Advanced Marine Hydrodynamics NA61202 3-1-0

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Lecture 1: Introduction, Course Structure and Some Background

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Spring 2023

Overview

Why do we need to study Marine Hydrodynamics ?

- Fluid Dynamical study of objects in an Oceanic/ Marine Environment. Examples, Naval Ships, offshore/ coastal structures.
- Safety and operability of our Engineering Design.
- To know how our design will work we need to understand how it is going to interact with the environment (i.e., waves and currents) it is going to subjected to.
- Analogous: Study of soils/ Earth Sciences in Civil Engineering.

Plan of the course

- part a
  - Revisiting some concepts in introductory Fluid Mechanics, i.e., Fluid Kinematics and Conservation Laws. (4) [1]
  - Elementary flows using Source, Sink, Dipole and Vortex flows. (3) [1]
  - Flow past an aerofoil using source-sink distributions.(2) [1]
  - Laminar boundary layer theory: Flow past a flat plate. (4)
- part b
  - Introduction to free surface waves: Airy wave theory. (4) [1]
  - Linear wave body interaction problem and calculation of wave induced forces. (3)
  - Wave resistance. (2)
  - Forward ship motions. (4)
  - Green water loading and slamming. (4)
- what we learn in part a will be extensively used in part b.

[1] Marine Hydrodynamics NA20202

Evaluation

- Part a: Assignments + tutorials: 20; Mid Sem: 20.
- Part b: Assignments + tutorials: 20; End Sem: 30.

Combined evaluation

- In-class engagement (questions and responses): 5.
- Attendance: 5.

Recommended Study Materials

- Fluid Mechanics and Fluid Machines by S K Som, G Biswas, S Chakraborty.
- Computational Fluid Dynamics The Basics with Applications by John D Anderson.
- Fundamentals of Aerodynamics by John D Anderson.
- Hydrodynamics by H. Lamb.
- Marine Hydrodynamics by J. N. Newman.
- Ocean Waves and Oscillating Systems Linar interactions including wave-energy extraction by Johannes Falnes.
- NPTEL lectures by S K Som and S Chakraborty.
- YouTube Lectures Fluid Mechanics 101 by Aidan Wimshurst.

- Higher Engineering Mathematics by B. S. Grewal.
- Mathematical Methods for Physicists by Arfken, Weber.
- Vector Analysis by Spiegel.

Partial and Oridnary Differential Equations (PDEs, ODEs)

- An ordinary differential equation is that in which all the differential coefficients are functions of a single independent variable. Example, $\frac{dy}{dt} + ny = Z(t)$.
- A partial differential equation is that in which there are more than one independent variables and the partial differential coefficients depends on them. Example, $\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}$. The solution is of the form $y = y(x, t) +$ some constant.
- For nonlinear equations, a differential coefficient might be multiplied with another coefficient in some terms. Example, $\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2} + y \frac{\partial y}{\partial x}$.
- The choice of solution strategy is heavily dependent on our type of our equations, i.e., linear/ nonlinear.
- Example of how does the linear and nonlinear solution look like: plot of wave force amplitude against incident wave amplitude.

Basic Solution Strategy to a linear ODE

Step 1

The Complimentary Function (CF): What we get as solution for $\frac{dy}{dt} + ny = 0$.

Step 2

The Particular Integral (PI): What we will get as solution for $y = \frac{Z(t)}{D+n}$, where the operation $\frac{d}{dt}$ is meant by the operator D.

The solution is of the form $y = \text{CF} + \text{PI} + \text{constant}$. We need more information (i.e., the boundary conditions) to get the final solution.

Step 1

We express our solution as a product of two functions each of one independent variable, i.e., $y = Y_1(x)Y_2(t)$. This is known as *Separation of variables*.

Step 2

Substitution of above back to equation 8 gives two ODEs, i.e.,

$$\frac{d^2 Y_1}{dx^2} = kY_1, \tag{1}$$

and

$$\frac{d^2 Y_2}{dt^2} = kc^2 Y_2. \tag{2}$$

Now, we can apply any strategy that we use to deal with an ODE.

The Integrating Factor

For an ODE of the form (known as Leibnitz linear equation)

$$\frac{dy}{dt} + n(t)y = Z(t), \tag{3}$$

we can multiply both sides by $e^{\int n dt}$ and get

$$\frac{d}{dt}\left(ye^{\int n dt}\right) = Z(t)e^{\int n dt}, \tag{4}$$

which when integrated gives

$$ye^{\int n dt} = \int Z(t)e^{\int n dt} dt + c.$$

The factor $e^{\int n dt}$ is known as Integrating Factor.

- Assume a function $f(z)$ (which we can think of as $u + iv$)of a complex variable $z = x + iy$. If $f(z)$ is single valued posses a unique derivative with respect to z at all points of a region R, then $f(z)$ is said to be analytic function.
- A point at which an analytic function ceases to aquire its derivative is called as a *Pole* or a *singularity*. Example,

$$f(z) = \frac{1}{z-a}, \tag{5}$$

  where, $z = a$ defines a pole for $f(z)$.
- The purpose of using poles is that it allows us to apply powerful tools to deal with integrals which are otherwise very difficult to deal with using real variables only.
- That calls for the need of *analytical extension*.

The Cauchy-Riemann (C-R) Equation

The rule of differentiating a complex function with respect to a complex variable holds as

$$f'(z) = \frac{\partial u}{\partial x} + \mathrm{i}\frac{\partial v}{\partial x}, \tag{6}$$

provided

The C-R equations

$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$ and $\frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x}$

Example, assume $f(z) = \log(z)$ and then find $f'(z)$.