MICHLET 9.33

User's Manual

MICHLET IS RESEARCH CODE!

Please check all estimates generated by the program against experimental results before committing any time or funds to your project as no liability can be accepted by Cyberiad.

Contents

1 INTRODUCTION

Michlet is a computer workbench that can be used for investigations into some aspects of ship hydrodynamics. Although it is not a ship design program, Michlet can be used for preliminary design work such as estimating the resistance, wave elevation patterns and bottom pressure signatures of monohulls, multihulls and submarines. GODZILLA, the optimisation module of Michlet, uses artificial life algorithms to search for hulls of minimum resistance, or for hulls with other specific characteristics.

Michlet is not an easy program for newcomers to hull design. A familiarity with the first few chapters of an introductory Naval Architecture text would be useful. There are several good WWW articles that might serve as sufficient introduction.

There are many opportunities to waste a lot of computer time and human effort with Michlet. Incorrect specification of parameters in the input file could result in completely useless output and it is imperative that users gain familiarity with the input file and its nuances.

2 INSTALLATION AND EXECUTION

2.1 Installing Michlet

- Create a directory named, for example, cyberiad
- Copy the zipped file you received or downloaded to that directory
- Unzip the file making sure to expand subdirectories
- The executable file is mlt933w.exe
- To exit from any screen, press Esc
- Press ? for help when the Lines Drawing screen is displayed

When you run Michlet for the first time, it will load in the details of a small monohull from the input file named in.mlt. That file and other examples are discussed in a separate manual.

2.2 File List

The following files and directories should be contained in the zipped file.

- mlt933w.exe : the executable file for the graphic version
- michlet.bat : batch file that runs the executable
- godzilla.bat : batch file that runs the executable in GODZILLA mode
- alleg42.dll : Allegro graphics dll
- libstdc++.dll : C++ dll
- in.mlt : the main input file
- docs : subdirectory containing documentation
- examples : subdirectory with examples and templates
- godzilla : subdirectory with optimisation examples and templates

2.3 Command Line Options

The batch file michlet.bat runs the graphic version of Michlet. The godzilla.bat file runs the graphic version in GODZILLA mode. You might find it convenient to set up Windows “shortcuts” to run Michlet in the different modes.

2.4 Removing Michlet

Michlet does not modify any system files so you can simply delete the directory into which you unzipped Michlet.

3 BASIC CONSIDERATIONS

3.1 Co-ordinate System

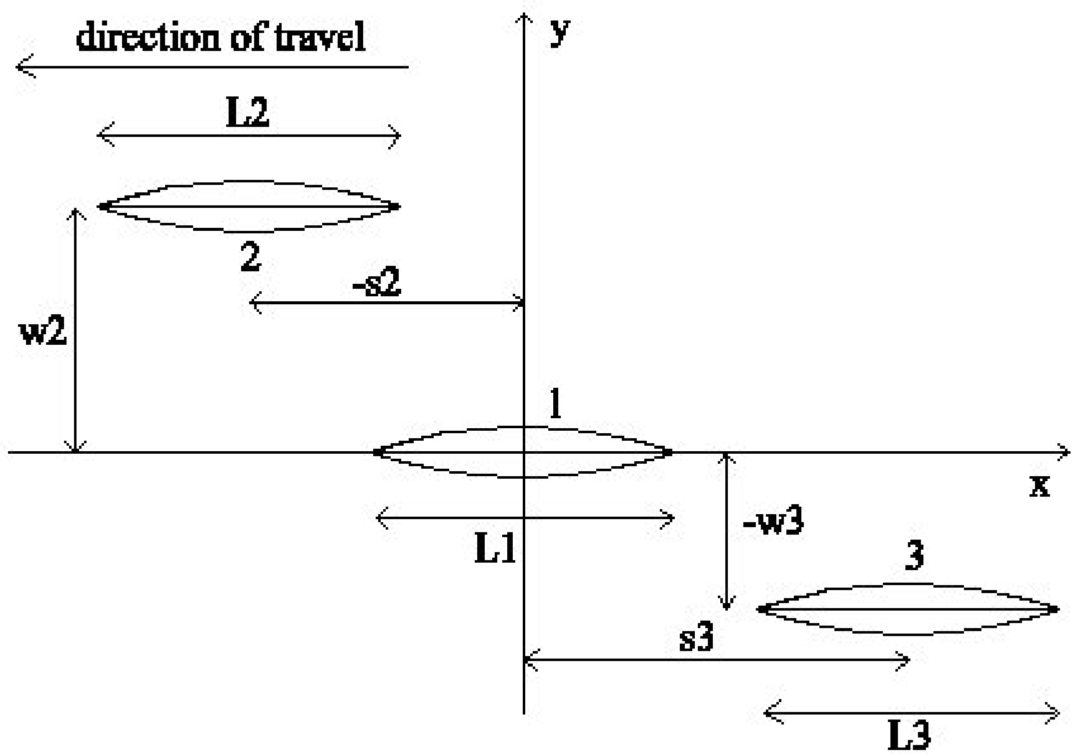

Figure 1: Co-ordinate system for general multihulls

The co-ordinate system and hull parameters are shown in Figure 1; x is positive astern, y is positive to starboard, and z is positive upwards. The undisturbed water surface is the plane $z = 0$. Hull centreplanes are parallel to the x-axis. The shapes of the hulls can be different from each other, however, they are assumed to be symmetric with respect to their own centreplanes. The overall vessel need not be laterally symmetric.

Each hull has a nominal centre point ($x = s_i$, $y = w_i$, $z = 0$). The centre of the main hull, hull 1, is always located at the origin. The centres of all other hulls are then measured relative to the main hull, i.e. to hull 1. s_i is the longitudinal separation distance of the i'th hull measured relative to the first hull and is defined as positive astern. Hence by definition, $s_1 = 0$. w_i is the lateral separation distance of the i'th hull relative to the first hull (positive to starboard). Hence by definition, $w_1 = 0$. For example, in the arrangement shown in Figure 1, s_2 has a negative value, and w_2 is positive; for hull 3, s_3 is negative and w_3 is positive.

4 SHIP WAVES

The wave elevation patterns in this note illustrate (very briefly!) some of the terminology used in ship wave theory. For a comprehensive graduate text see "Marine Hydrodynamics" [5]. A very comprehensive reference is "Surface Waves" by Wehausen and Laitone [8].

Data for the wave pattern contour plots in this section that show waves very close to the ship were prepared by the author using other programs that are not included in the Michlet package of programs.

We define the length-based Froude number of a vessel by $F_L = U/\sqrt{gL}$, where U is the ship speed in ms^{-1}, g is gravitational acceleration in ms^{-2}, and L is the length of the ship in metres.

