MAXSURF CONNECT Edition V22

Bentley

User Manual

MAXSURF Resistance

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MAXSURF Resistance Program & User Manual

Contents

About this Manual

This manual describes MAXSURF Resistance, a program used to predict the resistance of hull designs. The manual is organised into the following chapters.

Chapter 1 Introduction
Contains a description of MAXSURF Resistance, its theoretical fundamentals and its resistance prediction algorithms.

Chapter 2 Using MAXSURF Resistance
Explains how to use MAXSURF Resistance's analysis routines.

Chapter 3 MAXSURF Resistance Reference
Gives details of each of MAXSURF Resistance's menu commands.

Chapter 4 Theoretical Reference
Lists abbreviations and terms used in MAXSURF Resistance and contains a bibliography.

Users of the demonstration version of MAXSURF Resistance should refer to Appendix A Demonstration Version which describes the limitations imposed on the demonstration version.

Chapter 1 Introduction

MAXSURF Resistance provides a means of predicting the resistance of a ship hull. MAXSURF designs may be read in and automatically measured to obtain the required parameters, or the parameters may be typed by hand without the need for an existing MAXSURF design file. If the overall efficiency of the propulsion installation is known, or may be estimated, the power requirements of the design may be predicted.

Given the data required for the resistance prediction algorithms selected for analysis, MAXSURF Resistance will calculate the hull resistance at a range of speeds and will give results in graphical and tabular formats. These results may be copied to a spreadsheet or word processor for further analysis and/or formatting.

MAXSURF Resistance supports resistance prediction calculations for a wide range of monohulls and multihulls.

Many different approaches exist to predict the resistance of a vessel. MAXSURF Resistance implements several different resistance prediction algorithms, each applicable to various families of hull shapes. For example, some of the algorithms are useful for estimating the resistance of planing hulls, while others are useful for estimating the resistance of sailing boat hulls.

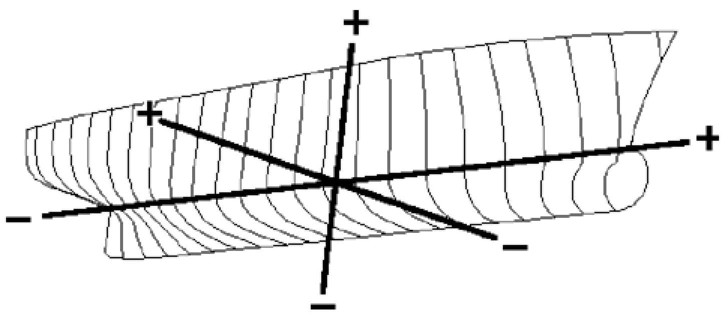
Besides resistance prediction calculations, MAXSURF Resistance can also be used to calculate the wave pattern generated by the vessel for a given velocity.

It should be emphasised that resistance prediction is not an exact science and that the algorithms implemented in this program, while they are useful for estimating the resistance of a hull, may not provide exact results.

Coordinate System

All Modules: Body plan, view from behind (stbd side of vessel on right-hand side of screen)
All Modules with the exception of Stability:Plan view from bottom (stbd side of vessel on upper half of screen); Stability has the Paln view from top (stbd side of vessel on lower half of screen)
All Modules:Profile view from stbd (bow on right-hand side of screen)

MAXSURF Modeler



Longitudinal:	+ve forward	-ve aft
Transverse:	+ve stbd	-ve port
Vertical:	+ve up	-ve down

The zero-point can be defined at any location in the model

Resistance Calculations Fundamentals

MAXSURF Resistance is essentially a resistance prediction program. A number of regression-based methods and one analytical method can be used to predict the resistance of the hull form.

It is normal naval architecture practice to break down the resistance into components which scale according to different laws. MAXSURF Resistance can calculate the resistance components in coefficient form. However, since different methods use different formulations, not all the resistance components may be available.

Total resistance is normally broken down into a Froude number dependent component – wave resistance (residuary resistance) and a Reynolds number dependent component – viscous resistance (friction resistance).

The bracketed names give an alternative breakdown:

Total resistance = Wave + Viscous = Residuary + Friction

Typically the friction resistance is predicted using the ITTC'57 ship-model correlation line or some similar formulation.

The viscous resistance includes a form effect applied to the friction resistance thus:

Viscous resistance = (1 + k) Friction resistance

, where (1 + k) is the form factor.

Where possible, MAXSURF Resistance calculates all the components of resistance and these may be plotted and tabulated separately.

In some cases the regression method predicts residuary resistance and no form factor. In these cases, it is not possible to calculate the wave resistance.

Data Input Options

In MAXSURF Resistance there are two ways to specify the input data that is used in the resistance algorithms:

- **Manually specify the input data***
- **Read the input data from a MAXSURF design and automatically measure the surface shape**

A combination of the two is also possible: read in and measure a MAXSURF design file and manually override the measured data. In any case, it is always advisable to check the automatic measurements of half angle of entrance, deadrise, chine type etc. as these can be difficult for MAXSURF Resistance to determine automatically.

Note also that the measured dimensions will take into account any skin thickness which has been added to the surfaces in the MAXSURF design. Deducted thickness will not be adjusted.

** = For the slender body method a mesh on the MAXSURF surface will be calculated which is then used to calculate the resistance. This means that, except for the wetted surface area, it is not possible to enter or edit the input data manually.*

Prediction methods

MAXSURF Resistance provides different algorithms for estimating hull resistance. These are divided in different groups dependent on the type of hull.

- **Methods for Planing Hulls**
- **Methods for Displacement Ships**
- **Methods Applicable To Yachts**
- **Analytical Method**

Also see: Appendix B Applicability on page 55 for information whether a method may be applicable for a particular design.

Methods for Planing Hulls

Savitsky (Pre-planing)

This algorithm is useful for estimating the resistance of a planing hull before it gets ‘onto the plane’; i.e. its pre-planing resistance.

Savitsky (Planing)

Used for estimating the resistance of planing hulls when in the planing speed regime.

Blount and Fox (Planing)

Used for estimating the resistance of planing hulls when in the planing speed regime. The algorithm is based on the Savitsky planing method with improvements to the algorithm at “hump speed”, the speed at which the vessel just begins to plane. The method is considered superior to the Savitsky planning method for vessels that have varying deadrise angles in the afterbody, or have a varying beam in the afterbody (i.e. not prismatic).

Lahtiharju

Used for estimating the resistance of planing hulls when in the planing speed regime.

Wyman

A universal formulation used for calculating the resistance of hull forms in both planing and displacement modes. The original method as set out by Wyman results in an Engine Power being calculated. As such, for MAXSURF Resistance to accurately predict the hull resistance, an overall efficiency must be added in the Efficiency dialog. The overall efficiency accounts for losses between the power developed at the engine (Brake Power) and the Effective Power (hull resistance).

From “The Masthead” issue of June 2008
http://www.westlawn.edu/news/WestlawnMasthead06_June08.pdf:
“The Wyman speed formula assumes the hull is the correct type and of normal form for the intended use. This includes proper location of the longitudinal centre of gravity and buoyancy and a prismatic coefficient in the suitable range. The formula also assumes that the running gear (propeller, reduction gear, shaft, strut, rudder) are properly sized and matched for best performance. There are many common variants of hulls and propulsion packages, however, and the following adjustments can be used to further refine the results:

Round bilge planing hulls(over SL ratio 2.9):	reduce speed by 6%
Deep vee planing hulls(deadrise midships aft >19 degrees):	reduce speed by 3 %
Low-deadrise planing hulls(deadrise midships aft < 8 degrees):	increase speed by 4%

Outboard and stern drive boats:	increase speed by 5%
Displacement full-keel sailboats:	reduce speed by 2%

SL=speed length ratio=velocity/sqrt(LWL), where velocity is in knots and LWL in ft.

These effects can be added in a single design to create and net increase/reduction in speed."

It is left to the MAXSURF Resistance user to decide whether any of the above criteria apply to their design and implement accordingly.

Methods for Displacement Ships

Wyman

The Wyman method can also be applied to displacement vessels.

Holtrop

This algorithm is designed for predicting the resistance of tankers, general cargo ships, fishing vessels, tugs, container ships and frigates.

Compton

This algorithm is designed for resistance prediction of typical coastal patrol, training or recreational powerboat type hull forms with transom sterns operating in the displacement and semi-planing regimes.

Fung

This algorithm is applicable for resistance prediction of displacement ships with transom stern hull forms (generally used for larger vessels than Compton). The regression is based on data from tests on 739 models at the David Taylor model basin and consists over 10 000 data points, Fung and Leibman (1995).

van Oortmerssen

Useful for estimating the resistance of small ships such as trawlers and tugs.

Series 60

Used for estimating the resistance of single screw cargo ships.

Korean Register of Shipping (KR) Barge

The method is based on the resistance prediction algorithm in "Rules for the Towing Survey of Barges and Tugboats" 2010 issued by Korean Register of Shipping and is suitable for box shaped vessels (e.g. barges) operating in displacement mode.

> **Note**
>
> If air resistance parameters are added in the input table, the applications air resistance calculation method is used NOT the KR air resistance method.

Methods Applicable To Yachts

Delft Series I, II and III

Sailing yacht resistance prediction, using the regression based on either Gerritsma et al (1991) or Gerritsma et al (1992).

Analytical Method

Slender body method

A slender body method, based on the work of Tuck et al (1999) and Couser et al (1996) is available in MAXSURF Resistance. This method uses a Michell (1898) based approach to compute the wave resistance of a port/starboard symmetrical monohull.

This method may be applied to many different hullforms including multihulls. However the individual hulls should be slender* and should be symmetrical about their local centreline. Planing forces are neglected in the slender body method which limits speed range applicability for this method. In general, sensible results can be obtained for a wide range of mono- and multihull vessels operating at normal Froude numbers.

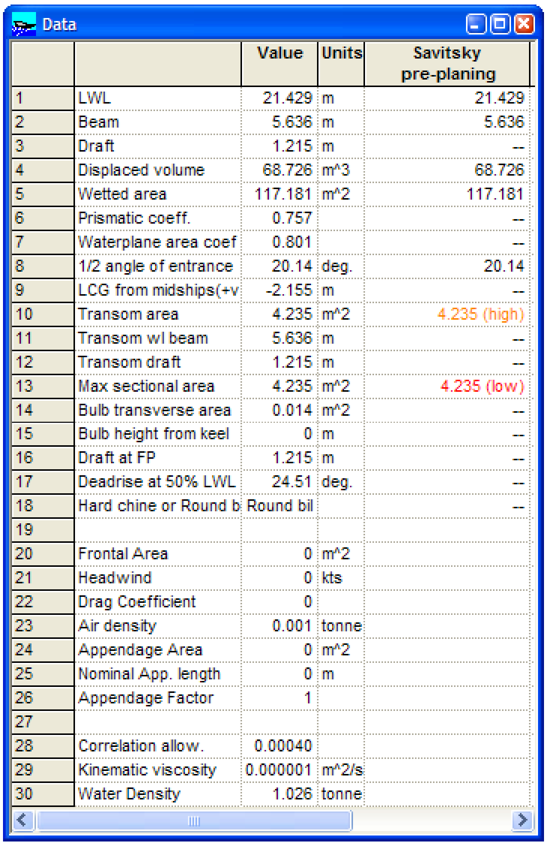
This method predicts only the wave pattern resistance component. To calculate the total resistance, MAXSURF Resistance calculates and adds the viscous resistance component using the ITTC'57 friction coefficient calculation method and the specified form factor.

See Using the slender Body Method on page 21.

** = have narrow beam compared to their length.*

Hull Parameter Validation

MAXSURF Resistance will check that the entered data is within the valid ranges for the selected methods. If the values are okay they will be displayed in black, if they are too low they will be displayed in red with the words (low), and if they are too high they will be displayed in orange with the word (high).



Data

		Value	Units	Savitsky pre-planing
1	LWL	21.429	m	21.429
2	Beam	5.636	m	5.636
3	Draft	1.215	m	--
4	Displaced volume	68.726	m^3	68.726
5	Wetted area	117.181	m^2	117.181
6	Prismatic coeff.	0.757		--
7	Waterplane area coef	0.801		--
8	1/2 angle of entrance	20.14	deg.	20.14
9	LCG from midships(+v	-2.155	m	--
10	Transom area	4.235	m^2	4.235 (high)
11	Transom wl beam	5.636	m	--
12	Transom draft	1.215	m	--
13	Max sectional area	4.235	m^2	4.235 (low)
14	Bulb transverse area	0.014	m^2	--
15	Bulb height from keel	0	m	--
16	Draft at FP	1.215	m	--
17	Deadrise at 50% LWL	24.51	deg.	--
18	Hard chine or Round b	Round bil		--
19				
20	Frontal Area	0	m^2	
21	Headwind	0	kts	
22	Drag Coefficient	0		
23	Air density	0.001	tonne	
24	Appendage Area	0	m^2	
25	Nominal App. length	0	m	
26	Appendage Factor	1		
27				
28	Correlation allow.	0.00040		
29	Kinematic viscosity	0.000001	m^2/s	
30	Water Density	1.026	tonne	

MAXSURF Resistance will still attempt to calculate the hull resistance if the data is out of range, but these results should be treated with caution since the accuracy of the method may be compromised if parameters are outside the valid range.

Because of the difficulty of accurately determining some measurements from the surface model, it is important to verify the following measurements:

- **1/2 angle of entrance**
- **Bulb transverse area**
- **Bulb height from keel**
- **Deadrise at 50% LWL**
- **Chine type: hard chine or round bilge**

Also see: Data Validation on page 17 for more information on data validation

Chapter 2 Using MAXSURF Resistance

You have been introduced to the way in which MAXSURF Resistance works and can now go on to learn in detail how to use MAXSURF Resistance by following the example outlined in this chapter.

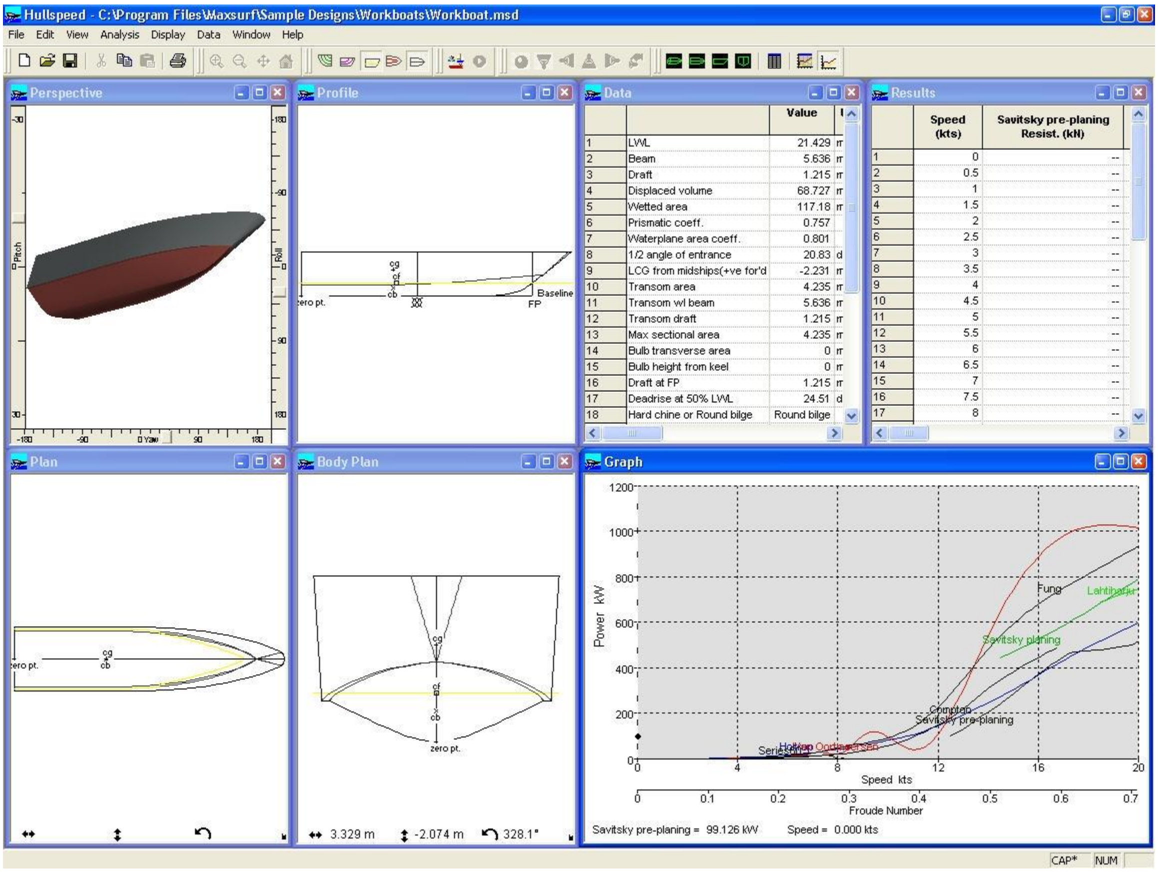
The example uses a simple planing hull form whose data are supplied in a MAXSURF Resistance file called ‘MAXSURF ResistanceExample.hsd’; these are measured from the MAXSURF design file ‘MAXSURF ResistanceExample.msd’.

The example goes through the steps needed to predict the resistance of the hull.

