2.016 Hydrodynamics

Prof. A.H. Techet

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Laboratory #3:
Ship Resistance and Model Testing

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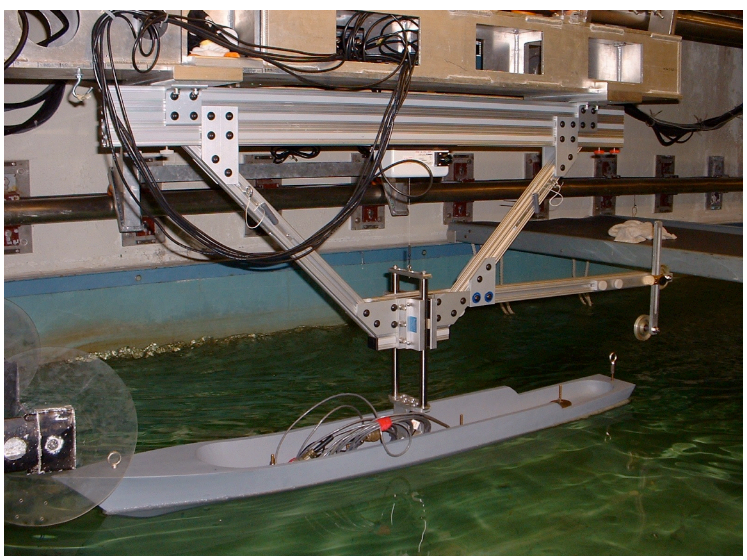
1.1 INTRODUCTION

Objectives: The purpose of this project is to familiarize you with model testing as a method for predicting ship resistance and powering requirements, and to investigate a ship's response in waves.

Following the methods discussed in class you will use dimensional analysis to determine the speeds at which to test a **100:1** scale ***USS Arleigh Burke*** class DDG (destroyer, guided missile) model ship, so that you can scale your data up to the full prototype destroyer. A photo of the test setup is below.



Lab setup: This lab is performed in the Ocean Engineering towing tank (48-015). The DDG-51 model is mounted to a free moving linear carriage, and rests in the water at its design draft. The model is towed at a forward speed such that the effects of drag can be observed.

Ship Model: The model is a **100:1** scale ***USS Arleigh Burke*** class DDG (destroyer, guided missile). The primary characteristics of the DDG 51 follow. The model tested will be without a sonar dome.

L_{PP}	466.0 ft	Length
T	20.69 ft	Draft
B	58.98 ft	Beam
C_P	0.625	
C_X	0.830	
C_b	0.519	
C_{wp}	0.789	
Δ	8240 LT_{sw}	Displacement
S_{ws}	29,754 ft^2	Wetted surface area

1.2 EXPERIMENTAL PROCEDURE

Part A: Ship Resistance Tests

1) If the full-scale ship operates up to 35 kts, determine the testing speeds for the 100:1 model used in these tests in order to have information about the ship resistance at 5, 10, 15, 20, 25, 30, and 35 kts. (note: 1 kts = 0.5144 m/s).

   Froude and Reynolds numbers are both important non-dimensional parameters for ship resistance model testing. The Reynolds number is $R_L = Ul/\nu$, where U is ship speed, l is ship length, ν is kinematic viscosity. The Froude number is $Fr = U/\sqrt{gl}$, where g is gravity.

   While dependency on the Reynolds number is important, typically we will scale the model tests with Froude number since the free surface effects are important. We must also ensure that the flow around the model is in the same flow regime, turbulent or laminar, as the actual full scale ship. (Note: In much of the hydrodynamics literature, you will find the Froude number defined as $Fr = U^2/gl$, which is equally acceptable, but yields slightly different looking graphs. So when you're reading a hydro paper, pay attention to this detail!)

Full Scale Ship					**Model Ship**	
Length (m)	**Speed (knots)**	**Speed (m/s)**	**g (m/s^2)**	**Fr**	**Length (m)**	**Speed (m/)**
142	5	2.57	9.81	0.07	1.42	0.26
142	10	5.14	9.81	0.14	1.42	0.51
142	15	7.72	9.81	0.21	1.42	0.77
142	20	10.29	9.81	0.28	1.42	1.03
142	25	12.86	9.81	0.34	1.42	1.29
142	30	15.43	9.81	0.41	1.42	1.54
142	35	18.00	9.81	0.48	1.42	1.80

2) Conduct an experiment at the tow tank facility to measure model resistance of the DDG 51 hull at equivalent speeds up to the maximum speed allowed by the carriage. Conduct multiple towing runs at each chosen test speed, if possible. The tow carriage speed is set in units of meters per second so calculate the desired tow speeds in these units. The tow speed limit is 1.5 m/s. Resistance data will be recorded on disc for later analysis using MATLAB.

