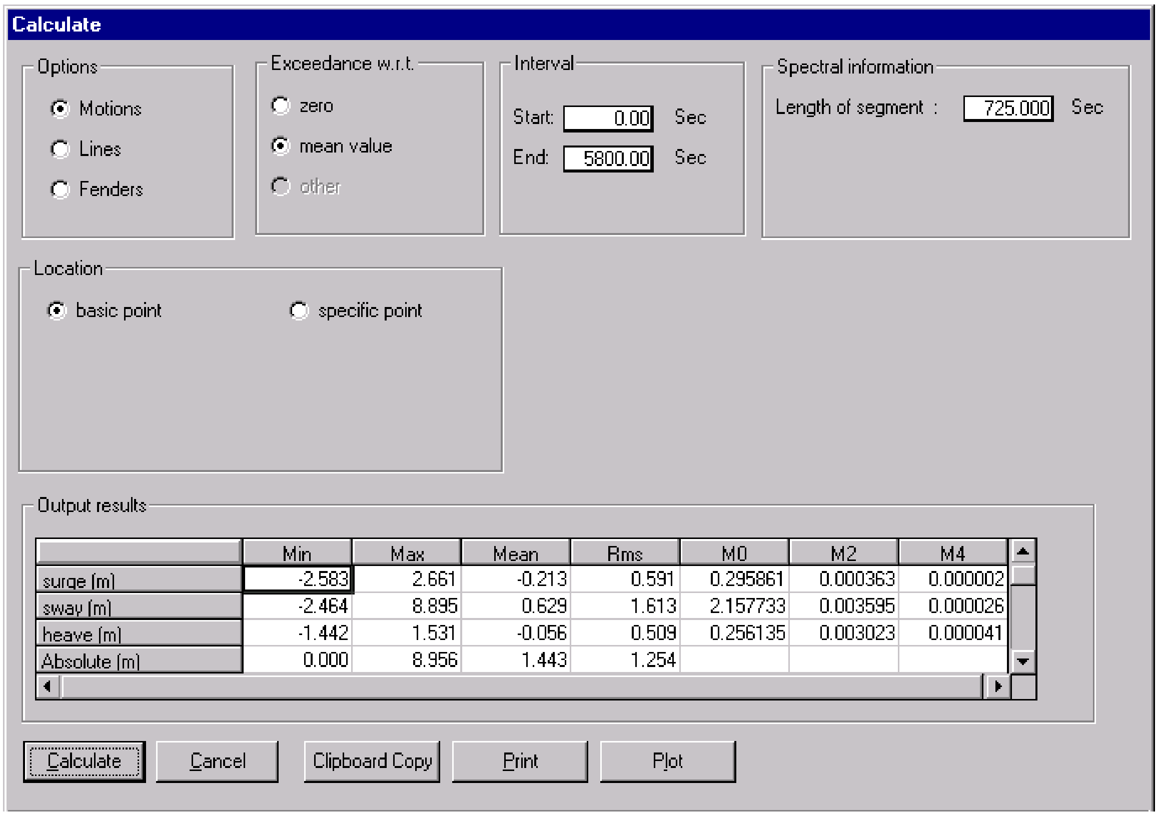