The depth-based Froude number is $F_h = U/\sqrt{gh}$, where h is the depth in metres. In infinitely deep water, $F_h = 0$. The subcritical range is defined as $F_h < 1$; the supercritical range is $F_h > 1$.

4.1 Near-field, Far-field, Transverse and Diverging Waves

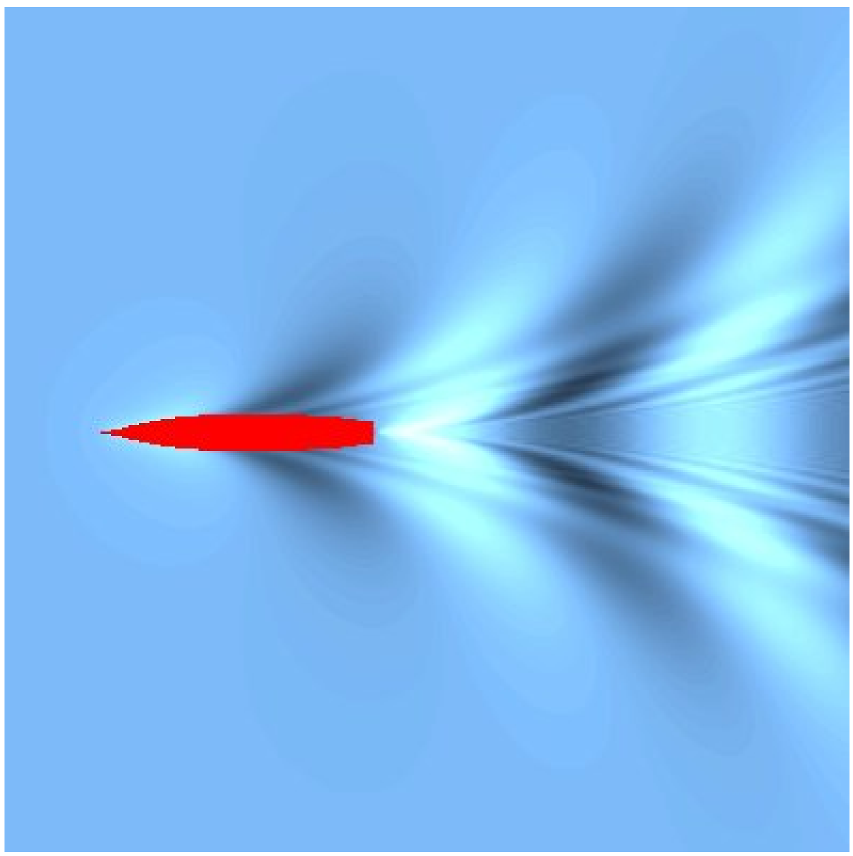

Figure 2: Wave pattern of DDG51 destroyer travelling at 15.4 ms^{-1} which corresponds to length-based Froude number $F_L = 0.4136$.

The near-field is the region close to the ship. In Figure 2, near-field effects are most evident near the bow, and it can be seen that they die away very quickly as the distance from the bow increases. Note that Michlet does not calculate near-field effects: data for near-field plots in this section were created using another program.

Far-field waves are those waves far behind the ship where near-field effects are negligible. Wave resistance is the energy that is needed to sustain the far-field wave pattern. Transverse waves are those waves travelling roughly perpendicular to the ship's track (the roughly vertical bands in the figure above); diverging waves are those travelling diagonally outwards.

4.2 Submergence Effects

The size of the waves that a body makes depends on how much of its volume is near the surface. Wave effects decay exponentially with depth.

