Naval Surface Warfare Center
Carderock Division

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Evaluation of a CFD Program AEGIR™ for Bare Hull Resistance and Seakeeping Prediction Capability

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14. ABSTRACT
In this study, a 3D potential flow, panel method based CFD tool called AEGIR™ was assessed for predicting bare hull resistance and seakeeping performance. The program was run on mid-range personal computers, and analyses were performed on few different hullforms including the Joint High Speed Sealift (JHSS) monohull, a catamaran, a trimaran and a hard-chined semi-displacement monohull. Two different bow configurations, an elliptical shaped bulb and a gooseneck shaped bulb, were considered for the JHSS monohull bare hull resistance. For the catamaran and trimaran hullforms, the demihull and the center hull alone configurations were also considered for bare hull resistance. Measured data from model tests was used as a benchmark for validation. The focus was mainly on bare hull resistance with a very limited study on seakeeping. For all the hullforms and configurations, the coefficient of residuary resistance, sinkage and trim over a range of Froude numbers in calm water were obtained in AEGIR™ and compared with model test results. A limited set of seakeeping runs were performed in AEGIR™ on JHSS Monohull with gooseneck bulb and the catamaran demihull to obtain heave and pitch RAOs in regular head sea waves.

The correlation between AEGIR™ and model test results for calm water performance (bare hull resistance, sinkage and trim) was excellent for the JHSS monohull configurations but was poor for other hullforms studied. The results are inconclusive for seakeeping assessment due to limited number of studies. The overall conclusion is that AEGIR™ performs well to predict calm water and head sea seakeeping performance for hullforms with small or no transoms.

15. SUBJECT TERMS
AEGIR™, Code Validation, Resistance, Seakeeping, JHSS Monohull, Bulbous Bow, Catamaran, Trimaran, CFD, 3D Potential Flow

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Abstract

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The correlation between AEGIR™ and model test results for calm water performance (bare hull resistance, sinkage and trim) was excellent for the JHSS monohull configurations but was poor for other hullforms studied. The results are inconclusive for seakeeping assessment due to limited number of studies. The overall conclusion is that AEGIR™ performs well to predict calm water and head sea seakeeping performance for hullforms with small or no transoms.

During the validation process, the team developed test matrices, test procedure, batch files, and spreadsheet files to streamline the testing processes. Feedback for developers has been compiled for consideration during future development of the software.

Acknowledgements

The authors would like to acknowledge the assistance of Dr. Colen G. Kennell, Mr. Jack Offutt and Mr. Steve Ouimette of the Center for Innovation in Ship Design, NSWCCD for their guidance, support, and mentorship throughout the project.

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The authors would also like to thank Mr. Brian Petersen of Applied Physical Sciences Corporation for providing excellent user support.

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Table of Contents

List of Tables

List of Figures

Acronyms, Coefficients, Variables, and File Extension

BEM – Boundary Element Method
BHR – Bare Hull Resistance
CAD – Computer Aid Design
CFD – Computational Fluid Dynamics
CISD – Center for Innovation in Ship Design
EB – Elliptical Bulb
FN – Froude Number
GB – Gooseneck Bulb
HSSL – High Speed Sealift
JHSS – Joint High Speed Sealift
LC – Light Cutter
ONR – Office of Naval Research
RAO – Response Amplitude Operator
NSWCCD – Naval Surface Warfare Center, Carderock Division
SWATH – Small Waterplane Area Twin Hull
SK – Seakeeping
.BOD - Body Input File
.DIS - Discretization File
.INC –Incident Wave Specification File
.INP - Master Input File
.MDD - Mode Definition File
.3DM – Rhinoceros™ 3D model

1 Introduction

AEGIR™ is a software package that shows great promise as a CFD tool for resistance and seakeeping performance prediction of many hullforms of interest to the Navy including monohulls, catamarans, SWATHs, trimarans, surface effect ships, and air cushion vehicles. The code was originally implemented by Mr. David Kring in late 1990's at MIT, with subsequent developments made in collaboration with Mr. William Milewski at Applied Physical Sciences Corporation. Mr. Brian Petersen and Mr. Benjamin Connell have contributed to the development over the last 3 years. This tool was used earlier in the design optimization scheme developed under High Speed Sealift program of Office of Naval Research, and the accuracy of the program in the hands of the developers was demonstrated in that effort. This made AEGIR™ highly desirable as a generic hydrodynamic analysis tool for CISD and for use in an educational environment. To evaluate its suitability for use by non-developers, a team consisting of a college intern of Naval Research Enterprise Intern Program, a naval architect from CISD and a visiting professor through ONR Summer Faculty Research Program, was formed and tasked with this effort as part of their summer research.

1.1   Objective

The AEGIR™ evaluation project has the following objectives:
- Assess suitability for use by non-developers
- Assess robustness of the program
- Evaluate reliability and accuracy of the resistance predictions for a variety of previously tested hullforms
- Assess accuracy of ship motions predictions for selected hullforms
- Provide constructive feedback to the developers

1.2   AEGIR™

AEGIR™ is a time-domain seakeeping code that uses an advanced, high-order boundary element method (BEM) to solve the three-dimensional potential-flow. It also includes a fully non-linear steady-state solver for sinkage, trim and wave resistance predictions. It interfaces with a popular CAD program Rhinoceros™ for hull geometry modeling and has an automated gridding feature that enables users with little CFD tool experience to create free surface and body geometry grids. The version that was primarily used in this evaluation is v0.88.100, except for the trimaran evaluation where a newer release, version v0.88.200, was used.

The simulations were run on the following computers:
- HP Intel Laptop - Core2 Duo CPU T7500, 2.19 GHZ, 1.98 GB of RAM
- Dell Intel Desktop - Core2 Duo CPU E6550, 2.33 GHZ, 3.25 GB of RAM
- Dell Intel Desktop - Xeno CPU 5160, 3.00 GHZ, 8.00 GB of RAM

The hullforms that were selected along with the test matrices used in the evaluation are described in section 2. The descriptions of the program architecture, input files, etc. are given in some detail in section 3. The AEGIR™ simulations and comparison with model test results are described in section 4 followed by discussion and conclusions in section 5.

2 Hullforms and Test Matrices

A range of hullforms that are of interest to the Navy and have available geometry files and model test data were selected for the study. They included a high speed slender monohull with two bulbous bow designs, a high speed semi-displacement catamaran, a hard-chined semi -planing monohull and a trimaran.

2.1   JHSS Monohull

The Joint High Speed Sealift (JHSS) project is a conceptual Navy design study that has well-documented model test data available to the team. The monohull variant of the JHSS hullforms considered four different bow shapes; two of the shapes, gooseneck and elliptical bulbs, were included in this evaluation.

A photo of the gooseneck bulb test model and the body plan along with principal characteristics of this hullform are shown in Figures 1 and 2. Similar figures for the hull with elliptical bulb are shown in Figures 3 and 4. The details on the hullforms and model test results can be found in reference 1 from which these figures are taken.
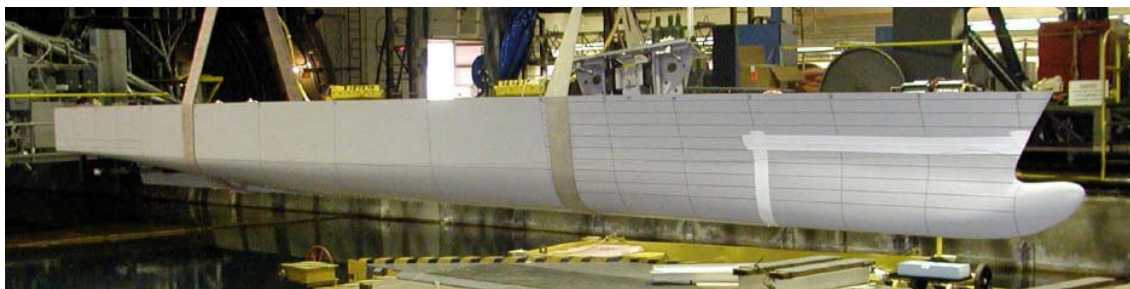
Figure 1. Tank Test Model of JHSS Monohull – Gooseneck Bulb

(taken from NSWCCD-50-TR-2007/066)
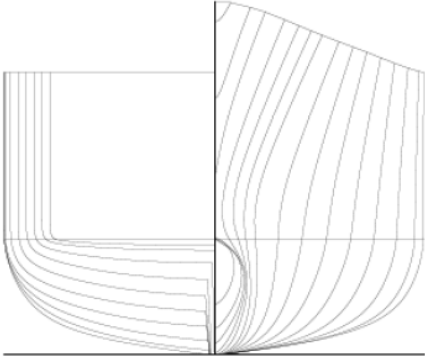
JHSS Propeller Hull With Gooseneck Bulb 04/19/2006

PRINCIPAL DIMENSIONS

LENGTH (LBP)	=	980.03 ft (298.71 m)
LENGTH (LWL)	=	977.89 ft (298.06 m)
BEAM (B_X)	=	104.87 ft (31.97 m)
DRAFT (T_X)	=	28.82 ft (8.78 m)
TRIM (+Bow)	=	0.00 ft (0.00 m)
DISPLACEMENT	=	36490.5 T (37074. t)
WETTED SURFACE	=	105221 sqft (9775. sqm)

NONDIMENSIONAL COEFFICIENTS

C_B	=	0.432	C_{VP}	=	0.608	L_E/LWL	=	0.529
C_P	=	0.538	C_{VPF}	=	0.812	L_P/LWL	=	0.000
C_{PF}	=	0.499	C_{VPA}	=	0.501	L_R/LWL	=	0.471
C_{PA}	=	0.587	C_S	=	2.979	FB/LWL	=	0.486
C_{PE}	=	0.522	LWL/B_X	=	9.324	FF/LWL	=	0.574
C_{PR}	=	0.556	B_X/T_X	=	3.639	$100C_\nabla$	=	0.136
C_X	=	0.802	A_T/A_X	=	0.032	$\Delta/(.01LWL)^3$	=	39.0
C_{WP}	=	0.710	B_T/B_X	=	0.746	I_E	=	4.25
C_{WPF}	=	0.495	T_T/T_X	=	0.044	i_R	=	2.99
C_{WPA}	=	0.942	A_B/A_X	=	0.113	i_B	=	2.89

MODEL SCALE DATA

SCALE RATIO	=	34.121
LENGTH (LBP)	=	28.72 ft (8.75 m)
LENGTH (LWL)	=	28.66 ft (8.74 m)
BEAM (B_X)	=	3.07 ft (0.94 m)
DRAFT (T_X)	=	0.84 ft (0.26 m)
DISPLACEMENT	=	2001.0 lbs (0.91 t)
WETTED SURFACE	=	90.38 sqft (8.40 sqm)

Figure 2. Principal Characteristics of Model 5653-3, JHSS Monohull – Gooseneck Bulb

(taken from NSWCCD-50-TR-2007/066)
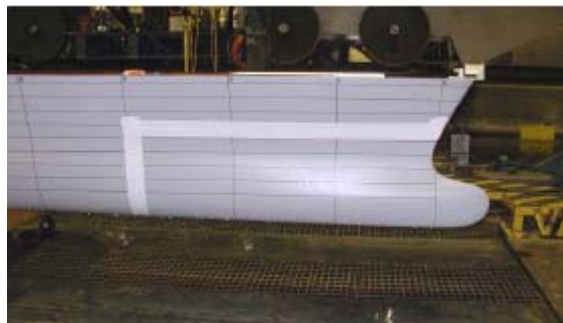
Figure 3. Tank Test Model of JHSS Monohull – Elliptical Bulb

(taken from NSWCCD-50-TR-2007/066)

JHSS Propeller Hull Elliptical Bulb 05/11/2006

PRINCIPAL DIMENSIONS

LENGTH (LBP)	=	950.51 ft	(289.71 m)
LENGTH (LWL)	=	949.42 ft	(289.38 m)
BEAM (B_X)	=	104.93 ft	(31.98 m)
DRAFT (T_X)	=	28.93 ft	(8.82 m)
TRIM (+Bow)	=	0.00 ft	(0.00 m)
DISPLACEMENT	=	36490.5 T	(37074. t)
WETTED SURFACE	=	105217 sqft	(9775. sqm)

NONDIMENSIONAL COEFFICIENTS

C_B	= 0.443	C_{VP}	= 0.607	L_E/LWL	= 0.531			
C_P	= 0.554	C_{VPF}	= 0.807	L_P/LWL	= 0.000			
C_{PF}	= 0.537	C_{VPA}	= 0.493	L_R/LWL	= 0.469			
C_{PA}	= 0.576	C_S	= 3.023	FB/LWL	= 0.504			
C_{PE}	= 0.561	LWL/B_X	= 9.048	FF/LWL	= 0.593			
C_{PR}	= 0.545	B_X/T_X	= 3.627	$100C_\nabla$	= 0.149			
C_X	= 0.799	A_T/A_X	= 0.036	$\Delta/(.01LWL)^3$	= 42.6			
C_{WP}	= 0.729	B_T/B_X	= 0.753	i_E	= 6.05			
C_{WPF}	= 0.532	T_T/T_X	= 0.047	i_R	= 2.76			
C_{WPA}	= 0.935	A_B/A_X	= 0.080	i_B	= 2.22			

MODEL SCALE DATA

SCALE RATIO	=	34.121	
LENGTH (LBP)	=	27.86 ft	(8.49 m)
LENGTH (LWL)	=	27.83 ft	(8.48 m)
BEAM (B_X)	=	3.08 ft	(0.94 m)
DRAFT (T_X)	=	0.85 ft	(0.26 m)
DISPLACEMENT	=	2001.0 lbs	(0.91 t)
WETTED SURFACE	=	90.38 sqft	(8.40 sqm)

Figure 4. Principal Characteristics of Model 5653-2, JHSS Monohull-Elliptical Bulb

(taken from NSWCCD-50-TR-2007/066)

2.2   Molland Catamaran

For evaluating catamarans in AEGIR™, a hullform from the "Molland Series" presented in references 3, 4 and 5 was used. In those studies, a systematic series of catamaran hullforms derived from the NPL round bilge monohull series were tested in various configurations and the results for resistance, sinkage and trim were presented. Model 5b from that series is used in the present evaluation. The demihull body plan is shown in Figure 5 and the principal characteristics of the model are given in Table 1.
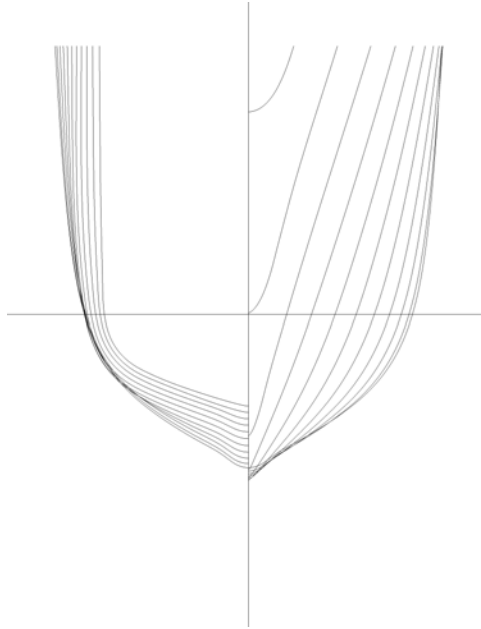
Figure 5. Catamaran Model 5b Demihull Body Plan