- Getting Started
- Taking Measurements from a MAXSURF design
- Opening a Data File
- Entering Data
- Calculating Resistance

Getting Started

Start up the program by double clicking on the program icon or selecting MAXSURF Resistance from the MAXSURF menu under the Start menu. MAXSURF Resistance will start up and display the following windows:



Perspective A perspective view of the hull being analysed.

Plan A plan view of the hull, looking from below.

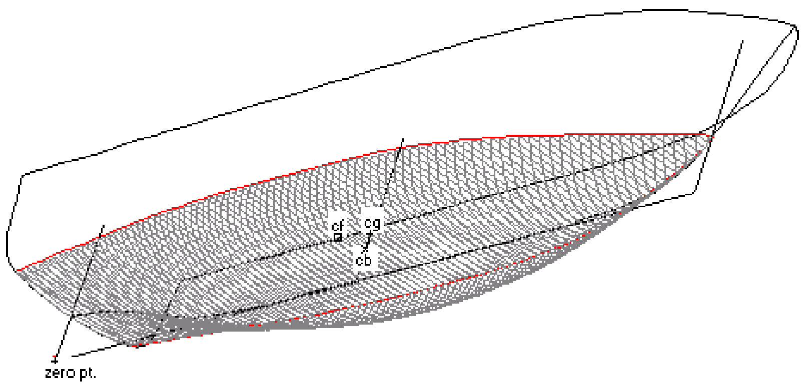
	Starboard above the centreline.
Profile	A profile view of the hull, looking from starboard with the bow to the right.
Body Plan	A body plan view of the hull, looking forward from the stern.
Data	The input data to be used for the analysis. This data may be measured from a MAXSURF design or typed manually.
Graph	A graph of the hull's predicted power or resistance vs. speed.
Results	A numerical display of the resistance and power prediction results, in a format useful for copying to a spreadsheet.

Taking Measurements from a MAXSURF design

MAXSURF Resistance may read and measure a MAXSURF design file directly. Because MAXSURF Resistance uses the same method as Hydromax to determine the hydrostatic properties of the design, the same rules and limitations about closed sections apply. See the Hydromax manual for more information on how to prepare a MAXSURF model before loading it into other applications of the MAXSURF suite.

To load a design, select Open Design from the File menu. When the design is loaded in, MAXSURF Resistance will automatically calculate the hull's hydrostatic characteristics using 200 sections.

At this point it is a good idea to check that the sections have been formed correctly. Do so by going to the perspective window and turning on the sections (in the Display | Contours dialog). The immersed sections are shown:



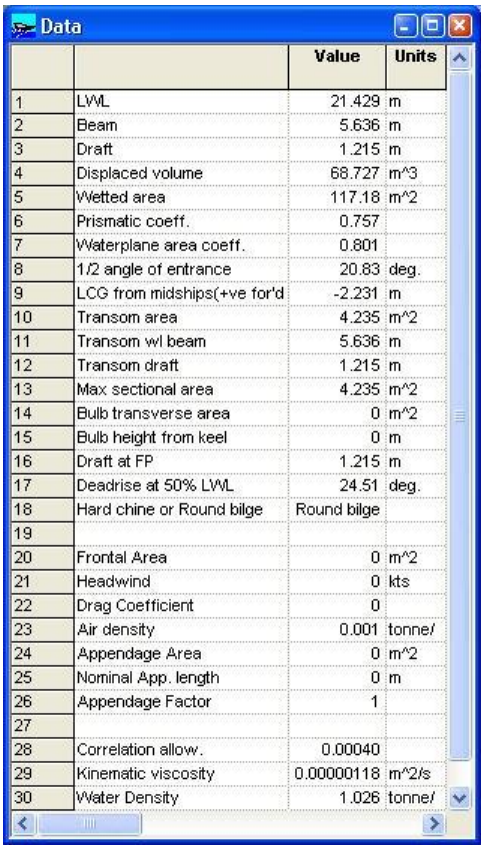
The hull is always measured at the DWL, so if you wish to measure the hull at a different draft, change the position of the DWL in the Frame of Reference dialog. (Data | Frame of Reference).

Once the measurements have been made, they can be edited if you so desire. Because of the difficulty of accurately determining some measurements from the surface model, it is important to verify the following measurements:

- **1/2 angle of entrance**
- **Bulb transverse area**
- **Bulb height from keel**
- **Deadrise at 50% LWL**
- **Chine type: hard chine or round bilge**

Opening a Data File

Choose Open Measurement Data from the File menu. Open the file titled ‘MAXSURF Resistance Sample_Workboat.hsd’ in the MAXSURF Samples folder. This file contains the data for a planing hull form. When it is read in, the Data window will fill with the relevant data:



Data

		Value	Units
1	LWL	21.429	m
2	Beam	5.636	m
3	Draft	1.215	m
4	Displaced volume	68.727	m^3
5	Wetted area	117.18	m^2
6	Prismatic coeff.	0.757	
7	Waterplane area coeff.	0.801	
8	1/2 angle of entrance	20.83	deg.
9	LCG from midships(+ve for'd	-2.231	m
10	Transom area	4.235	m^2
11	Transom wl beam	5.636	m
12	Transom draft	1.215	m
13	Max sectional area	4.235	m^2
14	Bulb transverse area	0	m^2
15	Bulb height from keel	0	m
16	Draft at FP	1.215	m
17	Deadrise at 50% LWL	24.51	deg.
18	Hard chine or Round bilge	Round bilge	
19			
20	Frontal Area	0	m^2
21	Headwind	0	kts
22	Drag Coefficient	0	
23	Air density	0.001	tonne/
24	Appendage Area	0	m^2
25	Nominal App. length	0	m
26	Appendage Factor	1	
27			
28	Correlation allow.	0.00040	
29	Kinematic viscosity	0.00000118	m^2/s
30	Water Density	1.026	tonne/

Entering Data

Note that in the Data window, there are three main columns. The first column contains explanations of the data in a particular row, the second column contains the data itself, while the third column contains the units for the data in that row. An extra column is added for each of the analysis methods used; data required for that method are copied into the new column.

Data may be typed into any column apart from the first and third columns. Changing any part of the data for a method will change that same piece of data for all methods, i.e. changing the length in any column will change the length in every column.

Note:

Input parameters: length; volume; prismatic coefficient and max sectional area are related by the formula below.

$$C_p = \frac{\nabla}{L \cdot A_X}$$

If data is measured from a design then this data will be consistent. However if the data are entered manually, MAXSURF Resistance will recalculate these values to maintain consistency. If either length (L), volume (∇) or Prismatic Coefficient (C_P) are entered, then Max Sectional area (A_X) will be recalculated. If A_m is entered then C_P will be recalculated.

The required data are as follows:

Length / Lwl

The length of the hull, measured on the waterline.

Beam

The maximum submerged width of the hull.

Draft

The maximum submerged depth of the hull.

Displaced Volume

The volume of seawater displaced by the hull.

Wetted Area

The submerged surface area of the hull.

For the slender body method, the wetted area is used to calculate the Friction and Viscous resistance coefficients only (the wave resistance is calculated directly from the surface model).

The wetted area is also used to calculate the resistance coefficients displayed in the Graph window.

Prismatic Coefficient

A measure of the extent to which the submerged volume of a hull fills a prism defined by the submerged length, multiplied by the area of the largest transverse section; i.e.

$$C_p = \frac{\nabla}{L \cdot A_X}$$

Water plane Area Coefficient

A measure of the extent to which the area of the water plane fills the rectangle defined by the length * beam; i.e.

$$C_{WP} = \frac{A_{WP}}{L \cdot B}$$

Half Angle of entrance

The angle measured in the plane of the water plane, between the hull and the centreline.

LCG from midships

The distance to the longitudinal centre of gravity, measured from amidships. Note that this distance is *positive forward*. I.e., an LCG 1.5m *aft* of midships will be entered as -1.5 .

Note that when MAXSURF Resistance measures a hull, it assumes that the vessel is in hydrostatic equilibrium at the DWL and the LCG is assumed to be at the LCB (longitudinal centre of buoyancy.

Transom Area

The submerged sectional area of the transom, measured when the vessel is at rest.

Maximum Sectional Area

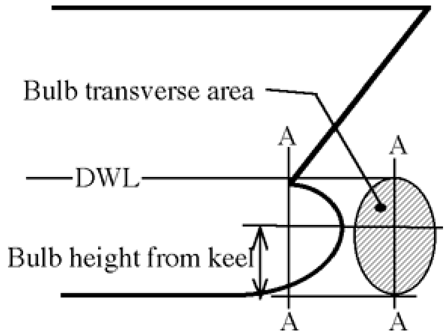
The largest submerged sectional area of the hull, measured when the vessel is at rest.

Bulb Transverse Area

The transverse sectional area of the bulb (if any) measured on the waterline at the stem.

Bulb Height from Keel

The distance from the keel line, to the transverse centre of area of the bulb section on the waterline at the stem.



Wetted Area

The submerged surface area of the hull.

Draft at FP

The draft at the fore perpendicular. This value can be left at zero, whereupon MAXSURF Resistance will assume it is the same as the value for the ‘draft’ item.

Deadrise at 50% Lwl

The deadrise, as measured at midships.

Frontal Area

The area of the vessel above the waterline, when viewed from the front. Set to zero to ignore wind resistance.

Drag Coefficient

The coefficient of drag for calculation of wind resistance. Expected values would be in the range of 0.8 - 1.2.

Air Density

The air density, at the appropriate ambient temperature. 1.293 kg/m^3 at 15 deg. C.

Appendage Area

The wetted area of appendages, used to calculate appendage drag. Set this to zero to ignore appendage resistance.

Nominal Appendage Length

This is a nominal length for the appendages which is used to calculate the Reynolds Number at which the appendages are operating. This Reynolds Number is used to calculate the skin friction drag of the appendages using the ITTC'57 formulation. Typically this length would be representative of the rudder (and keel, if applicable) chord.

Appendage Factor

A factor for estimating the resistance due to the drag on appendages. Expected values range from 1.0 to 3.0.

Correlation Allowance

A factor used for accounting for variations between model tests and full-scale trials. This factor is included only for the analysis methods which used a correlation allowance in their original formulation: Savitsky pre-planing; Lahtiharju; Van Oortmerssen and Series 60. The Holtrop method includes an implicit correlation allowance which is included at all times. The correlation allowance, or ΔC_F, may be estimated from the ITTC recommended formula:

$$C_A = \left[105\left(\frac{k_s}{L}\right)^{\frac{1}{3}} - 0.64\right] \times 10^{-3}$$

Where k_S is the hull roughness; typically $150\text{x}10^{-6}$m and L is the waterline length of the hull in the same units.

The Correlation Allowance value used for each particular method is listed in the Data Window in the “Correlation allow” row.

The table below should clarify which methods use which correlation factor:

Savitsky pre-planing	None
Savitsky planing	Varies with speed but based on user specified value
Blount and Fox	Varies with speed but based on user specified value
Wyman	None
Lahtiharju	user specified value
Holtrop	constant but calculated by regression method
Van Oortmeersen	user specified value
Series60	user specified value
Delft I,II	None
Delft III	None
Compton	fixed at 0.0004
Fung	fixed at 0.0005
KR Barge	None
Slender body	user specified value

Physical Properties of Sea Water

The values for the density and kinematic viscosity of the water may be edited by the user. The ITTC'57 values for salt water (3.5% salinity) at 15°C., for density and kinematic viscosity are as follows: density 1025.9 kg/m^3 and kinematic viscosity 1.18831×10^{-6} m^2/s.

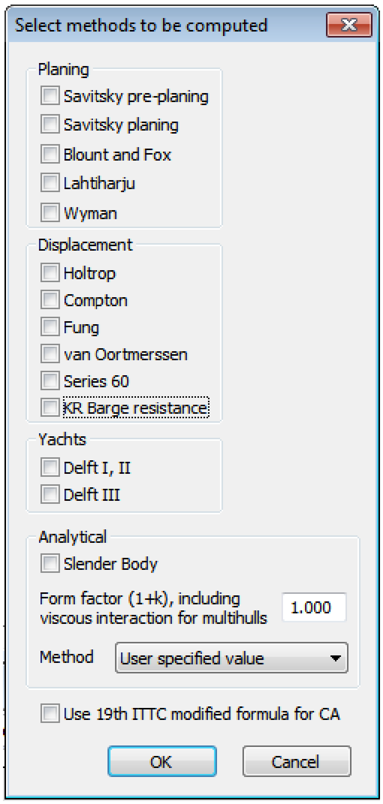
Calculating Resistance

Before viewing the results of the resistance calculations, you should validate your data, select a resistance prediction method and select a speed range. Once you have chosen these options, the results will be automatically displayed in the Results and Graph windows.

- **Selecting the Resistance Prediction Methods**
- **Data Validation**
- **Specifying Speed Range**
- **Viewing Results**

Selecting the Resistance Prediction Methods

To specify which methods to use, choose Methods from the Data menu, or alternatively use the - toolbar button. A dialog box will appear which allows you to select the resistance prediction methods that you wish to use.



As outlined on page 5, different methods are useful for analysing different hull types. Since a planing hull is to be analysed, select the methods pertinent to such a design.

Once a method has been selected, a column will appear in the Data window, with spaces to enter the data relevant to that method. In general the methods do not use all the data; only the data relevant to the analysis method is copied into that column. Unused data will contain '- -'.

Two additional columns will appear in the Results window for each resistance prediction method selected; one for the predicted resistance and one for the power required.

For the Slender Body method, a user-specified form factor has to be specified. To use the Holtrop and Mennen form factor, give a negative value (e.g. –1.0). The form factor is only applied to the slender body method resistance prediction. This method is explained in detail in the Using the slender Body Method section starting at page 21.

If the "Use 19th ITTC modified formula for CA" is checked then this method will be used. The 19th ITTC proposed a modified formula for C_A that splits it into a roughness factor DCf and correlation allowance:

- ΔC_F is the roughness allowance

$$\Delta C_F = 0.044\left[\left(\frac{k_S}{L_{WL}}\right)^{\frac{1}{3}} - 10 \cdot Re^{-\frac{1}{3}}\right] + 0.000125$$

where k_s indicates the roughness of hull surface. When there is no meas-ured data, the standard value of $k_s=150\times10^{-6}$ m can be used.

- C_A is determined from comparison of model and full scale trial results. When using the roughness allowance as above, the 19th ITTC recommended using:

$$C_A = (5.68 - 0.6 \log Re) \times 10^{-3}$$

Also see

Prediction methods on page 5 for more information on the different methods available in MAXSURF Resistance.
Appendix B Applicability on page 55 to investigate which method is appropriate for a particular type of vessel.

Wind and Appendage Resistance

Wind and appendage resistance may also be accounted for in the resistance calculation.

Entering the frontal area of the vessel, the drag coefficient and the air density will cause air resistance to be included in the analysis. Setting any of these values to zero will ignore air resistance.

The frontal area is the above-waterline area of the vessel when viewed from the bow, $A_{frontal}$. The drag coefficient, C_d, will depend on how 'streamlined' the vessel is. A very streamlined vessel would have a drag coefficient of less than one, say 0.8, while a less streamlined vessel would have a drag coefficient of greater that 1, say 1.2.

The wind resistance is calculated as follows:

$$R_{\text{wind}} = \tfrac{1}{2} \rho_{\text{air}} A_{\text{frontal}} V_{\text{rel.}}^2 C_{\text{d}}$$

Where ρ_{air} is the air density and $V_{rel.}$ is the relative wind speed.

Entering the wetted area of the appendages, and nominal appendage length (for calculation of appendage Reynolds Number), as well as an 'appendage factor', will cause the resistance of these appendages to be estimated by MAXSURF Resistance.

The wetted area of the appendages, $A_{appendage}$, is the total wetted surface of appendages, while the appendage factor, $f_{appendage}$, is an indication of the resistance of the appendages. Value for the appendage factor typically vary from 1.0 to 3.0.

The appendage resistance is calculated as follows:

$$R_{\text{appendage}} = \tfrac{1}{2} \rho_{\text{water}} A_{\text{appendage}} V_{\text{boat}}^2 f_{\text{appendage}} C_{\text{f}}$$

Where ρ_{water} is the water density and V_{boat} is the vessel speed. The skin friction coefficient, C_f, is calculated from the ITTC'57 formula, using the nominal appendage length to calculate the Reynolds Number.

Data Validation

Measurement data, either measured from a hull or entered by hand will automatically be compared with the limits of the chosen speed prediction methods.

In the Data window, measurements that are outside the valid range for a particular method will be highlighted in the column for the method in question. Data in red indicates that the value is too low, whilst data in orange is too high.

Please note that in some cases, the valid range for a particular method may be in terms of a ratio or coefficient such as B/T. In such a situation, if the B/T ratio was too high, the beam would be highlighted as being too high and the draft would be highlighted as being too low. In some cases, this can cause a value such as beam to be both too high and too low; this would occur if both B/T and L/B were too high.

Please refer to Appendix B Applicability, section Dimensions on page 56 for details of the valid ranges for the different analysis methods.

Also see: Entering Data on page 11

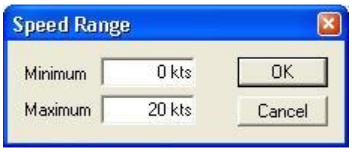
Specifying Speed Range

Once the prediction methods have been chosen, the speeds over which the analysis is to be carried out need to be set. To do this,

- **choose Speeds from the Data menu, or**

alternatively use the -toolbar button.

