Introduction to Hydrodynamic Analysis with Ansys Aqwa

Module 03: Aqwa Basics – Conventions and Theory

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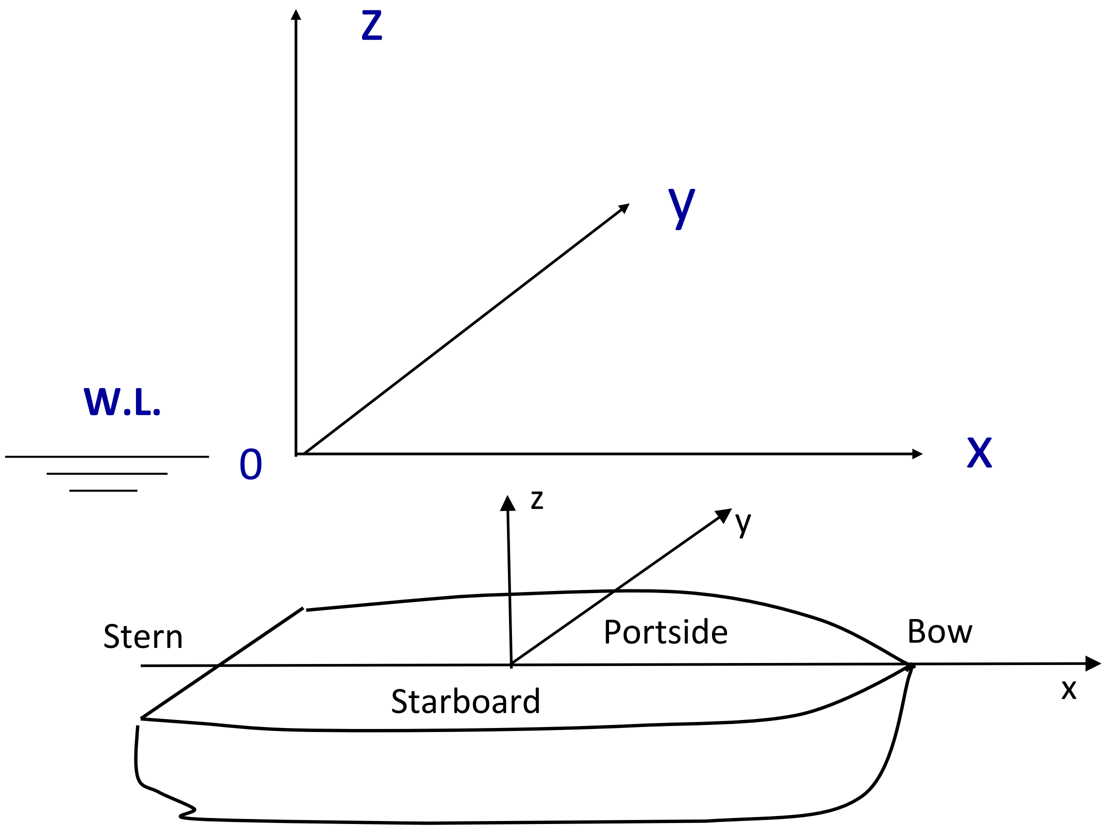
Aqwa Basics – Coordinate Systems

Aqwa Global Coordinate System

- **Referred to as the Fixed Reference Axes (FRA):**
  - The origin lies in the still water plane
  - The positive z axis is vertically upwards
  - A right handed system
  - It is not related to the directions North, South, East and West

- **Rigid body motions**
  - Surge, Sway, Heave - translational
  - Roll, Pitch, Yaw - rotational
  - The direction of motion is relative to the geometry definition of vessel/structure (x is not surge by default!!)