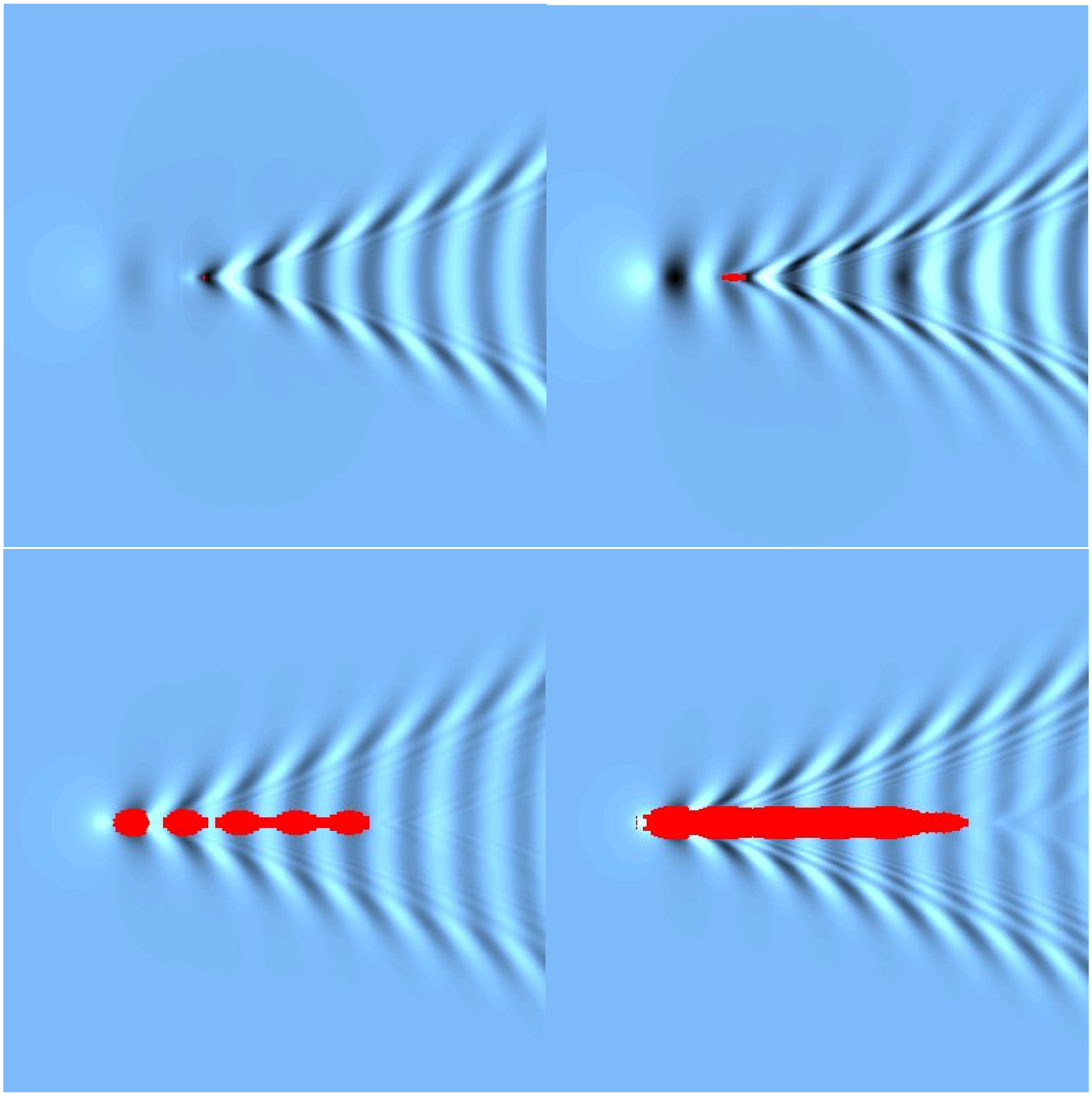

Figure 3: US LA class submarine travelling at 5.15 ms^{-1}. Top left: the conning tower of the submarine is just protruding through the surface. The tower contains only a small part of the total volume, however, it is much closer to the surface and thus makes the largest contribution to the wave system. Top right: the main hull is about to protrude. Bottom left: As the main hull approaches close to the surface, it makes larger waves. Near field effects are very evident, especially near the bow of the submerged main hull. Bottom right: As the main hull emerges through the surface, the wave pattern becomes more like that due to a normal surface-piercing vessel.

4.3 Water Depth Effects

Water depth can have a significant effect on the far-field waves created by ships and consequently on their wave resistance. The figures in this section were created using Michlet.

As F_h increases towards 1 (the critical Froude number), the wave pattern changes dramatically. The angle of the enveloping wedge (the Kelvin angle) widens, until at $F_h = 1$ it is perpendicular to the ship's

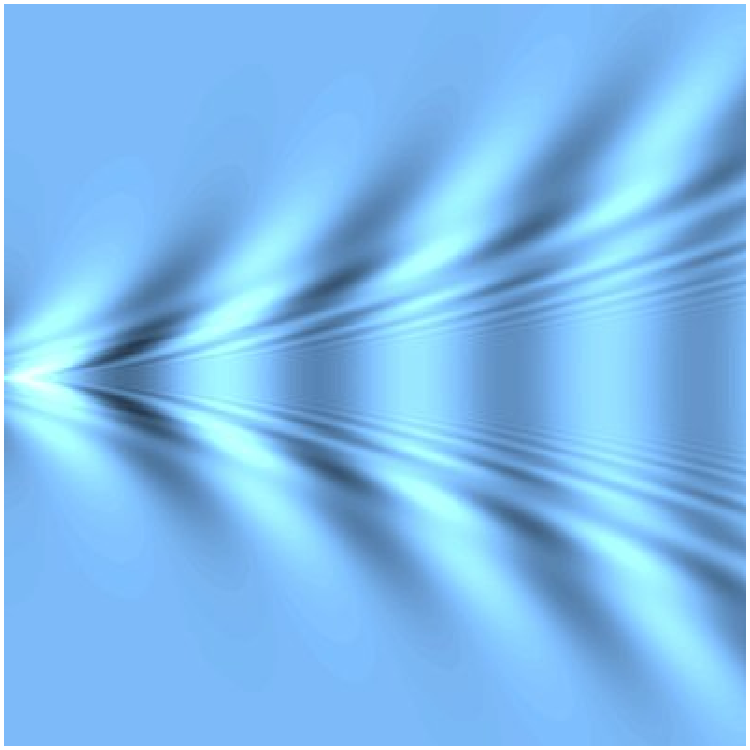

Figure 4: Far-field wave pattern for a DDG51 destroyer travelling at 15.4ms^{-1} in infinitely deep water. The length-based Froude number is $F_L = 0.41$. The depth-based Froude number is $F_h = 0$.

track.

4.4 Multihulls and Fleets

The wave patterns created by a multihulled vessel or by several ships travelling together can be extremely complicated. Interference between hulls can reinforce waves in one part of the pattern and cancel waves in another part. The degree of wave cancellation depends on the size and spacing of the hulls, and on their individual shapes.

The figures in this section were created using data from another program: (Michlet can only be used to predict the waves behind the aftmost vessel in the ensemble.)

