13.012 HW 8

Due: Tuesday November 23, 2004

For more information on Dimensional analysis you can refer to one of the following texts:

White <u>Fluid Mechanics</u> Chapter 5
Smits <u>A Physical Intro. to Fluid Mechanics</u> Chapter 8.

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1) Determine the moment acting at the base of a cylinder fixed at the seafloor, at a depth *H* below the free surface, due to incoming waves with frequency, ω, amplitude, *a*, wavelength, λ. Assume that the cylinder diameter is much smaller than the wavelength so that there is no diffraction and that the waves are deep water waves. The waves are such that λ/d is greater than 5, and $2a/d$ is between 1 and 10.

2) An autonomous underwater vehicle (AUV) shaped like a torpedo is being designed to operate in an area of the Atlantic Ocean with strong currents around U = 3 m/s. In order to determine the thrust needed for the vehicle a smaller scale model is tested in the propeller tunnel. The model is 10^{th} the size of the real AUV. The model is 75 centimeters long and diameter is 7.5 cm. The front of the torpedo is a hemisphere and the aft is tapered to the propeller.

   The full scale AUV will need enough thrust to maintain position in a 3 m/s current.

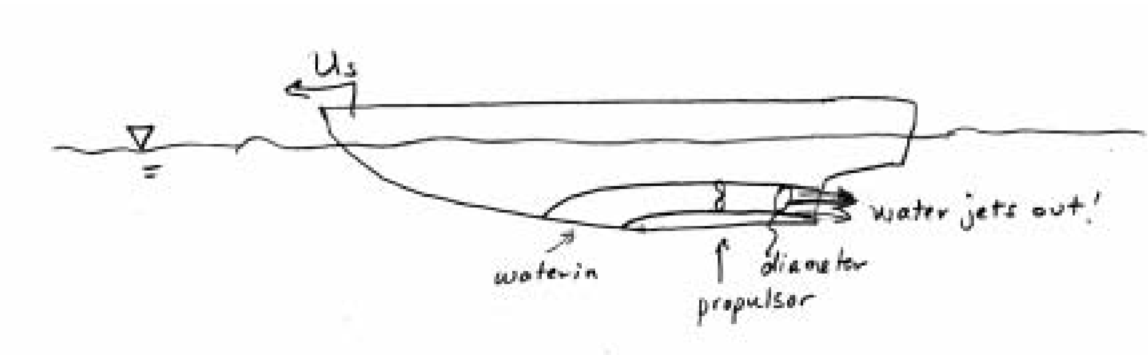
   In order to determine the thrust needed to overcome the current the model will be hooked up to a force balance and the drag on the hull measured at a certain towing speed (analogous to incoming current).

   a) What speed should the model be tested at to determine the necessary thrust on the full-scale vehicle?
   b) If the drag measured on the model at this design speed is 10N, then what is the maximum thrust needed to overcome the 3 m/s current for the full-scale AUV?
   c) List the most important non-dimensional parameters.

3) The diameter, *d*, of water droplets produced by a nozzle are dependent on the speed of water in the jet, *V*, the nozzle diameter, *D*, and the fluid properties, density, viscosity, and surface tension: ρ, μ, and Y.

   Determine the dimensionless parameters that govern this problem. Hint: use D, ρ, U to non-dimensionalize the other variables by.

4) A surface craft is driven by a single water jet propulsor. The ship has length, L_s=10m, beam, $B_s = L_s/10$, and cruising speed U_s, and is cruising in freshwater.



a) Give the non-dimensional parameters that are important for modeling the drag on the vessel.

b) A Towing Tank test on a 10:1 model was done in freshwater for a comparable full scale cruising speed of 20 m/s. The total resistance on the model was found to be F = 250 N. Determine the thrust required to be generated by the full scale vessel to propel it at its steady cruising speed, U_s = 20 m/s.

c) The ship has a fixed power plant, but it is possible to alter the geometry of the water jet in future designs. Determine the dependence of Power on several non-dimensional parameters. Consider the rotational speed of the propulsor, the exit velocity of the jet flow, the velocity of the ship and/or the diameter of the jet nozzle, as well as any other relevant parameters.

5) A ship 100 m long moves in fresh water at 15ºC. Find the kinematic viscosity of the fluid required to test a 5m long model based on Froude's Hypothesis. Comment on the feasibility of this requirement – is there a fluid you could use, what happens if you were on another planet like Mars or Jupiter?

6) A propeller of diameter d develops thrust T when operating at N revolutions per minute with a forward speed V in air of density ρ.

   a. Use dimensional analysis to express the dependence of thrust on several non-dimensional parameters. Try to choose groups that look familiar.
   b. The single propeller described here is to be replaced by a pair of two propellers operating at the same forward velocity and together produce the same total thrust in air with the same density as the single prop. Determine the diameter d_2 and rotational speed of each of the propellers in the pair to obtain the thrust generated by the one single propeller.
   c. Does the switch between a single prop and twin props require a change in power?

7) The lift force F on a high speed underwater vehicle is a function of its length L, velocity V (eg: fast vehicle where $V > 35$ knots), diameter d, and angle of attack α, as well as the density of the fluid. We will assume the vehicle does not exceed the speed of sound in water!

   a. Determine the dependence of lift on the appropriate non-dimensional parameters.
   b. If a 1/10-scale model is tested in a wind tunnel at the same pressure and temperature as encountered by the vehicle at depth, determine the velocity necessary to ensure dynamic similarity.
   c. What would the lift force be on the model in the wind tunnel be compared to the actual lift of the vehicle?
   d. Does it make sense to test such a vehicle in a wind tunnel versus a water tunnel?