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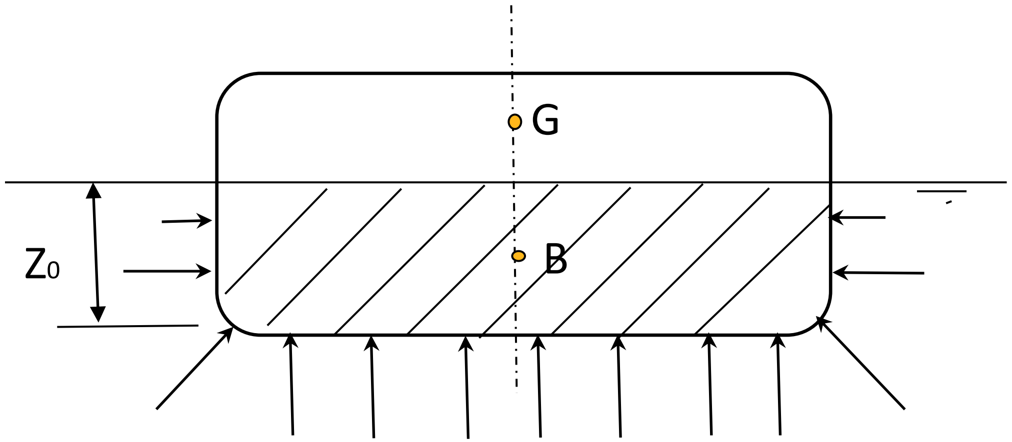
Aqwa Basics - Hydrostatics

Hydrostatics

- Archimedes' principle
  - Buoyancy of an immersed body is equal to the weight of the fluid displaced

- Hydrostatic pressure

$$p = \rho g Z_0$$



G: centre of gravity (COG)

B: centre of buoyancy (COB)

Buoyancy is the resultant of all hydrostatic force over the wetted surface

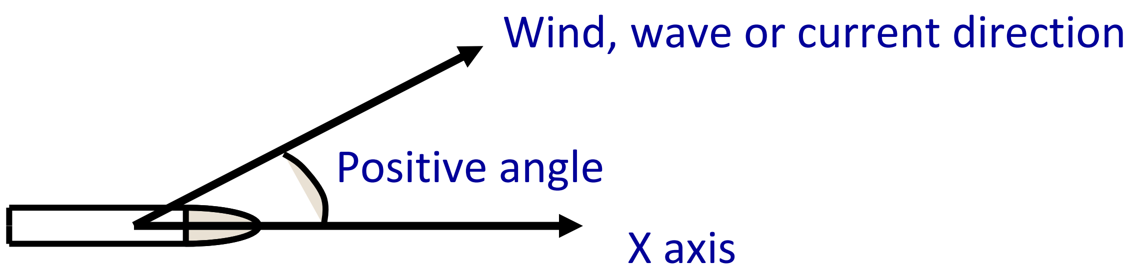
Aqwa Basics – Environment Definition

Environmental direction in Aqwa

- The wind, wave and current directions are defined in Aqwa as the directions that they are travelling towards.

- The direction is defined as the angle between the wind, wave or current and the positive x axis, measured anti-clockwise. For a ship facing forward to positive x axis, this means 0° is astern seas and 180° is head seas.

- Directions in Aqwa are input and output in degrees.