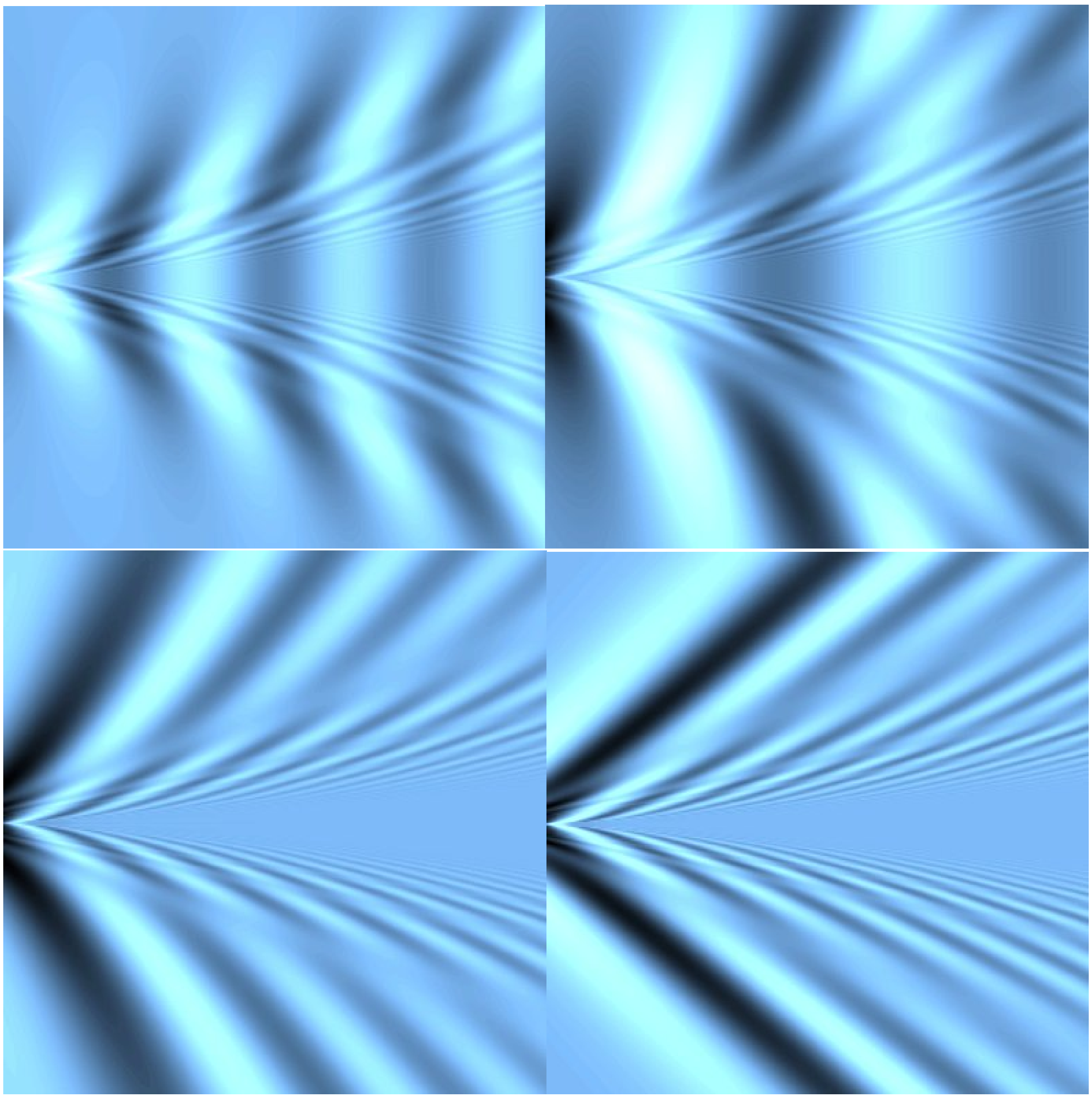

Figure 5: At $F_h = 0.8$ (top left), the enveloping wedge is wider, and the transverse wavelength is longer. When $F_h = 0.95$ (top right), the enveloping wedge is significantly wider; the transverse wavelength is almost twice as long as for the infinitely-deep situation. At $F_h = 1.05$ (bottom left) transverse waves have almost disappeared and the Kelvin angle is very large. For $F_h = 1.4$ (bottom right) transverse waves are still absent; the Kelvin angle is narrower.

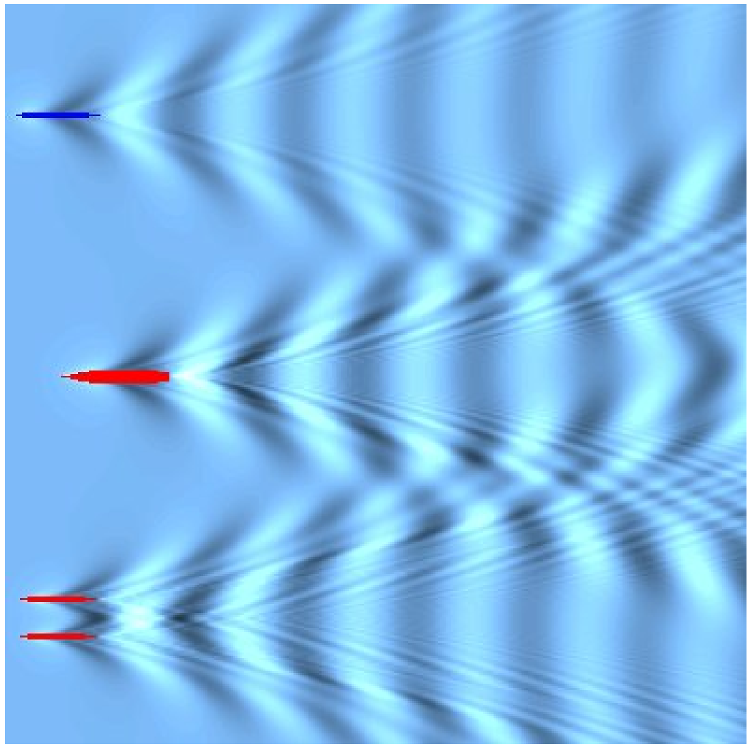

Figure 6: Wave pattern produced by a DDG51 destroyer, a US LA class submarine and a Wigley-hulled catamaran, each travelling at 15.4ms^{-1}. The submarine (uppermost vessel) is just submerged.

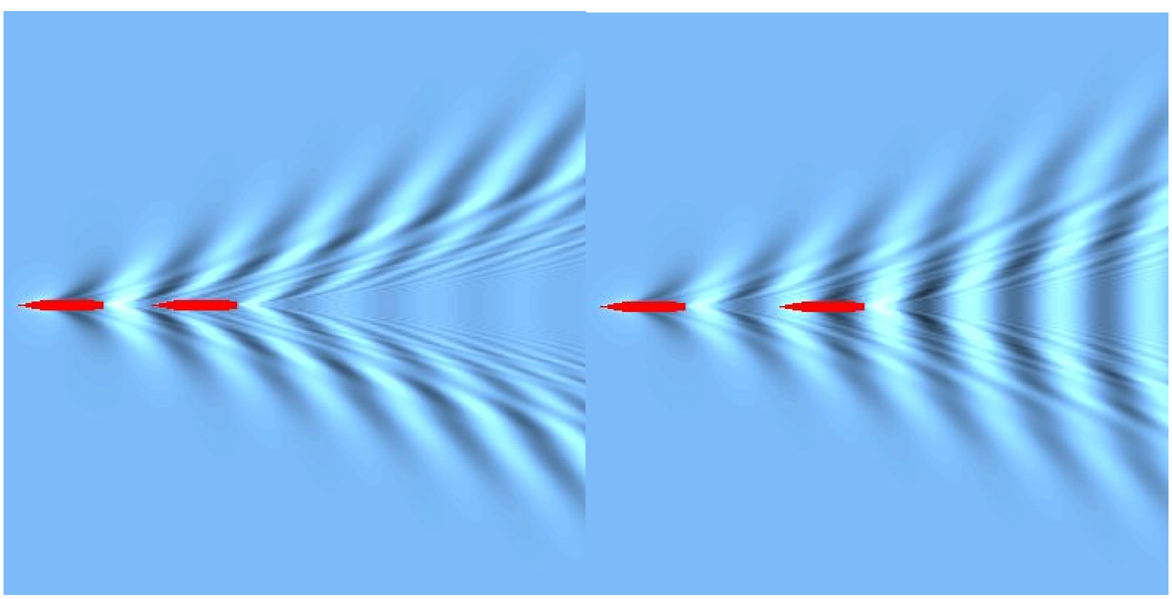

Figure 7: Left: Wave pattern of two identical DDG51 destroyers each of length 142m, travelling in tandem at a speed of 15.4ms^{-1}. The hull centres are separated by 1.5 transverse wavelengths, (approximately 229m). Note the very small transverse waves. Right: The separation length between hull centres is two transverse wavelengths (approximately 306m). Transverse waves are reinforcing.

Transverse wave cancellation depends on the length of the hulls and, for multihulls, the longitudinal spacing between hulls. If the longitudinal spacing between hull centres is 1/2 (or 3/2 or 5/2 etc) wavelength, there can be almost total cancellation, as shown in the left side plot in Figure 7. Maximum reinforcement of transverse waves occurs when the hull centres are separated by a whole number of transverse wavelengths, as shown in the plot at the right of Figure 7.

