

1. General

The wind module is part of the aNySIM program with which simulations can be performed with an unlimited number of bodies. The wind module calculates each timestep the wind forces on each body. The wind environment (wind speed and direction) is calculated before the actual simulation starts. The wind forces are calculated for six degrees of freedom.

2. Wind environment

The wind environment, comprising wind speed and direction, is calculated before the actual simulation starts. This means that timetraces are generated with a timestep equal to the aNySIM communication timestep. During a simulation the wind environment at a certain timestep is found by linear interpolation in the wind environment timetrace.

Please note that the wind module is only called once per communication timestep of aNySIM, i.e. the wind module is not within the iteration loop of the Runge-Kutta solving method.

The timetraces may contain constant or varying wind speed and direction, or the user may supply timetraces of the wind environment.

The following options are available for the generation of the wind environment timetraces:

For the wind speed:

- constant;
- wind spectrum:
 - Harris;
 - API;
 - Ochi;
 - Wills;
 - NPD;
 - Davenport;
 - user supplied spectrum;
 - none
- user supplied timetrace.

For the wind direction:

- constant;
- direction spectrum:
 - white noise;
 - user supplied spectrum;
- user supplied timetrace.

The result of selecting the "none" option for a spectrum is that the wind speed or direction remains constant.

Any combination of wind speed and direction is possible. For instance, to combine a varying wind speed with a constant wind direction a wind speed spectrum should be selected (other than "none") together with a "none" direction spectrum. Vice versa, a constant wind speed

and a varying wind direction can be generated with a "none" speed spectrum in combination with a white noise or user supplied direction spectrum.

In the user supplied timetrace both the wind speed and direction are present. As the signals in this timetrace comprise their mean and varying parts, it is possible to apply a changing mean wind speed and/or direction. This may be useful to simulate a wind squall.

For the generation of the wind environment timetraces a generic wind library has been used. This generic library can be found at the following directory: I:\Mtd\Dvf 6.6\Wind_v2005_0. In the same directory documentation can be found with descriptions of the various theoretical wind spectra [Ref. 1].

The wind environment timetraces are generated by summing up a finite number of harmonics:

$$X(t) = X_0 + \sum_{i=1, N} X_i \cos(\omega_i t + \varepsilon_i)$$

where: X_0 mean wind speed or direction
 X_i amplitude of the i-th harmonic
 ω_i frequency of i-th harmonic
 ε_i phase of i-th harmonic

The amplitudes of the harmonics are derived from the speed or direction spectrum:

$$X_i = \sqrt{2 S_X(\omega) d\omega}$$

where: $S_X(\omega)$ spectral density of wind speed or direction
 $d\omega$ frequency step

The frequency step $d\omega$ depends on the duration of the simulation:

$$d\omega = \frac{2 \pi}{\text{duration}}$$

The number of harmonics N is selected such that it is a power of 2, in order to use the Fast Fourier Transform efficiently, and that it is equal to or larger than the number of timesteps of the simulation.

The maximum frequency which is used is then $\omega_{\max} = N \times d\omega$. If a user supplied spectrum is used and its maximum frequency is less than ω_{\max} the amplitudes of the involved harmonics are set to zero.

The harmonics frequencies ω_i are found by linear interpolation in the user supplied spectrum.

The phases ε_i of the harmonics are random. The inputted seed numbers are used to initialize the random number generators.

If the wind shielding option is applied one vessel may experience the influence of one other vessel on the wind speed and direction. Both the vessel which experiences the influence (the "downstream" vessel) and the vessel which causes this influence (the "upstream" vessel) must be selected by the user. The underlying model has been taken from the Shuttle program [Ref. 2] and is based on modeltests in the windtunnel of the NLR [Ref. 3].

In the windtunnel tests the wind wake field of a tanker was measured for a range of headings w.r.t. the wind direction at a certain distance behind this tanker. An analytical method scales and extrapolates the measured wakes to any other distance behind the upstream vessel. Because the wind speed and direction in the wind wake is position dependent the downstream vessel may be split-up in a number of segments, each with its own wind coefficients. Then the wind wake is calculated at each segment centre, the segment wind forces are calculated and summed to obtain the total vessel wind forces.

It must be noted that the wind shielding model is only applicable to a configuration with two tankers in tandem position.

3. Wind forces

The aNySIM wind module calculates the wind forces for six degrees of freedom. The following formulas are used:

Surge wind force:	$F_x = \frac{1}{2} \rho C_{FX} U^2 A_f$
Sway wind force:	$F_y = \frac{1}{2} \rho C_{FY} U^2 A_l$
Heave wind force:	$F_z = \frac{1}{2} \rho C_{FZ} U^2 A_l$
Heel wind moment:	$M_x = \frac{1}{2} \rho C_{MX} U^2 A_l L_{pp}$
Trim wind moment:	$M_y = \frac{1}{2} \rho C_{MY} U^2 A_f L_{pp}$
Yaw wind moment:	$M_z = \frac{1}{2} \rho C_{MZ} U^2 A_l L_{pp}$

where: ρ air density (normally 0.00125 ton/m³)

U relative wind speed

A_f front wind area

A_l side wind area

L_{pp} vessel length

The relative wind speed accounts for the vessel velocity and, if wind shielding is applied, the velocities in the wind wake.

The wind coefficients C_{FX} , C_{FY} , C_{FZ} , C_{MX} , C_{MY} and C_{MZ} are to be supplied by the user in a file, see the input description for its format. With these coefficients also the reference height, to which the coefficients apply, must be given.

The wind module checks whether the reference height of the coefficients is equal to the reference height of the user supplied spectra or timetraces. In case of a standard spectrum the reference height is set at 10 m above sea level.

If the reference heights are different the wind module reports an error message and aNySIM will stop