Molland Catamaran - Model 5b			
Principal Dimensions		**Non-dimensional Coefficients**	
Length (LWL)	= 1.6 m	S/L =	0.2
Beam Overall	= 0.47 m	L/B =	11
Demihull Beam (B)	= 0.145 m	B/T =	2
Draft (T)	= 0.073 m	L/V1/3 =	8.5
Volume (V)	= 0.00667 m^3	CB =	0.397
Δ	= 0.00684 MT	CP =	0.693
Wetted Area	= 0.276 m^2	CM =	0.565
LCB	= 0.1024 m aft of Φ		

Table 1. Principal Characteristics of Molland Catamaran Model 5b

2.3 Semi-Planing Hard-Chine Monohull

Marinette Marine Corporation developed a 143 ft semi-planing, hard-chine Light Cutter design as part of the Integrated Deep-Water System for the US Coast Guard. The hullform was model tested at 1/20th scale for bare hull resistance, appended hull resistance, trim wedge optimization and seakeeping at Davidson Laboratory, Stevens Institute of Technology (Reference 6). The body plan is shown in Figure 6 and the principal characteristics are given in Table 2.
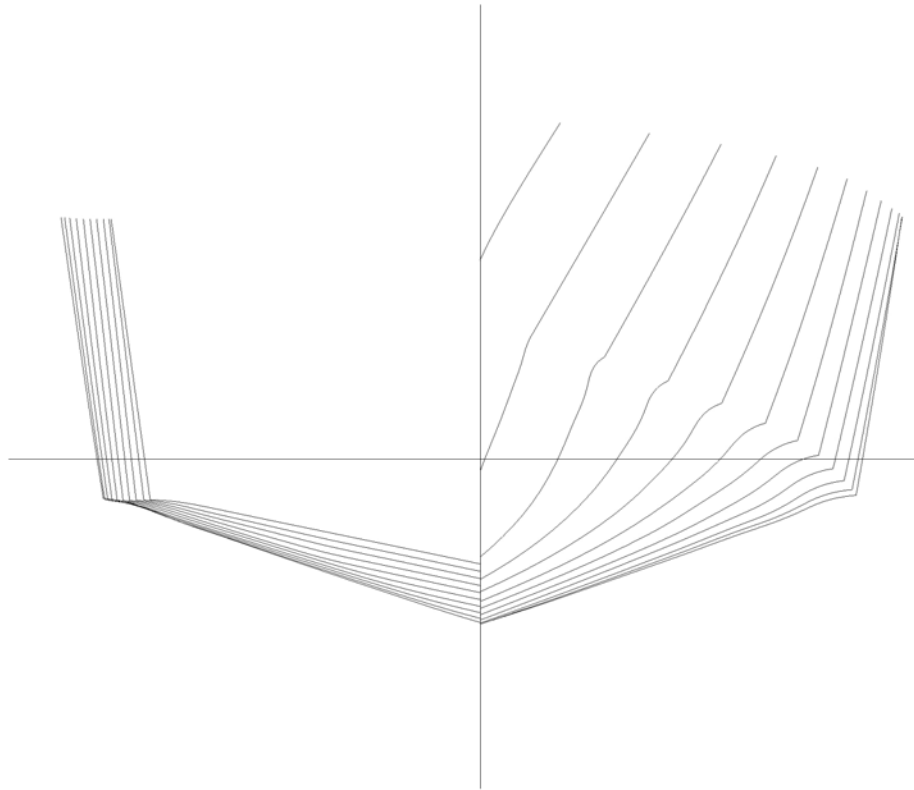
Figure 6. Semi-Planing, Hard-Chine Monohull Body Plan

Semi-Planing Hard-Chine Monohull		
Coast Guard Light Cutter		
Principal Dimensions	**Non-dimensional Coefficients**	
Length (LOA) = 43.6 m		
Length (LWL) = 39.5 m	CB =	0.432
Beam (B) = 7.4 m	CP =	0.752
Draft (T) = 1.6 m	CM =	0.575
Δ = 204 LT	CW =	0.784
Wetted Area = 271.3 m^2	At/Ax =	0.27
LCB = 2.54 m aft of Φ	1/2 α =	18 deg
Scale Ratio = 21.6		

Table 2. Principal Characteristics of Light Cutter

2.4 Trimaran

The trimaran hullform used in the evaluation is a concept design developed at NSWCCD for the JHSS mission, designated as the Mark Selfridge Trimaran. This was extensively model tested at Webb Institute, Stevens Institute, US Naval Academy and University College London as part of an ONR sponsored research project. The center hull has a bulbous bow and transom stern, and the sidehulls are symmetric displacement type hullforms. The details on the hullform, resistance model tests for outrigger location optimization and results are given in reference 7. The body plan is shown in Figure 7 and the principal full-scale characteristics are given in Table 3.
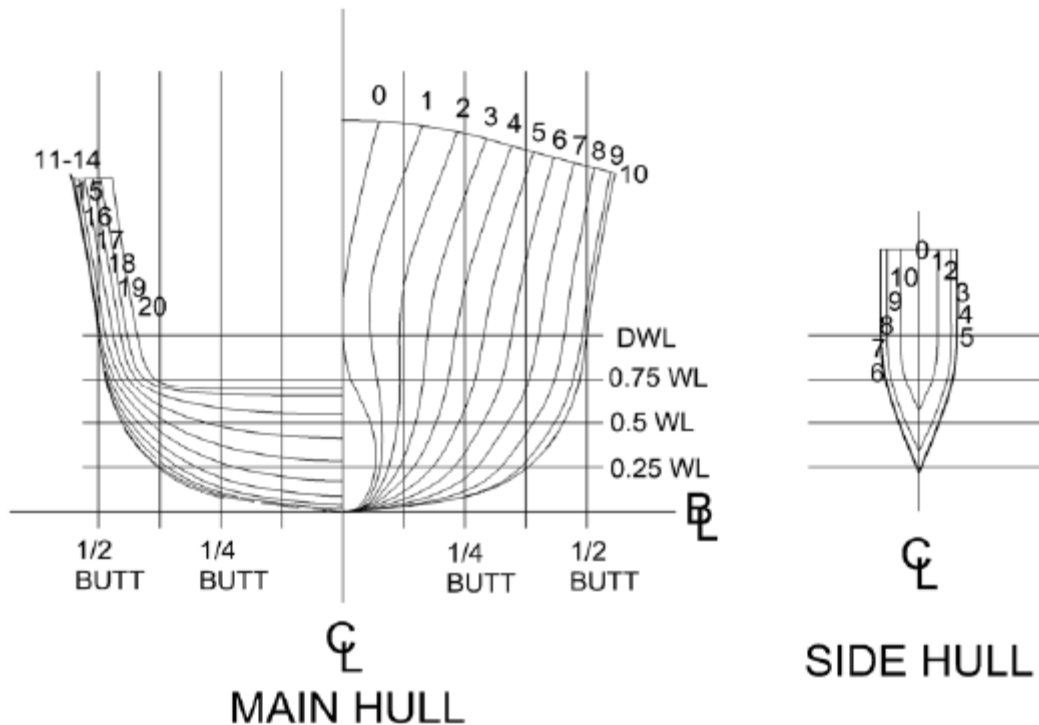

Figure 7. Trimaran Body Plan

Trimaran			
Centerhull		*Sidehull*	
Length =	268.3 m	Length =	77 m
Beam =	25.9 m	Beam =	3.8 m
Draft =	9 m	Draft =	7.1 m
WA =	7520 m^2	WA =	910 m^2
	Total Displacement =	32,200 MT	
	LCB =	12.35 m aft of Φ	
	Scale Ratio =	125.77	

Table 3. Principal Characteristics of Trimaran

2.5   Test Matrices

The complete matrix of test conditions that have been used in the AEGIR™ evaluation is given in Table 4.

For the JHSS monohull, both the gooseneck bulb and elliptical bulb configurations were evaluated at the design draft over a range of ship speeds from 15 to 45 knots for bare hull resistance. The gooseneck bulb configuration was also evaluated in regular head sea waves at two ship speeds over a range of wave lengths.

The Molland Catamaran Model 5b was evaluated in the demihull configuration and one catamaran configuration for barehull resistance at the design draft over a range of Froude numbers. The demihull configuration was also evaluated in regular head sea waves at Fn=0.2 over a range of wave periods.

The semi-planing, hard-chine monohull was evaluated for bare hull resistance at the design draft over a range of speeds.

The trimaran was evaluated in the "center hull alone" and one trimaran configuration for bare hull resistance at the design draft over a range of Froude numbers.

Hull Configuration	Loading Condition	Test Condition	Speed (kts)	Speed (Fn)	Wave Length / Ship Length	Wave Period
JHSS-GB	36490.5 LT	BHR	15 kts to 45 kts in 1 kt increments	-	-	-
		SK	25 kt & 36 kt	-	0.744, 0.809, 0.844, 0.882, 0.923, 0.966, 1.013, 1.116, 1.237	-
JHSS-EB	36490.5 LT	BHR	15 kts to 45 kts in 1 kt increments	-	-	-
Molland Model 5b Demihull	6.8424 kg	BHR	-	0.20 to 1.00 in 0.05 increments	-	-
		SK	-	.20 (0.79 m/s)	-	0.5, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.5, 3.0 secs
Molland Model 5b Catamaran with S/L = 0.2	13.6848 kg	BHR	-	0.20 to 1.00 in 0.05 increments	-	-
Semi-Planing Hard-Chine Monohull	204 LT	BHR	4 kts to 34 kts in 1 kt increments	-	-	-
Trimaran Center Hull Alone	32200 MT	BHR	-	0.1 to 0.5 in 0.02 increments	-	-
Trimaran Configuration		BHR	-		-	-

Table 4. AEGIR Evaluation Matrix

3 AEGIR™ Architecture

3.1 Overview

AEGIR™ is a single executable file that runs from the command prompt under windows and requires multiple input files for specifying the geometry, discretization and solver parameters. Figure 8 shows the overall architecture of AEGIR™ program.
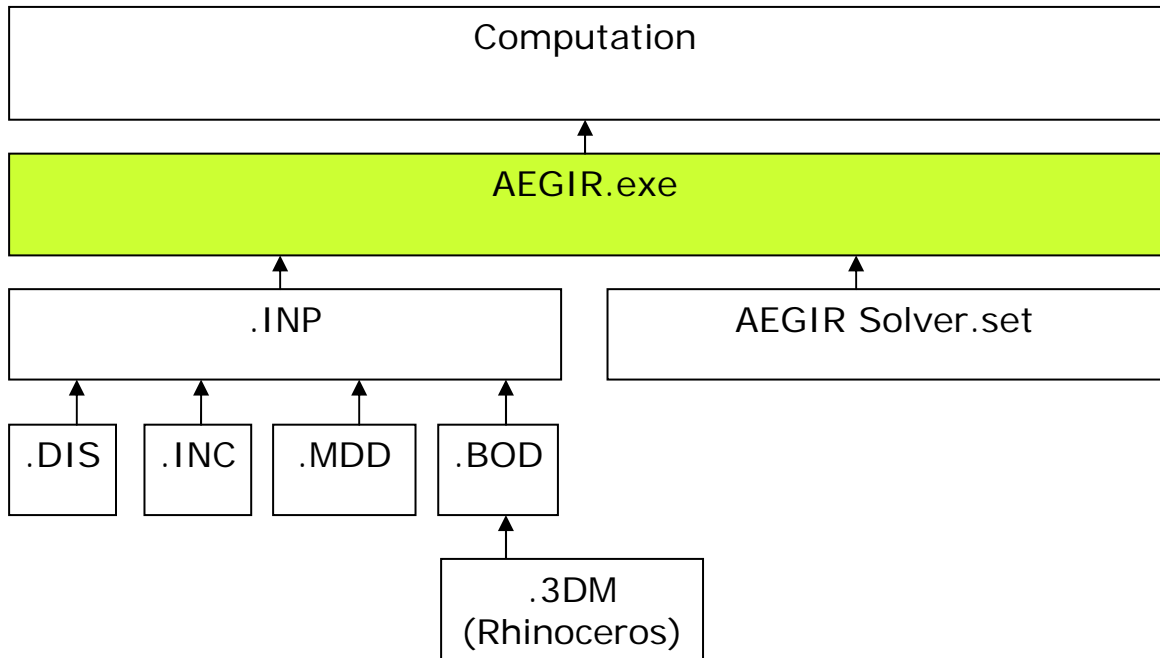
Figure 8. AEGIR^{TM} Flowchart

AEGIR™ automatically builds the body and free surface grid based on few user specified parameters related to domain size and panel density. For monohulls, the software typically required three categories of patches: outer free surface, transom free surface (water surface behind ship's transom), and the hull. Figure 9 shows a typical extent of computational domain and numerical grid. The ability to directly import the CAD geometry from Rhino and the automated gridding process significantly reduced the workload for the user. After computation, AEGIR™ generates multiple files for data analysis. The input and output files are described in some detail in the following sections.

