

# 13.42 Design Principles for Ocean Vehicles

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## Laboratory #1: Wave Spectra and ship response in waves

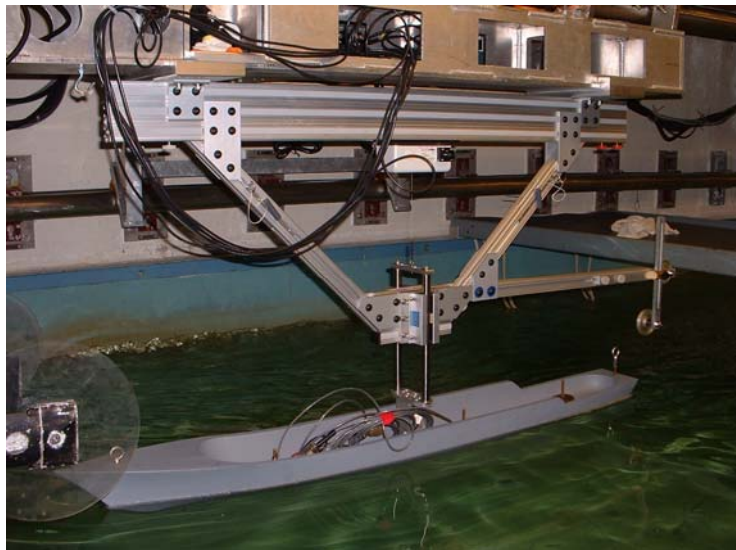
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### 1.1 INTRODUCTION

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**Objectives:** The object of this lab is to measure the response of a model ship due to incident waves. Students will analyze the response in heave and pitch motions of a **100:1** scale *USS Arleigh Burke* class DDG (destroyer, guided missile) model in both monochromatic and multi-frequency wave trains.



**Lab setup:** This lab is performed in the Ocean Engineering towing tank. The DDG-51 model is mounted to a free moving linear carriage, and rests in the water at its design draft. In the first part of the lab waves are generated by wave paddle at one end of the tank and the model is fixed. In the second part of the lab, the model is towed at a forward speed in head seas such that the effects of encounter frequency 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	
$\Delta$	8240 LT <sub>sw</sub>	Displacement
$S_{ws}$	29,754 ft <sup>2</sup>	Wetted surface area

## 1.2 EXPERIMENTAL PROCEDURE

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- 1- Calibrate the wave probes.
  - 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 and pitch response.
  - This step is already done for each lab, simply ask your TA for the constant values.
- 3- Run **SIX** monochromatic frequency waves and record the heave and pitch data. Please use the chart at the end of this handout. The chart will determine which frequencies each team will run. By taking data this way we will have 36 points of applicable data that can then be processed together to make a more detailed response plot, allowing more thorough analysis of the ship model.
- 4- Run the Bret Schneider spectrum. Record the data from two wave probes and the heave and pitch sensors.
- 5- Run the same SIX monochromatic frequency waves and run the model with a forward speed you choose, and record the data.
  - Please use the chart again.
- 6- Run the Bret Schneider spectrum with forward speed. Record the data from the two wave probes and the heave and pitch sensors.

**Data format:** There will be four general measurements made in this lab. Two wave probe outputs in Volts, and the heave and pitch response (also in Volts). The data is collected by the DasyLab program, 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 from DasyLab to a common directory, which can be accessed by all the students in the class.

**Post Processing:** Post processing of this lab is made easier by using several Matlab scripts. The MATLAB scripts are provided in a ZIP archive on the 2.22 Labs page of MIT OCW.

You will also need the MATLAB Signal Processing Toolbox. 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.
- 3- Run **response\_plot.m**. Response\_plot.m requires an array be input at the beginning of the file – the data each student collected from **analyze\_response.m** should be inserted here.
- 4- Run **bret2.m** it will plot the Bret Schneider spectrum from your recorded data, and the heave and pitch responses to these waves.
- 5- Running **bret\_compared.m** to see the comparison between the actual heave and pitch responses and the heave and pitch predictions made with the transfer function created by looking at the individual monochromatic waves. The heave, wave, and pitch amplitude arrays will have to be re-entered in the beginning of the **.m** file for this function to work properly.

### 1.3 LAB WRITE UP AND DATA ANALYSIS

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Treat your project write-up like a “formal” lab report. Type the final report and embed all figures into the text as appropriate. Final lab reports will be approximately 10-20 pages on average.

Provide an introduction, an equipment diagram and a narrative of what you actually did during the laboratory and to process the data afterwards, including the calibration (*even*

*though the calibration data was given to us before the lab it is a good idea to ask how it was done!*). Ensure you address any questions raised in this assignment. Plots should be well integrated and referenced in your discussion of the data. You may work in groups in gathering the experimental data for this project but **your analysis and discussion must be your own.**

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 and pitch frequency response of the ship in monochromatic waves?
- 2- Do you observe any cancellation frequencies in heave and pitch? If so at what frequencies to the motions die off? Does this make sense given the length of the ship and the characteristics of the waves at that frequency?
- 3- Do you think that the response curves in heave and pitch made from the single frequency waves are accurate? Where might sources of error come from?
- 4- How does the ship response in the Bretschneider wave train compare to the response plot for monochromatic waves?
- 5- Are there any sea states or wave frequencies (consider only head seas) this ship should try to avoid operating in? If so please elaborate.
- 6- Consider the cancellation frequency for the model ship, do you anticipate this will change for the full scale ship?
- 7- How does moving the model with a forward speed affect the heave and pitch response?
- 8- Throughout your discussions consider the error sources in this lab and how they might affect your data.

<b>Lab 1</b>	<b>Lab 2</b>	<b>Lab 3</b>	<b>Lab 4</b>
0.4	0.5	0.6	0.7
0.8	0.9	1	1.1
1.2	1.3	1.4	1.5
1.6	1.7	1.8	1.9
2	2.1	2.2	2.3
2.4	2.5	2.6	2.7