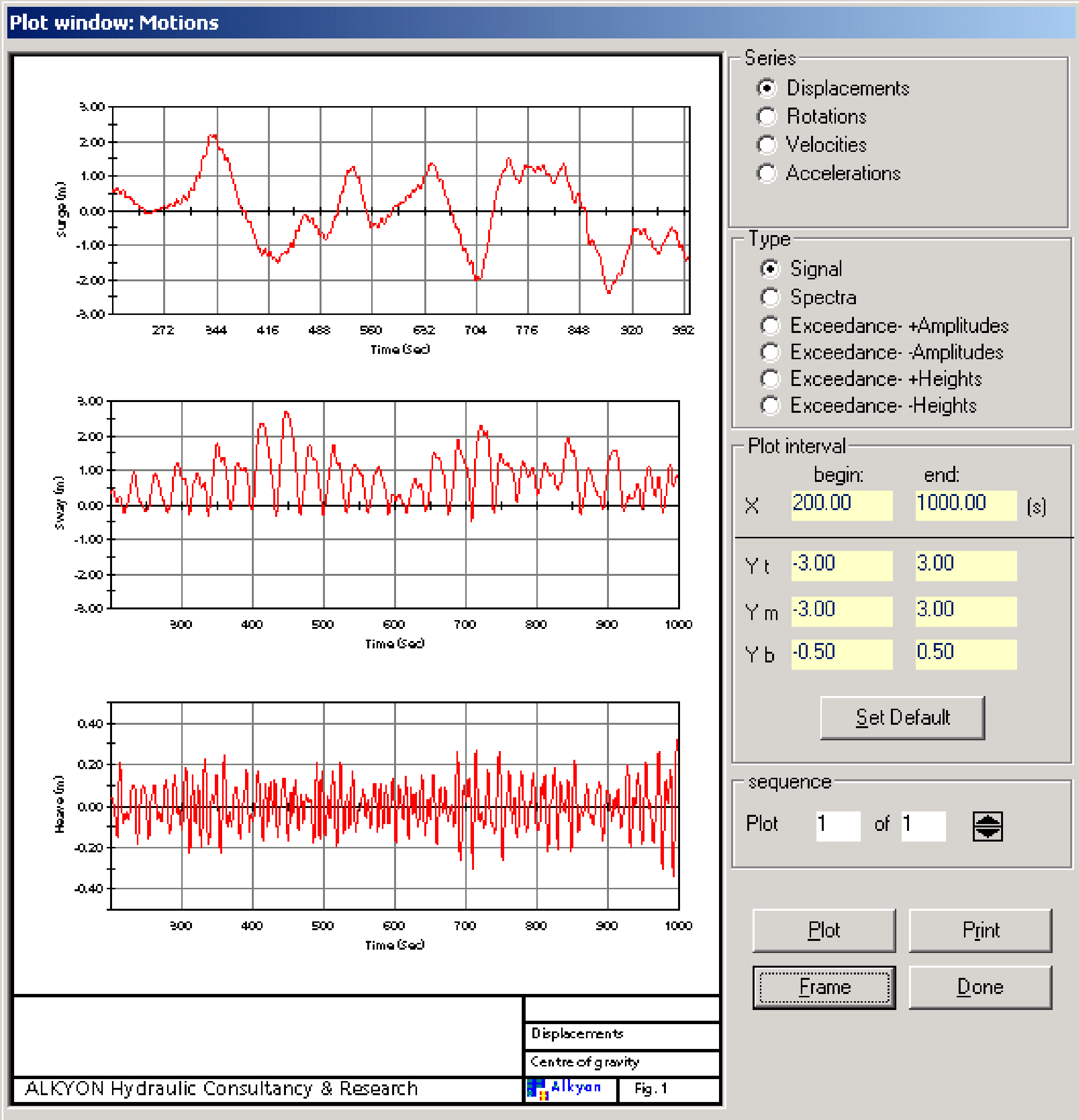