Figure 9. Typical Computational Domain and Numerical Grid in AEGIR™

3.2   Input Files

.3DM file (3D model file): a Rhinoceros™ file that contains the geometry of hullforms. AEGIR™ has a capability to take a semi hull to exploit the benefit of symmetry. All the hulls that the team used were semi hull forms.
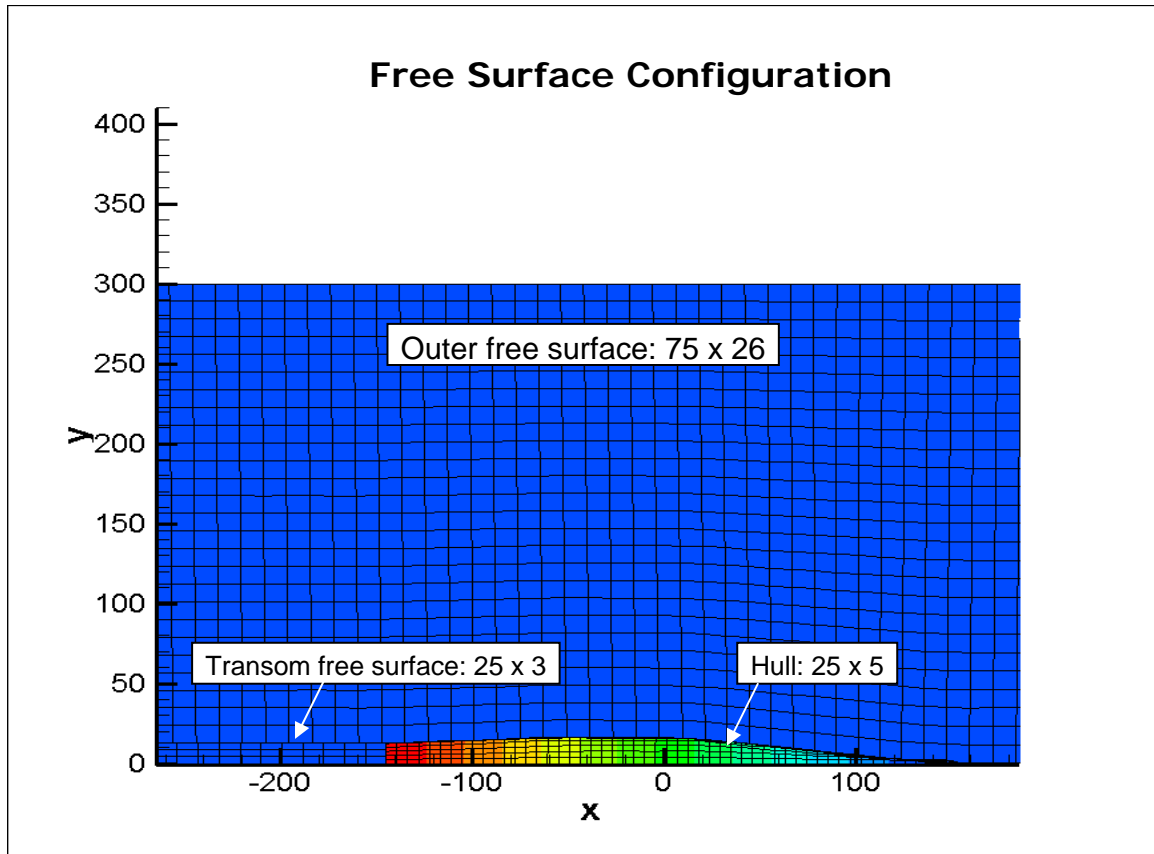
.BOD file (BODY file): This file links the Rhinoceros™ file to the program. User can specify which Rhinoceros™ file for AEGIR™ to read. User can define mass of the ship and the location of the center of gravity, and motion output location. Appendix B – Typical AEGIR™ Input Files to see the complete list of parameters .BOD file can define.

.DIS file (discretization file): A user can define the panel density of free/transom free surface, size of free surface domain, and body/hull patches in the Rhinoceros™ file. AEGIR™ requires the user to identify in the .DIS file all the patches contained in the corresponding geometry .3DM file. The typical size of free surface domain size is 3 ship-lengths by 1 ship-length. Once the user defines the panel densities of all panels, AEGIR™ automatically generates gridding. Appendix B – Typical AEGIR™ Input Files to see the complete list of parameters .DIS file can define.

.INC file (incident wave file): Period, heading, amplitude and phase of incident wave can be defined in this file. A user can set up different incident waves to analyze seakeeping motions in different wave conditions. Appendix B – Typical AEGIR™ Input Files to see the complete list of parameters .INC file can define.

.MDD file (mode definition file): The user can define mean body position and generalized mode definition for seakeeping predictions. Among six degrees of freedom in a ship motion, the user can choose which motions to extract via this file. Please refer to Appendix B – Typical AEGIR™ Input Files to see the complete list of parameters .MDD file can define.

AEGIR_solver.set (Solver set file): User can specify computation settings related to number of iterations, tolerances etc in this input file. Computation time and results vary depending on solver settings. Please refer to Appendix B – Typical AEGIR™ Input Files to see the complete list of parameters solver set can define.

3.3   Geometry File – Rhinoceros™

The geometry of the hull must be developed in a very specific way for AEGIR™. The geometry cannot be a polysurface, but all patches that build the hullform have to be a surface. All surface polygons have to be quadrilaterals. U direction of the surface must face downstream, and V direction of the surface must point downward in majority of cases. More detailed instructions on how to build the CAD file for AEGIR is given in Appendix A.

3.4   Output Files

The basic results from AEGIR are given in '.stf1' file (steady output table) for steady state resistance calculation and '.bdm' file (body motion history) for seakeeping simulations. The '.stf1' file contains hull wetted surface area, displaced volume, sinkage, trim, and wave resistance and the '.bdm' file contains time history of the motion at each degree of freedom.

In addition, AEGIR™ produces multiple Tecplot files during computation that aid the user in visualizing the numerical set-up and results. Tecplot is a CFD graphing, plotting, and visualization software that is widely used in CFD community. User can check the hull form, grid configuration, and wave pattern via Tecplot output files. Figure 10 is one of Tecplot files that AEGIR™ generated. Z axis is magnified by 10 to show the wave pattern. Note that the hull is in semi hull configuration with symmetry option to reduce computation time. Figure 11 is 2D version of figure 9 showing wave elevation.
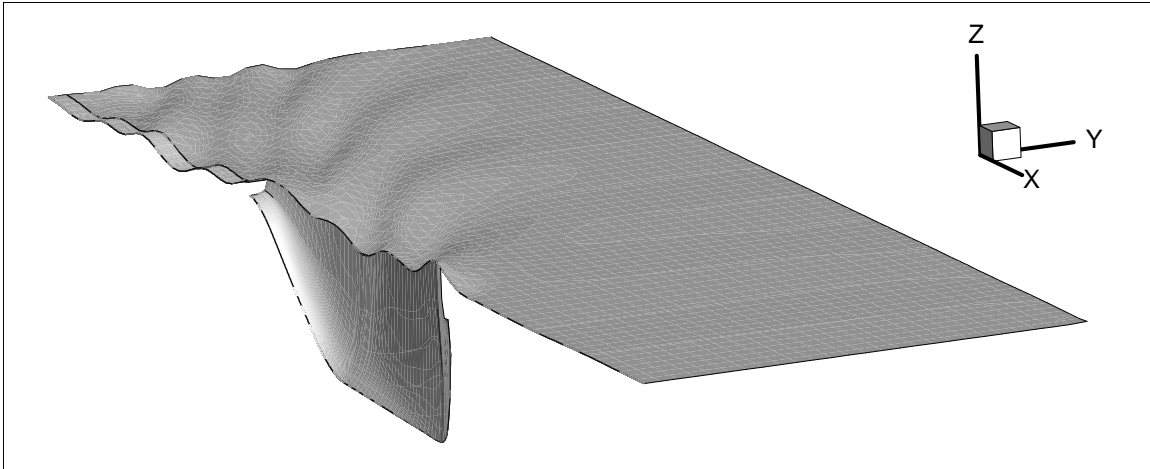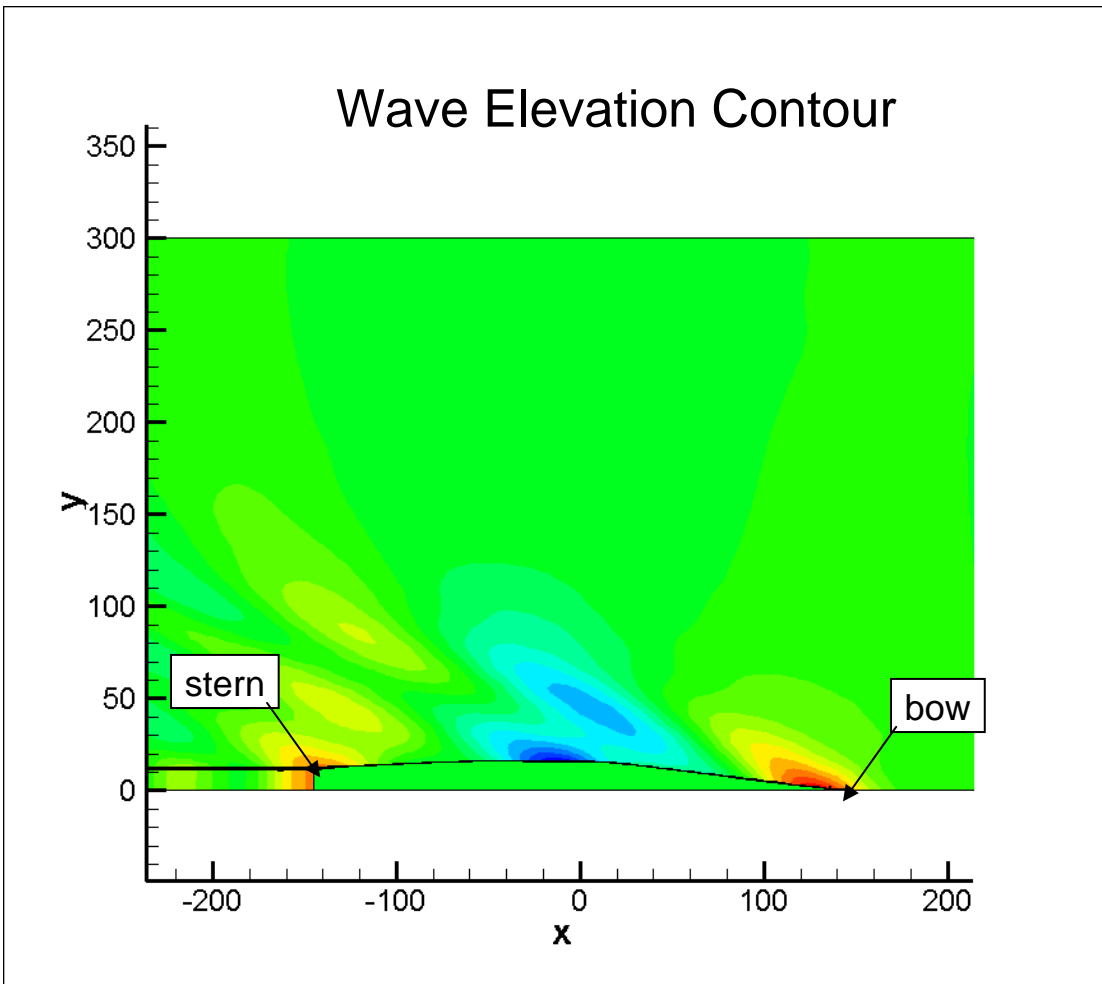
Figure 10. Tecplot File 3D

Figure 11. Tecplot File 2D

4 AEGIR™ Simulations and Comparison with Model Test Results

The AEGIR™ simulations were performed on the four hullforms and the test matrices given in section 2, and the results were compared with experimental results obtained from model tests.

4.1 Setup and Convergence

The computational model needed to be setup and tested for convergence before the actual data runs. In addition to specifying various file names and basic hull information in proper AEGIR™ input files, the parameters that need to be updated are the speed and output file names for each run. The spatial discretization is one of the critical areas of concern and a convergence study needs to be performed for the selection of panel density. Figure 12 below shows the results of a convergence study on the JHSS gooseneck bulb, where Cr is plotted against the number of free surface panels along the stream-wise direction (with a corresponding increase in the cross stream direction and the body panels). This is performed at a few different speeds. Based on these results a suitable panel density is chosen for simulations. For the catamaran and trimaran hullform configurations, convergence could not be obtained and a high enough panel density suitable for the available RAM was chosen for the simulations.
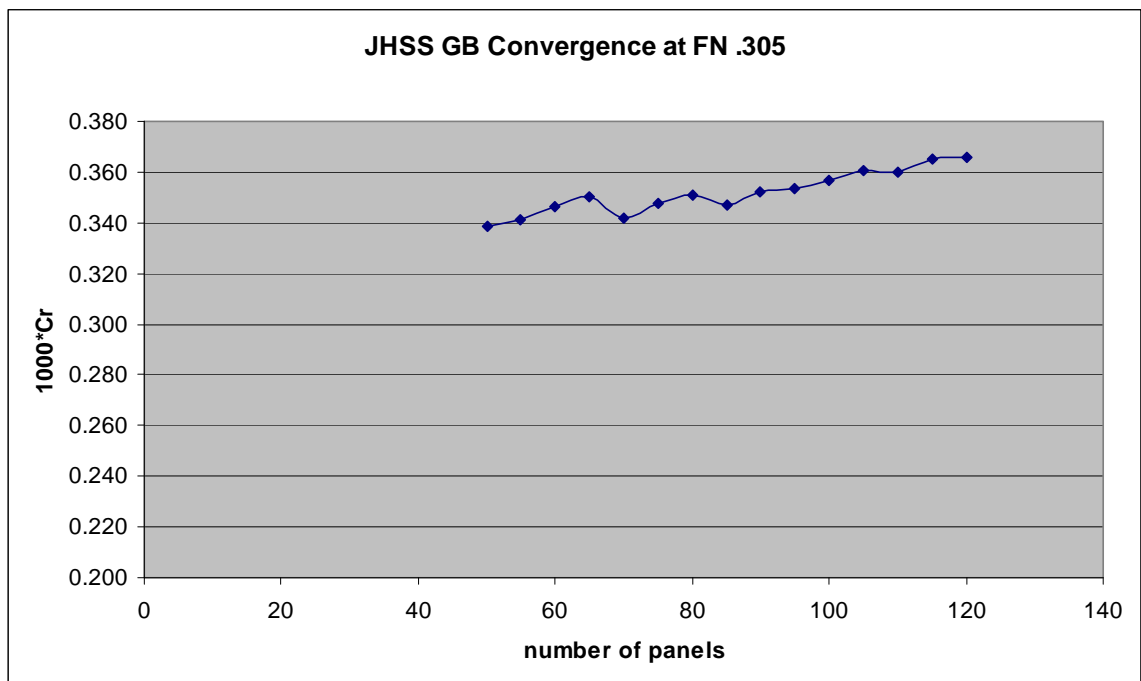

Figure 12. Typical Convergence Plot

4.2 Calm Water Performance

The nonlinear steady-state solver with dynamic sinkage and trim option was used, the number of wave iterations was limited to 10, and the number of sinkage and trim iterations was limited to 3. In some cases, the results did not converge within 10 iterations but the differences between the iterations were small in general and the values from the 10th iteration are taken as the results from the simulations. Also, it must be noted that AEGIR™ computes the wave making resistance and no form factor was used throughout this study in comparing with the model residuary resistance.