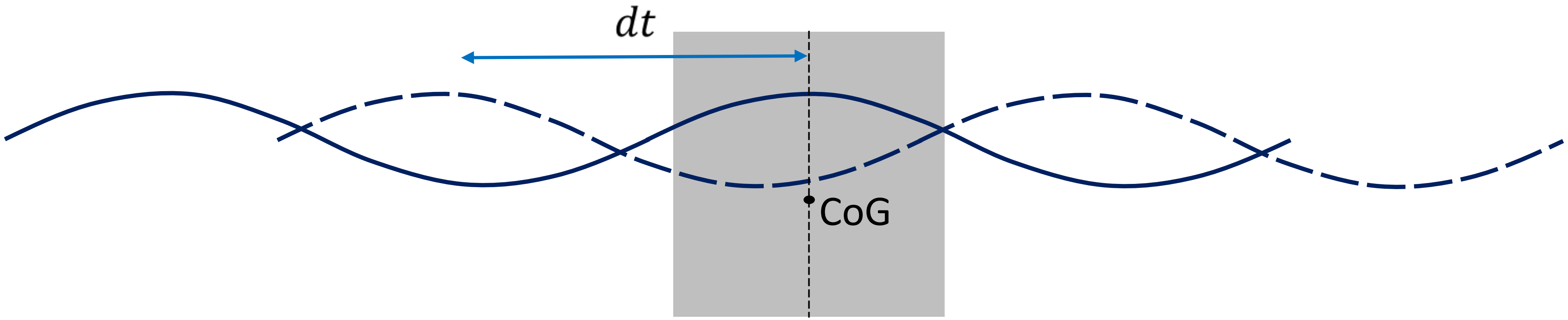
Aqwa Basics – Phase Definition

Phase angle

- In Aqwa, the phase angle (φ in degrees) of a parameter defines the time difference (dt) from the time when the wave crest is at the COG of the structure to the time when the parameter reaches its peak value:

$$dt = \varphi T/360, \text{ where } T \text{ is the wave period}$$

- A positive phase angle indicates that the parameter lags behind the wave.



Aqwa Basics – Wave Definitions

Regular waves

- Airy waves (linear wave)

  $\eta = A\cos(-\omega t + kx)$, where A is wave amplitude; ω is wave frequency (rad/s); k is wavenumber

- Stokes second-order waves

$$\eta = A\cos(-\omega t + kx) + \frac{1}{2}kA^2\cos^2(-\omega t + kx)$$

Irregular Wave Spectra

- Pierson-Moskowitz, JONSWAP, Gaussian, Ochi-Hubble, Bretschneider, TMA formulated spectra
- User-defined spectrum
- Cross swell
- Imported time history of wave elevation
- Can be long- or short-crested (directional spread seas)

Aqwa Basics – Wind and Current Definitions

Wind

- Uniform wind
- Ochi and Shin wind spectrum
- API wind spectrum
- NPD wind spectrum
- User-defined wind spectrum

Current

- Uniform velocity current
- Velocity profiled current
  - ➢ Dimensional
  - ➢ Non-dimensional
  - ➢ Formulated from tide and wind specification (DNV-GL RP C205)

Basic Theory in Aqwa

Wave forces for diffracting structures (modelled with panel elements)

- Incident wave force (Froude-Krylov force) from the pressure in the undisturbed waves
- Diffraction force due to a stationary structure disturbing the incident waves
- Radiation force due to the oscillation of the structure, which generates waves
- Drift force which is the net force due to high order effect

Basic Theory in Aqwa

Three-Dimensional Potential Theory solution:

- Ideal fluid, irrotational, incompressible
- Small wave elevation
- Viscous forces are not taken into account

Boundary Condition problem is solved by satisfying:

- Body boundary condition
- Linearized free surface condition
- Sea bed boundary condition
- Radiation condition
- Solution for diffracted and radiated wave potentials uses a pulsating source distribution (zero speed solution with optional forward speed corrections)

Basic Theory in Aqwa

Theory applies to finite depth and diffraction problem is solved in frequency domain

- Shallow water solution is available

Both first-order and second-order wave forces are calculated

- Second-order forces can be calculated from either far field or near field solutions:
    - Far field uses rate of change of momentum to calculate forces in the horizontal plane only (X/Y/RZ) for a single structure in unidirectional waves, and with no forward speed
    - Near field uses a mean wetted body surface integration approach, which is applicable for all cases, but may be less accurate than far field

Basic Theory in Aqwa

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, $C_m = 1 + C_a$

Basic Theory in Aqwa

Full Quadratic Transfer Function (QTF)

- Components at both difference and sum frequencies
- Each with in-phase and out-of-phase parts
- The second order wave potential does not contribute to the diagonal terms of the QTF matrix, so that it has no effect on the mean wave drift force. However, the second order wave potential contributes to the off-diagonal terms of the QTF. It has been found that in shallow water the drift force coefficients can be increased significantly by the second order potential. Therefore, the inclusion of the second order incident and diffracted potential is necessary for the accurate evaluation of the second order wave exciting forces in shallow water. In Aqwa this is done using the Pinkster approximation (Pinkster, 1980).

