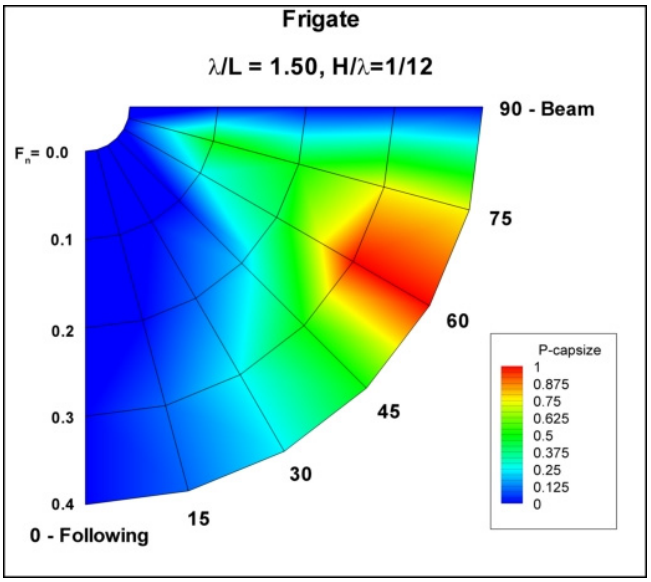
Seakeeping and manoeuvring behaviour of ships in waves and wind

MARIN internal use only

FREDYN

The computer program FREDYN simulates the dynamic behaviour of a steered ship subjected to waves and wind. All six degrees of freedom are computed in the time domain, where the motions can be large up to the point of capsize. Non-linearities arise from rigid-body dynamics with large angles and fluid flow effects. A non-linear strip theory approach is used to compute the hydrodynamic forces acting on the hull. The program is intended to be used in the initial design stage when model test data are not available. Both intact and damaged ship can be dealt with.



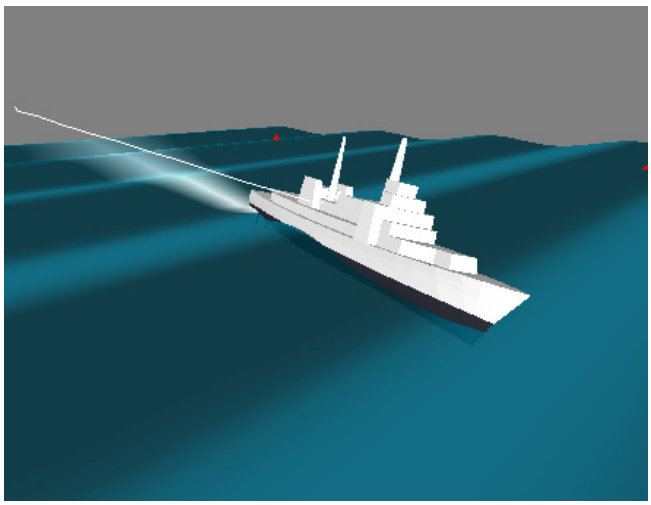
Capsize probability of a frigate as function of the wave direction and Froude number

Computational approach

In the initialisation part the hydrodynamic coefficients are calculated for six degrees of freedom. From the geometry of the hull, rudders, bilge keels and propellers coefficients (mass, added mass, radii of gyration, damping retardation functions, buoyancy forces and moments, propeller and rudder forces, bilge keel effects) are determined.

In the time domain simulation the ship motion components are determined from a set of six coupled differential equations of motion. Integration of the calculated accelerations provides the ship velocities and a second integration leads to the ship position at each time step. The total forces are divided into the following contributions: diffraction, Froude-Krylov, radiation, viscous damping, buoyancy, rudder, propeller, wave and wind forces. The program can handle regular waves and irregular long and short-crested seas. Wind can also be taken into account by specifying a constant velocity, or a wind spectrum for modelling wind gustiness. The behaviour of the ship depends on the type of manoeuvre specified and on the characteristics of the auto pilot or the human helmsman.

For damaged ships, a Bernoulli type method is used to compute water ingress through openings in the hull. The forces due to the mass of the ingressed water are added to the total forces, including inertia effects.



Visualisation of a frigate sailing in stern quartering seas

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Input

The input consists of:

- The geometry in terms of 21 frames or a 3D surface mesh
- Internal compartments for damage calculations and hull openings
- Draught aft and forward
- Weights
- Resistance curve and propeller characteristics
- Geometry of rudders and bilge keels
- Wind data
- Wave spectrum type, significant wave height and average period
- Initial position and speed
- Type(s) of manoeuvre (automatic pilot, constant rudder angle, meander, overshoot, zig-zag, harmonic oscillation human navigator)
- Characteristics of the automatic pilot or human helmsman

Output

The output at each time step consists of:

- The ship's position
- The velocities and rotation rates for six degrees of freedom
- The rudder angles
- The force and moment contributions of the different components
- Statistics of all quantities at the end of each run

Validation

FREDYN has been validated against model tests for mainly naval ship types. For frigate-type hull forms in particular, both excitation forces and motion response in waves have been considered in detail, including conditions leading to capsize. Besides the seakeeping behaviour, also the manoeuvring behaviour of different ship types has been correlated extensively with model test results. Validation material for damaged ships is available as well.

Applications

FREDYN has been developed for the initial design stage of ships, such as frigates. It can be used to analyse the manoeuvrability characteristics in calm water or in waves, as well as the seakeeping performance in moderate to severe seas. Also, capsize risk assessment and survivability studies can be performed, both for intact and damaged ships.

References

- Hooft, J.P.; "Mathematical Description of the Manoeuvrability of High-speed Surface Ships", MARIN report No. 47583-1-MO, Wageningen, 1987.
- De Kat J.O. and Paulling J.R.; "Prediction of Extreme Motions and Capsizing of Ships and Offshore Vehicles", Proc. of the 20th OMAE Conference, Rio de Janeiro, June 2001.

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