4.2.1 JHSS Monohull – Gooseneck Bow, Elliptical Bow Configurations

Gooseneck Bulb

The steady state resistance, sinkage and trim results from AEGIR™ along with the experimental data are shown in Table 5. Figure 13 shows the comparison of *Cr* and Figure 14 shows the comparison plot of sinkage and trim. The agreement on sinkage and trim between the AEGIR™ results and the model data is very good. The Cr data compared fairly well between the two sets of results, with *Cr* values from AEGIR™ being consistently lower throughout the speed range. However, when the reported Cr from model tests is corrected for skeg drag (using L_skeg/LWL = 0.4 and A_skeg/Wetted Surface Area = 0.06), the Cr results matched very well.

			1000CR			Sinkage (m)		Trim (deg)	
knots	m/s	Fn	Model Test	Corrected	Aegir	Model Test	Aegir	Model Test	Aegir
15	7.72	0.143	0.398			0.08		-0.03	
16	8.23	0.152	0.365			0.09		-0.04	
17	8.75	0.162	0.340						
18	9.26	0.171	0.318			0.12		-0.05	
19	9.77	0.181	0.300	0.103	0.0687		0.13		-0.08
20	10.29	0.190	0.287	0.092	0.0694	0.15	0.14	-0.06	-0.09
21	10.80	0.200	0.280	0.087	0.0630		0.16		-0.10
22	11.32	0.209	0.281	0.089	0.0586	0.18	0.18	-0.08	-0.11
23	11.83	0.219	0.288	0.098	0.0611		0.19		-0.12
24	12.35	0.228	0.299	0.110	0.0847	0.21	0.21	-0.10	-0.13
25	12.86	0.238	0.312	0.124	0.1169	0.23	0.24	-0.11	-0.14
26	13.38	0.247	0.323	0.137	0.1287	0.24	0.26	-0.12	-0.15
27	13.89	0.257	0.330	0.145	0.1249		0.28		-0.17
28	14.40	0.267	0.333	0.149	0.1223	0.29	0.31	-0.14	-0.19
29	14.92	0.276	0.330	0.147	0.1240		0.33		-0.21
30	15.43	0.286	0.325	0.143	0.1425	0.35	0.38	-0.17	-0.23
31	15.95	0.295	0.321	0.140	0.1364		0.40		-0.24
32	16.46	0.305	0.323	0.143	0.1470	0.42	0.43	-0.21	-0.25
33	16.98	0.314	0.337	0.158	0.1562		0.47		-0.27
34	17.49	0.324	0.369	0.191	0.1677	0.51	0.51	-0.24	-0.30
35	18.01	0.333	0.423	0.246	0.1993	0.56	0.55	-0.25	-0.32
36	18.52	0.343	0.504	0.328	0.2705	0.60	0.60	-0.26	-0.34
37	19.03	0.352	0.613	0.438	0.3959		0.66		-0.33
38	19.55	0.362	0.748	0.574	0.5667	0.70	0.71	-0.25	-0.30
39	20.06	0.371	0.903	0.729	0.6979		0.76		-0.28
40	20.58	0.381	1.071	0.898	0.8662	0.79	0.81	-0.19	-0.23
41	21.09	0.390	1.241	1.069	1.0445		0.86		-0.15
42	21.61	0.400	1.402	1.231	1.2306	0.87	0.90	-0.07	-0.06
43	22.12	0.409	1.549	1.378	1.3967		0.92		0.05
44	22.64	0.419	1.680	1.510	1.5246	0.94	0.93	0.08	0.16
45	23.15	0.428	1.812	1.643	1.6004	0.97	0.93	0.14	0.25

Table 5. JHSS Monohull- Gooseneck Bulb: Resistance, Sinkage and Trim Results
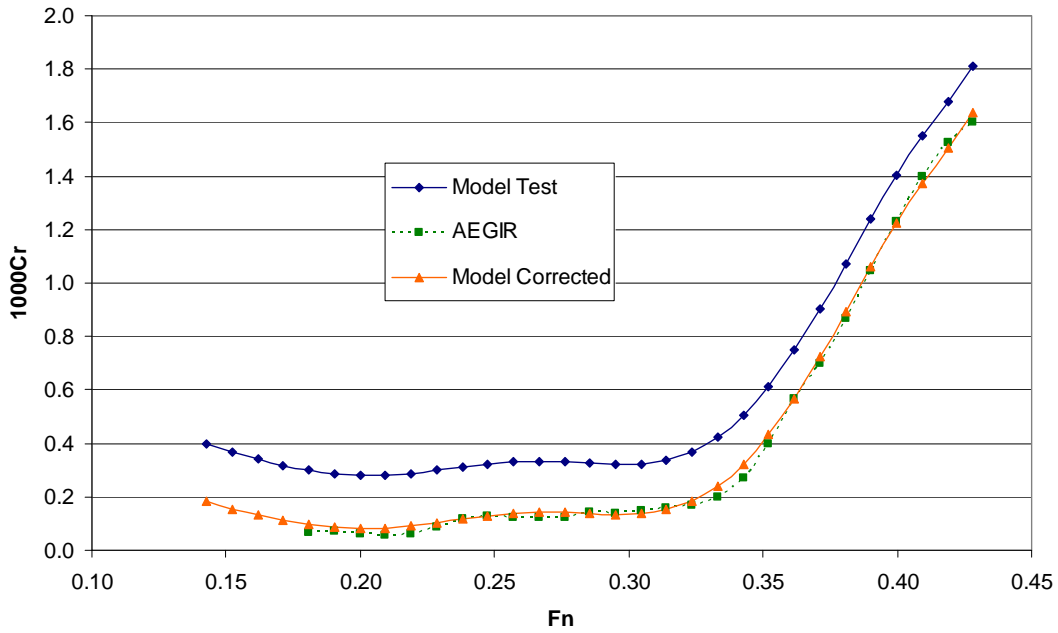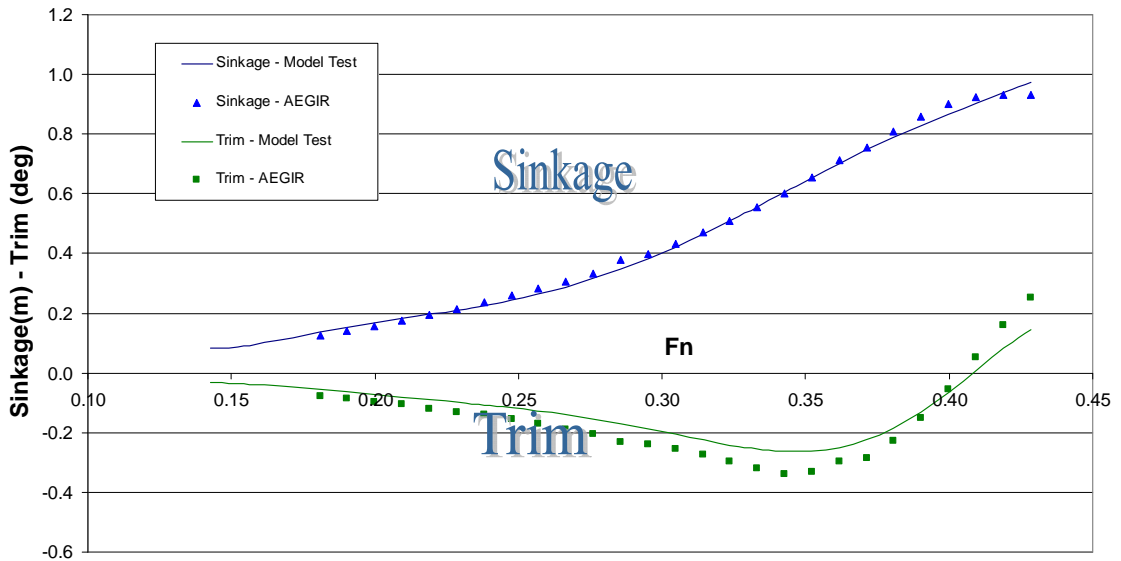
Figure 13. JHSS-GB: Cr Comparison

Figure 14. JHSS-GB: Sinkage and Trim Comparison

16

Elliptical Bulb

Similar results on resistance, sinkage and trim for the JHSS hullform with elliptical bulb are shown in Table 6, Figures 15 and 16. The correlation between the simulations and the model test results was very good for this bulb configuration as well.

Speed			1000CR			Sinkage (m)		Trim (deg)	
knots	m/s	Fn	Model Test	Corrected	Aegir	Model Test	Aegir	Model Test	Aegir
15	7.72	0.143	0.398	0.184		0.08		-0.03	
16	8.23	0.152	0.365	0.154		0.09		-0.04	
17	8.75	0.162	0.340	0.131					
18	9.26	0.171	0.318	0.112		0.12		-0.05	
19	9.77	0.181	0.300	0.096	0.0687		0.13		-0.08
20	10.29	0.190	0.287	0.085	0.0694	0.15	0.14	-0.06	-0.09
21	10.80	0.200	0.280	0.079	0.0630		0.16		-0.10
22	11.32	0.209	0.281	0.082	0.0586	0.18	0.18	-0.08	-0.11
23	11.83	0.219	0.288	0.091	0.0611		0.19		-0.12
24	12.35	0.228	0.299	0.103	0.0847	0.21	0.21	-0.10	-0.13
25	12.86	0.238	0.312	0.118	0.1169	0.23	0.24	-0.11	-0.14
26	13.38	0.247	0.323	0.130	0.1287	0.24	0.26	-0.12	-0.15
27	13.89	0.257	0.330	0.138	0.1249		0.28		-0.17
28	14.40	0.267	0.333	0.143	0.1223	0.29	0.31	-0.14	-0.19
29	14.92	0.276	0.330	0.141	0.1240		0.33		-0.21
30	15.43	0.286	0.325	0.137	0.1425	0.35	0.38	-0.17	-0.23
31	15.95	0.295	0.321	0.134	0.1364		0.40		-0.24
32	16.46	0.305	0.323	0.137	0.1470	0.42	0.43	-0.21	-0.25
33	16.98	0.314	0.337	0.152	0.1562		0.47		-0.27
34	17.49	0.324	0.369	0.185	0.1677	0.51	0.51	-0.24	-0.30
35	18.01	0.333	0.423	0.240	0.1993	0.56	0.55	-0.25	-0.32
36	18.52	0.343	0.504	0.322	0.2705	0.60	0.60	-0.26	-0.34
37	19.03	0.352	0.613	0.432	0.3959		0.66		-0.33
38	19.55	0.362	0.748	0.568	0.5667	0.70	0.71	-0.25	-0.30
39	20.06	0.371	0.903	0.723	0.6979		0.76		-0.28
40	20.58	0.381	1.071	0.892	0.8662	0.79	0.81	-0.19	-0.23
41	21.09	0.390	1.241	1.063	1.0445		0.86		-0.15
42	21.61	0.400	1.402	1.225	1.2306	0.87	0.90	-0.07	-0.06
43	22.12	0.409	1.549	1.372	1.3967		0.92		0.05
44	22.64	0.419	1.680	1.504	1.5246	0.94	0.93	0.08	0.16
45	23.15	0.428	1.812	1.637	1.6004	0.97	0.93	0.14	0.25

Table 6. JHSS Monohull- Elliptical Bulb: Resistance, Sinkage and Trim Results
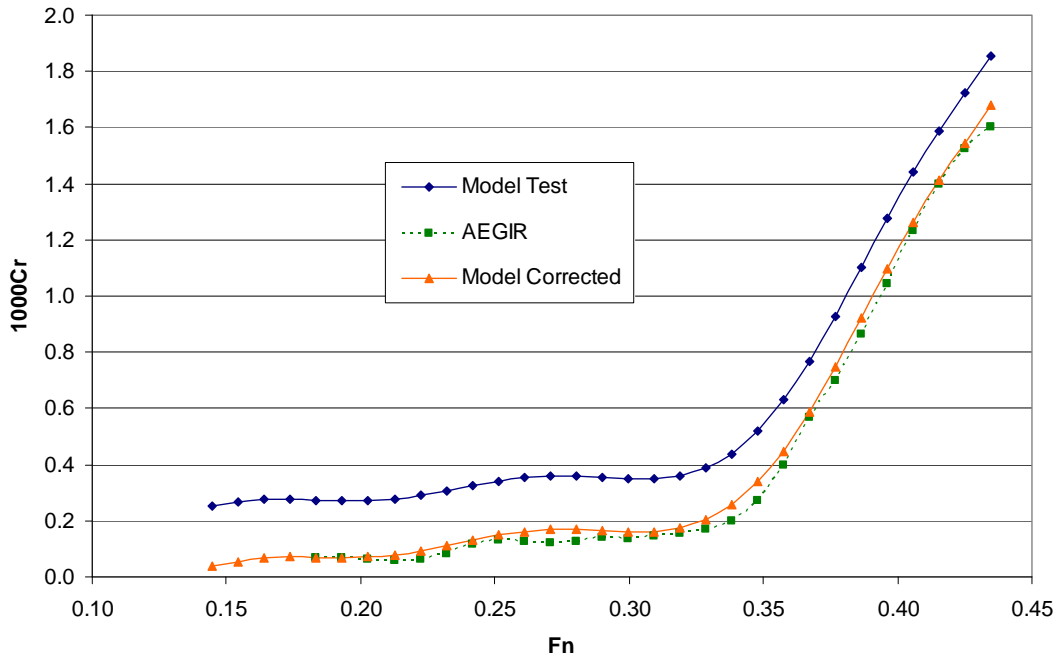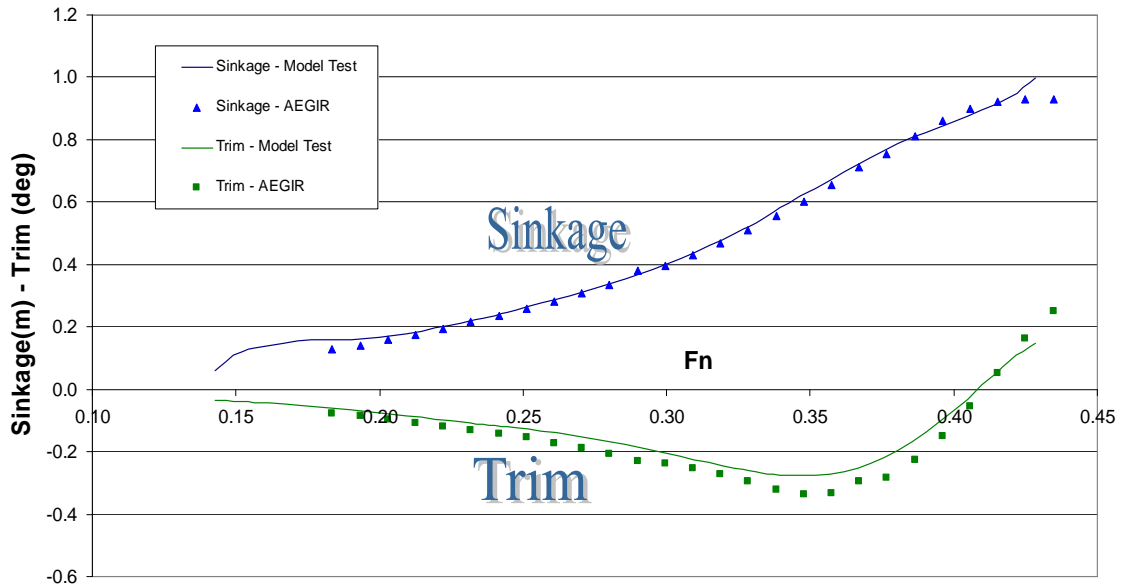
Figure 15. JHSS-EB: Cr Comparison

