Introduction to Hydrodynamic Analysis with Ansys Aqwa

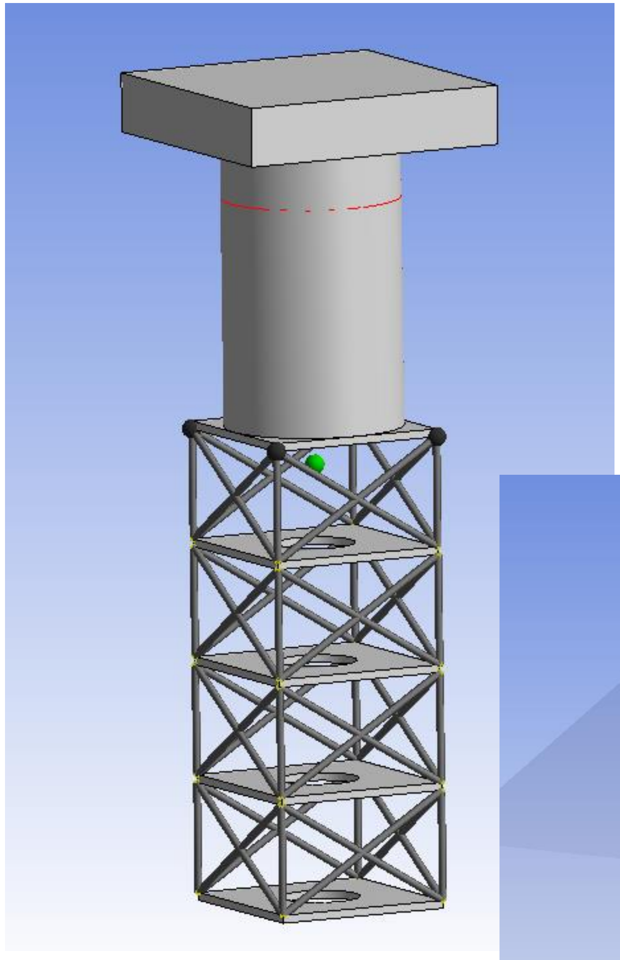
Module 08: Slender Bodies, Drag Linearization and Nonlinear Drag

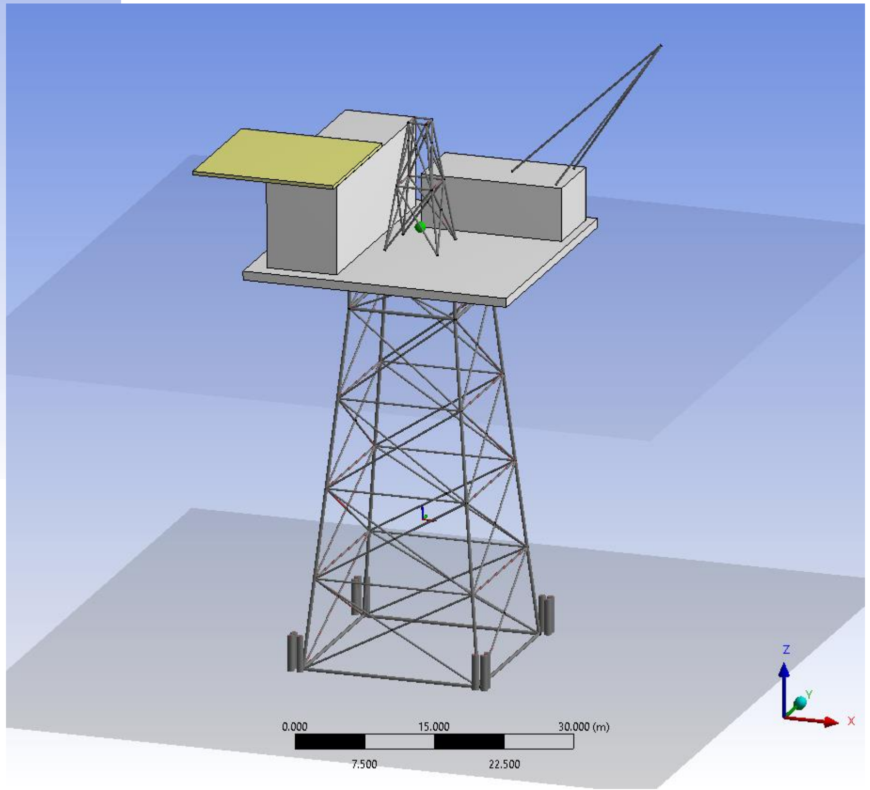
Release 2021 R2

Ansys

Slender Body Modelling

- In the previous lectures we have only looked at structures with a significant volume displacement that requires the utilization of panel elements to include the effects of wave diffraction and radiation.
- Aqwa can also include slender bodies. For these it is assumed that there will be no interference effect on the approaching wave, and that loading can be described in a simple formula that includes both viscous drag and added mass effects.