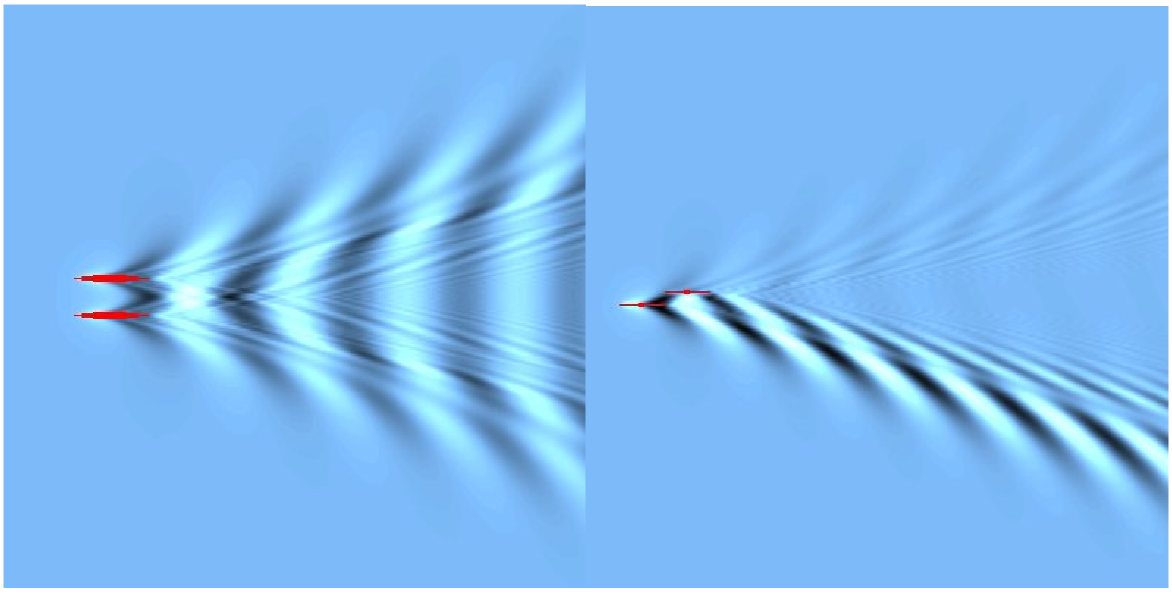

Figure 8: Wave pattern created by a catamaran travelling at a speed of 15.4 m^{-1}, equivalent to a length-based Froude number of 0.53 (left). Wave pattern created by two SWATH-like hulls in a Weinblum arrangement travelling at a speed of 15.4ms^{-1} (right).

In general, diverging waves are more difficult to cancel. The degree of cancellation depends on hull shape and, for multihulls, the lateral hull spacing.

For standard side-by-side catamarans, diverging waves shed at particular propagation angles can be cancelled by using a lateral spacing that can be calculated using a fairly simple formula. See "Optimum Hull Spacing of a Family of Multihulls" [7].

It is possible to almost completely eliminate waves on one side of a two-hulled ship using two identical hulls if asymmetric hull placement is allowed. In the plot at the right of Figure 8, transverse waves have been cancelled by choosing the appropriate longitudinal hull spacing; diverging waves on the starboard side have almost been eliminated by a judicious choice of lateral spacing, and by using a hull shape that makes very small diverging waves. Using four identical hulls in a diamond arrangement can significantly reduce waves shed on both sides of the vessel, with an attendant large reduction in wave resistance. However, the increased surface area of the four hulls leads to a much larger frictional resistance.

5 RESISTANCE

Michlet calculates a variety of resistance components. Wave resistance is estimated using Michell's thin-ship theory augmented for (among others) transom stern effects and boundary layer displacement thickness effects.

For monohulls and for the individual hulls of a multihull, output includes:

- R_h : Hydrostatic resistance on transom stern
- R_f : Skin friction
- R_{wtrans} : Wave resistance of transverse wave system
- R_{wdiv} : Wave resistance of diverging wave system
- $R_w = R_{wtrans} + R_{wdiv}$
- R_{form} : Form drag
- R_t : Total resistance
- R_r : Residual resistance $= R_t - R_f$

Note that for supercritical depth-based Froude numbers, R_{wtrans} is always equal to zero: there are no transverse waves!

As well as the components defined above, Michlet also calculates the following interference resistance components:

- $R_{wtinter}$: Interference resistance of transverse waves
- $R_{wdinter}$: Interference resistance of diverging waves
- $R_{winter} = R_{wtinter} + R_{wdinter}$

Note that for these interference components, positive values mean no beneficial interference, (i.e. resistance is increased) negative values mean that there is some beneficial wave cancellation (i.e. resistance is decreased).

6 INPUT FILES

Michlet uses plain text files for input and output. In addition, some plots are saved as pcx graphic files. Text files can be read and saved using plain text editors: I recommend WinEdt (see www.winedt.com). Please note that you cannot use word-processors (for example, Word) to edit Michlet input files, unless you force them to save files in ASCII format. A great advantage to using WinEdt is that a button can be set up on its toolbar to launch Michlet with one mouse click. Michlet input and output files can be loaded into WinEdt, and when Michlet terminates, output files in WinEdt are updated. No doubt there are other inexpensive editors that have similar capabilities.

There are many shareware graphics programs that can be used to view pcx files and to convert them to other graphic formats if necessary.

When Michlet is run, it reads in a file named in.mlt and clears all output files in the directory where the Michlet executable files reside. If you do not save previous output, old results will be overwritten and lost. If your results are important, do not leave them in the same directory as the executable files: save them immediately to a safe directory, disc, flash stick, or other storage medium.

6.1 in.mlt

Initial input to Michlet is via the plain text file called in.mlt.

At this stage, it is probably a good idea to have an example in.mlt file loaded into your text editor, or to have a printout of one handy.

Comments can be placed in the file by preceding them with the # symbol, which should appear in the first column of the line. Comments should be no longer than 79 characters, and should not be placed within a column of numbers. For example, it is quite acceptable to add comments before a table of offsets, but it is not advisable to use them between the rows of the offset table.

If errors are encountered while the in.mlt file is being read, a message will be displayed on-screen and also written to the out.mlt file before the program terminates. Tracking down errors in the in.mlt file can be a little tricky. Sometimes an error in one input line will cause an error to be reported for a line further on in the in.mlt file. If an error is encountered, and no immediate reason for the error can be discerned, check a few lines back in the file to see if something was improperly specified.

A number of example files are included with this version of Michlet and these are described in more detail in another manual.

6.2 Input Files Created by Delftship (tm)

Delftship version 5 can export Michlet input files from its File Export menu. The method works very well with vessels that do not have propellers and other elaborate appendages.