Figure 16. JHSS-EB: Sinkage and Trim Comparison

Gooseneck Bulb vs. Elliptical Bulb
The model tests indicated superior bare hull resistance performance for the monohull with gooseneck bulb compared to other bow configurations. AEGIR™ results were used to compare the performance of gooseneck bulb against the elliptical bulb. Figure 17 shows the ratio of Cr between the two bulb configurations plotted against Froude number for the model test results and the AEGIR™ results. Contrary to the model test results, the AEGIR™ results indicated superior performance by the elliptical bulb in the intermediate speed range of 28-35 knots.
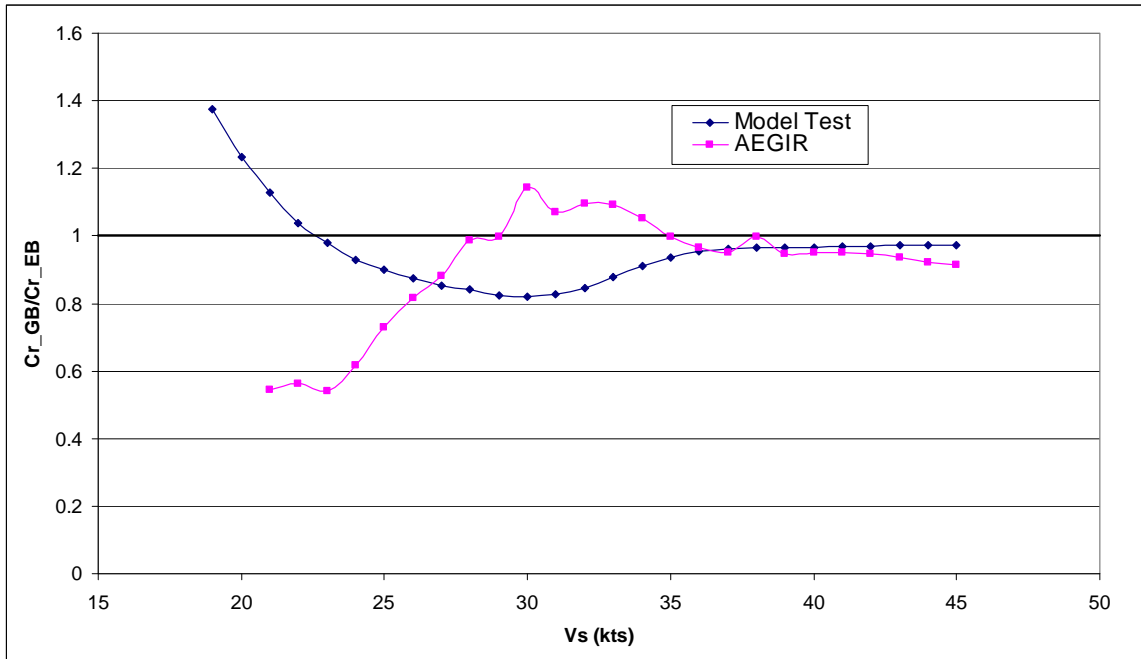

Figure 17. Comparison of the Two Bulb Configurations

4.2.2 Molland Catamaran Hull 5b: Demihull, 0.2 Spacing Configurations

The Cr curves for the demihull and catamaran configuration with s/l=0.2 are shown in Figure 18. The correlation between AEGIR™ results and the model test data is very poor and AEGIR™ simulations have failed at some of the speeds.
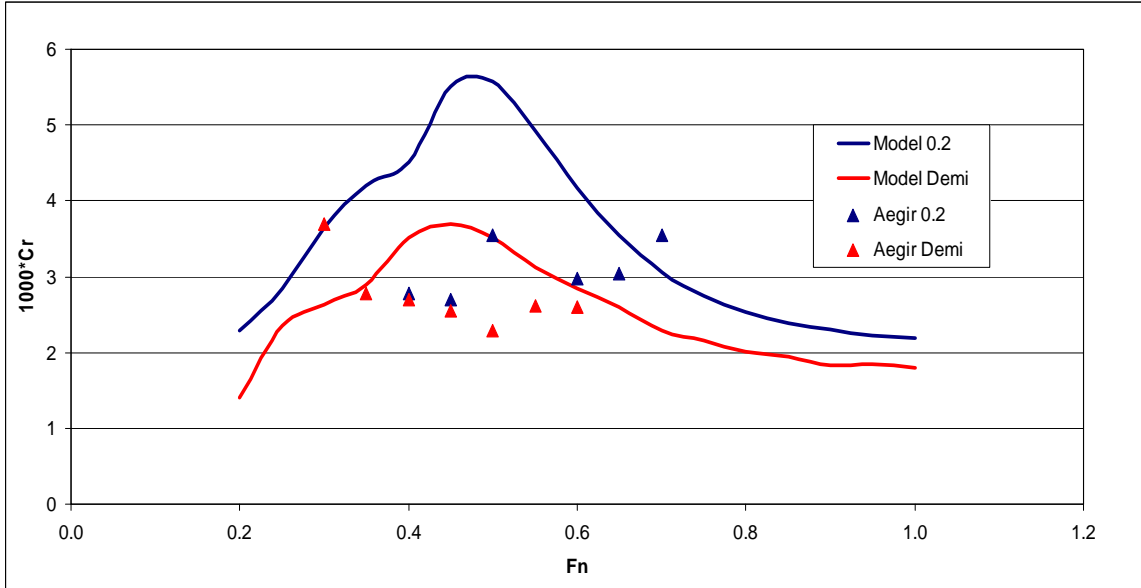
Figure 18. MC5B - Cr Comparison

4.2.3 Hard-Chine Semi-planing Monohull – USCG Light Cutter

The plots for Cr, sinkage and trim for the Light Cutter are shown in Figures 19, 20 and 21. The correlation between AEGIR™ results and the model test data is poor and AEGIR™ simulations have failed at low speeds.
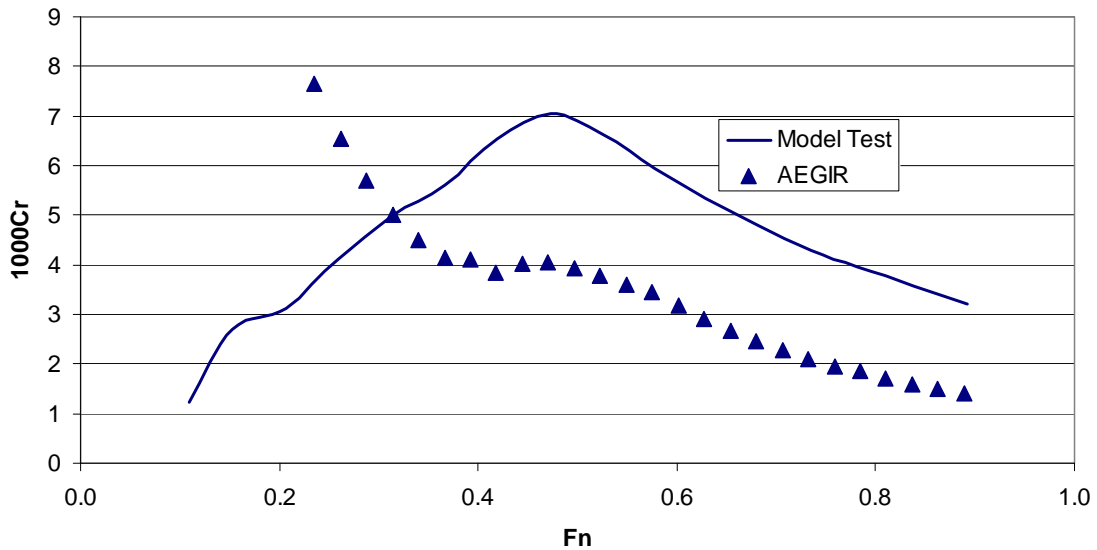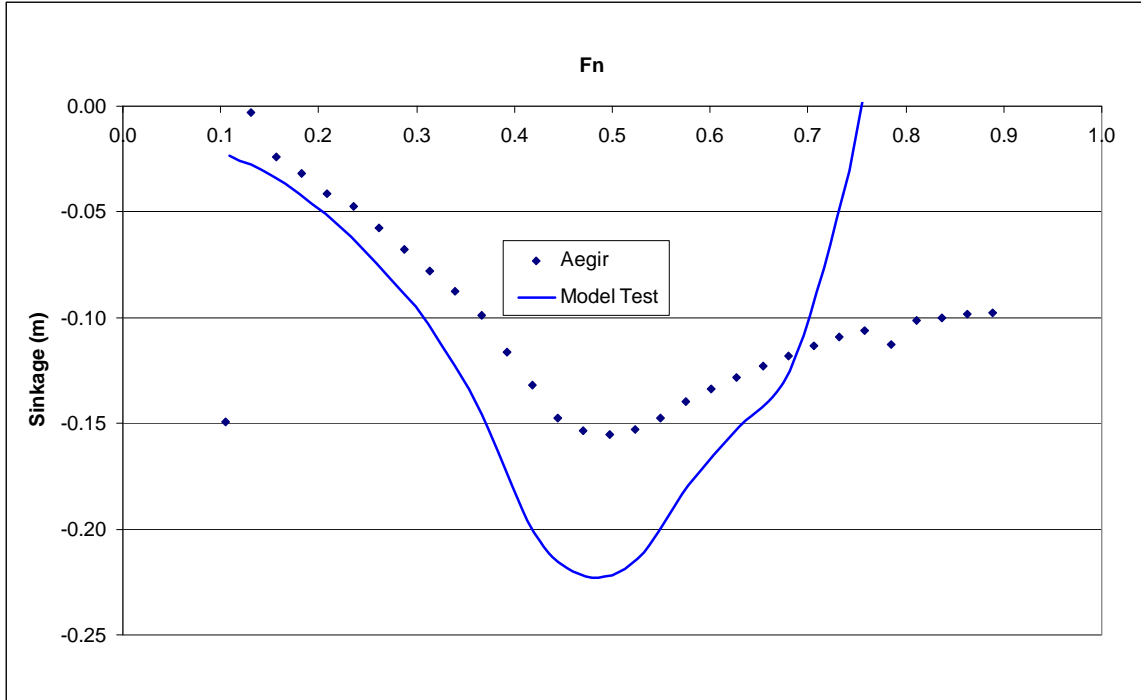

Figure 19. Light Cutter - Cr Comparison

Figure 20. Light Cutter - Sinkage Comparison
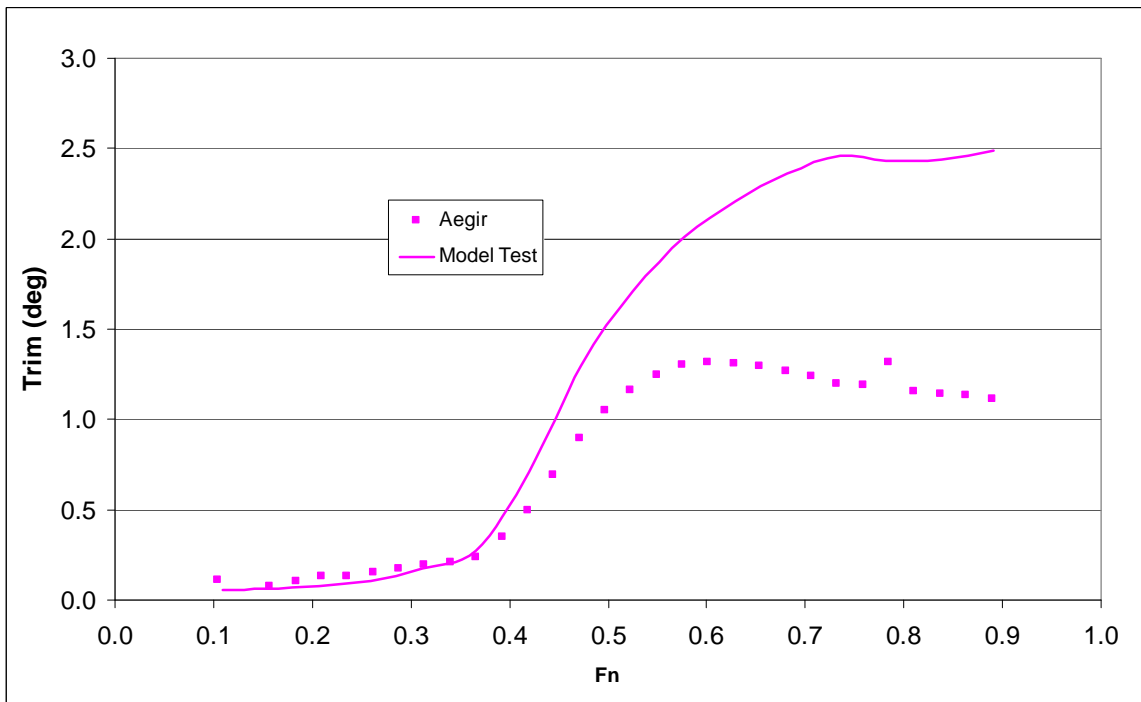

Figure 21. Light Cutter - Trim Comparison

4.2.4   Trimaran – Centerhull Configurations

The plots for Cr, sinkage and trim for the trimaran center hull alone configuration are shown in Figures 22 and 23. The correlation for sinkage and trim between AEGIR™ results and the model test data is fairly good throughout the speed range. The correlation for resistance is fair at Froude numbers above 0.3. However, below Fn=0.3, AEGIR™ resistance values were significantly higher than model test results.