A dialog box will appear:



- **Enter the minimum speed**
- **Enter the maximum speed**
- **Click on the OK button**

Viewing Results

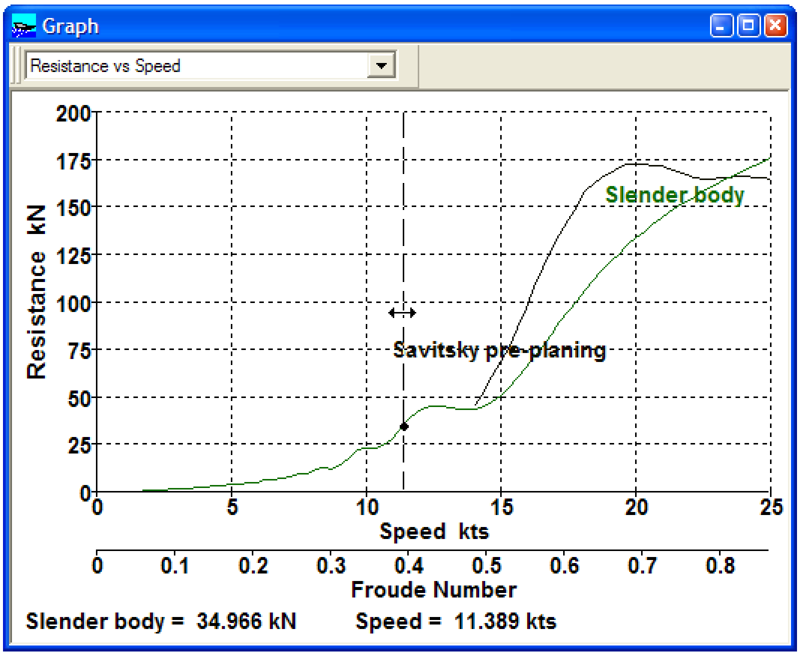
For the regression analysis methods (all methods except analytical), the resistance and power are automatically calculated whenever a change is made to the input data. The analytical results can only be obtained after solving the analysis, see Using the slender Body Method on page 21 for more information.

Results Table

A table with the calculation results will be tabulated in the Results window.

Results Graph

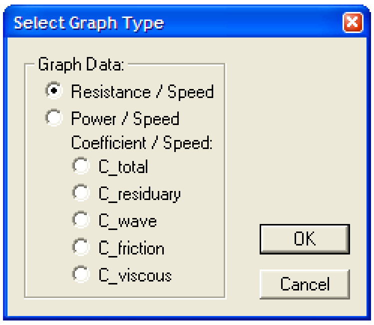
A graph of the results will appear in the Results Graph window.



Clicking on any of the curves in the graph will show the resistance and speed values at that point in the bottom left of the Graph window.

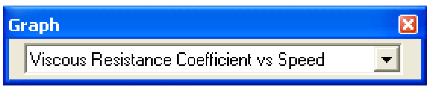
Double clicking on the graph will bring up a table with all the graph data points.

The type of graph displayed can be changed by selecting Graph Type from the Display menu.



As well as graphs of resistance or power, it is possible to plot the individual resistance coefficients.

Alternatively this can be done by selecting the required component from the pull-down list in the Graph toolbar:



Please note that not all methods calculate all the resistance components; many of the methods use the residuary + friction approach and hence the wave and viscous components cannot be derived. The following table summarises which components are calculated by each method.

Method	R_T	R_R	R_W	R_F	R_V	R_{Cor}	R_{App}	R_{Air}	θ_D
Savitsky pre-planing	yes	no	no	no	no	yes	yes	yes	no
Savitsky planing	yes	yes	no	yes[1]	no	yes	yes	yes	yes

Blount and Fox	yes	yes	no	yes[1]	no	yes	yes	yes	yes
Wyman	yes	yes	no	yes[ITTC'57]	no	no	yes	yes	no
Lahtiharju	yes	no	no	no	no	yes	yes	yes	no
Holtrop	yes	yes	yes[2]	yes[ITTC'57]	yes	yes[3]	yes	yes	no
Compton	yes	yes	no	yes [ITTC'57]	no	yes	yes	yes	no
Fung	yes	yes	no	yes [ITTC'57]	no	yes	yes	yes	no
van Oortmerssen	yes	yes	no	yes [ITTC'57]	no	yes	yes	yes	no
Series 60	yes	yes	no	yes[4]	no	yes	yes	yes	no
Delft I, II	yes	yes	no	yes[5]	no	no	yes	yes	no
Delft III	yes	yes	no	yes[5]	no	no	yes	yes	no
KR Barge	yes	yes	no	yes[6]	no	no	yes	yes	no
Slender Body	yes	yes	yes	yes [ITTC'57]	yes[7]	yes	yes	yes	no

Table notes:

1:	The ATTC'47 (Schoenherr) friction line is used, but a modified wetted surface area is used: $C_f = \left[\dfrac{0.242}{\log_{10}(R_e C_f)} \right]^2$
2:	The Holtrop wave resistance also contains the "bulb" and "transom" components
3:	The Holtrop method includes a regression equation for determining the correlation allowance coefficient; this is used rather than the user-specified value.
4:	Uses alternative friction line: $C_f = \dfrac{0.083}{[\log_{10}(R_e) - 1.65]^2}$
5:	Uses ITTC'57 friction line, but Reynolds Number is based on a shorter length: 0.7 L_{PP}
6:	Rf [ton] = 0.000136 * F_1 * A_1 * V^2 with F_1 : hull surface condition coefficient, 0.8; A_1 : surface area below waterline [m^2]; and V : velocity [kn]
7:	If the user specified form factor is negative, the slender body method uses the form factor as calculated by the Holtrop method.
ITTC'57	Uses the ITTC'57 friction line: $C_f = \dfrac{0.075}{[\log_{10}(R_e) - 2]^2}$

$\mathbf{R_T}$	Total resistance; either expressed as: $R_T = R_R + R_F + R_{Cor} + R_{App} + R_{Air}$ or $R_T = R_W + R_V + R_{Cor} + R_{App} + R_{Air}$
$\mathbf{R_R}$	Residuary resistance; total hydrodynamic resistance less skin friction resistance. Does not include R_{Cor}, R_{App} or R_{Air}
$\mathbf{R_W}$	Wave resistance; resistance due to energy input into the generation of free surface waves.
$\mathbf{R_F}$	Friction resistance; skin friction of equivalent flat plate area, typically uses the ITTC'57 ship-model correlation line or Schoenherr friction line.
$\mathbf{R_V}$	Viscous resistance; skin friction viscous resistance plus allowance for 3D form effects of the hull. Typically by the use of a form factor (1+k). In this case $R_V = (1+k)\, R_F$
$\mathbf{R_{Cor}}$	Correlation allowance resistance; additional resistance for correlation from model to ship scale
$\mathbf{R_{App}}$	Appendage resistance; resistance of appendages such as rudder, etc.
$\mathbf{R_{Air}}$	Air resistance; wind resistance of above-water hull and superstructure
$\boldsymbol{\theta_D}$	Running Trim vs Speed.

Using the slender Body Method

This analytical method is based on the so-called slender ship or slender body method. It computes the energy in the free surface wave pattern generated by the vessel and hence the wave resistance of the vessel. To calculate the total resistance, MAXSURF Resistance calculates and adds the viscous resistance component using the ITTC'57 friction coefficient calculation method and the specified form factor.

The following section explains how to use the slender body method provided in MAXSURF Resistance to compute the resistance of both mono- and multihull vessels. The information given here also applies to the calculation of the free surface wave patterns described later in this manual since they use the same theoretical basis.

In this section:

Model Validation

Except for the wetted surface area, the input data for the slender body method is not displayed in the input table and can thus neither be validated nor modified by the user. To make sure that MAXSURF Resistance interprets the surface model correctly, it is recommended to check the slender body mesh.

This can be done by turning on the SB mesh option in the Display menu. The number of sections used can be increased for greater accuracy, though this will increase the computation time. Particular attention should be paid to the mesh of multihulls and vessels with transom sterns. See the following sections for more details.

It is also recommended to read the papers on the slender body method listed in the Bibliography on page 50. The following section can be used as a guideline:

> The slender body method assumes the vessel to be slender (i.e. high length:beam or slenderness ratios). Ideally the slenderness ratio should be as high as possible, but in practice, good results can be obtained for slenderness ratios of around 5.0 to 6.0. If the vessel's Froude number is reduced, the minimum slenderness ratio to which the method is applicable also reduces. The maximum Froude number for which sensible results can be obtained depends on the vessel's slenderness ratio. It has been found that, for very slender vessels (slenderness ratios greater than 7.0), the slender body method may give sensible results for Froude numbers as high as 1.0. The slender body method may be applied equally well to round bilge and chine hull forms. Hulls with transom sterns are dealt with by automatically adding a "virtual appendage". This method is described in detail in Couser et al (1996).

Also see:

Appendix B Applicability on page 55

Calculating the Slender Body Resistance

After making sure that the vessel can be analysed with the slender body method,

- **Select the Slender Body Method in the Methods dialog from the Display Menu**

- **Specify the form factor, see below for explanation**

This method is slower than the regression (non-analytical) methods in MAXSURF Resistance, and so is not automatically calculated. To calculate the resistance,

- **Select Analysis | Solve resistance analysis or use the solve toolbar button .**

This will calculate a mesh on the MAXSURF surface and calculate the resistance.

Form Factor

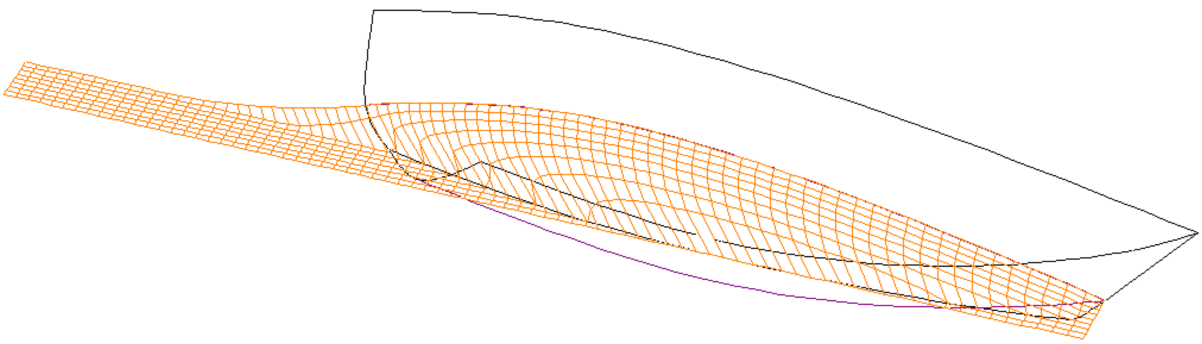
The form factor to be used for the slender body analysis can be specified in the Methods dialog. If a form factor of less than zero (negative) is entered, the Holtrop and Mennen formulation for form factor will be used.

Note:

This method uses the MAXSURF hull surfaces directly, so a full model is required and changing the measurement parameters, other than wetted surface area, will not affect the results. Wetted surface area is used only to compute the friction resistance and the resistance coefficients displayed in the Graph window.

Slender Body Analysis Geometry

The analysis mesh for the slender body analysis can be displayed by ticking "SB Mesh" in the Display menu.



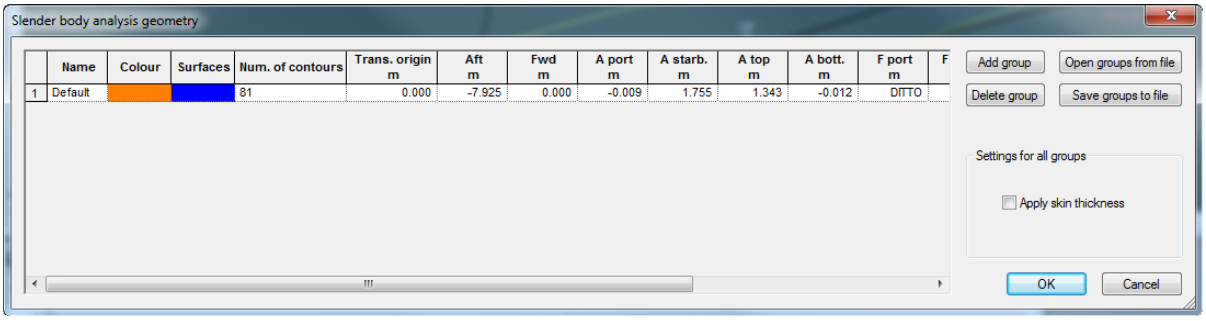
Slender body mesh (orange grid) for MORC sample model

If the vessel type (monohull, multihull) has been correctly setup in MAXSURF, the geometry should be correctly interpreted by MAXSURF Resistance. The mesh is a series of sections and waterlines forming a rectangular grid that is symmetrical about the hull's centreline. For multihulls this means that there is one such mesh for each individual hull. This mesh is symmetrical about the local hull centreline; for example, a catamaran's slender body mesh consists of one mesh that is symmetrical about the demihull centreline and mirrored about the catamaran's centreline. This means that each individual hull must be symmetrical about its own centreline, but the overall model can be asymmetrical (e.g. a proa).

If the hull has an immersed transom, an appendage is added to the slender body mesh which blends all the waterlines back into the local centreline; this can be seen in the image above. See Modelling the Transom on page 24 for more information.

Editing the Slender Body Geometry

In some cases it may be necessary to edit the slender body mesh. This is done by selecting “SB Analysis Geometry” from the analysis menu. A dialog is displayed with a table containing one row for each mesh group; you need one group for each individual hull in the model:



Dialog for definition of slender body groups

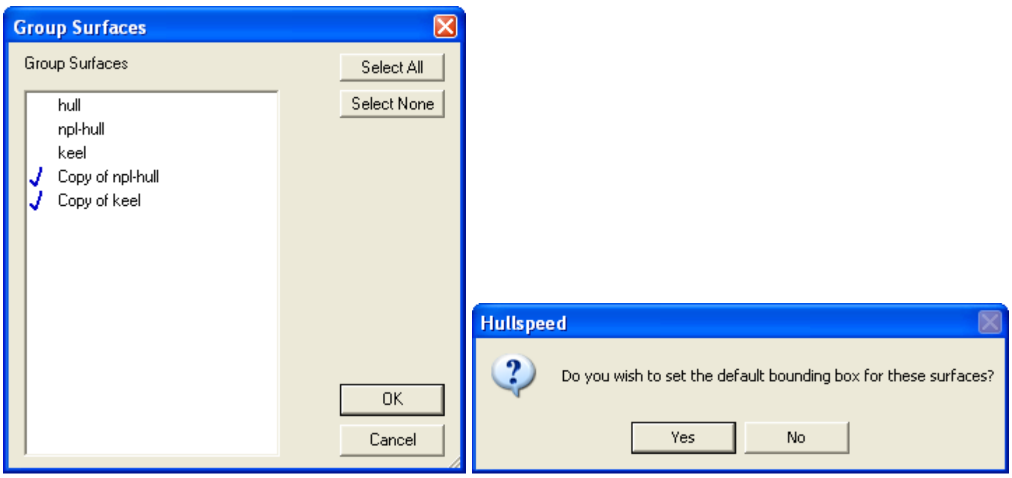
This dialog is the same as that used for definition of the Shipflow groups in Hydrolink. Of main interest for MAXSURF Resistance are the following columns:

Colour:

The colour the mesh is drawn

Surfaces:

The surfaces to be used to calculate the offsets. Double click on the surfaces cell to select which surfaces should be used. It is best to choose only the surfaces that define the sections, this is especially true for multihulls. When you close the surface dialog you will be asked if you want to automatically set the bounding box to the selected surfaces. Clicking “Yes” will set the bounding box to the rectangular extents of a box containing the selected surfaces.



Selection of the surfaces to be grouped for measuring the slender body mesh

Num. of contours:

The number of contours for the mesh; the number of waterlines is chosen automatically to match the number of sections. The greater the number of sections the better the accuracy of the analysis (but the analysis will also take longer).

Trans. origin:

This is used as the local hull centreline. For monohulls this should be zero, for multihulls this should be the local symmetry plane / centreline of the individual hull. For example, for a catamaran this is the transverse position of the demihull centreline.

Aft, Fwd, A port, A starb, A top, A bott, F port, F starb, F top, F bott:

The last 10 columns define a longitudinally prismatic (or tapered) box which defines the boundary of the mesh. The definition of the bounding box is similar to the way tanks are defined in Hydromax: the Aft and Fwd columns define the longitudinal aft and forward extents of the box, the A port, A starb, A top and A bott columns define the port, starboard, top and bottom extents of the box at the aft plane. The corresponding four columns prefixed with F, can be used to define a tapering box with different port, starboard, top and bottom extents on the forward plane.

Open and Save buttons:

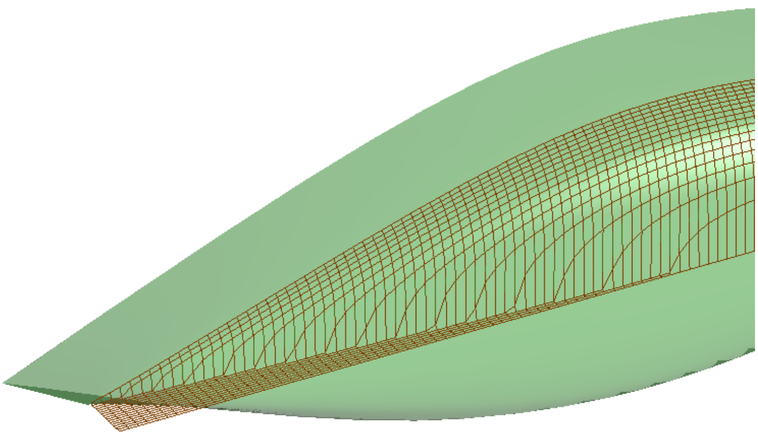
The data in the dialog can be saved and retrieved using the Save and Open buttons in the dialog. This can be useful if you have customised the slender body mesh definition and want to be able to retrieve it easily.

