Irregular Wave Forces on a Large Vertical Circular Cylinder

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Introduction

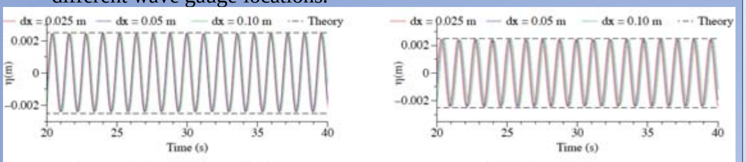
- The real sea state can not be defined by the regular waves.
- Fast fourier transformation (FFT) can be used to simplify the random sea surface into a summation of simple sine waves.
- Present study employs the open-source CFD model REEF3D to study the regular and irregular wave forces

Numerical Model

- Reynolds Averaged Navier-Stokes (RANS) equations are the governing equations of computational fluid dynamics (CFD).
- Explicit TVD third-order Runge-kutta scheme and fifth-order finite difference WENO scheme in multi-space dimensions are used.
- k-w model is used to model the turbulence.
- Level set method (LSM) is used for modelling the free surface
- The relaxation method is used in the present numerical model to generate and
- absorb the waves.
- First-order irregular waves are used which are obtained by the summation of linear regular wave components. JONSWAP spectrum is used for the wave generation.

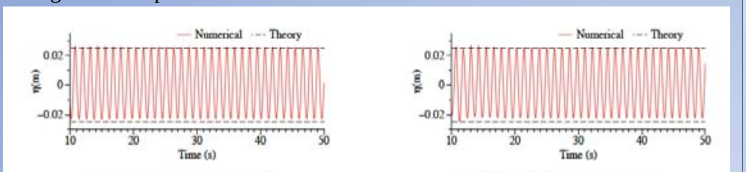
Validation with regular waves

- Two cases with different wave steepness are tested in an empty wave tank. Grid refinement study is performed for one of them.
  Case 1: H = 0.005m, T=1.2s (linear waves)
  Case 2: H: 0.05m, T = 1.2s (2nd-order Stokes waves)
- For grid refinement study, different grid sizes dx = 0.10m,0.05m and 0.025m are tested for case 1. Figure below shows the comparison with theory for two different wave gauge locations.



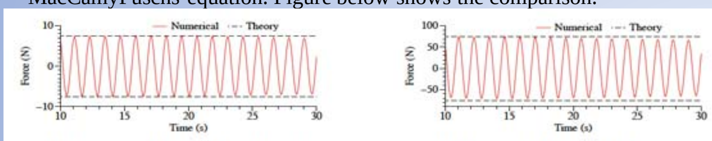
(a) Wave gauge located at $x = 2$ m (b) Wave gauge located at $x = 8$ m

- Grid size dx = 0.025m is chosen for further simulations.
- Figure below presents the results for the case 2.



(a) Wave gauge located at $x = 2$ m (b) Wave gauge located at $x = 8$ m

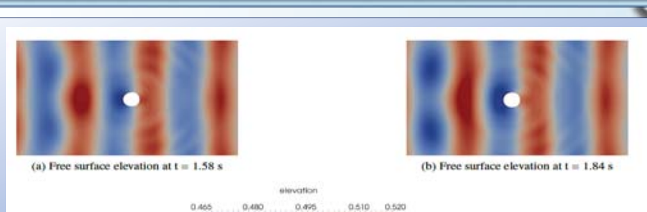
- Simulations are performed with a vertical cylinder of diameter D = 0.50m in a NWT 15m long, 5m wide and 1m deep. Water depth is 0.5m.
- Numerical forces are compared with the analytical forces calculated using MacCamyFuschs equation. Figure below shows the comparison.



(a) Regular waves with $H = 0.0050$ m and $T = 1.2$ s (b) Regular waves with $H = 0.050$ m and $T = 1.2$ s

- A very good match is observed between the numerical and analytical results.

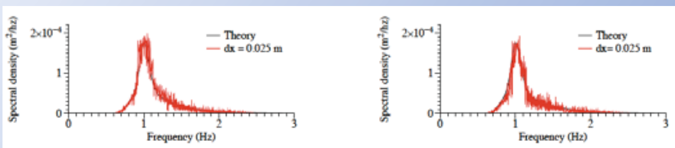
Next figure shows the free surface features around the cylinder for case2. Diffraction around the cylinder can be noticed.



(a) Free surface elevation at t = 1.58 s (b) Free surface elevation at t = 1.84 s

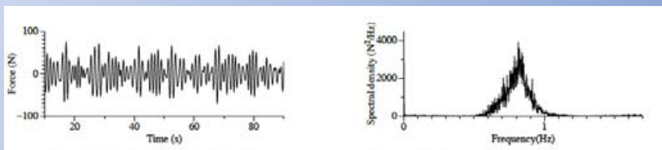
Testing with irregular waves

- Irregular wave generation is validated by comparing the numerical wave spectrum with the theoretical spectrum. Grid refinement study is also performed. Wave parameters are: H_s = 0.03m, T_p=1.0s
- For grid refinement study, different grid sizes dx = 0.10m,0.05m and 0.025m are tested. The figure below shows the results for dx =0.025m.



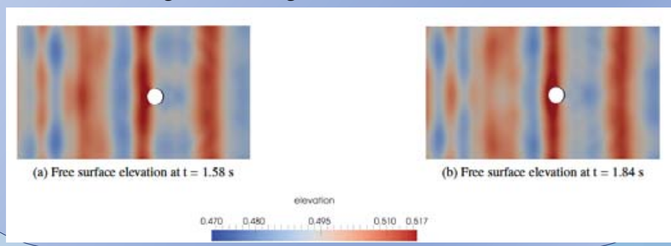
(a) Wave gauge located at $x = 2$ m (b) Wave gauge located at $x = 8$ m

- Interaction of irregular waves of H_s: 0.05m, T_p = 1.2s with a vertical cylinder of diameter D = 0.50m in a NWT 15m long, 5m wide and 1m deep is studied. Water depth is 0.5m.
- Figure below presents the results numerical force results for this case.



(a) Irregular wave force (N) over time (s) (b) Irregular force spectrum (N^2/Hz) over a frequency range (Hz)

- Free surface features around the cylinder are shown in the figure below. Irregular wave surface can clearly be noticed. Diffraction is less clear as compared to the regular waves because H_s signifies only the highest of one--third of wave heights in an irregular wave terrain.



(a) Free surface elevation at t = 1.58 s (b) Free surface elevation at t = 1.84 s

Conclusions

- Diffraction becomes more visible as the wave steepness increases.
- Irregular waves with the same significant wave height as the wave height of regular waves do not necessarily show the similar diffraction pattern.
- The numerical model REEF3D can be used as a good tool to study the regular and irregular wave forces on a vertical cylinder.

Acknowledgments

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