If the input file does not work with Michlet, check the offset table in the in.mlt file to see whether Delftship has been able to represent the hull accurately. Often, changing the number of stations and waterlines in the Delftship File Export Michlet screen can solve problems.

7 GENERAL INPUT VARIABLES

The Input File Type and Input File Subtype are used to control the types of input file that can be used. In this version of Michlet, leave them both set to 0. Similarly, Output File Type and Output File Subtype are used to control the types of output files that are generated. In this version of Michlet, use 0 for both.

7.1 Course Particulars

- 0 : No effect
- 1 : Submerge hull

Choosing 0 for the Course Particulars has no effect on calculations.

Choosing 1 for the Course Particulars requires the submergence depth of the hull to be specified on the next line, as shown below.

```
# Course Particulars (0=None, 1=Submerge by depth on next line)
1
# Submergence Depth (metres) (min 0.0, max 10000.0)
5.0
```

The submergence depth is defined as the distance from the undisturbed free-surface to the top of the hull. The depth must greater than or equal to zero. In the example above, the top of the hull will be 5.0 metres below the water surface.

Note that using Option 1 in conjunction with non-zero values of trim and sinkage defined below could lead to unusual results.

If you decide to use choose option 0 after using option 1, remember to remove the line containing the submergence depth or an error will result.

7.2 Number of Vessels

The number of hulls for the vessel or ensemble must be an integer equal to 1, 2, 3, 4 or 5.

7.3 Fluid Properties

The gravitational acceleration (in ms^{-2}) should be entered as a decimal. Most Michlet examples use a value of $g = 9.80665\ \text{ms}^{-2}$.

Water density (in kgm^{-3}) must be entered as a decimal. Most example files use a value of 1025.9 kgm^{-3}, the density of sea water at 15°, or 999.0 kgm^{-3}, the density of fresh water at 15°.

Water kinematic viscosity (in $\text{m}^2\text{s}^{-1} \times 10^{-6}$) must be entered as a decimal. Most example files use a value of 1.18831 (sea water at 15°), or 1.13902 (fresh water at 15°). Note the units that are used.

The (non-dimensional) base eddy kinematic viscosity, ν_B, must be entered as a decimal. Most example files use a value of 10.0. This quantity, which is not a property of water alone, depends on the nature of a particular flow.

The main effect of eddy viscosity is to damp high frequency waves. However, if a wave pattern seems to be corrupted by spurious, very high frequency waves, it could be because the value for N_θ (see below) is too small. First try increasing the value of N_θ, then, if that doesn't fix the problem (and if it is actually a problem) increase the size of the base eddy viscosity.

The eddy kinematic viscosity, ν_T, is calculated according to the formula

$$\nu_T = \nu + LU\nu_B \tag{1}$$

where L is the length of the vessel, U is the ship speed, and ν is the kinematic viscosity of water.

Water depth (in metres) must be entered as a decimal. To simulate infinite depth use a large value (e.g. 10000.0m). You must ensure that hulls (in their squatted attitudes) do not run aground!

The next four parameters are not used in any calculations in this version, however the program expects appropriate values to be present.

Air density (in kgm^{-3}) must be entered as a decimal. Most example files use a value of 1.26 kgm^{-3}.

Air kinematic viscosity (in $\text{m}^2\text{s}^{-1} \times 10^{-6}$) must be entered as a decimal. Most example files use a value of 14.4.

Wind speed (in ms^{-1}) must be entered as a decimal.

Wind direction (degrees) must be entered as a decimal. The convention is that 0° corresponds to a head wind; 180° signifies a tail wind.

7.4 Ship Speed Range

The next three parameters specify the speeds (in ms^{-1}) at which to calculate the resistance and wave elevations, via the minimum speed, U_{min}, the maximum speed, U_{max}, and the number of speeds, N_U. The minimum speed and maximum speed must be decimals. N_U must be an integer greater than or equal to 2 and less than or equal to 101.

From version 9.30 onwards, speeds can be specified at non-uniform intervals. To do this, first put in a negative integer to flag that you will be specifying a list of speeds. Then, on a separate line, specify the number of speeds follwed by a list of speeds. For example

```
-1
5
1.1
1.5
2.2
4.0
6.0
```

will cause Michlet to use the 5 listed speeds.

7.5 Leeway

The Leeway parameter is reserved for future enhancements. Leave it set to 0.

7.6 Number of Stations and Waterlines

The number of stations, N_x, used to represent the hull surface must be an odd integer greater than or equal to 5 and less than or equal to 81. The number of waterlines, N_z, must be an odd integer greater than or equal to 5 and less than or equal to 81. The actual bow and stern ends are counted as stations.

7.7 Ship Loading Type

The Ship Loading Type determines the formula to be used in the calculation of the distance from the baseline to the centre of gravity of the ship (i.e $\overline{KG}$, in naval architectural parlance). In this version of Michlet, the only allowable value is 3, which requires three comma-separated Ship Loading Formula Parameters to be specified on a separate line. Suppose that these three parameters are a,b and c. The three-parameter formula used in this version of Michlet is:

$$KGOA = a(TOA + bLOA^c) \tag{2}$$

where

TOA is the maximum draft, and LOA is the overall length of the ship. For monohulls TOA and LOA are just the draft and length of the hull, respectively.

If you are unsure of where the centre of gravity is located for your vessel, a reasonable rough estimate is the maximum draft. In this case, use the following line in the input file
1.0,0.0,0.0

Remember to take into account the fact that you have used a rough estimate when interpreting your results!

7.8 Wave Resistance Parameters

N_θ is used in the calculation of the wave integrals, e.g. see Tuck and Lazauskas [7]. It must be an even integer greater than or equal to 10 and less than or equal to 4096. For reasonable accuracy (2-3 figures) of wave resistance calculations N_θ should be set to at least 160 for monohulls, 320 for dihulls, 640 for trihulls, 960 for tetrahulls, and 1280 for pentahulls. The value should be set to larger values for wave elevation calculations far from the ship. Note that some example files distributed with Michlet use smaller values than these recommendations. The purpose of the examples is to provide quick demonstrations of certain features; accuracy is of secondary importance.

Before embarking on your own design problem, check that N_θ is large enough to ensure accurate solutions, but not too large so that run times are unbearably long.

Before calculating wave resistance and other ship wave quantities, Michlet first adds an estimate of the boundary layer displacement thickness to the hull offsets. In general, the effect of the boundary layer is small, except for small model-sized hulls. For larger ships travelling at high speeds the effect is negligible. The default in Michlet is to include boundary layer effects, and these can increase execution time. To perform calculations without boundary layer effects use a negative value for N_θ. For example, if the value -160 is input, this will cause Michlet to use 160 intervals of θ in all wave calculations and the boundary layer displacement thickness will not be added to the hull offsets.