Basic Theory in Aqwa

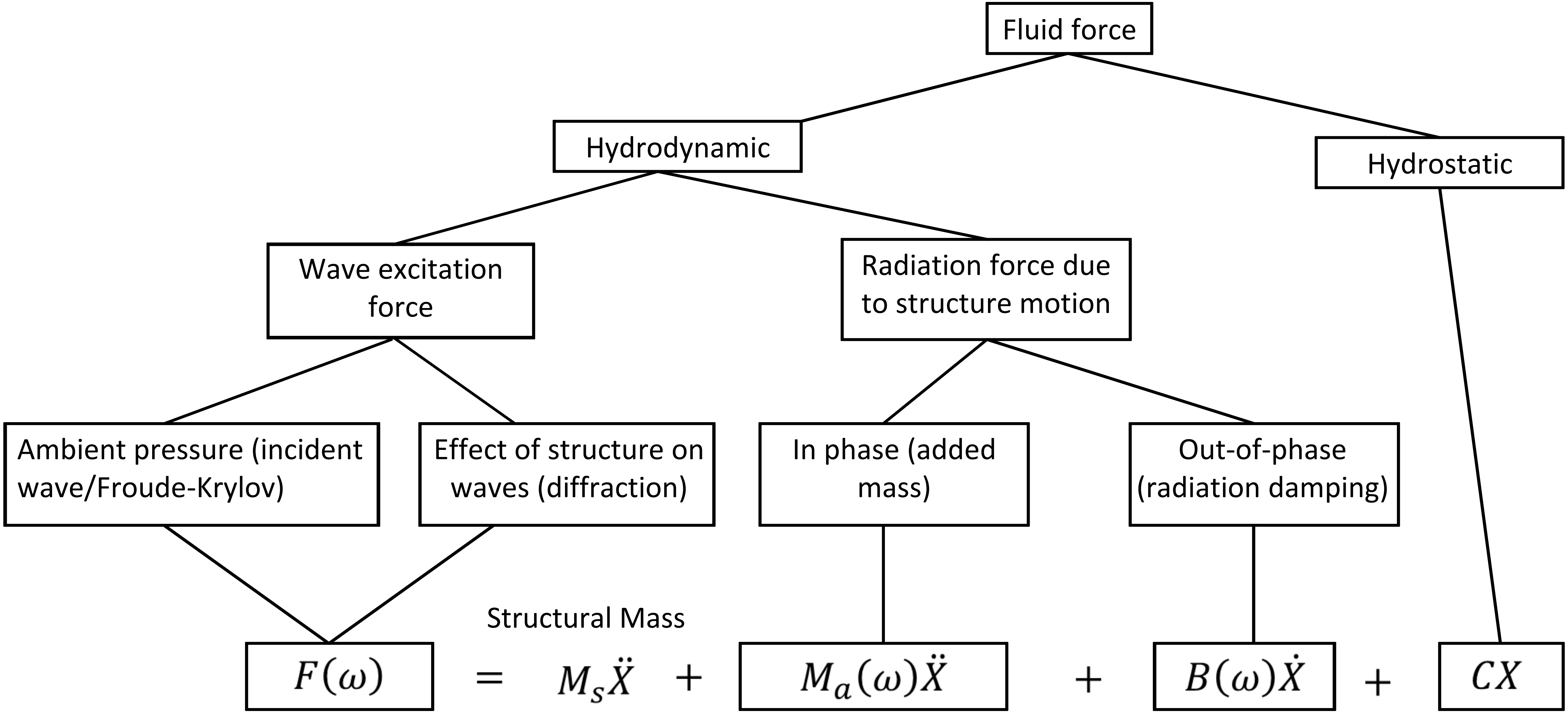
Equations of Motion

- The response X of a structure in waves is calculated by solving the equation of motion in the frequency domain for a unit wave amplitude:

$$\left[-\omega^2\left(M_s + M_a(\omega)\right) - i\omega B(\omega) + C\right]X(\omega) = F(\omega)$$

- M_s is structure mass
- M_a is added mass (frequency-dependent)
- B is damping (frequency-dependent)
- C is hydrostatic stiffness
- F is wave excitation force (incident and diffracting forces).

Basic Theory in Aqwa



Theory in Aqwa

Full theoretical background can be found in the Aqwa Theory Manual, available via the Ansys Online Help System

ansyshelp.ansys.com