Morison Elements

Recap: hydrodynamic forces for non-diffracting structures (modelled with Morison elements)

- For slender cylindrical elements ($\frac{D}{\lambda} < 0.2$, in which D is the element diameter and λ is the wavelength) the hydrodynamic force F (including drag) per unit length can be calculated using the Morison equation:

$$F = \underbrace{\rho\Omega a_w}_{\text{Froude-Krylov}} + \underbrace{\rho C_a \Omega a_w}_{\text{Wave inertia}} - \underbrace{\rho C_a \Omega \ddot{X}}_{\text{Radiation}} + \underbrace{\frac{1}{2}\rho C_d D V|V|}_{\text{Drag}}$$

  - a_w and $\ddot{X}$ are the accelerations of the flow and of the body, respectively
  - C_a and C_d are the added mass and drag coefficients of the element
  - V is the relative velocity between the flow and the body
  - Ω is the volume of the element (per unit length).

- The Froude-Krylov and wave inertia terms are sometimes combined and written in terms of the inertia coefficient, $C_m = 1 + Ca$

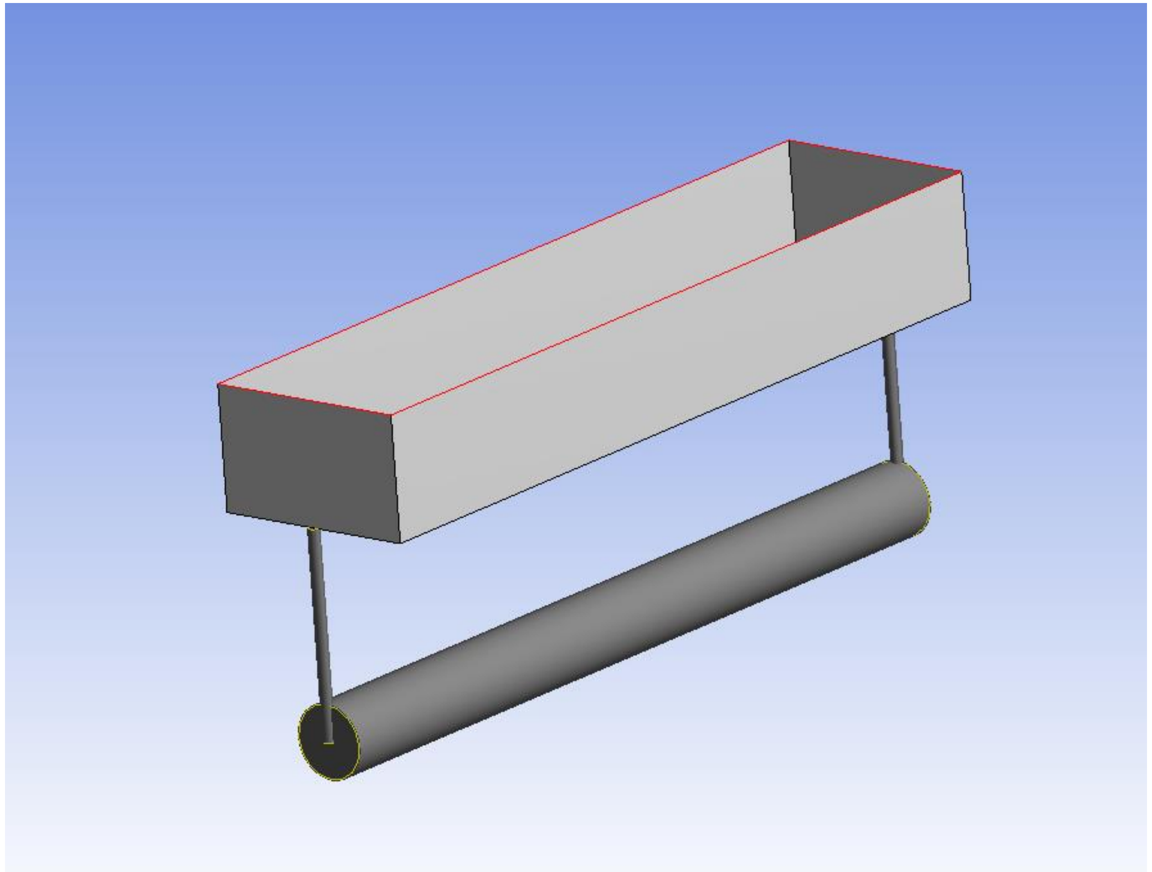
Morison Elements

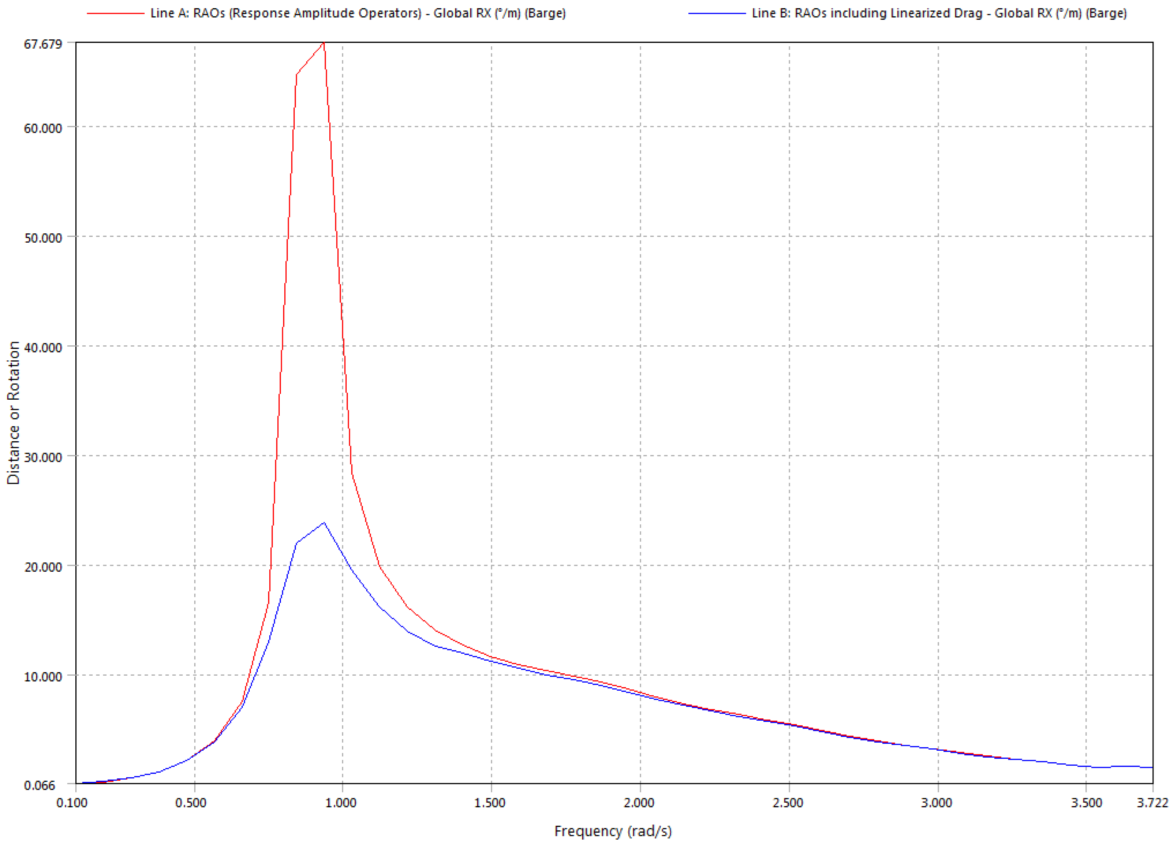
- While the diffracting elements provide a linear solution to the wave frequency loading, Morison elements include *nonlinear* viscous drag effects. For frequency domain solutions we need to consider how to include these viscous effects in a linear fashion.

- In both the radiation/diffraction analysis and a frequency statistical analysis the drag linearization is undertaken for a specific spectrum.