7.9 Viscous Resistance

7.9.1 Skin-friction

Choices for the skin-friction method are:

- 0 : None
- 1 : ITTC 1957
- 2 : Grigson's algorithm

7.9.2 Form factors

Form factors can be applied separately to the viscous drag component and to the wave drag component.

Choices for the viscous form factor method are:

- 0 : None

- 3 : Dual

The viscous drag form factor can be useful for analysing (and designing for) the effects of hull fouling. For example, if we assume (by rule of thumb!) that there is a 0.1% increase in friction resistance per day, then after 6 months we should make an allowance of approximately 18% beyond the usual ITTC friction. In this case, use a value of 1.18 for the viscous form factor.

It is important to note that the ITTC line is not a skin friction line. An excellent history of the ITTC line and its inadequacies can be found in Grigson [2]. The ITTC line is considered to be a correlation line and as such it contains some allowance for three dimensional (i.e. form) effects. If further form effects are included, there is a danger of double-counting. In some cases, (e.g. correlating experiments and computer estimates) this will not necessarily be a problem.

The dual viscous drag form factor can be used when you want to apply a form factor to the wave resistance as well as to the skin-friction. This method has been used by L.J. Doctors and his colleagues and students; an excellent collection of hulls and form factors can be found in the recent thesis by Robards [6].

The wave form factor can also be very useful to improve correlations with experiments of hulls that violate the thin-ship assumption. For example, submarine bodies tend to have rounded noses, but are otherwise they are quite thin and slender. A single form factor applied to the wave resistance predicted by Michlet is often all that is needed to greatly improve agreement with experiments.

7.10 Sea-Bed Pressure Signatures

Pressures exerted by the vessel onto the bottom of the ocean can stir up sediments and trigger some types of anti-ship mines.

Choices for the pressure signature method are:

- 0 : None
- 1 : Slender body approximation due to E.O. Tuck. Valid only for slender vessels and for sub-critical depth-based Froude numbers (i.e. $F_h < 1$).

7.11 Wave Pattern Domains

Wave elevations can be calculated over two differently-shaped domains.

In Figure 9, the co-ordinate origin is at the centre of Hull 1 (refer back to Figure 1).

The sectorial patch on the left of Figure 9 requires five parameters. R_0 and R_1 (both decimals greater than 0.0) determine the (radial) extent of the wave elevation patch. The value of β determines the angular extent of the patch either side of the track of hull 1. The number of radial nodes, N_R and the number of beta nodes, N_β, (both integers between 2 and 200, inclusive) determine the fineness of the grid for the calculation of wave elevations. A value of 100 for both parameters gives reasonable results for reasonable running times.

Calculation of wave elevations can be quite time-consuming, and it is best to first calculate on a coarse grid (i.e. use a small number for N_R and N_β) until you are satisfied with the location of the patch, and the aspect ratio of the plot. The number of grid points can be changed on-screen when Michlet is running.

The rectangular patch on the right of Figure 9 requires six parameters; x_0, x_1, y_0, y_1, N_x, and N_y. The co-ordinate origin is the same as given in Figure 1. For this plot, elevations will be calculated at $N_x \times N_y$ points in the patch.

Note that the wave-height estimates are not accurate close to the ship. The patch in which elevations are calculated should be no closer than about one ship length astern of the stern of the aftmost hull in the ensemble. In some cases, it might be even better to use one wavelength behind the stern of the aftmost hull. For infinite depth, the wavelength, λ can be estimated using the formula:

$$\lambda = 2\pi U^2/g \tag{3}$$

where U is the ship speed in ms^{-1} and g is gravitational acceleration. The situation is more complex for finite depth water, and will not be dealt with in this manual.

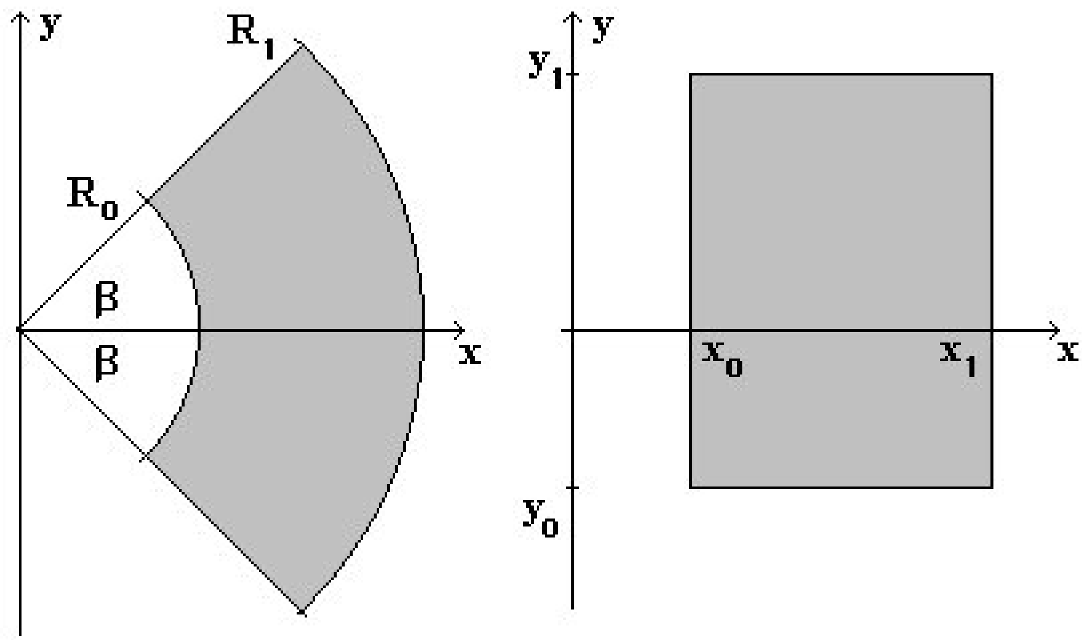

Figure 9: Wave elevation contour domains

Also note that more intervals of θ (see above) are necessary when the patch is located a very long way behind the ship. It is imperative that you first try a few test runs to see what value of N_θ gives results that are of sufficient accuracy for your particular application. If you use a value that is larger than is necessary, computation times will be longer than necessary. If too few are used, accuracy could be compromised.

The beaches and walls section of the input file is reserved for future use, however the program expects valid values to be present.

7.12 Hull Offset Data

Hull offset formats are described in detail later in this manual.

7.13 Hull Geometry

7.13.1 Displacement volume, hull length and draft

Following the offset table for the first hull, the displacement volume, length and draft must be specified.

7.13.2 Demihull separation distances

After the draft has been specified, the longitudinal and lateral separation distances (relative to the first hull) must be specified. For a monohull, these will both be set to 0.0, irrespective of the values entered by the user (refer to Figure 1).

