

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY**  
**Department of Mechanical Engineering**

**2.701 PRINCIPLES OF NAVAL ARCHITECTURE**  
**Fall 2014**

**PROJECT #6: SHIP RESISTANCE MODEL TESTING**

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Date Due: November 12, 2014

Reference:

1. Principals of Naval Architecture Series: Ship Resistance and Flow. Chapter 8
2. "A simple method for the evaluation of the form factor and the low speed wave resistance" (C.W. Prohaska)

### **1. Background**

In ASSET, initial powering estimates come from ratios with "like-type" ships and then further refined using one of many other methods such as Taylor Standard Series method. However in model testing the total resistance force is measured directly. The method used to turn model scale resistance data into full-scale ship EHP was developed by William Froude in 1872.

The Froude method, as discussed in class, considers the total model resistance as the sum of a frictional resistance component and a residuary resistance (literally everything other than friction) component. Under his hypothesis the two are separated and each scaled differently. The frictional component is scaled based on Froude's experiments with flat plates towed under water. The residuary resistance is scaled by requiring the coefficient of residuary resistance to be the same for two geometrically similar ships traveling at corresponding speeds. Corresponding speeds are speeds where the speed-length ratio is constant (constant Froude number in non-dimensional terms).

Over the years towing tank facilities in different countries developed improvements to the basic Froude approach. In 1978 the International Towing Tank Congress (ITTC) adopted a updated standardized procedure for performing ship resistance experiments and calculations. The ITTC-78 method considers the total model resistance as the sum of a viscous component and a wave making component (see reference material). The viscous component uses the 1957 ITTC friction line to estimate a frictional resistance coefficient. To include the effect of hull shape and viscous pressure drag a form factor is estimated and applied to the frictional resistance coefficient to make a viscous resistance coefficient. Froude's hypotheses is still applied to the wave making resistance, where the coefficient of wave making resistance is the same for two geometrically similar ships traveling at the same Froude number.

## 2. Assignment

Observe/conduct a model test for a 1/100<sup>th</sup> scale model of the USS ARLEIGH BURKE DDG-51 Class guided missile destroyer. Compare the model test results to full scale resistance data provided from ASSET.

## 3. Process:

### 3.1. Prepare for model testing:

- Tests will be conducted using a 1/100<sup>th</sup> scale model ( $\lambda = 100$ ) of the DDG-51 class guided missile destroyer at ship speeds from 5 to 30 knots in 5 knot intervals.
- Use Froude scaling to determine the model speeds for the towing tank tests.
- Given the full load displacement for the DDG-51, determine how much the model must weigh (in lbs) to replicate this condition

### 3.2 Conduct model tests:

- The MIT Towing Tank is located in the Parson's Laboratory
- Calibrate the force block (or calibration data provided)
- Record the water temperature in the towing tank
- Record the voltage output for each speed and use the calibration to convert into the total model resistance (in lbf).
- Truncate the data over a period of at least a few seconds where the model has reached full speed and take the average value of total resistance

### 3.3 EHP Expansion:

- Use the ITTC-1978 method to expand the model test data to full scale.
- Use the measured water temperature (fresh water) for the model and 59° F (salt water) for the ship.

## 4. Deliverables:

**D-1:** Describe and comment on your observations during the tow tank experiment. What are the limitations of most model tests? How are you able to account for or resolve them?

**D-2:** Comparative plot of predicted and actual full scale EHP vs speed for the DDG151.

1. Use the data below for full scale comparison.
2. Calculate the form factor using Prohaska's method (section 8.3.3) and include a copy of the plot in your report (see Figure 8.6 for an example).
3. You can approximate the frontal area for the DDG-51 as  $A_T = B \times B/2$

**D-3:** A plot of the predicted ship scale resistance coefficients vs. Froude number for the DDG-51

1. Plot the  $C_{TS}$ ,  $(1+k) C_{FS}$ ,  $C_{WS}$ ,  $\Delta C_F$  and  $C_{AA}$ .
2. Comment on the shape of the coefficient of wave making resistance graph.

**D-4:** Spreadsheet with your calculations.

**D-5:** Answer the following questions:

1. From section 8.2.2 – is the model an appropriate size for the MIT towing tank? What happens when a model is too large for the tank it is tested in? MIT tank dimensions are 100ft x 8 ft x 4ft.
2. From section 8.2.2: Do we need to be concerned about the critical depth Froude number in any of our tests? What assumption is violated if we do exceed this value?
3. Determine the static ballasting requirements (draft and weight) for the model to replicate the full scale ship in the condition listed below.
4. Are there any runs that will not be in the turbulent regime (by Reynolds number)? If so, how do we account for this? Why do we want the model tests to be in the turbulent regime?
5. Comment on any significant differences between the EHP from the ITTC-78 expansion and the values from ASSET.

Use the following values for the characteristics of the full scale DDG51:

LOAD LENGTH, FT	467.35	FULL LOAD BEAM, FT	59.56
FULL LOAD DRAFT, FT	21.90	FULL LOAD PRISMATIC COEF	0.6023
FL WETTED SURF AREA, FT2	32248.8	FULL LOAD MAX SECT COEF	0.8301
FULL LOAD WT, LTON	9000.9	CORR ALW	0.00040

SPEED KT	-----EFFECTIVE HORSEPOWER, HP-----					TOTAL	DRAG LBF
	FRIC	RESID	APPDG	WIND	MARGIN		
5.00	76.	27.	81.	3.	15.	203.	13214.
6.00	130.	46.	131.	5.	25.	337.	18328.
7.00	202.	73.	197.	8.	38.	520.	24190.
8.00	298.	110.	280.	12.	56.	756.	30784.
9.00	419.	156.	382.	18.	78.	1052.	38095.
10.00	569.	214.	504.	24.	105.	1415.	46115.
11.00	750.	289.	648.	32.	137.	1855.	54961.
12.00	965.	400.	817.	41.	178.	2401.	65196.
13.00	1217.	540.	1011.	53.	226.	3046.	76355.
14.00	1508.	719.	1233.	66.	282.	3808.	88646.
15.00	1842.	941.	1484.	81.	348.	4696.	102015.
16.00	2222.	1119.	1759.	98.	416.	5614.	114330.
17.00	2649.	1336.	2064.	118.	493.	6661.	127679.
18.00	3127.	1633.	2405.	140.	584.	7889.	142814.
19.00	3658.	1950.	2777.	165.	684.	9234.	158377.
20.00	4246.	2545.	3199.	192.	815.	10996.	179167.
21.00	4892.	3517.	3679.	222.	985.	13295.	206302.
22.00	5600.	4434.	4188.	256.	1158.	15635.	231591.
23.00	6371.	5347.	4731.	292.	1339.	18080.	256159.
24.00	7210.	6397.	5318.	332.	1541.	20797.	282376.
25.00	8117.	7842.	5966.	375.	1784.	24085.	313935.
26.00	9097.	9933.	6692.	422.	2092.	28236.	353886.
27.00	10152.	13267.	7533.	473.	2514.	33937.	409595.
28.00	11283.	18092.	8502.	527.	3072.	41476.	482701.
29.00	12495.	24037.	9575.	586.	3735.	50428.	566643.
30.00	13789.	30763.	10733.	648.	4475.	60407.	656149.

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