Further information on this dialog can be found in the Hydrolink manual in the Shipflow export section

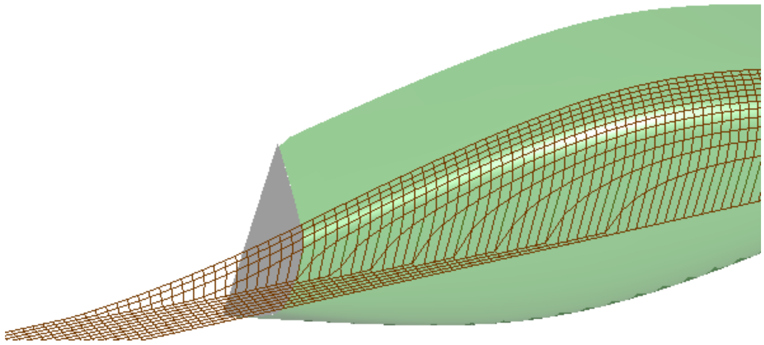
Modelling the Transom

The slender body mesh is created by calculating the hull surface offsets on a regularly spaced grid of sections and waterlines. Mesh points which fall off the hull surface are given an offset of zero and remain on the hulls centreline. For the slender body theory, the mesh must start and finish with waterlines that lie on the centreline, i.e. the bow and stern sections must have all points at zero offset. (It is possible to remove this requirement for the stern by applying a transom correction).

MAXSURF Resistance deals with transoms in a special manner; the mesh is brought back to the centreline plane behind the model by applying a “virtual appendage” which is smoothly attached to the transom. This method was found to give good results for monohull and catamaran forms with transom sterns (Couser 1996, Couser et al 1998).

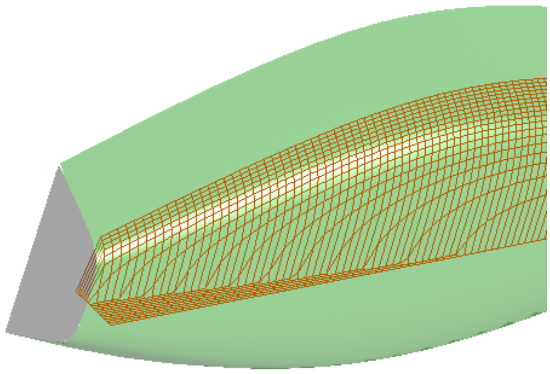


Mesh layout for the stern of a canoe-bodied hull without transom – Mesh follows hull



Mesh layout for a hull with a transom– Artificial closure of mesh behind transom using a smoothly attached "virtual appendage"

The "virtual appendage" can be removed by making the aft extent of the mesh bounding box end just after the end of the transom – see below:



With the aft bounding box of the mesh terminating just aft of the transom, the "virtual appendage" is removed

Note:

The virtual appendage is not included in the wetted surface area calculation. It is only used to artificially close off the numerical model to calculate the wave resistance.

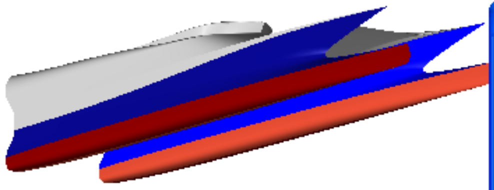
Note that removing the virtual appendage will affect the free-surface wave pattern and wave resistance calculation. The calculated free surface wave pattern with and without the virtual appendage can be used to judge whether this appendage should be added or not. From the work of Couser 1996, Couser et all 1998, it can be seen that adding the virtual appendage gives good results for monohulls and multihulls with transoms sterns.

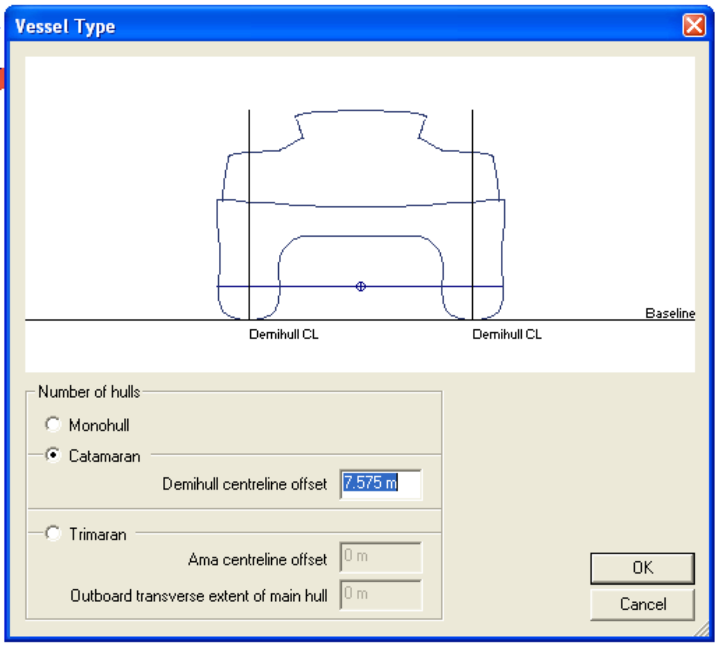
Multihull Mesh Examples

MAXSURF Resistance is able to compute the resistance of multihulls (catamarans, trimarans, pentamarans etc.) using the theoretical slender body method. There is no limit to the number and position of the individual hulls, but each hull must have transverse symmetry about its local centreline plane. To use this capability, it is important that the vessel type (see the MAXSURF manual) is set up correctly. There should be one mesh group (one row in the SB Geometry dialog, see page 23) for each individual hull of the model. Some example mesh definitions for different types of multihulls are shown below:

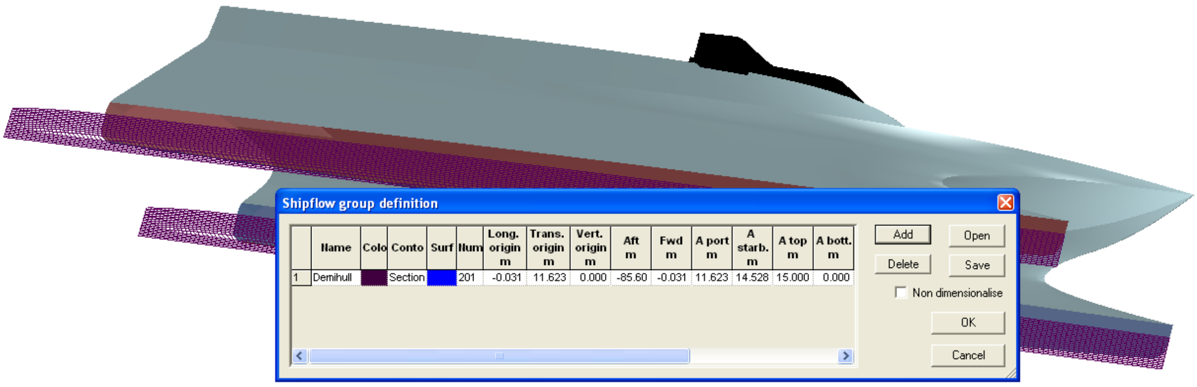
Catamaran

If the vessel type is correctly defined in MAXSURF, MAXSURF Resistance will automatically generate a symmetrical mesh that is centred on the local demihull centreline.



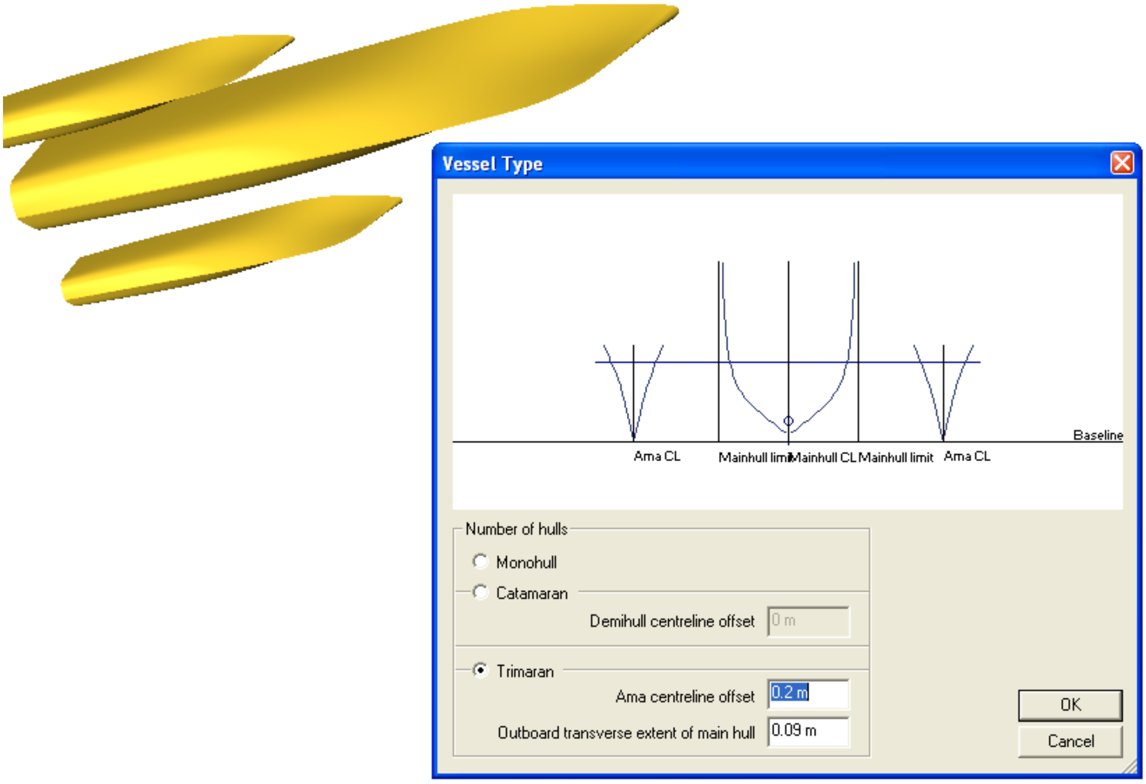


Vessel Type dialog setup in MAXSURF for a catamaran



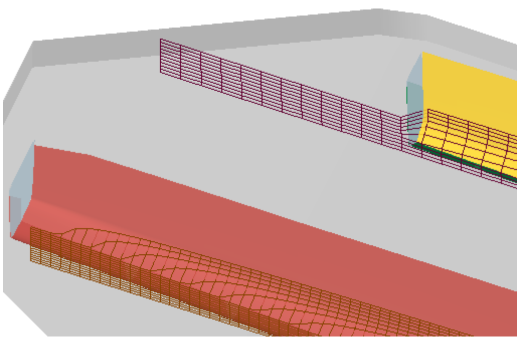
Catamaran has a single mesh mirrored about the vessel centreline.
The mesh is symmetrical about the local demihull centreline

Trimaran

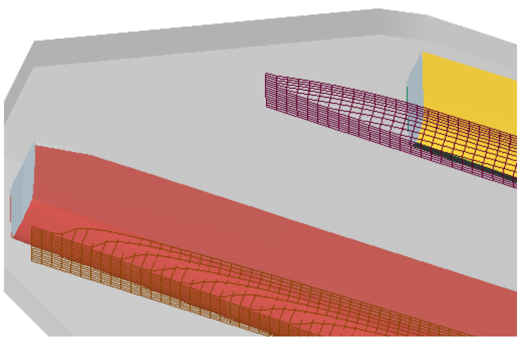


Vessel Type dialog setup in MAXSURF for a trimaran

Two meshes will be required, one of the main hull and one for the outer hull (referred to as “ama”). If the vessel type is correctly defined in MAXSURF, these two meshes will be automatically defined. However it may be necessary to change the longitudinal extents of the meshes, especially if the hulls have transoms. It may also be necessary to select which surfaces define the main hull and which define the ama. The simplest way to do this is to double click in the Surfaces cell, select only the surfaces required for the specific mesh and then click OK. Then click Yes to set the bounding box extents to the selected surfaces.



Incorrect: Default grid for Trimaran sample. Ama grid extends too far aft and the virtual appendage shape shows a rapid transition aft of the ama transom



Correct: Ama grid has been set to use only the ama surfaces and the bounding box has been set to those surfaces: correct transom closure on ama

Shipflow group definition

	Name	Colo	Conto	Surf	Num	Long. origin m	Trans. origin m	Vert. origin m	Aft m	Fwd m	A port m	A starb. m	A top m	A bott. m
1	Mainhull		Section		161	-0.029	0.000	0.000	-77.17	-0.029	0.000	5.000	10.096	-0.323
2	Ama		Section		81	-24.763	12.000	0.000	-64.68	-24.76	11.994	13.164	6.773	-0.031

Add Open Delete Save Non dimensionalise OK Cancel

Correct Mesh definition for trimaran sample above, Aft extent for Mainhull is –77.17, but only –64.88 for Ama

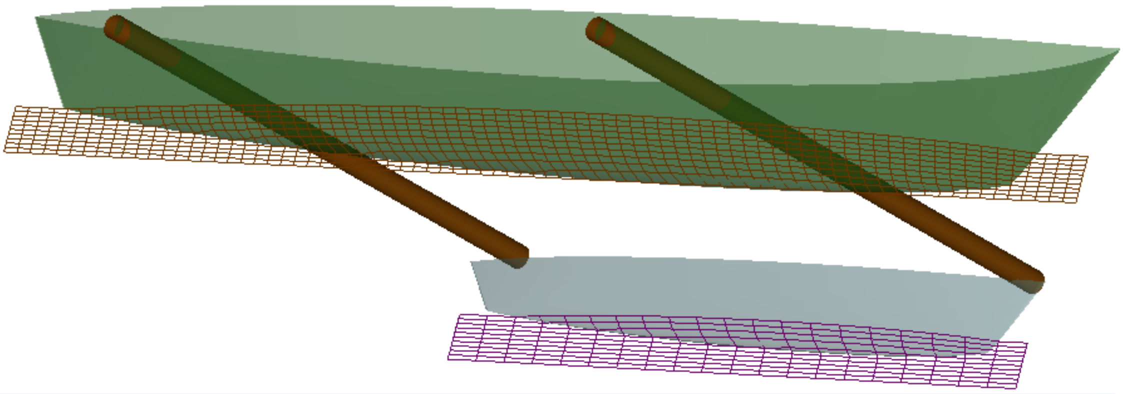
These files may be found in: Program files\MAXSURF\Sample Designs\Multihulls\Trimaran\Trimaran.msd
The mesh definition file is: TrimaranHSmeshDefn.hyd

Proa

It is possible to model asymmetrical vessels provided that each individual hull is symmetrical about its own centreline. In the example below, the main hull is a symmetrical surface, whilst the outrigger (referred to as ama) is made up of two surfaces that are:

- **asymmetrical about the vessel's centreline (there is no ama on the other side of the centreline)**
- **mirrored about the ama centreline**

Two mesh groups are required. The one for the main hull is defined as if the main hull were a monohull. For the ama, the transverse origin is specified as the transverse offset of the local centreline of the ama hull, and only the starboard side of the ama hull is used.

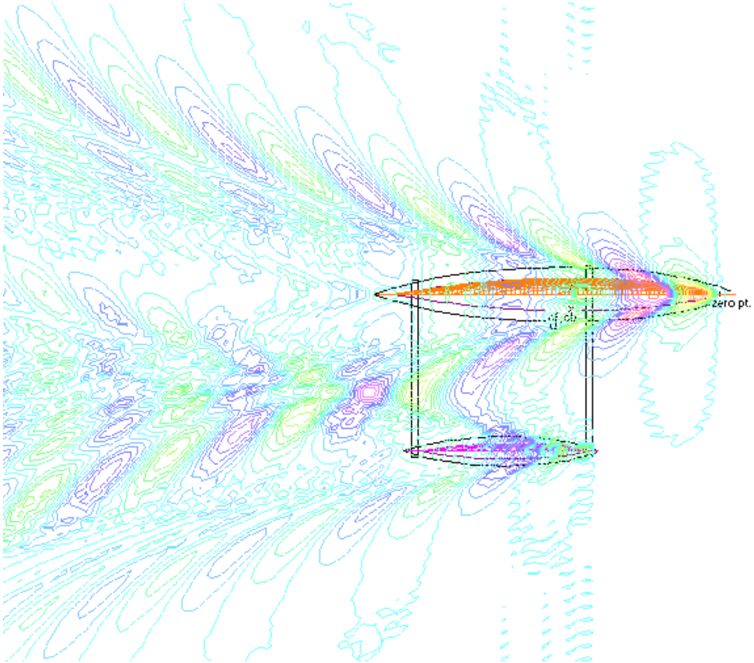


Shipflow group definition

	Name	Colour	Contours	Surfaces	Num	Long. origin m	Trans. origin m	Vert. origin m	Aft m	Fwd m	A port m	A starb. m	A top m	A bott. m	F port m	F starb. m	F top m	F bott. m
1	Ama		Section		21	-3.754	-4.829	0.000	-9.694	-3.754	-4.831	-4.378	0.913	0.217	DITTO	DITTO	DITTO	DITTO
2	Main		Section		81	0.509	0.000	0.000	-10.57	0.509	-0.004	0.842	1.291	-0.006	DITTO	DITTO	DITTO	DITTO

Add Open Delete Save Non dimensionalise OK Cancel

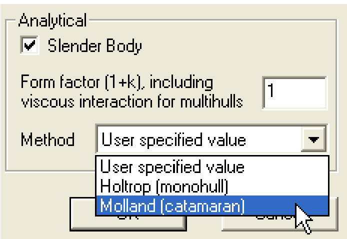
Slender body mesh definition for main hull and ama



Wave pattern calculated for proa model

Calculating the Form Factor

MAXSURF Resistance can automatically calculate the form factor that is used during the slender body analysis. You can chose to specify the form factor directly, or use MAXSURF Resistance's Holtrop for Monohulls or the Molland algorithm for catamarans.



