Chapter 6

Ship Motions in Irregular Seas
Experiment

The EN455 class has been tasked with determining the answer to the following question:

- Does the motion of a DDG-51 allow for theoretical flight operations when operating in reasonable sea state conditions (SS4 through SS5)?

There is great interest in performing model tests. However, only head seas can be considered and there is only funding for one sea state to be considered. Therefore, you have been asked to investigate additional operating conditions using simulations. Your assignment is to conduct these investigations and give a report back to the customers with a description of your actions on their behalf and a summary of your findings.

6.1 Computer Programming Laboratory

You will need to calculate the SOE’s for the DDG-51 in pitch (at the LCG) and vertical accelerations at the flight deck location using Maxsurf Motions. This will require running the simulation at a minimum of two speeds (15 and 20 knots) and a range of headings to allow for a full polar plot representation. The output will be two polar plots per sea conditions - one for significant pitch amplitude and one for vertical accelerations at the flight deck location.

Your goal is to calculate the SOE’s for pitch and vertical acceleration (at the flight deck) using MaxSurf Motions.

1. Input the DDG-51 in the proper ballasted conditions. Then input the wave spectrum based on the desired significant wave height and modal period using the 2-parameter ITTC spectrum. Finally, specify at least two speeds, a full range of headings (from 0° to 180°), and the remote location.

2. Perform the full seakeeping analysis. BEWARE that this can take a long time if you have lots of heading angles and/or speeds!

3. Locate the desired Polar Plots for pitch and remote location:absolute vertical acceleration.

4. Recreate these plots using the Matlab codes provided.

5. Identify the points on the plots that coincide with the conditions for experimental testing. We will compare these predicted values with the values calculated from the experiment.
6.2 Experimental Laboratory

6.2.1 Ship Motions in IW PreLab

Your goal is to calculate the significant pitch amplitude based on the input wave energy spectrum and the previously calculated pitch transfer function.

1. Determine the desired input wave spectrum based on the desired significant wave height and modal period using the Bretschneider equation.

2. Transform the wave energy spectrum into the encounter wave slope spectrum using the equation

\[ S_\alpha(\omega) = \frac{\omega^4}{g^2} S_\zeta(\omega) \]

\[ S_\alpha(\omega_e) = S_\alpha(\omega) \frac{g}{g - 2\omega U \cos \mu} \]

3. Determine the RAO in pitch

\[ RAO_{x_5} = \left( \frac{X_5}{k_0} \right)^2 \]

4. Calculate the pitch motion spectrum

\[ S_{x_5}(\omega_e) = S_\alpha(\omega_e) \cdot RAO_{x_5} \]

5. Find the significant pitch amplitude

6.2.2 Ship Motions in IW Experiment

In this lab you will calculate significant values for pitch and vertical acceleration and compare those to defined limits for aircraft operations.

Seakeeping Limitations on Aircraft Operations

Use the following limits (from Seakeeping by Design by Comstock et al. (1980) ) to determine operational limits for aircraft operations:

<table>
<thead>
<tr>
<th>MOTION</th>
<th>LIMIT*</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>3°</td>
<td>CG</td>
</tr>
<tr>
<td>Vertical Acceleration</td>
<td>0.4g</td>
<td>flight deck</td>
</tr>
</tbody>
</table>

*Motion limits are significant single amplitude values
Procedure

We will be testing a $1/36^{th}$ scale model of the DDG-51 Arleigh Burke class guided missile destroyer. You ballasted the model in a previous lab to represent the full load displacement and pitch inertia for the actual ship. The pitch transfer function was also determined in a previous lab.

Before running the model, be sure to record the following information about the experiment:

- Model geometry information ($L_{WL}$, $B_{max}$, draft ($D$), displacement ($\Delta$), LCG position, pitch gyroradius ($k_5$) and scale ratio ($R$)).

We will be testing at model speeds which are equivalent to 15 and 20 knots for the full scale ship.

1. Each run will consist of sending an irregular wave train of a given modal period and significant wave height down the tank, then starting the towing carriage and recording data.

2. The following measurements for each run should be recorded:
   - Carriage velocity (ft/s), pitch response (deg), vertical acceleration (g)
   - Encounter wave elevation (in) using a stationary wave gage mounted on the side of the tank

3. You are required to ride the carriage and observe at least one data run.

4. Create a data summary spreadsheet. After each run, enter the following data:
   - data run number
   - programmed modal period ($T_0$)
   - programmed significant wave height ($H_{1/3}$)
   - model speed

Data Analysis Guidelines

1. Create a table with the tank information, including
   - tank dimensions (length, width, water depth)
   - model geometry (length, beam, displacement, $k_5$, etc.)

2. Your goal is to calculate the significant pitch amplitude and significant vertical acceleration from the experimental time history.
   - Calculate the variance of the pitch time history.
   - Calculate the variance of the vertical acceleration time history.
   - Calculate the significant pitch and vertical acceleration amplitudes.
     (a) Determine the RMS value from the variance
(b) The significant amplitude is the average of the highest 1/3rd amplitudes.

- Calculate the significance wave height from the stationary wave probe.
  
  (a) Calculate the variance from the wave elevation time history.
  
  (b) Determine the RMS value from the variance
  
  (c) Find the significant wave height from the RMS of the wave elevation.