- Note that in the Hydrodynamic Diffraction system, while the modified RAOs may be reported and plotted, they are not stored in the hydrodynamic database for use in any subsequent Hydrodynamic Response analysis (which will deal with the viscous drag effects directly, in the time domain, or by drag linearization for a frequency statistical analysis). Likewise, the QTFs are not re-computed.

Drag Linearization in a Hydrodynamic Diffraction Analysis





Calculation of Linearized Drag

In the Morison equation the nonlinear drag force per unit length is:

$$F_d = \frac{1}{2}\rho C_d D V|V|$$

Where V is the relative fluid velocity. We replace the $|V|$ term by a factor multiplied by the r.m.s. velocity to estimate an equivalent linear term. In the literature this factor is given as $\sqrt{8/\pi}$ (Borgman 1967).

We thus have:

$$F_d{}^* = \frac{1}{2}\rho C_d D \alpha V_{\mathrm{rms}} V$$

Where $\alpha = \sqrt{8/\pi}$ and V_{rms} is calculated from a defined irregular wave spectrum.

As V is a relative velocity, the RAO calculation is iterative.

Calculation of Linearized Drag

Modified RAO equation:

$$\left[-\omega^2\left(M_s + M_a(\omega)\right) - i\omega\{B(\omega) + B_{DL}(\theta)\} + C\right]X(\omega,\theta) = F(\omega,\theta) + F_{DL}(\omega,\theta)$$

Iterative calculation:

- RAOs
- Relative velocity for each component of the spectrum
- RMS velocity
- Drag coefficients
- New RAOs – check for convergence

Calculation of Linearized Drag

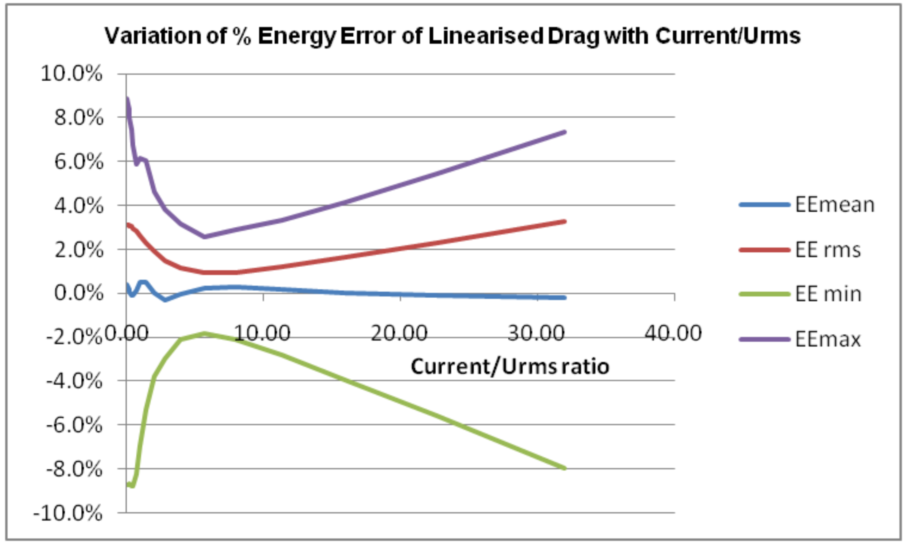
When current is included, we assume that the linearization factor is in the form:

$$\beta = \sqrt{\alpha^2 {V_{\mathrm{rms}}}^2 + \gamma {V_c}^2}$$

Where

$$\gamma = 4 - 2e^{-r}$$
$$r = V_c / \alpha V_{\mathrm{rms}}$$

Found by numerical investigation of the error in dissipation of drag energy.



Additional Drag Linearization Functionality

- In a frequency statistical analysis, further drag linearization may be included in the simulation:
    - Current hull drag
    - Wind drag
    - Dynamic cables

- With the exception of dynamic cables, drag linearization is requested by setting the Linearized Morison Drag option in the Analysis Settings. When cable dynamics is employed, drag linearization for the cables is always applied.