The Molland et al. method uses the demihull slenderness ratio, $L/\nabla^{1/3}$, to determine the form factor according to the following equation:

$$(1 + \beta k) = 3.03\ (L/\nabla^{1/3})^{-0.40}$$

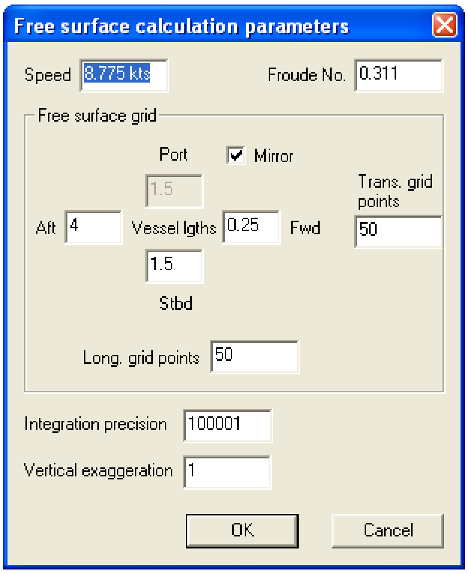
Note that this expression is for the form factor, $(1+\beta k)$, of the complete catamaran including viscous interaction effects between the demihulls.

For more information please refer to the Bibliography on page 50.

Calculating Free Surface Wave Pattern

MAXSURF Resistance may be used to calculate the wave pattern generated by a vessel. The wave pattern is calculated using a Michell / Slender Body type approach, i.e. the same method as the slender body resistance prediction; see Analytical Method. This free surface wave pattern calculation ignores the effects of viscosity and wave breaking.

The wave pattern is calculated on a grid specified in the Analysis | Free Surface Calculation Parameters dialog.



Free surface speed

The Speed field in the Free Surface Calculation Parameters dialog allows you to specify the vessel speed at which you wish to calculate the wave pattern. This can either be specified directly as a speed or as a Froude Number.

Free surface grid area

The area over which the free surface is to be calculated is specified in terms of vessel lengths. You can specify the number of vessel lengths forward and aft of the vessel as well as to port and to starboard. In addition, you can also specify the number of grid points to be used in the transverse and longitudinal directions. If the vessel is symmetrical, you can specify a symmetrical free surface, so that only the starboard side of the free surface is calculated and then simply mirrored about the centreline to produce the port side.

If you have an asymmetric model like the proa described in the previous section. You cannot select the Mirror option as the wave pattern will have port and starboard asymmetry.

Free surface integration precision

The integration precision option refers to the accuracy of free surface calculation; the higher the number, the greater the accuracy (note that the integration method requires that this number be odd and it will be adjusted if required). The calculation can be quite slow (press and hold the Escape ‘Esc’ key to abort) and is greatly affected by the number of grid points and the integration precision. For 3D rendered views, acceptable results can be achieved with relatively low settings, however to obtain smooth contour plots a very large number (of the order of 30,000) may be required. These values also depend on the Froude Number.

Free surface wave height vertical exaggeration

You can exaggerate the displayed wave pattern by changing the Vertical exaggeration.

After the wave pattern has been calculated, this exaggeration factor can be changed without having to recalculate the wave pattern. To do this, edit the value and close the dialog with Cancel instead of OK. This will apply the amplification without recalculating the free surface.

Wave Pattern Display

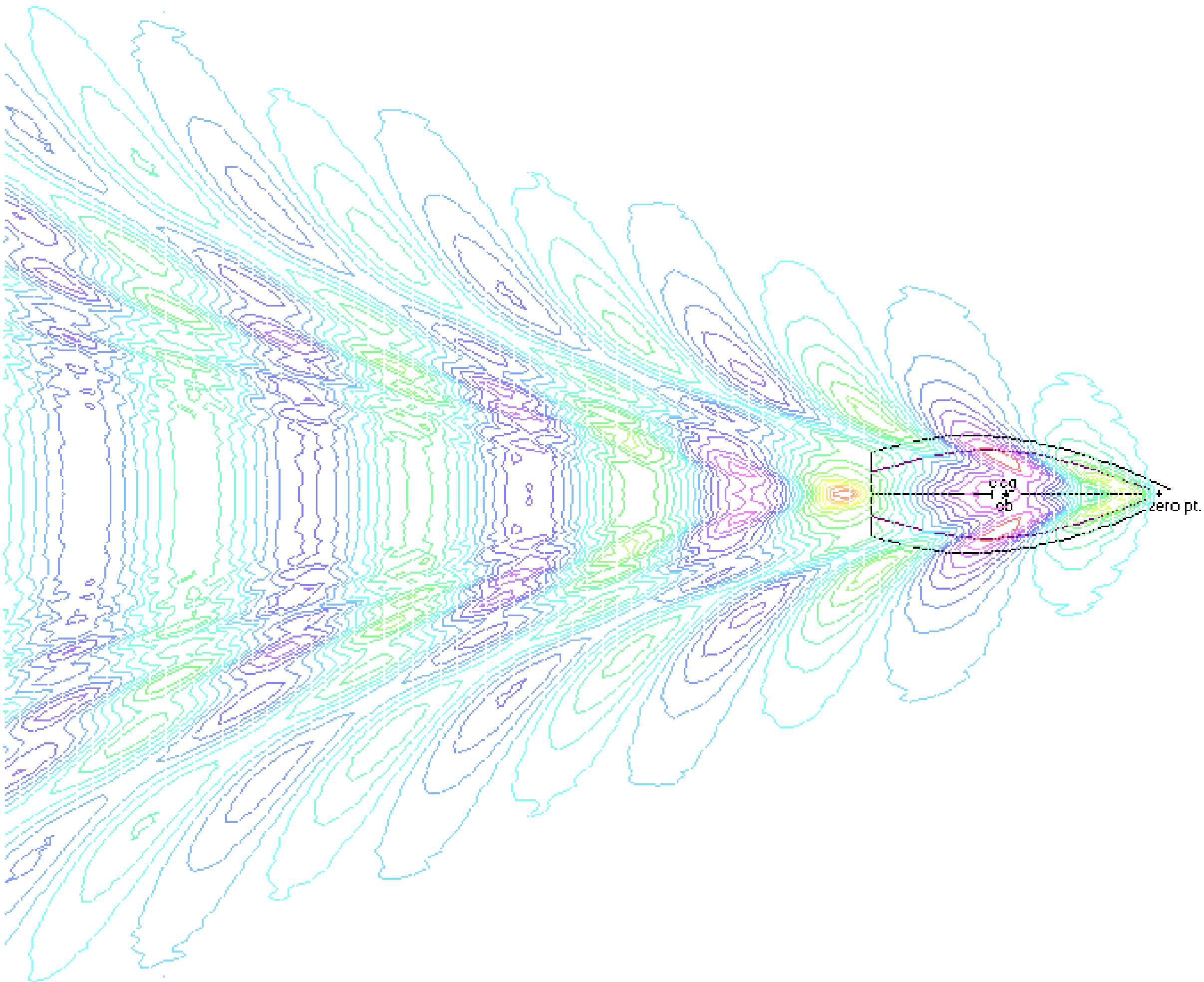
The wave pattern may be displayed in all view windows in MAXSURF Resistance in various ways. The display options are dependent on the frontmost view window and can be selected from the Display window.

2D view

In the 2D view windows, i.e. Plan, Profile or Body Plan, you can display the

- **Wave Grid**
- **Wave Contours, isometric elevation lines**

The image below is an example of a monohull isometric elevation contours in plan view.

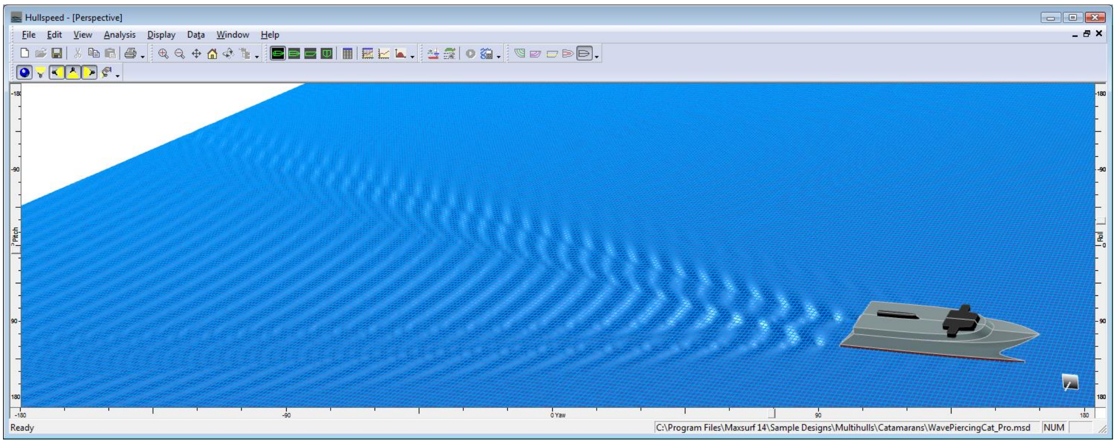


3D view

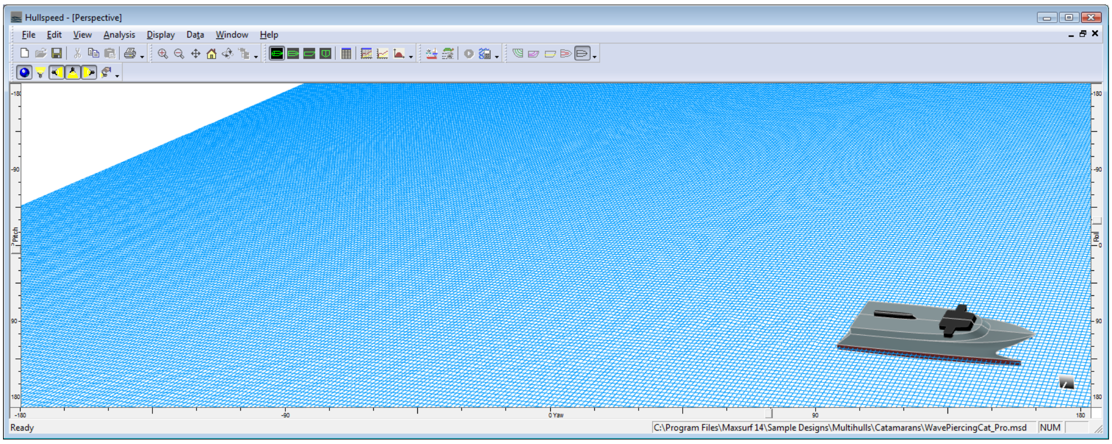
In the 3D view Perspective window you have the option of displaying the free surface wave pattern with- and without rendering (Display | Render).

Also you can additionally display the

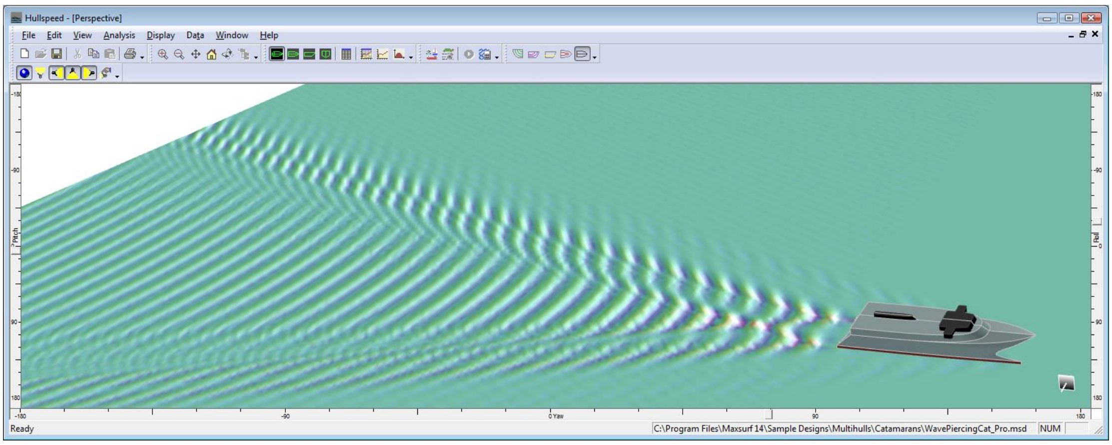
- **Solid Wave Render, only when Render is turned on**



Rendering of waves and wave grid with ocean colour



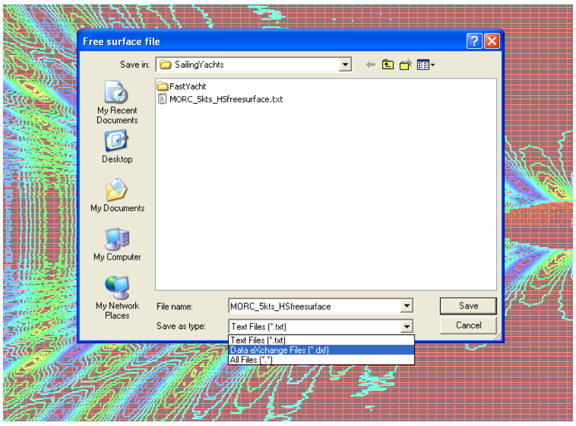
Rendering of wave grid only

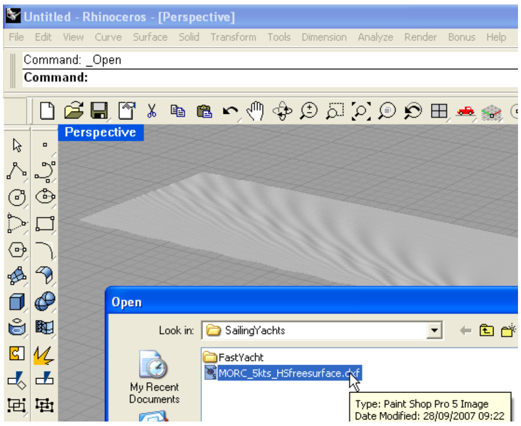


False-colour rendering of wave contour. Ocean colour disabled

Saving and Loading Wave Patterns

Because the calculation of wave patterns can be quite time consuming, these can be saved and reloaded from the File menu. The file can be saved in two formats: Firstly, a relatively simple text format which allows users to load the data into other application for producing (for example) wave cuts; the data is tab delimited to facilitate loading into MS Excel. Alternatively the file may be saved as a DXF mesh file – which can be rendered in Rhino3D for example.





Wave pattern text file format

The file format is as follows:

The first number is the file format version (1). The second indicates if it should be mirrored or not (0 not mirrored; 1 mirrored).

The next two lines give the number of points in the longitudinal and transverse direction respectively.

The rest of the data is based on a grid (this should be apparent when you view the data in Excel). The first line is the list of transverse positions for the grid (from port to starboard). The subsequent lines then give the longitudinal position in the first column (starting from aft moving forward) followed by the free surface elevations for the free surface grid points. All measurements are relative to the MAXSURF model zero point and are in the current length units.

A transverse cut through the wave pattern can be made by looking at a single row and a longitudinal cut can be made by looking at a single column.

The two final lines at the bottom of the table give details of the model and speed used to calculate the wave pattern.

Accuracy of Wave Pattern Calculations

Several features of the numerical methods required to compute the wave pattern cause it to be less accurate than the calculation of the wave resistance. Not least of these, is the fact that the computation for the wave resistance is equivalent to computing the wave pattern at one single grid point on the free surface and thus significantly less computational intensive. Also, in the case of the resistance computation, the functions that must be integrated are smoother and can thus be integrated with more accuracy. The “Integration precision” option in the Free Surface Calculation Parameters dialog controls the precision with which the main integration is performed and this will affect the smoothness and accuracy of the calculated wave pattern. For accurate results, this should be above 50,000 and in most cases it is advisable to use 100,000. However, this can take a few 10s of minutes on a 3GHz Pentium4, depending on the number of grid points being evaluated.

Thus the wave pattern calculation is generally to be used for presentation purposes or where an indication of the likely wave pattern is required. This is particularly true closer to the vessel since the accuracy of the wave pattern will be higher several vessel lengths aft of the vessel.