The trimaran configuration could not be run on AEGIR™ version v0.88.100 apparently due to an implementation error in reading the discretization file. An updated version v0.88.200 was provided by APSC which did not have this error and ran the simulations. However, due to limitations on time and computer memory, no results could be obtained for the trimaran configuration.
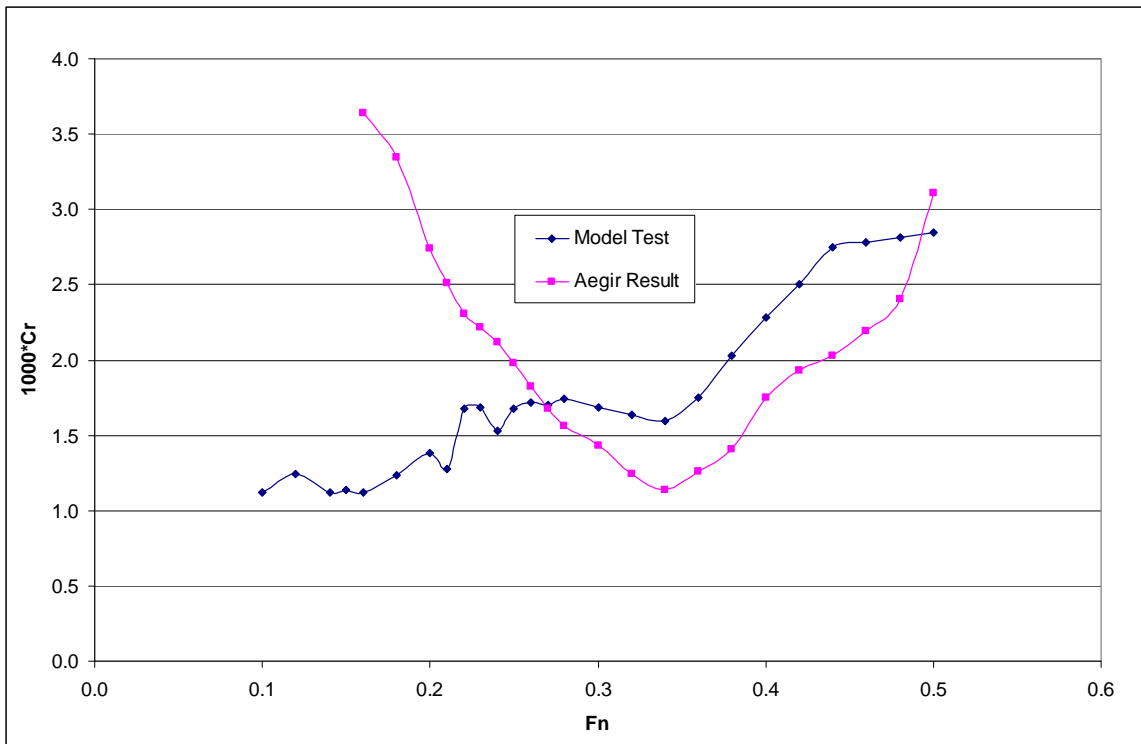

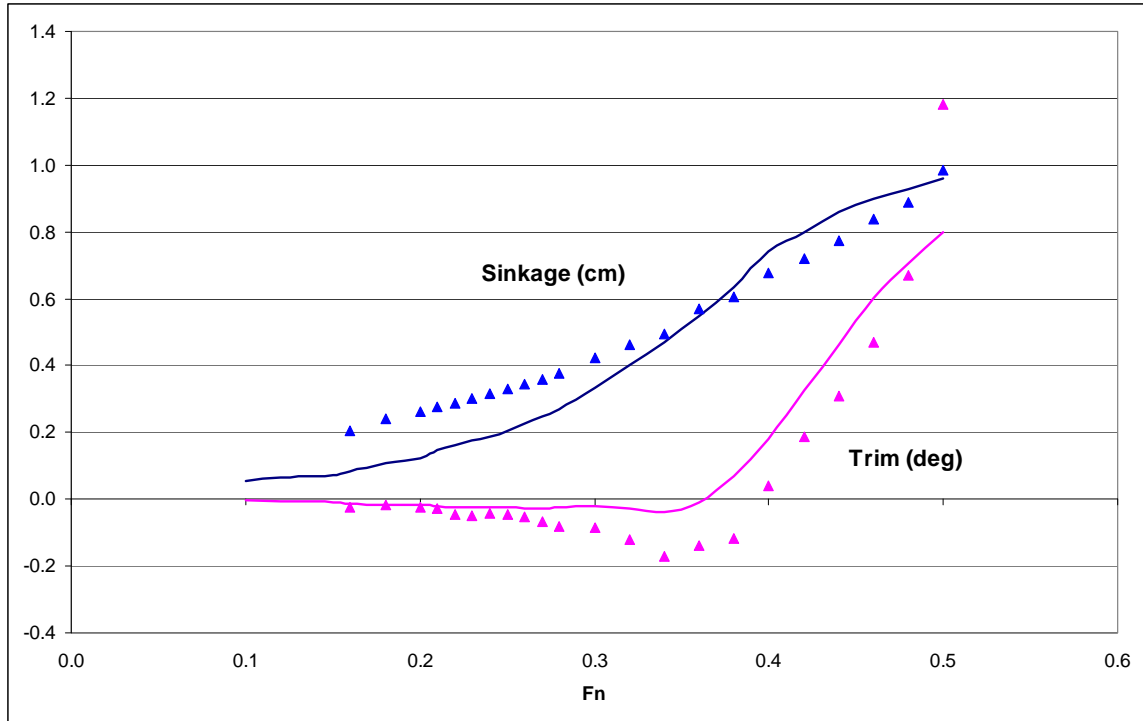**Figure 22. Trimaran Center Hull - Cr Comparison**

Figure 23. Trimaran Center Hull - Sinkage and Trim Comparison

4.3 Regular Wave Head Sea Seakeeping (RAOs)

A very limited seakeeping evaluation study in regular sinusoidal head sea waves was performed to obtain heave and pitch response amplitude operators (RAOs) of the JHSS Monohull with gooseneck bulb and the catamaran demihull.

4.3.1 JHSS Monohull with Gooseneck Bulb

The heave and pitch RAOs over a range of wavelengths from AEGIR™ simulations are shown in Figures 24 and 25 for speeds of 25 knots and 36 knots respectively. A comparison with test data could not be made as the model test results were not made available in time. However the magnitudes and trends of both the heave and pitch motions predicted by AEGIR™ look very reasonable for the simulated conditions.

4.3.2 Catamaran Demihull

The heave and pitch RAOs against non-dimensional encounter frequency at Fn=0.2 for the catamaran demihull are shown in Figure 26 along with model test results taken from Reference 5. The correlation between AEGIR™ results and the model test data is quite good.
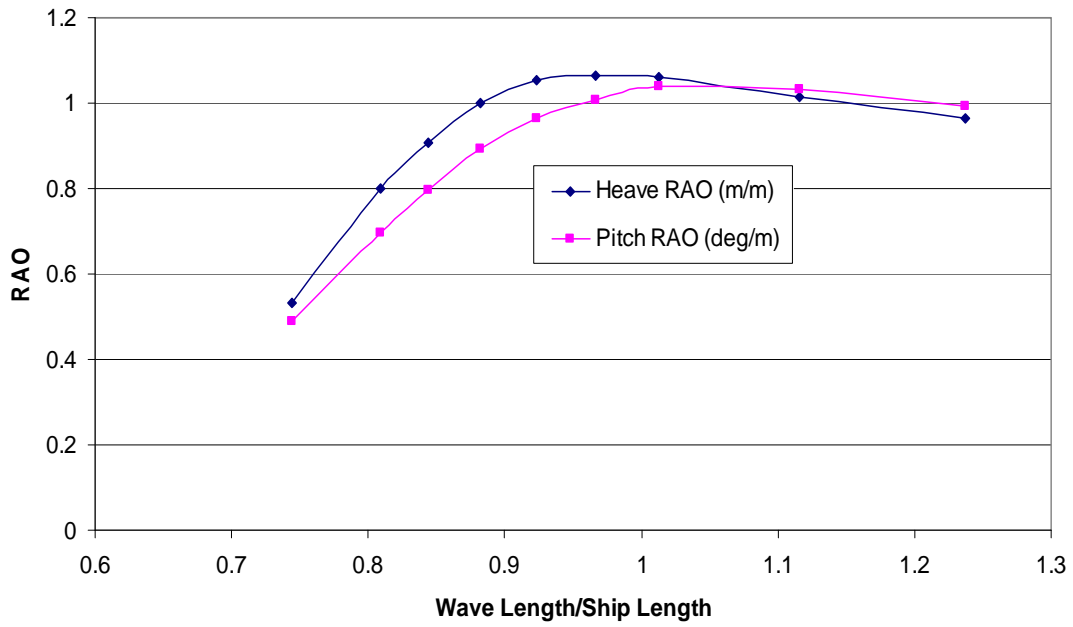
23

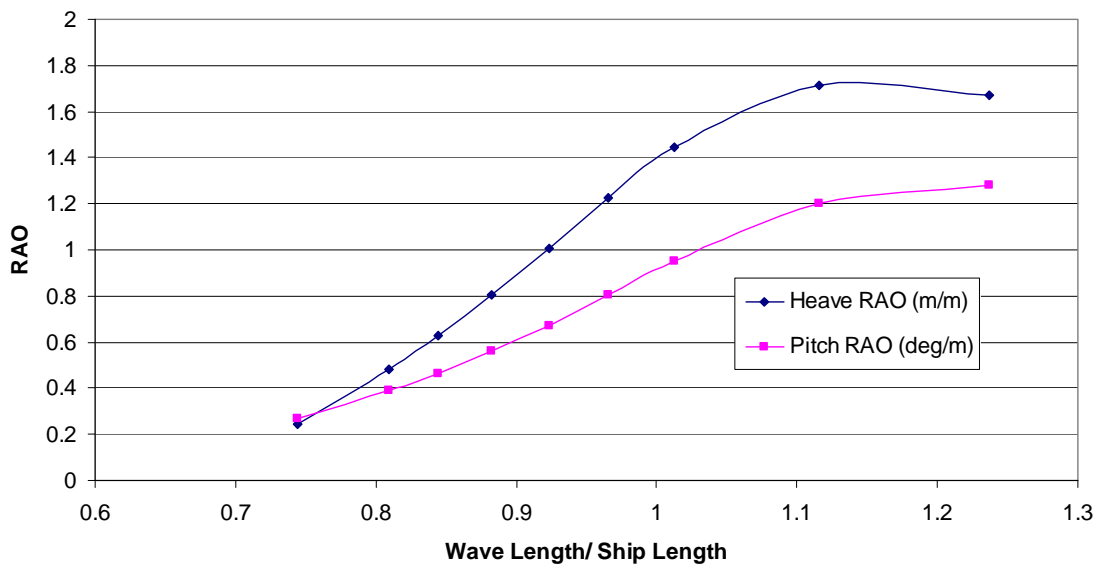**Figure 24. JHSS-GB: Head sea RAOs at 25 knots**

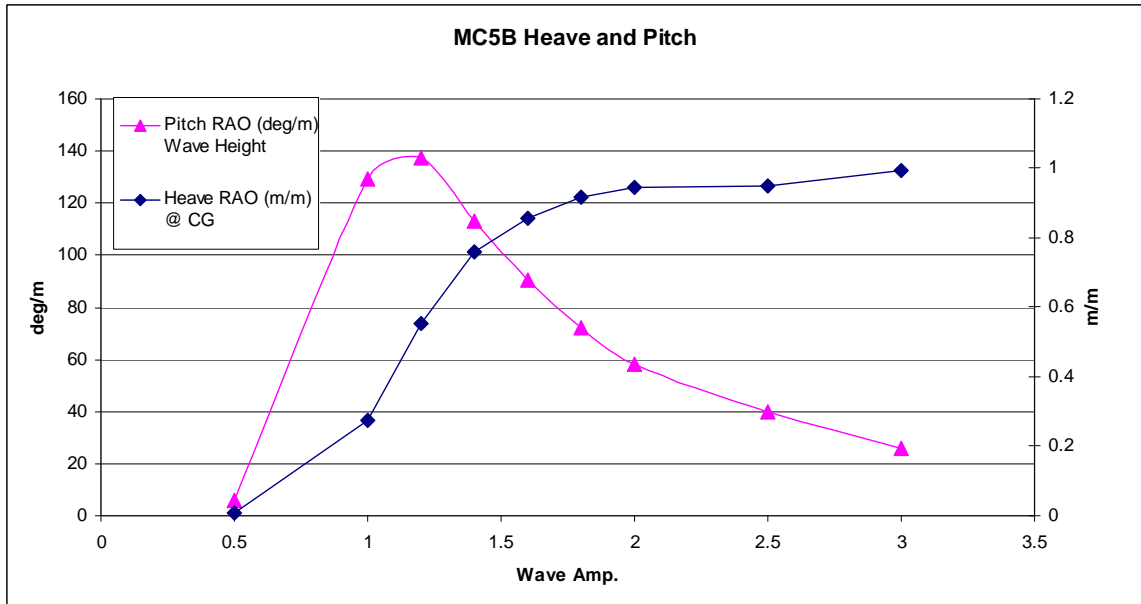**Figure 25. JHSS-GB: Head sea RAOs at 36 knots**

Figure 26. MC5B Demihull - RAO Comparison at Fn=0.2

5 Discussion and Conclusions

5.1   Performance of AEGIR™

The correlation between AEGIR™ results and model test data for bare hull resistance, sinkage and trim for both the JHSS monohull configurations of gooseneck and elliptical bulb was excellent. However AEGIR™ prediction for the relative merit between the two configurations for bare hull resistance is contrary to the model test results through most of the speed range.

The Cr correlation between AEGIR™ predictions and model test results for the hard-chine, semi-planing hullform was fair for Froude numbers above 0.4 with AEGIR™ results showing similar trend to the model test results but with consistently lower values.

The correlation for the catamaran hull form was poor. The AEGIR™ results were significantly off from the model test data both for the Demihull and catamaran configurations. This could be due to AEGIR's inability to correctly model the transom flow for this hullform with a relatively larger transom.

The correlation for the trimaran center hull was fair for Froude numbers between 0.34 and 0.5, but the correlation was poor at Froude numbers below 0.34 with Cr steadily increasing with decreasing speed.

The limited evaluations for motions in head sea regular waves with encouraging results indicated the applicability of AEGIR™ for seakeeping predictions.

The poor correlation in some configurations could partly be due to the limitations of the personal computers that have been used, on which larger panel densities could not be run due to limitations on available RAM. However, the results from simulations of various vessels indicate a general trend of poor AEGIR™ predictions for hullforms with larger transoms.

5.2   Conclusions and Feedback

AEGIR's innovative features of automated gridding and geometry input through Rhinoceros™ have great utility for non-CFD experts. As beta users, the group sees great potential for this program to be used in initial design stage. However, the resistance prediction at low FN and for hulls with larger transom sterns must be improved.