Details

Details of Analysis Settings	
Name	Analysis Settings
Computation Type	Frequency Statistical Analysis
Parallel Processing	Program Controlled
Use Cable Dynamics	Yes
Frequency Response Specific Options	
Analysis Type	Wave and Drift Frequencies
Direction of Output for RAOs	Program Controlled (^ Irregular Wave 1 (C4))
Spectrum Sub-Direction of Output for RAOs	Main Direction (0.0°)
Axis System for Significant Motions and Nodal ...	Local Structure Axes
Starting Position	Determined by Upstream System
Common Analysis Options	
Calculate RAOs with Mooring Lines	No
Apply Drift Force with Multi-Directional Wave I...	No
Linearized Morison Drag	Yes

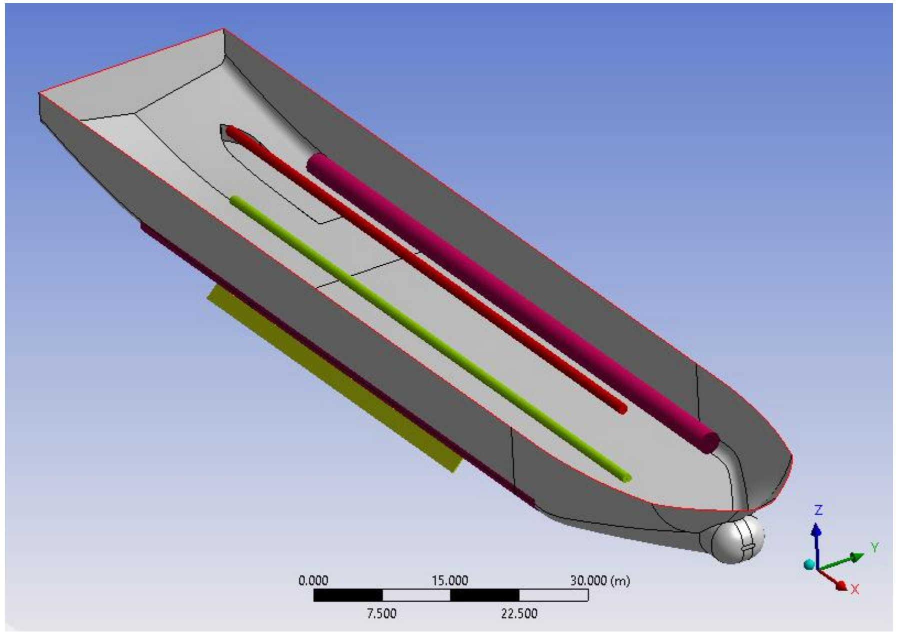
Nonlinear Drag Modeling

- We have seen that in the frequency domain we must employ a linearization for nonlinear drag forces.
- In time domain calculations we can evaluate the Morison equation directly for Morison elements (slender bodies and Disc elements) as well as dynamic composite catenary cables.
- Wind Force Coefficients and Current Force Coefficients are used to account for wind and current effects; a 6x6 matrix of Morison Hull Drag coefficients can also be defined to estimate hull drag.
- Wave Drift Damping is automatically accounted for when time domain drift forces are included.
- Aqwa also allows Nonlinear Roll Damping and Yaw-Rate Drag to be modeled.

Nonlinear Roll Damping and Yaw-Rate Drag

- Nonlinear Roll Damping can be defined by:
  - A single Quadratic Roll Damping Coefficient
  - Bilge Vortex Shedding, estimated from defined geometric bilge parameters
  - Bilge Keel Damping, estimated from keel dimensions according to ITTC recommendations

Details	
Details of Nonlinear Roll Damping	
Name	Nonlinear Roll Damping
Visibility	Visible
Activity	Not Suppressed
Nonlinear Roll Damping	
Nonlinear Roll Damping	Combine Coefficient and Bilge Parameters
Quadratic Roll Damping Coefficient	1000 N.m/(°/s)²
Bilge Central Line Definition	
Aft End Position Definition	Manual Definition
Aft End X Position	-40 m
Aft End Y Position	0.0 m
Forward End Position Definition	Manual Definition
Forward End X Position	40 m
Forward End Y Position	0.0 m
Bilge Roll Damping Details	
Bilge Type	Bilge Vortex Shedding and Bilge Keel Roll Damping
Bilge Radius	1.3 m
Depth to Bilge	8.7 m
Offset of Bilge from Central Line	11.7 m
Bilge Keel Details	
Bilge Keel Length	50 m
Bilge Keel Breadth	2 m
Midship Cross-Section Coefficient	1
Advanced Bilge Keel Options	Program Controlled



- Yaw-Rate Drag requires the definition of a Force Coefficient and the vessel centreline.