Power prediction in MAXSURF Resistance

There are various different powers which may be of interest to the naval architect:

Effective horsepower (ehp)

Power to push the naked hull through the water at a given speed. This is the product of the naked hull resistance and the ship velocity. The corresponding value including hull appendages is called ehp’. Where:

1 / appendage coefficient = ehp / ehp’

Thrust horsepower (thp)

This is the thrust horsepower developed by the propulsors. And in the case of a propeller is given by the product of the propeller thrust, T, and the inflow velocity into the propeller V_1

The ratio of the ehp to thp is known as the hull efficiency and for most vessels is close to unity. It can be expressed as a Taylor wake factor (or fraction) and augment of resistance or Froude wake factor and thrust deduction factor

Hull efficiency η_H = ehp’ / thp

Delivered horsepower (dhp)

This is the power delivered to the propulsors when propelling the ship. Relate to this is dhp’ which is when the propulsor is operating in open water.

Propeller open water efficiency η_o = thp / dhp’; for typical propellors thi s might be of the order of 50% – 70%

Relative rotative efficiency η_R = dhp’ / dhp

Shaft horsepower (shp)

This is the power needed to propel the complete ship. When compared with the delivered power, this depends on the losses in the transmission system:

Shaft transmission efficiency = dhp / shp

Propulsive coefficient (PC)

The ratio of the effective horsepower to the shaft horsepower is the propulsive coefficient

PC = η_H η_o η_R Shaft transmission efficiency / Appendage coefficient

Quasi-propulsive coefficient (QPC)

Ignoring the transmission losses, thus the ratio of the effective horsepower to the delivered hosepower is the quasi-propulsive coefficient

QPC = η_H η_o η_R / Appendage coefficient

The power calculation given by MAXSURF Resistance is simply the product of Resistance, velocity and efficiency. The efficiency is specified by the user and the same efficiency is used to calculate the power over the whole speed range.

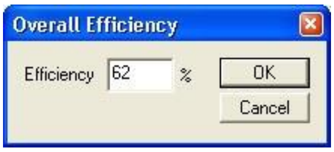
$$P = \frac{R \cdot V}{\eta}$$

, where

V is the ship velocity;
η , the efficiency
R, the resistance.

The efficiency you should use depends on what power you are looking at. For example if you want the effective power the efficiency would be unity; if you wanted the shaft power the efficiency would be the propulsive coefficient (PC) which accounts for propulsor efficiency, hull efficiency, relative rotative efficiency, appendage coefficient and the shaft transmission losses there are many sources that document these efficiencies and how to compute them.

The power calculation uses the efficiency specified by the user; the same efficiency is used at all speeds. The efficiency may be changed by selecting Efficiency from the Data menu. The efficiency is entered as a percentage.



Chapter 3 MAXSURF Resistance Reference

This chapter summarises the overall structure of windows, toolbars and menu commands used in MAXSURF Resistance, including a glossary and references.

- Windows
- Toolbars
- Menus

Windows

MAXSURF Resistance uses a range of windows.

View Windows

MAXSURF Resistance has four view windows which are exactly the same as the windows in MAXSURF.

Data Window

Displays the input data that is used for the selected methods. The input data may be measured from a MAXSURF design or typed manually.

Graph Window

Displays a graph of the hull's predicted power or resistance vs. speed and Froude number. See Results Graph on page 18.

Results Window

A numerical display of the resistance and power prediction results, in a format useful for copying to a spreadsheet. See the Results Table on page 18.

Toolbars

Users of the Windows version of MAXSURF Resistance can use the icons on the toolbars to speed up access to some commonly used commands. You can hold your mouse over an icon to reveal a pop-up tool tip of what the icon does.

File Toolbar

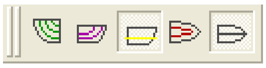
The File toolbar contains icons which execute the following commands:
New Data – Open Design – Save Design | Cut - Copy - Paste | Print Preview

View Toolbar

The View toolbar contains icons which execute the following commands:
Zoom – Shrink – Pan – Home View – Rotate – Assembly window.

The Rotate command is only available in the Perspective window. The Assembly window is not available in MAXSURF Resistance.

Contours Toolbar



The Contours toolbar contains icons which facilitate the display of surface contours:
Sections – Buttocks – Datum WL – Waterlines – Edges

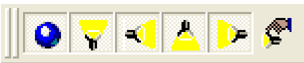
Analysis Toolbar

The Analysis toolbar is used to access the most commonly used analysis commands.
Analysis methods – Speed range | Solve (for slender body method only) – Calculate free surface

Window Toolbar

The Window toolbar contains icons which make the corresponding window come to the front:
Perspective – Plan – Profile – Body Plan – Data window – Results window – Graph window

Render Toolbar



The Render toolbar contains icons for rendering the MAXSURF model in the perspective view:
Render on/off – Light 1 – Light 2 – Light 3 – Light 4 – Light properties

Menus

MAXSURF Resistance uses the standard set of Windows menu commands for File, Edit and Window operations.

- File Menu
- Edit Menu
- View Menu
- Analysis Menu
- Display Menu
- Data Menu
- Windows Menu
- Error! Reference source not found.

File Menu

The File menu contains commands for opening and saving files, exporting data and printing.

Open Design

Selecting Open will open a MAXSURF file for measuring.

Close Design

Selecting Close will close the MAXSURF file. Note that, since you cannot edit the MAXSURF design in MAXSURF Resistance, you cannot save the MAXSURF file.

New Measurement Data

Selecting New will clear the current set of measurement data in anticipation of a new set. If the current data has been changed since it was last saved, a dialog box will appear asking whether you wish to save the current set of data. If you select Yes, the current set of data will be saved to the disk before the Data window is cleared.

Open Measurement Data

Opens a data file previously saved from MAXSURF Resistance.

Close Measurement Data

Select Close Measurement Data when you wish to finish with the current set of data. Before closing, a dialog box will appear asking whether you wish to save the current set of data. If you select Yes, the current set of data will be saved to the disk.

Save Measurement Data

Saves the measurement data in a file for later recall. If the data was changed after selecting New Measurement Data, MAXSURF Resistance will prompt the user to specify a name for the new file.

Save Measurement Data As

Saves the current MAXSURF Resistance data file with a different (user-specified) name.

Open Free Surface

If a free surface wave pattern has been calculated and saved previously, it may be reopened with this command to save having to recalculate it.

Save Free Surface As

If a free surface wave pattern has been calculated it may be saved in a text file or DXF mesh file. It can then be reopened at a later date. The free surface file is a simple text file and can be imported into Excel or other applications for plotting wave cuts etc. See Saving and Loading Wave Patterns on page 33.

Import nuShallo mesh.

Import a nuShallo mesh file directly for analysis in Resistance.

Export Bitmap Image.

As in the other MAXSURF applications, this command may be used to export a bitmap file of the rendered perspective view.

Export Wavefront mesh.

Export the rendered mesh as a Wavefront mesh file for use in 3rd party rendering software.

Page Setup

The Page Setup dialog allows you to change page size and orientation for printing.

Print

Choosing the Print function prints out the contents of the foremost MAXSURF Resistance window. See the MAXSURF manual for more information.

Exit

Exit will close down MAXSURF Resistance. If MAXSURF Resistance has a set of data open that has not been saved to disk, you will be asked whether you wish it to be saved.

Edit Menu

The Edit menu contains commands for copying and pasting data and working in tables.

Undo

Undo will undo the last change made in the Data window.

Cut

Cut cannot be used in MAXSURF Resistance.

Copy

You can copy data from the MAXSURF Resistance windows. In the Data and Results windows highlight the columns and rows you wish to copy and select Copy or type Ctrl+C.

To copy the row and column titles press Shift whilst selecting Copy (Ctrl+Shft+C). This data may then be pasted into other applications such as spreadsheets and word processors.

Paste

You may paste data from spreadsheets, etc. into the Data window.

View Menu

The View menu contains commands that control the appearance of the display in the frontmost windows.

Zoom

The Zoom function allows you to examine the contents of the frontmost view window in detail by enlarging any particular area to fill the screen.

Shrink

Choosing Shrink will reduce the size of the displayed image in the frontmost view window by a factor of two.

Pan

Choosing Pan allows you to move the image around within the frontmost view window.

Home View

Choosing Home View will set the image back to its Home View size. MAXSURF Resistance starts up with default Home View settings for each of the view windows. However, the Home View may be set at any time by choosing the Set Home View function.

Set Home View

Choosing Set Home View allows you to set the Home View in the frontmost view window.

To set the Home View, use Zoom, Shrink, and Pan to arrange the view as you require, then select Set Home View from the View menu.

Rotate

Activates the Rotate command, which is a virtual trackball which lets you freely rotate a design in the Perspective view window.

Colours and Lines

The Colour function allows you to set the colours used in the power/resistance graph or the colours of the contours used to display the MAXSURF design in the view windows.

MAXSURF Resistance will display a list of display items that can be modified. These display items are dependent on the frontmost window.

Font

Font allows you to set the size and style of text used in the frontmost window.

Toolbars

Allows you to select which Toolbars are visible, see Toolbars on page 37 for further details.

Status Bar

Makes the Status Bar at the bottom of the screen visible. This Status Bar displays information about the current state of what is being viewed in the window as well as short descriptions of the functions of some commands as your mouse passes over them and indicates the state of some control keys.

Analysis Menu

The Display menu contains commands for setting the analysis parameters and solving the analysis.

Methods

Selecting Methods will bring up a dialog box which allows the user to select which prediction methods will be used. The methods chosen will be saved together with its required input data.

Speeds

Selecting Speeds will bring up a dialog box which allows you to select the speed range over which the analysis will be performed.

Efficiency

Selecting Efficiency will display a dialog box which allows the user to specify the efficiency, η , used to calculate the ship's power, *P*, from the resistance, *R*:

$$P = \frac{R \cdot V}{\eta}$$

, where

V is the ship velocity

The efficiency is entered as a percentage.

Measure Hull

Selecting Measure Hull will cause MAXSURF Resistance to calculate the data it requires from the MAXSURF file currently loaded. The user will be asked to select the surfaces to be included in the measurement process. For designs such as yacht hulls, it is advisable *not* to include the surfaces, which define the appendages, such as the rudder and keel.

If this option is chosen, any data already input by the user will be over written by the measured values.

SB Analysis Geometry

Used to set up the surfaces and bounding box to be used to calculate the slender body mesh. You can also specify the number of sections to be used and the colour of the drawn mesh.

Barge Analysis Geometry

Used to define the category of barge bow shape to be used.

Solve Resistance Analysis

All analysis methods other than the slender body method are computed as soon as any of the analysis parameters are changed. However, the computation time for the analytical slender body method is considerably slower; for this method, you must tell MAXSURF Resistance to perform the analysis by selecting the Solve Resistance Analysis command.

Calculate Free Surface

Calculates the wave pattern generated by the vessel for the specified speed using the slender body method.

Display Menu

The Display menu contains commands for changing the display.

Graph Type

Allows the user to select whether a Power vs. Speed; Resistance vs. Speed or Resistance Coefficient vs. Speed graph is shown in the Results Graph window.

Note that in the case of the Resistance Coefficient vs. Speed graph, the y-axis is multiplied by a factor of 1000.

Contours

The contours command lets you select which contours are displayed in the design views.

SB Mesh

The SB Mesh command in the Display menu display the hull surface mesh used for the slender body method. The mesh parameters may be modified with the SB Analysis Geometry command in the Analysis menu. See the Wave Pattern Display on page 31 for more information.

Wave Grid

Displays a rectangular wire-frame, grid connecting the points at which the wave pattern elevation has been calculated

Wave Contours

Displays isometric wave elevation contours for the computed free surface. In rendered mode a false-colour rendering is used.

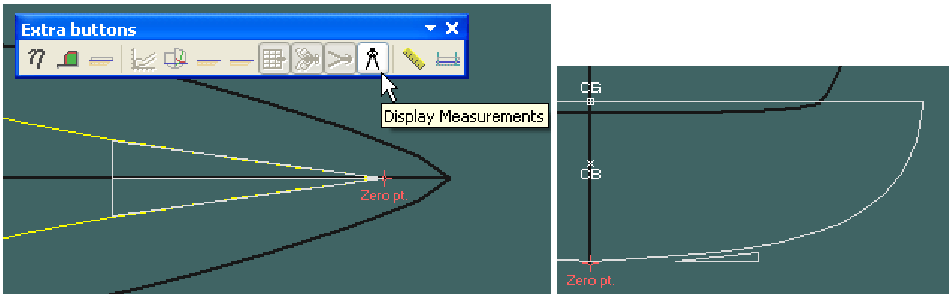
Wave Solid Render

In rendered mode, selecting Wave Solid Render will shade the rendered free surface. For printing, a better result is often achieved just with the wave grid displayed.

This function is only available in the Perspective window with rendering switched on.

Measurements

This command turns of the display of the half-angle of entrance and deadrise measurements.



Render

Displays a rendered view of the model in the Perspective window (only if a MAXSURF model has been loaded). If the free surface has been calculated, it will also be rendered.

Rendering is only available in the Perspective window.

Data Menu

The Data menu contains commands for changing the data used to calculate the hull's resistance.

Units

The default units to be used for linear dimensions, mass, speed, force and power may be selected from the units menu. Changes to the default units will be reflected in the Data, Results and Graph windows. Data, with the exception of density, may be entered in non-default units by adding the appropriate units suffix.

Coefficients

Specify options for the calculation of various hull coefficients of form (Block, Prismatic, Waterplane, etc. coefficients).

Frame of Reference

Allows the user to change the draft at which calculations are performed.

Windows Menu

The Windows menu allows you to arrange and make any window selected from the menu the active window.

Cascade

Displays all the windows behind the active windows.

Tile Horizontal

Layout all visible windows across the screen.

Tile Vertical

Layout all visible windows down the screen.

Arrange Icons

Rearranges the icons of any iconised window so that they are collected together at the bottom of the MAXSURF Resistance program window.

Data

Brings up the data window.

Results

Brings up the Results window.

Perspective

Brings up the Perspective window.

Plan

Brings up the Plan window.

Profile

Brings up the Profile window.

Body Plan

Brings up the Body Plan window.

Graph

Brings up the graph window. See the Results Graph on page 18.

Help Menu

Provides access to Resistance help and other resources.

Resistance Help

Display the Resistance help manual.

Resistance Automation Reference

Display the Resistance Automation reference help manual.

Online Support

Provides access to a wide range of support resources available on the internet. You must have internet access to access this functionality.

Service Request Manager

Submit and manage your technical support requests with Bentley Systems. You must have internet access to access this functionality.

Check for Updates

Provides access to our website with the most recent version listed. You must have internet access to access this functionality.

News

Display the Bentley Systems Offshore news feed. You must have internet access to access this functionality.

CONNECT Advisor

Display the Bentley Systems CONNECT Advisor. You must be logged in with the CONNECTION Centre to access this functionality.

Legal Notice

Display the Bentley Systems Legal Notice.

About Resistance

Displays information about the current version of Resistance you are using and other diagnostic information. Use this to obtain version and diagnostic information when reporting a problem to the Support Staff at Bentley Systems, Incorporated.

Bentley Cloud Services Menu

Provides access to Bentley Cloud Services resources. You must be logged in with the CONNECTION Centre to access this functionality.

Associate Project

Register the current file you are working on with a CONNECTED Project.

Disassociate Project

Unregister the current file you are working on from a CONNECTED Project.

CONNECTION Centre

Display your personal CONNECTION Centre web portal in your web browser.

ProjectWise Projects

Display the CONNECTED Project in your web browser.

Chapter 4 Theoretical Reference

This chapter contains a list of terms and abbreviations used in this manual, and provides a literature list for all the resistance prediction methods used in MAXSURF Resistance.

- Glossary
- Bibliography

Glossary

This glossary describes the key words and abbreviations used in this manual.

Half Angle of entrance

The angle measured in the plane of the water plane, between the hull and the centreline.

Appendage Area

The wetted area of appendages, used to calculate appendage drag. Set this to zero to ignore appendage resistance.

Appendage Length, nominal

A nominal length used to calculate the Reynolds Number of the appendages and hence the appropriate skin friction coefficient

Appendage Factor

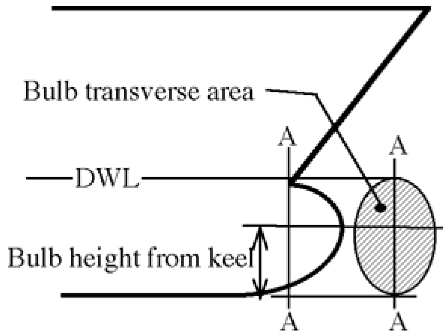
A factor for estimating the resistance due to the drag on appendages. Expected values range from 1.0 to 3.0.

Beam

The maximum submerged width of the hull.

Bulb Height from Keel

The distance from the keel line, to the transverse centre of area of the bulb section on the waterline at the stem.



Bulb Transverse Area

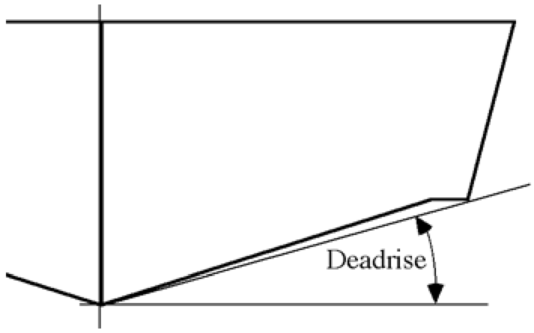
The transverse sectional area of the bulb (if any) measured on the waterline at the stem.

Correlation Allowance

A factor for accounting for variations between model tests and full-scale trials.

Deadrise at 50% Lwl

The angle measured in the section plane between the hull and the horizontal, as measured at midships.