The text-based user-interface and input file preparation was a bit tedious and prone to syntax errors. Integration of easier graphical user interface will greatly enhance the utility of the program.

The user notes should be improved to include more guidelines on panel densities, convergence studies, output files and error messages.

Furthermore, the following lists some of the suggested improvements[1]
- option to include multiple speeds in the INP file
- option to input simple 2-parameter spectrum in the INC file
- include CPU time and convergence in the .stf1 output file
- implement panel density factor
- implement ability to exploit multi-core CPU environment

References

1. Cusanelli D.S., "Joint High Speed Sealift (JHSS) Baseline Shaft & Strut (Model 5653) Series 1: Bare Hull Resistance, Appended Resistance, and Alternate Bow Evaluations", NSWCCD-50-TR-2007/066 (Aug 2007)
2. Cusanelli D.S., Metcalf, B.J. and Powers A.M., "JHSS Baseline Shaft & Strut (BSS) Model 5653-3 - Added Resistance & Powering and Ship Motions – Seastate 6 Random Waves an Regular Waves", NSWCCD-50-TR-2009/041
3. Molland A.F., Wellicome J.F. and Couser P.R., "Resistance Experiments on a Systematic Series of High Speed Displacement Catamaran Forms: Variation of Length-Displacement Ratio and Breadth-Draught Ratio", RINA Transactions, 1995
4. Insel, M. and Molland, A.F. " An Investigation Into the Resistance Components of High Speed Displacement Catamarans", RINA Transactions, 1991
5. Molland A.F. et al. " Experimental Investigation of the Seakeeping Characteristics of Fast Displacement Catamarans in Head and Oblique Seas", RINA Transactions, 2001
6. Datla, R. "Bare Hull Resistance, Appended Resistance and Wedge Optimization Model Tests of 143 ft Light Cutter Design", Davidson Laboratory Technical Report DL-TR-01-2799, 2001.
7. Qi, J. "Experimental Study for the Optimization of Side-Hull Location for Resistance of a Trimaran", Ph D Dissertation, Stevens Institute of Technology, 2008.

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[1]Following the presentation of this study, Bill Milewski of APSC has provided numerous pre- and post-processing tools that automate some of these items.

Appendix A – AEGIR™ Notes

Geometry File - Rhinoceros®

One of AEGIR™'s key features is that hull geometries can be created using 3D modeling software and used as direct input for the program rather than creating meshes within the CFD tool itself. While AEGIR™ requires these models to be created in a very specific format, the process is relatively straightforward. This section serves to describe the modeling process, outline the basic rules for geometry files, and also provide guidance on how to recreate exiting 3D models of hullforms in a way that is compatible with AEGIR™.

Basic Geometry Rules

Coordinate System

In AEGIR™, the model should be oriented in the following fashion: The positive X-direction is upstream of the flow, therefore the direction from the bow to the stern should be in the negative X-direction. The positive Y-direction is from centerline to port. The positive Z-direction is out of the fluid, therefore the direction from the keel to the deck edge/Shear Line is in the positive Z-direction. The model space origin (0,0,0) should be placed at the waterline, on the centerline, at the Longitudinal Center of Gravity. Figure XX shows a properly oriented monohull with the origin defined by the intersection of the X, Y, and Z axes.
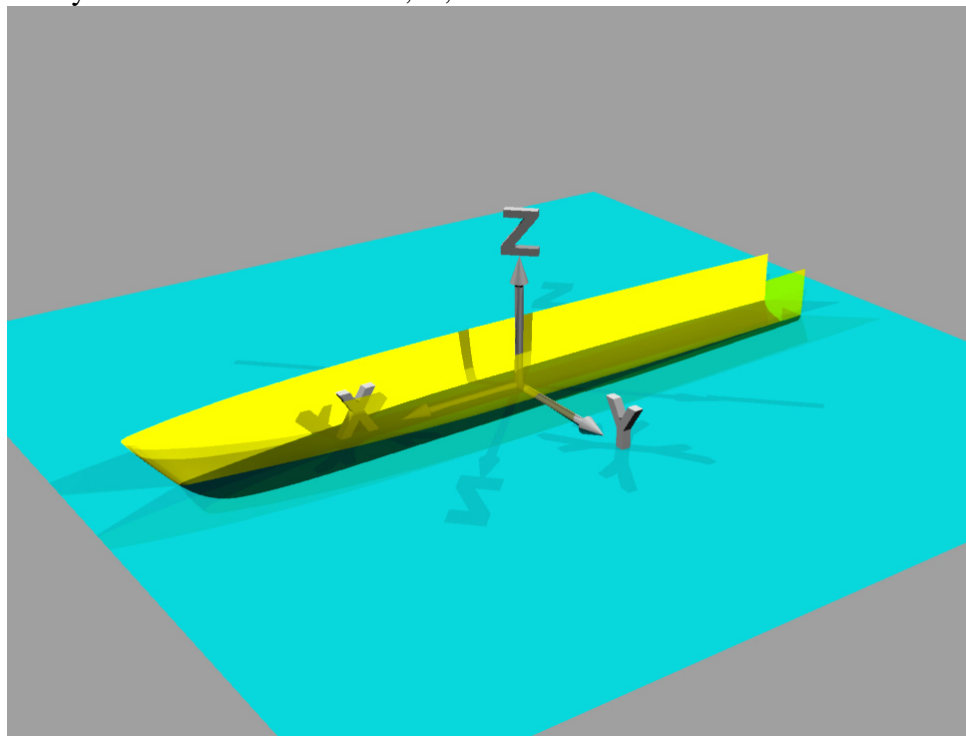

Figure 27 AEGIR™ Coordinate System

Surfaces

AEGIR™ requires the hull geometry to be modeled and recognized in Rhinoceros® as a "surface" not a "polysurface." This can be checked by selecting the surface, opening the 'Properties' box and noting the "Object" description. Also, AEGIR™ requires all surfaces to be constructed as quadrilaterals by definition, with four boundary edges, regardless of actual visual appearance. This means that triangular shaped surfaces must have one of their edges split in two to create a four-edged surface.

The next concern for surfaces is the direction of the Surface Normal Vector. This vector must always point in a direction into the hull. Since the normal vector is the cross product of the u- and v-vectors, it's direction is determined by checking the directions of the u- and v-vectors. To determine these vectors' directions, type the **dir** command into the command line, or from the 'File' toolbar select: Analyze > Direction. When prompted, select the surface in question and hold the mouse pointer over the surface. The u-vector positive direction is represented by the red arrow and should point in the streamwise direction (in the direction of flow) from bow to stern, in the negative x-direction. The v-vector is represented by the green arrow and typically, on the port side of the hull, the v-vector should point downward, from sheer line to keel line. For models of full hullforms (as opposed to half-hulls), the starboard surface will continue the v-vector convention from the port side and therefore point from the keel line to the sheer line on the starboard side surface.

Once the u- and v-vectors directions are known, one can then determine the direction of the Surface Normal Vector. Typically, the "Right Hand Rule" can be used to make this determination. Two methods of implementing this are described below for guidance.

> Method 1:
> - Align right hand fingers with positive u-axis
> - curl fingers toward positive v-axis, making a fist
> - Direction thumb sticks out is cross product = normal vector
>
> Method 2 (from Rhinoceros® Help File):
> - Form a right angle with the thumb and forefinger of your right hand. When your thumb points in the positive x-direction (u vector), your forefinger points in the positive y-direction (v-vector), and the palm of your hand faces in the positive z-direction (normal vector). See Figure XX below.
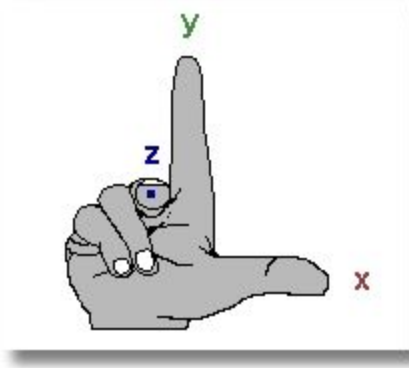
Figure 28 Right Hand Rule

Source: Rhinoceros® Help File Glossary

Creating Hullforms

Creating a Hullform from a Lines Plan or Table of Offsets

When creating a new 3D model of a hullform geometry, the following guidance should prove to be helpful in creating a successful model that is compatible with, and properly recognized in AEGIR™.

Start by using a body plan of a hullform already developed or use the table of offsets to create a body plan of the hullform by traditional Ships' Lines Drawing conventions. For additional guidance regarding Lines Drawings, please refer to Principles of Naval Architecture Volume I: Stability & Strength, Chapter I, Section I.

Space out the stations/cross-section curves in the longitudinal direction (x-axis) at the appropriate station spacing. Draw the sheer line/deck edge using the **InterpCrv** command and picking the top ends of the station lines at points along the curve. Draw the keel line and bow stem line using **InterpCrv** command where the station lines terminate at the centerline. If the hullform has hard chines, the station lines should be drawn in separate segments with endpoints at the chines, keel line, and sheer line.

Create the hull surfaces using the **Sweep2** command. The keel, sheer, and chine lines act as rail curves while the stations act as cross-section curves. Surfaces need to have four edges. This means that the bow line must be **split** from the keel line to create a separate, fourth edge. The bow line will also need to be split at intersections with the chine.
See the figure below for a visual example of this split, the fourth edge indicated by the yellow curve.
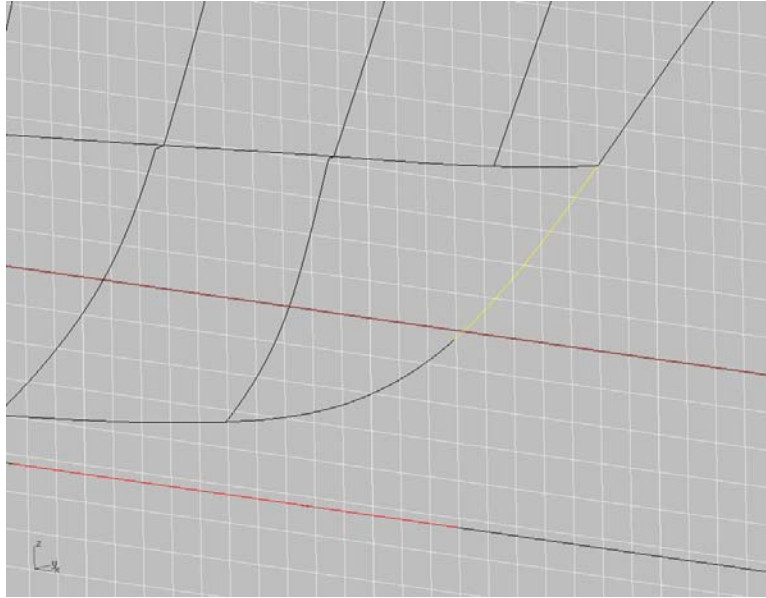
Figure 29 Geometry: Sweep2

Since it is likely that the hull lines are not fair, it is sometimes prudent to only use every other station to develop the surface and reduce the chance of radical unfairness. Often it is best to create this surface a few times using different numbers of stations to determine which method provides the best fit. In general, the **Loft** command generates "polysurfaces" which are not recognized/compatible as AEGIR input. Also, in general, surfaces cannot be joined together by **Join**, **BooleanUnion**, or other commands to make one continuous surface; this would create a polysurface. Use the **MergeSrf** command for joining surfaces.

Sometimes it is necessary to include a surface representing the transom of a hullform. AEGIR requires the transom to be trimmed just below the waterline (a typical value is 1mm below the waterline). The most reliable method is to create the transom surface to the correct dimensions (just below the waterline) the first time. In general, use the **EdgeSrf** command with four edges to define the surface.

Often on a round bilge hullform, this will require the transom section line to be split into three pieces. The first split will be where the top edge of the transom surface intersects the section curve, thus separating the top portion of the section line that is not used to define the transom surface. The second split will be at an arbitrary point on the section line below the waterline that allows the section line to become two separate curves, and by definition allowing for a fourth edge to define the transom surface and keep to the requirements of surfaces having four edges.
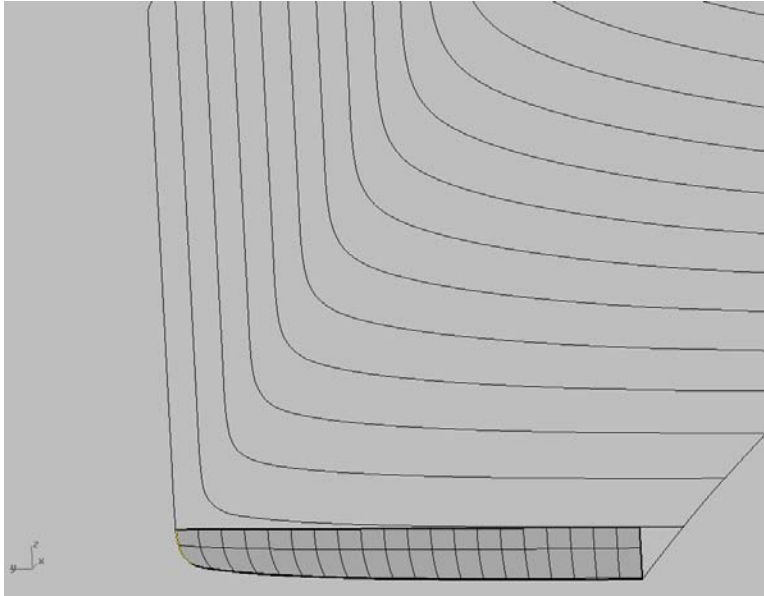
Figure 30 Geometry: Transom Patch

When using a port half hull model, the surface defining the transom should have the normal vector pointing into the body, meaning the u-vector should point inboard towards centerline and the v-vector should point from deck edge to keel.

Creating a Hullform from an existing 3D Model Geometry

To validate AEGIR™ it was necessary to test hullforms that have undergone physical model tests to compare resistance data to the predictions made from the program. Most of the hullforms tested had 3D models already available, although rarely were they in a form suitable for use as an AEGIR input file. Therefore, these hull geometries needed to be remodeled. The following guidance is provided to help a user convert a pre-existing hullform to a format that meets the necessary requirements for successful analysis with AEGIR™. This guidance is a product of the lessons learned from remodeling most of the hullforms used to validate AEGIR™, testing them in the program, and then remodeling again in a trial and error fashion until the program recognized the geometry properly, and the resulting program output was reasonable.

When a pre-existing 3D model is to be rebuilt, the first steps are to delete any extraneous objects and layers until only the surfaces describing the hullform remain. Then, orient the geometry properly in the coordinate space to meet the requirements described previously in the section on basic rules.