- Statistical analysis in PostMoorings

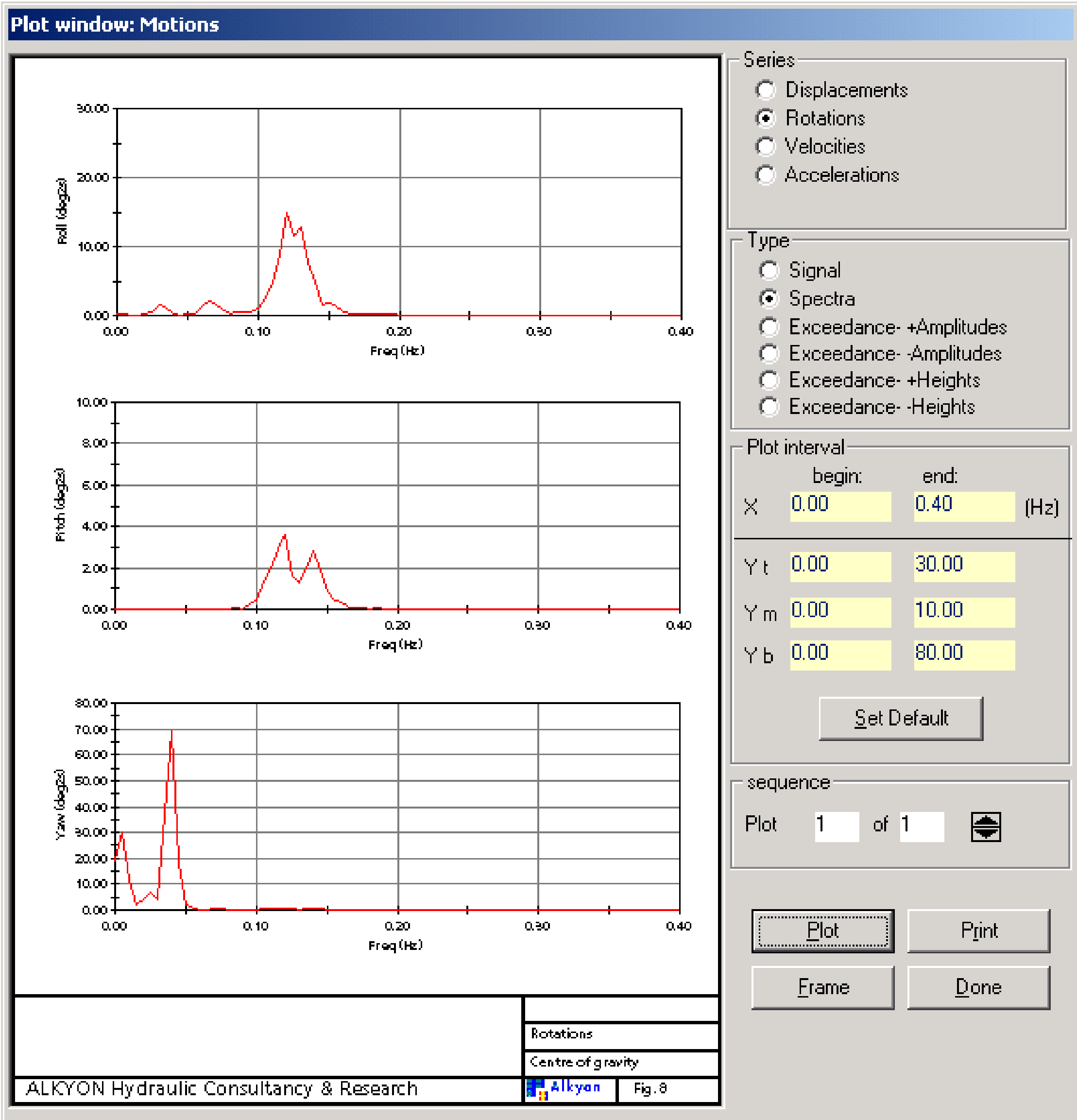


	Min	Max	Mean	Rms	M0	M2	M4
surge (m)	-2.583	2.661	-0.213	0.591	0.295861	0.000363	0.000002
sway (m)	-2.464	8.895	0.629	1.613	2.157733	0.003595	0.000026
heave (m)	-1.442	1.531	-0.056	0.509	0.256135	0.003023	0.000041
Absolute (m)	0.000	8.956	1.443	1.254			

- Plot of timeseries in PostMoorings



- Plot of spectra in PostMoorings



- Plot of exceedance distribution in PostMoorings