Density, Air

The air density, at the appropriate ambient temperature. The default value is 1.293 kg/m^3 for air at 15°C.

Density, Sea

The sea density, at the appropriate ambient temperature and salinity. The ITTC 1967 value, for salt water (3.5% salinity) at 15°C., of 1025.9 kg/m^3 is given as the default.

Displaced Volume

The volume of seawater displaced by the hull.

Draft

The maximum submerged depth of the hull. Sometimes also referred to as "draft".

Draft at FP

The draft at the fore perpendicular. This value can be left at zero, whereupon MAXSURF Resistance will assume it is the same as the value for the 'draft' item.

Drag Coefficient

The coefficient of drag for calculation of wind resistance. Expected values would be in the range of 0.8 - 1.2.

Efficiency

The efficiency used to calculate the ship's power from its resistance.

$$P = \frac{R \cdot V}{\eta}$$

Frontal Area

The area of the vessel above the waterline, when viewed from the front. Set to zero to ignore wind resistance.

Froude Number

A dimensionless speed measurement:

$$F_n = \frac{V}{\sqrt{gL}}$$

Length, *L*, is typically used, but may be inappropriate for some measurements, such as for a planing hull, where the waterline length varies with speed. In such circumstances, beam may be substituted for length, as may draft etc.

Kinematic Viscosity

The kinematic viscosity of sea water. The ITTC 1967 value, for salt water (3.5% salinity) at 15°C., of 1.18831x10^{-6} m^2/s is given as the default.

LCG from midships

The distance to the longitudinal centre of gravity, measured from midships. Note that this distance is positive forward. That is, an LCG 1.5m aft of midships will be entered as -1.5.

Length / Lwl

The length of the hull, measured on the waterline.

Maximum Sectional Area

The largest submerged sectional area of the hull, measured when the vessel is at rest.

Prismatic Coefficient

A measure of the extent to which the submerged volume of a hull fills the prism defined by the submerged length, multiplied by the area of the largest transverse section.

$$C_p = \frac{\nabla}{L \cdot A_X}$$

Transom Area

The submerged sectional area of the transom, measured when the vessel is at rest.

Transom Beam

The maximum submerged width of the transom.

Transom Draft

The maximum submerged depth of the transom.

Water plane Area Coefficient

A measure of the extent to which the area of the water plane fills the rectangle defined by the length * beam.

$$C_{WP} = \frac{A_{WP}}{L \cdot B}$$

Wetted Area

The submerged surface area of the hull. For the slender body method, the wetted area is used to calculate the Friction and Viscous resistance coefficients only; the wave resistance is calculated directly from the surface model.

The wetted area is also used to calculate the resistance coefficients displayed in the Graph window.

Volume Froude Number

A dimensionless speed measurement based on the cube-root of the displaced volume.

$$F_n = \frac{V}{\sqrt{g\nabla^{1/3}}}$$

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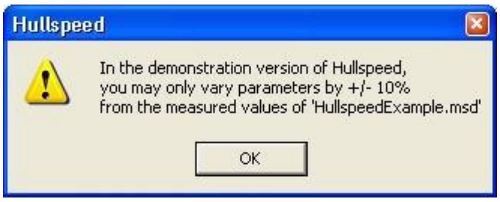
Appendix A Demonstration Version

It should be noted that the demonstration version of MAXSURF Resistance is locked to two sample models:

1. The MAXSURF Resistance Sample_Workboat.msd design this model will automatically open on starting the demonstration version of MAXSURF Resistance. It is saved in;
   C:\Program Files\MAXSURF Demo\Sample Designs

2. The MORCYacht_1Surface.msd design this is saved in;
C:\Program Files\MAXSURF Demo\Sample Designs\SailingYachts

The MAXSURF Resistance input Data may be changed within +/-10% of the values of the sample designs. If data is changed beyond this limit a warning will be given and the resistance will not be predicted and "calc." will be displayed in the Results table:



Appendix B Applicability

Since the algorithms are designed for specific hull types, they will be most accurate when certain conditions are satisfied. These conditions are:

- **Hullshape**
- **Speed**
- **Dimensions**

Hullshape

The hullshape is very important in determining whether a particular method is applicable to a particular design. A thorough knowledge of the resistance prediction method is required. See the Bibliography section on page 50 to find the relevant documents on each of the methods available in MAXSURF Resistance.

Speed

The resistance prediction algorithms are useful only within certain speed ranges; these limits are:

Algorithm:	**Low - speed limit**	**High - speed limit**
Savitsky (pre-planing)	$Fn_V = 1.0$	$Fn_V = 2.0$
Savitsky (planing)	$Fn_b = 1.0$	None, see note below
Blount and Fox	$Fn_V = 1.0$	None, see note below
Lahtiharju (round bilge)	$Fn_V = 1.5$	$Fn_V = 3.8$
Lahtiharju (hard chine)	$Fn_V = 1.5$	$Fn_V = 5.0$
Wyman	0.0	depends on “DL ratio”
Holtrop	0.0	$Fn_L = 0.80$
Van Oortmerssen	0.0	$Fn_L = 0.50$
Series 60	$Fn_V = 0.282$	$Fn_V = 0.677$
Delft	0.0	$Fn_L = 0.75$
Compton	$Fn_L = 0.1$	$Fn_L = 0.6$
Fung	$Fn_L = 0.134$	$Fn_L = 0.908$
KR Barge	0.0	$Fn_L = 0.50$
Slender Body	0.0	Up to $Fn_L \approx 1.0$ depending on slenderness ratio

For some algorithms, MAXSURF Resistance will calculate the resistance only for speeds within the limits indicated above. For the other algorithms, MAXSURF Resistance will calculate the resistance for any speed. The user should be aware that the accuracy of the algorithms is expected to decrease beyond the limits outlined above.

Gerr (2008) gives this information regarding the applicable speed range for the Wyman method: "The Wyman speed formula offers exceptional results at *SL* ratios over 2 and fairly good results at *SL* ratios under 2"

where *SL* is given by: $SL = \frac{\text{speed[kn]}}{\sqrt{\text{length on waterline[ft]}}}$;

and *SL* is related to Froude number by $Fn = 0.2976\,SL$

Note regarding speed ranges. Some of the formulae (Savitsky planing, Lahtiharju and Holtrop) are able to calculate the vessel resistance for any speed. However, the regression equations were derived from resistance data within specified speed ranges and these are noted in the table above. The Savitsky (planing) formula (and hence Blount and Fox method) was derived from theory based on the planing behaviour of a prismatic hull; whilst there is no theoretical upper speed limit, results for speeds above approximately Fn_V = 6.0 to 7.0 should be treated with caution.

Fnb - Beam Froude number
Fn_V - Volume Froude number
Fn_L - Length Froude number, see Glossary for definition of these Froude numbers.

Dimensions

The resistance prediction algorithms are useful only within certain limits of hull dimension. These limits are:

Algorithm:	**Requirement:**				
Savitsky	3.07	<	$L/V^{1/3}$	<	12.4
(pre-planing)	3.7	<	ie	<	28.6
	2.52	<	L/B	<	18.26
	1.7	<	B/T	<	9.8
	0	<	At/Ax	<	1
	-6.56%	<	LCG/L	<	0.3%
Blount and Fox			LCG_{bf}/L_{cp}	<	0.46
Lahtiharju	4.47	<	$L/V^{1/3}$	<	8.30
(Round Bilge)	0.68	<	B^3/V	<	7.76
	3.33	<	L/B	<	8.21
	1.72	<	B/T	<	10.21
	0.16	<	At/Ax	<	0.82
	0.57	<	Cm	<	0.89
Lahtiharju	4.49	<	$L/V^{1/3}$	<	6.81
(Hard Chine)	2.73	<	L/B	<	5.43
	3.75	<	B/T	<	7.54
	0.43	<	At/Ax	<	0.995
Holtrop	0.55	<	Cp	<	0.85
	3.9	<	L/B	<	15

Algorithm:	**Requirement:**				
	2.1	<	B/T	<	4.0
van Oortmerssen	8	<	L	<	80
	3	<	L/B	<	6.2
	0.5	<	Cp	<	0.73
	-8%	<	LCG/L	<	2.8%
	5	<	V	<	3000
	1.9	<	B/T	<	4.0
	0.70	<	Cm	<	0.97
	10	<	ie	<	46
Series 60	0.6	<	Cb	<	0.8
	5.5	<	L/B	<	8.5
	2.5	<	B/T	<	3.5
	-2.48%	<	LCB	<	3.51%
Delft	2.76	<	L/B	<	5.00
	2.46	<	B/T	<	19.32
	4.34	<	$L/V^{1/3}$	<	8.50
	-6.0%	<	LCB	<	0.0%
	0.52	<	Cp	<	0.60
Compton					
	-0.13	<	LCG/L	<	-0.02
	4.0	<	L/B	<	5.2
	0.00368	<	V/L^3	<	0.00525
Fung					
	0.00057	<	V/L^3	<	0.01257
	1.696	<	B/T	<	10.204
	0.526	<	Cp	<	0.774
	0.556	<	Cx	<	0.994
	14.324^{o}	<	ie	<	23.673^{o}
	2.52	<	L/B	<	17.935
	0.662	<	Cwp	<	0.841
Slender Body					
	≈ 4 or 5[1]	<	$L/V^{1/3}$	<	no limit

[1] The minimum slenderness ratio to which the slender body method can be applied depends on the Froude number at which the resistance is being evaluated. As the Froude number is reduced, the minimum slenderness ratio to which the method can be applied is also reduced. As a rough guide, at a Froude number of unity, the minimum slenderness ratio would be between approximately 7.5 and 8.0. If the Froude number were reduced to 0.2, then the method could be applied to slenderness ratios as low as 4.0.

Where:

L	Length on the waterline
L_{cp}	Projected length of chine. (onto longitudinal axis of vessel).
B	Beam on the waterline
T	Draft of hull
At	Transom sectional area
Ax	Maximum sectional area
V	Displaced volume
Cm	Midship sectional area coefficient
Cp	Prismatic coefficient
Cwp	Water plane area coefficient
Cx	Maximum sectional area coefficient
ie	Half angle of entrance
LCB	Longitudinal centre of buoyancy, measured from midships, positive is forward.
LCG	Longitudinal centre of gravity, measured from Midships, positive is forward.
LCG_{bf}*	LCG for Blount Fox method measured from the transom
Deadrise	Mean deadrise, or deadrise at 50% Lwl.
wsa	Wetted area of hull.
Bt	Transom beam at waterline
Tt	Transom draft
Abulb	Bulb transverse area.

* Even though the Blount and Fox method specifies using LCG from transom in the original paper the user still enters the LCG relative to the midships (or Resistance calculates it) in MAXSURF Resistance. When the Blount and Fox calculations are performed internally the LCG relative to the transom is calculated and used.

MAXSURF Resistance will allow calculations beyond these limits; however, the user should be aware that the accuracy of the algorithms is expected to decrease beyond the limits outlined above. In some cases, the algorithm may become very sensitive to parameters outside the specified range.

Appendix C Slender Body Method

In this appendix the results of the slender body (thin ship) resistance prediction method have been compared against model test data for the following hull forms:

- Wigley hull
- NPL round-bilge

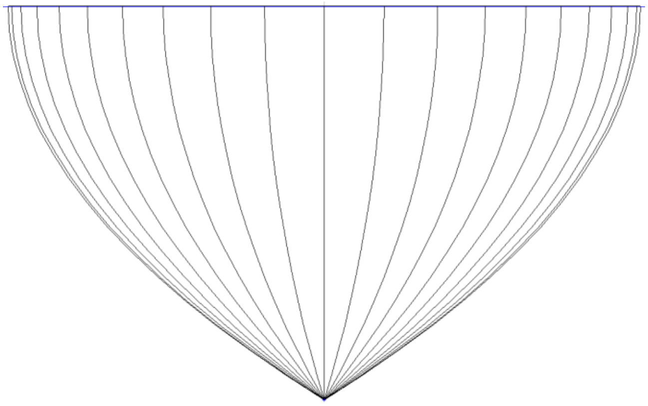
Wigley hull

Results for the simple Wigley hull form are given below. Here results are compared with two theoretical methods Insel (1990) and Michlet as well as experimental results from Insel (1990). MAXSURF Resistance can be seen to be in close agreement with the other two analytical methods. Although there is a reasonable amount of scatter in the experimental results, it appears that the theoretical methods tend to over-predict the wave resistance. In the case of the experiments, the model was held fixed in trim and sinkage, i.e. the model was kept at the datum waterline.

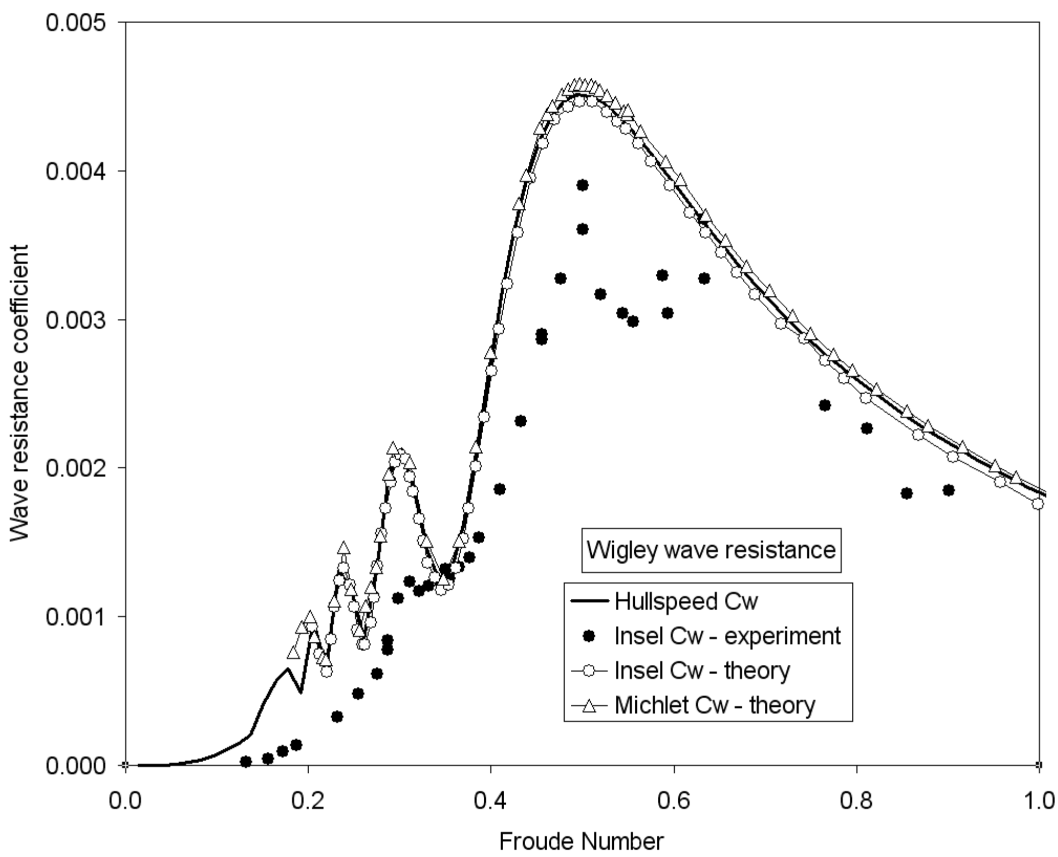
Wigley parabolic hull parameters:

L/B	10.0
B/T	1.6
C_B	0.44
C_P	0.44
C_M	0.44
WSA/L^2	0.1488

Monohull:

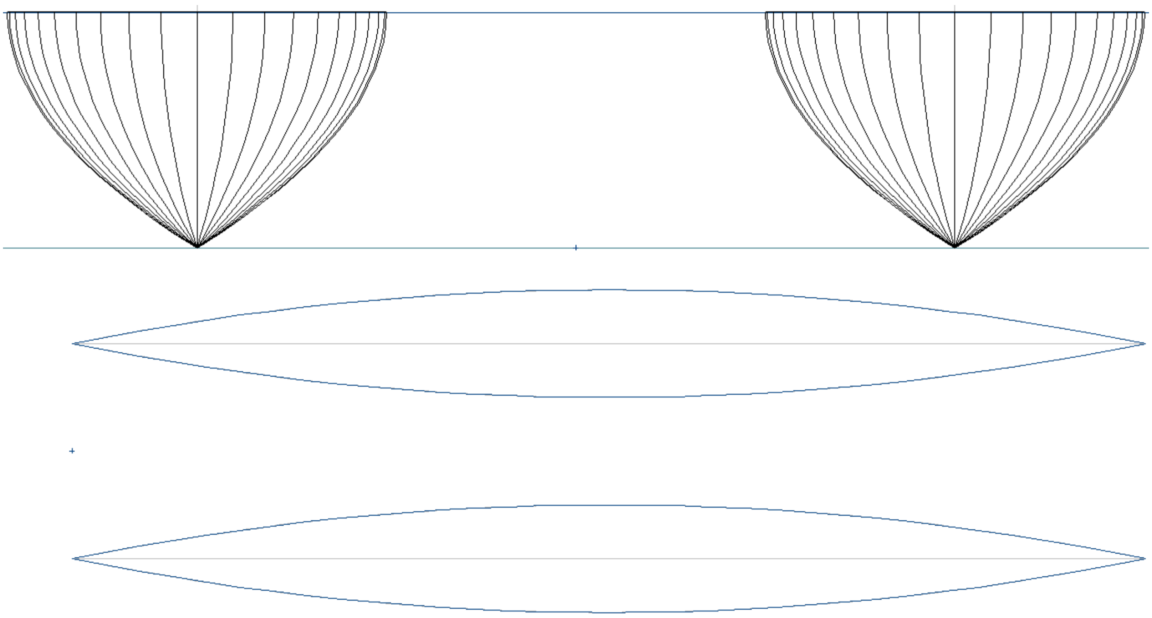


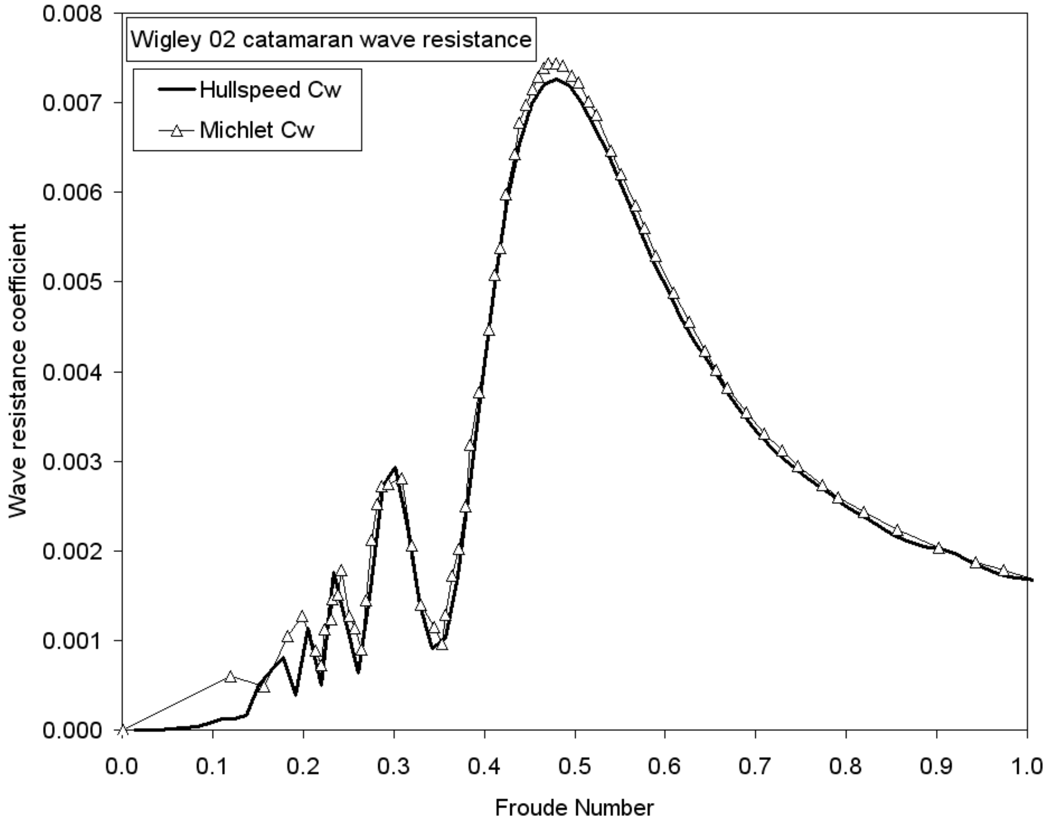
Wigley hull bodyplan



Comparison of results for Wigley hull

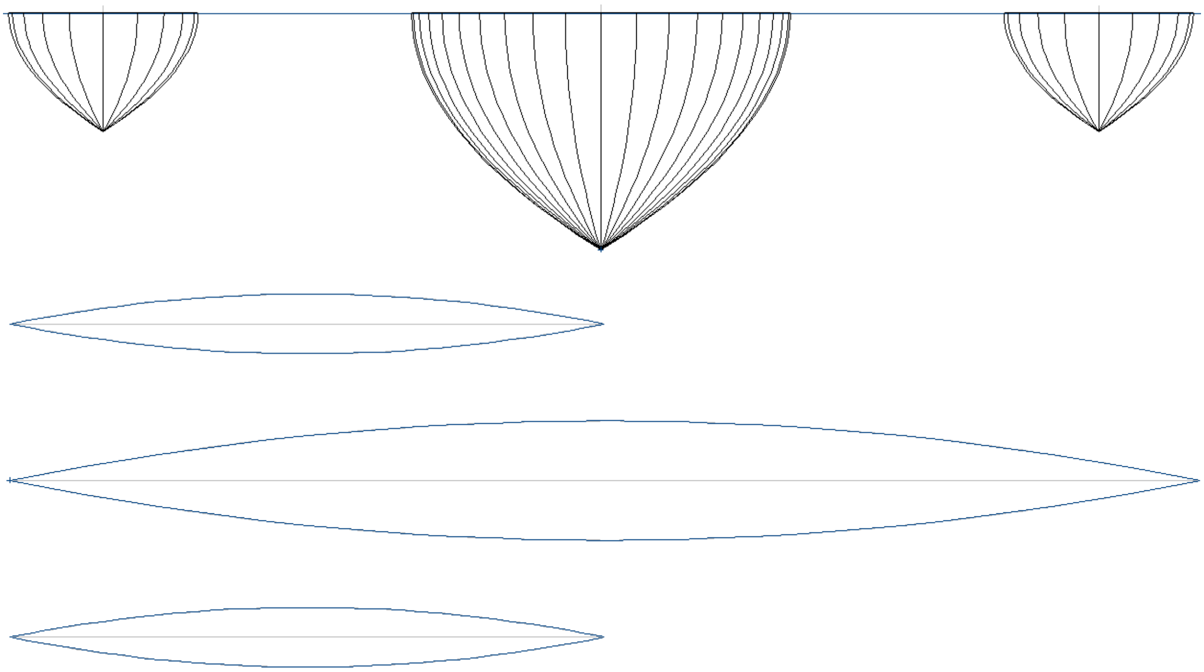
Catamaran: centreline separation / length = 0.2

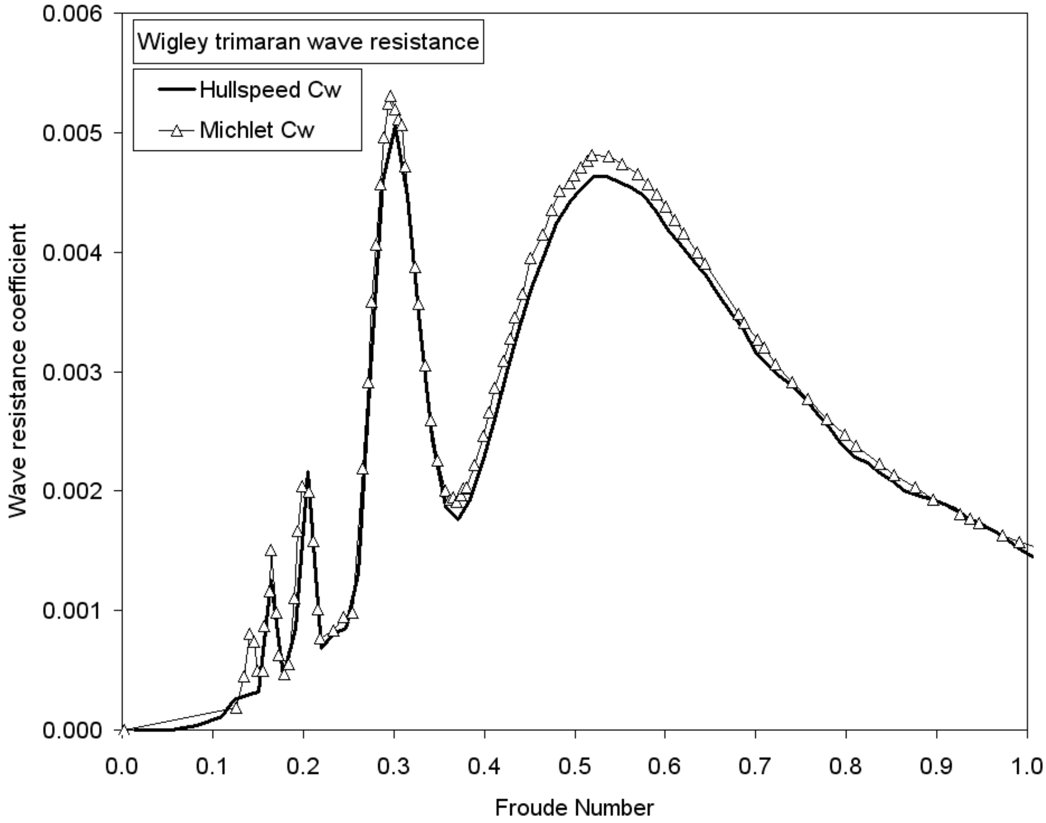




Comparison of results for Wigley catamaran

Trimaran: ama half main hull dimensions





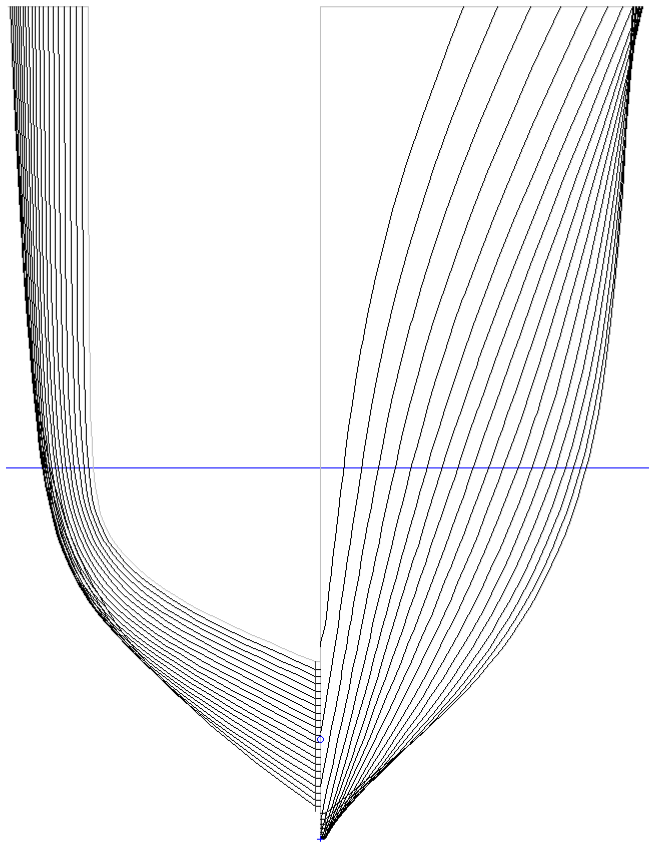
Comparison of results for Wigley trimaran

NPL round-bilge

The following graph shows a comparison between results from MAXSURF Resistance, other theoretical methods and experimental results for a transom-sterned hullform. The model is a stretched NPL round-bilge form. For transom-sterned hulls, MAXSURF Resistance adds a “virtual appendage” which models the air-gap behind the transom when the water releases cleanly from the transom edge (high-speed condition) and the turbulent viscous wake behind the transom at slow speed (low speed condition) – this method is described in detail in Couser et al (1996). For these experimental results the model was free to sink and trim; the theoretical results of Couser et al (1996) included the actual running trim and sinkage as measured during the experiments and hence the very close agreement with the experimental results. The results for MAXSURF Resistance use a fixed waterline, since, in general, the trim and sinkage condition at each speed is not known. The results from MAXSURF Resistance show good agreement with the experimental results, particularly when the transom is clearly in the high or low speed condition; in the transition condition, around Froude number = 0.5, MAXSURF Resistance under-predicts the resistance.

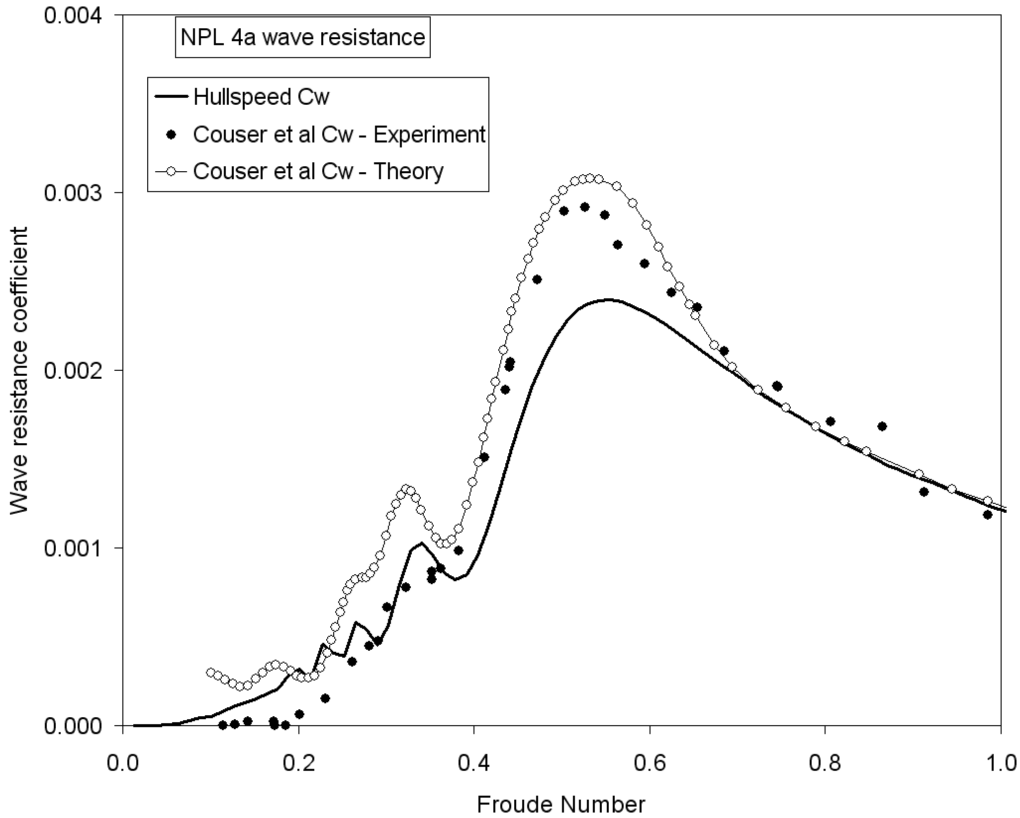
NPL round bilge, mode 4a (Couser et al 1996 notation) hull parameters

L/B	10.4
B/T	1.5
C_B	0.397
C_P	0.693
C_M	0.565
WSA/L^2	0.1359



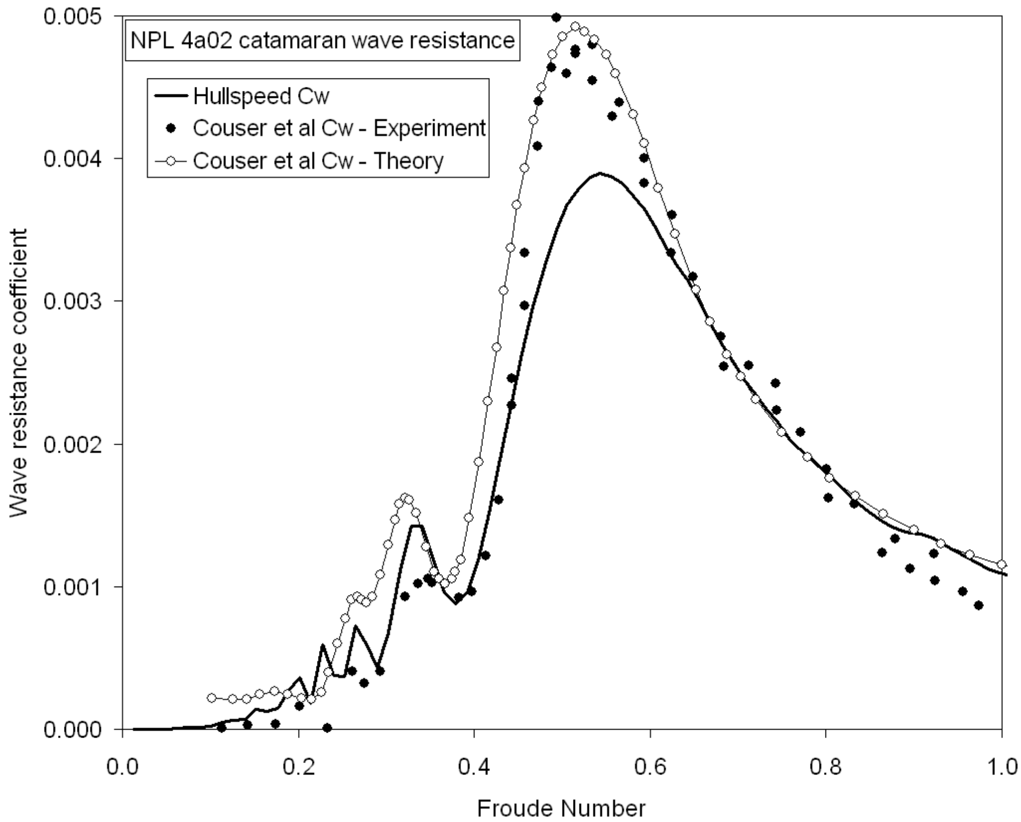
NPL (model 4a) hull bodyplan

Monohull:



Comparison of results for NPL (model 4a) hull - monohull

Catamaran: centreline separation / length = 0.2



Comparison of results for NPL (model 4a) - catamaran S/L = 0.2

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