Use the **Contour** command to create evenly spaced surface contours representing the model's section curves or stations. Also, duplicate the edges of the surface (**DupEdge**) that were not captured by the **Contour** command.

The sheer and keel lines should be duplicated from the existing surface edges. If multiple surfaces make up the hull along it's length, join these segments into one continuous keel line and sheer line. If the bow section contains complex curvature, such as a bulb, it should be modeled as an independent surface from the rest of the hull and therefore its edges should not be included in the joining of the aft edges. If necessary, use the **trim** or **split** commands to separate the bow from the aft body at an arbitrary point. Also, if the hullform has a chine, the chine should be drawn as a curve in the longitudinal direction as well.

Rebuild the sheer, chine, and keel lines, specifying the same number of points as the number of contour and edge curves that represent the section/station curves that terminate at these lines. In other words, if the aft portion of the keel line has 16 stations that terminate on that line, it should be rebuilt with 16 points. Turn on the edit points for the sheer and keel line with the **EditPtOn** command and reposition each edit point to the appropriate end of a section curve.
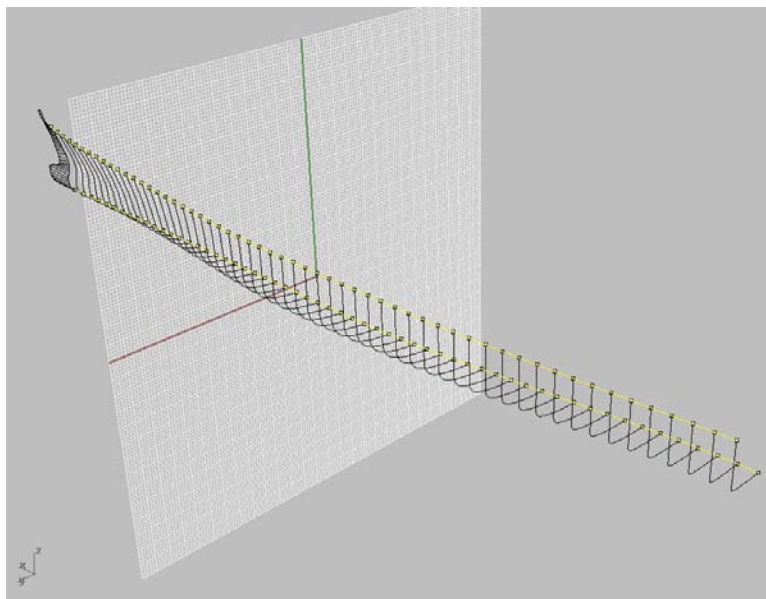

Figure 31 Geometry: Rebuild

Use the **Sweep2** command to generate the new hull surfaces, selecting the keel and sheer lines, and chine line if applicable, as the rail curves and the station curves as the cross-section curves. Chined hulls often should be built with more than one surface, with one surface extending from keel to chine, another from lower chine to upper chine, if applicable, and another surface extending from chine to sheer line. In the dialog box that appears, choose the option to rebuild section curves with a high number of control points to maintain fidelity in hull curvature (approx. 60 control points). Surfaces can be rebuilt with fewer control points later.

As mentioned before, bow sections with complex curvature should be modeled separately to allow for a greater number of section curves with smaller spacings to best capture the complex curvature at the bow due to flare and the bulb. Duplicate the four edges of the surface that represents the bow and rebuild the aft vertical edge and the edge representing the forwardmost line of the bow or stem with the exact same number of points.

With the forward and aft edges of the bow section rebuilt with the same number of points, enter the **EditPtOn** command to display the two lines' edit points. Each line should have the same number of points. Use the **section** command to begin drawing section lines that generally run fore and aft. The command will prompt you to choose a surface, which is the pre-existing bow surface. Then draw the section lines from the forward bow line edge to the aft vertical edge with the sections starting and ending on the edit points. Thus, if a section line starts at the third point from the top end of the bow line, it should end at the third point from the top of the aft vertical edge line. This will be close to, but not exactly parallel to the X-Y Plane.
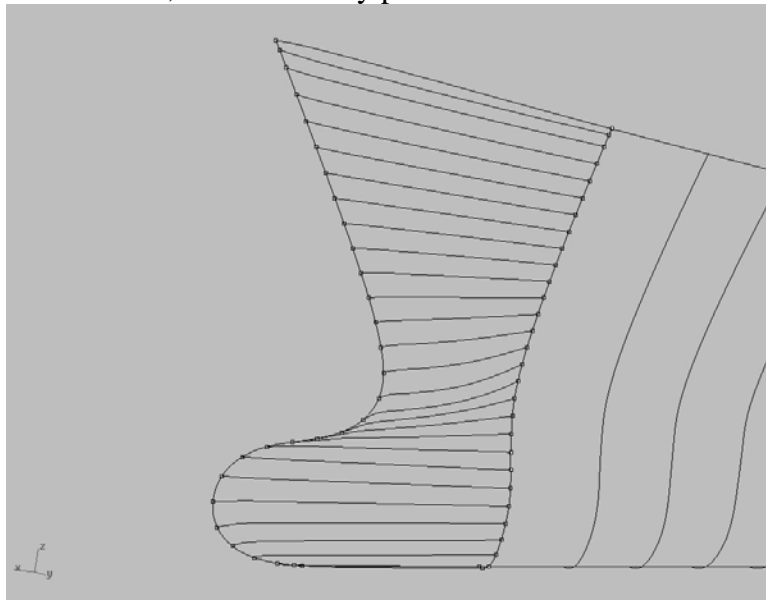

Figure 32 Geometry: Bow

Once all the sections are created, use the **Sweep2** command to generate the new bow surface, with the forward and aft vertical edge lines acting as rail curves and the section lines acting as the cross-section curves. With the bow surface created, use the **Dir** command to check and adjust the u- and v-vectors of the bow and aft surface to the correct orientation to have the Surface Normal Vector pointing into the body.

With the surfaces built and oriented properly, rebuild them to have the same number of control points in the v-direction and whatever number is necessary or appropriate for the u-direction. At this point, use the **MatchSrf** command to align the forward surface's edge with the aft surface's edge. A little trial and error is necessary with selecting the options in the dialog box, as well as what order to choose the options when performing **MatchSrf** command multiple times. Once the two surfaces have their edges aligned, use the MergeSrf command to merge the surfaces.

You may need to use the **RemoveControlPoint** or **RemoveKnot** commands to remove rows or columns of control points or knots from the surface to eliminate hard curvature in the surface. Rebuild the new single surface to create a uniform and less dense distribution of control points.

Appendix B – Typical AEGIR™ Input Files

.BOD file

```
v0.88.100
*** AEGIR™ BODY INPUT FILE (BOD) ***

[COMMENTS (3 lines)]
 ' JHSS monohull'
 ' metric units '
 ' Values based on Model 5663 Test - 8.78m draft'

[GEOMETRY FILE]
 'jhss_mh_sym.3dm'   ! 3DM   Rhinoceros™ CAD file

[MASS DISTRIBUTION]
  1     ! number of lumped masses
!  {mass      cg_x cg_y cg_z  rg_x  rg_y  rg_z    mom_xy}
    37086534. 1.438 0.  5.89  12.04 72.2  72.2    0.

[MOTION OUTPUT LOCATIONS]
  4     ! number of output locations for absolute and relative motions ... xyz on following rows
   144.49 0    21.47
   94.15  0    37.2
   -0.31  0    14.18
   -142.11    0    16.64
```

.DIS file

```
v0.88.100
*** AEGIR™ DISCRETIZATION FILE (DIS) ***

[COMMENTS (3 lines)]
 ' JHSS Monohull - High Speed DIS '
 ' Transom Patch NOT Included in CAD'
 ' Transom Cond set to 4'

[TEMPORAL DISCRETIZATION]
   0.05      ! Time-step size
   51        ! Period for spatial filter [no. of time-steps]

[FREE SURFACE DOMAIN SHAPE AND SIZE]
! (FS_ID) determines the free surface shape and input {see docs}
   3     ! (FS_ID)... 3 = symmetric monohull w/ transom; 4 = asymmetric monohull w/ transom; 7 = symmetric catamaran
   450.    ! Free surface upstream extent
  -450.    !  "       downstream extent
   300.    !  "       outer extent
   170.0  2.0   ! Beach upstream width and nominal strength
   170.0  2.0   !  " downstream width " "
   135.0  2.0   !  " outer width " "

[SPATIAL DISCRETIZATION]
   1.0      ! Mesh density (factors all span & tpan)

! Free surface   patch names according to (FS_ID) {see docs}
! {id   patch_name   order   span   tpan   sspc   tspc   econd 1,2,3,4}
  1   'OFS1'     3    75    26    1    1    0 0 0 0
  2   'TFS1'     3    34    4     1    1    0 0 0 0

! Body #1
  2   0        ! Number of patches
  1             ! Number of hulls
! Hull #1 on Body #1
    1           ! Number of layers on body#1
    1           ! layer id

! LAYER 1
 2  0              ! No. of patches in Layer 1
 2                 ! GroupClass
 'Hull'       ! Layername from Rhinoceros™ File
! {id   patch_name      order   span   tpan   sspc   tspc   edge1 edge2 edge3 edge4}
  1   'Port Fwd Hull'   3    12    5    1    1    0 0 0 0
  2   'Port Aft Hull'   3    50    5    1    1    0 0 0 0

[NUMERICAL SCHEMES]
 1 4        ! motion scheme, order
 1          ! free-surface scheme
 2          ! time-derivative order
 8 2 2 2 4 5      ! quad: self, far, galerkin, force, output, interp
 2 3 4         ! fast solver: subpanels, proj. order, grid depth
 1          ! 0= Galerkin BIE, 1= Collocation for BIE and FSC
 4          ! unsteady transom condition
```

.MDD file

```
v0.88.100
*** AEGIR™ MODE DEFINITION FILE (MDD) ***

[COMMENTS (3 lines)]
 ' JHSS Monohull '
 ' '
 ' '

[MEAN BODY POSITIONS] ... rotations in degrees
! CAD to HULL coordinates  (eg. multihull separation; baseline adjust)
! body_id    t_x t_y t_z rot_x    rot_y    rot_z
    1    0.   0.   0.   0.   0.   0.
! HULL to MEAN coordinates  (eg. sinkage, heel, trim, ect...)
! body_id t_x t_y t_z rot_x    rot_y    rot_z
    1    0.   0.   0.   0.   0.   0.

[GENERALIZED MODE DEFINITION] (in mean frame)
    2          ! number of modes
! name   mode body    surge    sway    heave    roll pitchyaw
 'heave' 1   1   0.   0.   1.   0.   0.   0.
 'pitch' 2   1   0.   0.  -.09  0.   1.   0.

[FREE MODES]
    2          ! number of free modes (list on following line, leave an extra blank line if 0)
 1 2

[FORCED MODES]
 0               ! number of forced modes

[INITIAL CONDITIONS] (displacement about the mean position)
    0          ! number of modes (IC is zero if not set)

.INC
v0.88.100
*** AEGIR™ INCIDENT WAVE SPECIFICATION FILE (INC) ***

[COMMENTS (3 lines)]
 ' Regular Wave '
 ' LWL = 298.06 m'
 ' Head Seas'

[WAVE COMPONENTS]
    1     ! number of incident wave components
! period   heading   amplitude   phase
15.37        180.0    2.46      0.
```

.INP file

```
v0.88.100
*** AEGIR™ MASTER INPUT FILE (INP) ***

[COMMENTS (3 lines)]
 ' JHSS Monohull'
 ' High Speed - No Transom Patch - Symmetric '
 ' MOTIONS IN REGULAR SEAS '

[PHYSICAL CONSTANTS]
     9.81    ! gravitational acceleration
     1025.9     ! density of water
     1.    ! kinematic viscosity of water
     0.    ! water depth with a flat sea floor (0 for no floor)

[FORMULATION] {order => 0=exact, 1=linear, 2+= higher-order pert.}
     0     ! time-domain (=0) or steady-state (=1)
     1     ! free surface radiation condition   {order}
     1     ! free surface diffraction condition {order}
     1     ! incident wave description        {order}
     1     ! body boundary condition          {order}
     1     ! hydrostatic forces and Froude-Krylov forces     {order}
     1     ! linearization : 1= Neumann-Kelvin, 2= Double-Body
     0     ! forward-speed, steady-state forcing for the linear time-domain problem: 0 = no, 1= yes
     0     ! added resistance: 0=none

[RUN SETTINGS]
     0     ! integral equation solver : 0= direct, 1= accelerated
     0     ! local flow decomposition : 0= default, 1= always on
   .true.   ! flow symmetry about x-z plane
   .false.   ! flow symmetry about y-z plane

[SHIP SPEED]
     12.86     ! mean forward speed Fn = 0.312
     0.0    ! mean side-slip speed
     0.0    ! mean turn rate

[RUN TIMES]
     0.    ! start-up ramp time
     100.        ! simulation end time
     0.    ! period for restart saves (no restart if =0.)
     200        ! skip factor for binary data dump for TECPLOT movies
     4      ! number of wave pattern snapshots; (times on next line)
   25 50 75 100

[INPUT FILES]
 'jhss_mh_high.dis' ! DIS   domain and discretization settings
        1            ! number of bodies (one BOD file per body)
 'jhss_mh_high.bod'     ! BOD   body geometry info and inertia
 'jhss_mh.mdd'      ! MDD   modal motion and force definition
 'jhss_rao_744.inc'           ! INC   incident waves
 '0'            ! VIS   viscous model
 '0'             ! LDD     load plane definition
 '0'              ! SV2   restart input

[OUTPUT FILES]
 '0'              ! SVB     base flow save file
 'save1.sv1'     ! SV1     save file for time-domain BVP setup
 'save2.sv2'     ! SV2   restart output
 'JHSS_ bhrao'    ! output files (.wvp,.bdf,.bdm,.mdf,.mdm)
```

Appendix C – Typical Batch File

```
@echo off

cd "C:\Documents and Settings\cisduser\Desktop\AEGIR™"

set counter=25
set limit=20

:loop

set start=%TIME%
copy "JHSS_eb\input\JHSS_BHR_V%counter%.inp" "JHSS_eb\jhss_BHR.inp" /y
AEGIR™.exe "JHSS_eb\JHSS_BHR.INP"
set end=%TIME%
copy "JHSS_eb\JHSS_BHR.stf1" "JHSS_eb\output\JHSS_BHR_new_V%counter%.stf1" /y
echo %start%, %end% >> "JHSS_eb\output\JHSS_BHR_new_V%counter%.stf1"

set /a counter=%counter%-1
if not %counter%==%limit% goto loop
```