3) For each case observe the wake pattern and the bow wave on the model. How do these appear to change for each run?

4) Consider the effect that ship's motion might have on the resistance data. Does the model pitch or heave significantly during the runs? If so would this affect the data?

<u>Part B: Ship Motion in Waves</u>

1) Calibrate the wave probes. (This may have been done ahead of time by the TA or lab assistant)
   a. With the water in a calm state, record data at this zero point, then place a block of known height under the probes and record the data. By subtracting the voltage each team can then calibrate the volts to height for each of the probes.

2) Calibrate the heave response.
   a. This step is already done for each lab, simply ask your TA for the constant values.

3) Run **3-4** monochromatic frequency waves and record the heave data when the ship is fixed in place.

4) Run the same **3-4** monochromatic frequency waves and run the model with a forward speed you choose, and record the data.

Data format: There will be four general measurements made in this section. Two wave probe outputs in Volts, and the heave response (also in Volts). The data is collected through a data acquisition PC card. The format of each file is in ASCII format. This format is compatible with both Matlab and Excel. Each run will have to be named appropriately and notes should be taken by each group to ensure that each run is recorded properly. The TA will transfer the data to a common directory, which can be accessed by all the students in the class.

Post Processing: Post processing of this part of the lab is made easier by using several Matlab scripts. The Matlab scripts are in the 2.016 website.

You will need the signals toolbox in MATLAB available on Athena. The data can be processed as follows:

1- Calibrate the wave probes using **parsedasci.m** to find the mean value of each wave probe height. Then put this data into a matrix and find the slope.

2- Run the matlab script **analyze_response.m** for each run. It will ask for a filename corresponding to your datafile (e.g. filename.asc). Type the filename and press enter. The data will be plotted on the screen. You can zoom in or out (type **help zoom** or click on the magnifying glass on the plot window) so that you can see the responses. When you hit the return key you will then be able to click with the mouse on amplitudes or wavelengths. INSTRUCTIONS on where to click are printed as the title of the plot! Click in appropriate places, and then the program will output information you will need to write down or put in some sort of array.

1.3 LAB WRITE UP AND DATA ANALYSIS

Treat your project write-up like a formal lab report. Use the lab report template, and write clearly and concisely.

Part A: Specific Tasks to include in the laboratory write up:

1) In the introduction explain the procedure for testing a model ship in the towing tank, discuss theory that was used in your calculations and considerations made during the testing.

2) Discuss the method used to determine the friction and residual resistance on the full scale ship hull based on the data you collected from the model. Cite references where necessary and include these references in a bibliography at the end of your report. Also, include any equations or relations you used to calculate the data.

3) Analyze your results. Specifically, submit plots of:
    - R_f vs Speed
    - R_R vs Speed
    - Total Resistance vs. speed
    - Coefficient of resistance vs. Reynolds number
    - Coefficient of resistance vs. Froude number

   Using these required plots, discuss your results. Address significant differences. Identify possible sources of experimental error. Estimate the error based on your multiple measurements and data processing.

4) Estimate the horsepower required to propel the ship at 35 kts based on your resistance estimates.

5) Discuss the effects of ship towing speed on the ship wake and bow waves. Do the bow waves grow, shrink, or stay the same with increased towing speed. What does the wake look like behind the vessel as the speed increases? How do you expect these effects to scale with increased Froude number? Increased Reynolds number?

6) Discuss whether the flow on the model ship was laminar or turbulent. How do you know?

7) Summarize your results in a conclusions section and discuss possible improvements or things you would do differently the next time you test a model ship.

Part B: Specific questions to answer in the laboratory write up are listed below.

Figures (plots, tables, sketches, etc.) will be very useful in helping to answer each question. Figures should be embedded with the text and plots should have appropriate axis labels and units where appropriate.

1- Describe and discuss the heave frequency and amplitude response of the ship in monochromatic waves?
2- How does moving the model with a forward speed affect the heave response?
3- Throughout your discussions consider the error sources in this lab and how they might affect your data.