

13.42 Design Principles for Ocean Vehicles Homework #7

Out: Thursday, 1 April 2004
Due: Thursday, 8 April 2004

1. Consider a flexibly-mounted circular cylinder in a steady flow of water (see Figure 1), where the mass per unit depth of the cylinder is M and its diameter is d :

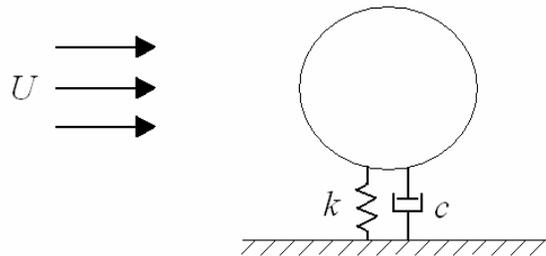


Figure 1 – Flexibly-mounted cylinder in a steady flow

- a. Write down an expression for the natural frequency of the system in terms of the given parameters.
- b. Given that $U = 10$ m/s and $d = 0.1$ m, find the frequency of vortex shedding. (Assume that the cylinder has a *smooth* surface and that the distance between the cylinder and the wall is $\gg d$.)
- c. Given that the system is in *lock-in*, what is the frequency of vortex shedding, of the cylinder response, and of the unsteady drag force (in terms of the expression derived in part a.)?

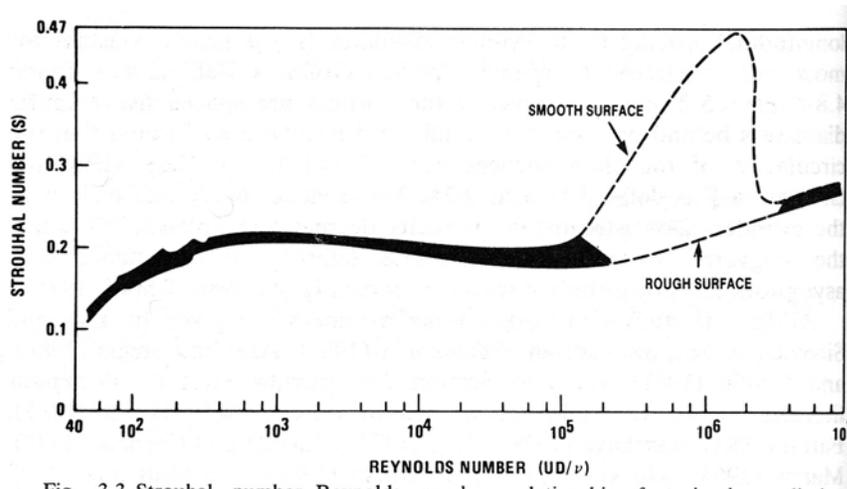


Fig. 2.2 Strouhal number versus Reynolds number for a circular cylinder.

2. Consider a slender cylindrical buoy of diameter d and draft T fixed in deep water subject to ambient plane progressive waves of amplitude A and frequency ω (see Figure 2):

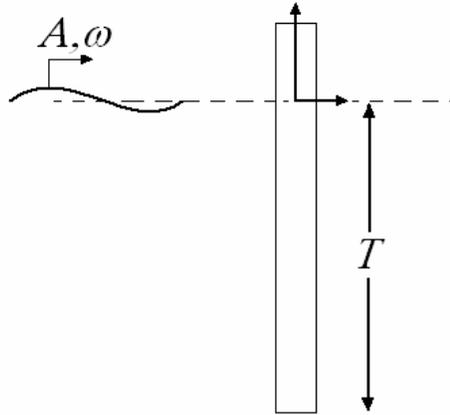


Figure 2 – Cylindrical buoy in waves

- a. Assuming that $\lambda \gg d$ and that $A \approx 2d$, write down an expression for the surge excitation force.
 - b. Derive the Froude-Krylov term in this expression by integrating the pressure about a section of the cylindrical buoy and then applying the long wavelength assumption ($\lambda \gg d$).
 - c. Explain the significance of the added mass term.
 - d. Explain why the expression (from part a.) may not be adequate for cases where the wavelength is of the order of the buoy diameter.
3. Consider a rigid circular cylinder, diameter 1.0m, mounted at an incline angle of 15 degrees from vertical, slanting away from the incoming waves.

- a. Determine the sectional lift and drag on the cylinder (force per unit length acting on a small strip of the cylinder) when it is subjected to incoming deepwater waves with amplitude $a = 0.9$ m, frequency 1.1 rad/s, and wavelength 30m.

(Hint: first determine the tangential and normal component of the forces acting on the cylinder. You can approximate the coefficient of friction as: $C_f \approx 1/100 \cdot C_d$.)

- b. What implications does this method of force decomposition have on the forces acting on vertical cylinders (angle zero degrees) in waves?

4. A rigid circular cylinder with diameter, $d = 1.8$ m, is rigidly mounted at the seafloor. The water depth in this region is 50 meters and waves can be considered deep water waves. Monochromatic, linear waves are incident on the cylinder from one direction. The waves have frequency $\omega = 2.0$ rad/s and amplitude $a = 1.1$ m. There is no current in this location in addition to the waves and we can neglect effects due to the cylinder piercing the free surface.

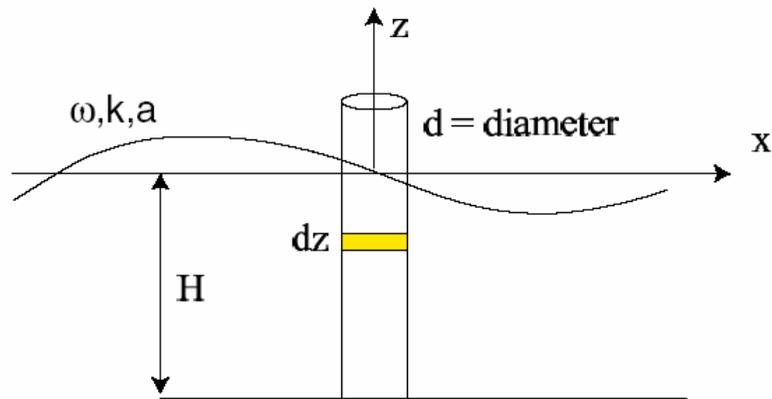


Figure 3 – Rigidly mounted vertical cylindrical in waves

Using the appropriate form of Morrison's Equation:

- Calculate the MAXIMUM total force acting on the cylinder in the x-direction.
- Determine the phases (time in the wave cycle) of the incident wave, $\eta(x,t)$, at which the horizontal force acting on the cylinder is MAXIMUM and is MINIMUM. (Consider this relative to the wave elevation at $x=0$, the centerline of the buoy).
- Compare the total force over one period to the inertial and drag components of the force over that same time.
- Calculate the moment acting on the cylinder about the seafloor mount.
- Find the location of the center of force along the height cylinder (relative to the seafloor).
- In the early morning the waves have lower amplitude but similar frequency. Repeat parts (a) through (c) for the case where the wave amplitude is 0.25 meters and the frequency is the same as above.