7.13.3 Loading type

The Loading Type determines the formula to be used in the calculation of the distance from the baseline to the centre of gravity. The method to be used is identical to that used for the Ship Loading Type, described above. Here though, the loading applies to the hulls individually. For a multihull, the individual hulls can be loaded using one formula, and the KG of the ensemble as a whole can be calculated using another formula. This can lead to interesting results during the optimisation of multihulls.

7.13.4 Trim and sinkage

Trim and sinkage can be specified in a variety of ways. Trim must be specified in degrees (positive bow up) and must lie between -10° and 10°. Sinkage is positive when draft is increased, negative when the hull rises out of the water. If experimental values are to be input, they must be given as the fraction of the untrimmed, unsunk, hull maximum draft. E.g. 0.1 means that the hull will be "sunk" by 10% of the (untrimmed, unsunk) hull draft; -0.1 means that the hull will rise out of the water by 10%.

Sinkage must lie between -1.0 and 1.0, inclusive. Also note, that trimmed and sunk offsets will be poorly approximated if the number of stations and/or waterlines is small. You should use at least 11 of each, preferably 21 or more of each, for reasonable estimates. For hulls with small immersed transom sterns, more waterlines might be necessary.

When a positive sinkage is specified, the hull is pushed downwards. If no offsets are available for the above-water portion, it will be assumed by the program that the above water portion has the same shape as the waterplane. (Clearly this simplification can lead to considerable inaccuracies for hulls with very flared sections when large trim and sinkage values are used.) Offsets can be specified for the portion of the hull that is above the undisturbed free surface, as long as the draft is specified as the distance from the lowest portion of the hull to the top of the hull: negative values of sinkage can then be used to "lift" the hull into its static position.

For example, suppose that the cross-sections of our hull are semi-circles of draft 1.0m. If we specify a positive sinkage, say 0.25, the program will 'push' the semi-circular cross-section downwards by 25% of the draft, i.e. by 0.25 x 1.0m = 0.25m, and it will also assume that the offsets above the waterline are the same as the offsets of the semi-circle at the waterline. The underwater offsets will be comprised of a semicircular bottom portion, and a vertical-sided portion above that.

Now suppose that we use the offsets for a full circle instead of a semi-circular cross-section, and we also use a draft of 2.0m. A (negative) sinkage of -0.5 will cause the circular cross-sections to be "lifted" out of the water by 50% of the full draft, (0.5 x 2.0m = 1.0m). In other words, the underwater offsets will be the same as those of the semi-circular cross-section. The advantage is that any sinkage larger than -0.5, e.g. -0.25, will in effect cause the hull to be pushed downwards relative to the -0.5 sinkage we specified. In this case, however, the program does not assume that there are no above-water offsets, since those offsets are available. The obvious disadvantage of this method is that the displacement volume must be specified for the fully-submerged hull, i.e. from the lowest point to the top. In the present simple example, we would have to double the displacement used for the semicircular hull.

The options and parameters for trim are as follows. (Sinkage is specified in the same manner). The only valid value for the Trim type is 3. (Other methods are crippled in this version).

After the trim type, specify the number of speeds at which trim values will be specified.

Trim can be specified for an ascending sequence of speeds and does not have to be given at equally-spaced intervals. For example, the following lines could be used to specify trim at four speeds.

```
#Trim Method
3
#Trim: Number of speeds (integer: greater than or equal to 2)
4
#Trim: speed, angle
0.5,0.0
5.0,0.2
6.0,0.3
10.0,0.35
```

The line containing "3" tells Michlet we want trim type 3; the line containing "4" specifies that we will give values at 4 speeds. The four pairs of comma-separated values contain the speed and the trim at that speed. Trim at speeds other than those specified will be interpolated.

Sinkage is specified in a similar way to trim.

Heel is not used in this version, but valid values are expected by the program. Use the default values supplied in the example files.

7.14 Appendages

The Number of Appendages should be left as 0 in the present version of Michlet.

7.15 Other Particulars

The Other Particulars field is reserved for special applications and should be left as 0 in this version of Michlet.

7.16 Multihull Geometry

If the number of hulls was set as 1 earlier in the in.mlt file, any further lines in the input file will not be read. If the number of hulls is 2 or more, then the details of the second hull, and the displacement volume, hull length, and hull draft, etc of the second hull are also required.

Similarly, for the third, fourth and fifth hulls.

8 HULL OFFSETS

It does not matter whether the offsets describing each hull are in dimensional or non-dimensional form. Michlet will automatically scale the offsets to the individual hull displacements.

It is very important to note that all hull offsets input to Michlet, or output by Michlet, are for the underwater portion of the hull only. You can, however, specify a value for the sinkage to raise or lower the hull with respect to the undisturbed free surface (see the section on Trim and Sinkage earlier in this manual).

8.1 Offset Tables

All offsets at the bow (the first row) must be equal to zero (decimal). Stern offsets (the last row) may all be zero (no transom) or some non-zero if there is a transom stern of a shape determined by the non-zero offsets. The number of rows (cross-sections) and columns (waterlines) in the offset data must be the same as the number of stations and waterlines specified earlier. Offsets are separated by commas, and there is no comma at the end of each row.

Hull offsets in comma-separated format can also be read from file. For example, if the input line for the first hull contains only the value -1, then Michlet will read offsets from the file useroff1.csv. If the offset input line for the second hull was specified in the same way, Michlet would read offsets from the file useroff2.csv. Similarly for hulls 3, 4 and 5.

8.2 Mathematical Hull Series

Using tables of offsets in the input file can sometimes be tedious. Michlet allows specification of an initial hull shape by using shape functions and parameters in place of the offset tables. This is possible because Michlet expects a table of offsets to always begin with a row of zeroes. If the first number in the first row is not zero, Michlet assumes that what follows are either the parameters for a parametric hull series, or that a table of offsets is to be read from a file, or that the hull is represented using Michlet's spline format which will be read from file.

8.2.1 Series 1

This hull series takes three shape parameters. All must lie between 0.0 and 1.0, inclusive. The series is such that if a parameter has value 0.0, then the shape is rectangular, 0.5 corresponds to an elliptical shape, and 1.0 creates a parabolic shape. Intermediate values will produce shapes intermediate between these familiar shapes.

Let $X(x) = 4x(1-x)$, with $0 \le x \le 1.0$. Then the non-dimensional offsets are given by

0 if $X = 0$ or if $X^{f_2} < z$, otherwise $Y(x, z; f_0, f_1, f_2) = 1/2FG^{f_1}$.

Here $F = X^{f_0}$, $G = 1 - z^2 X^{-2f_2}$ and $0 \leq x, z, f_0, f_1, f_2 \leq 1$.

At any given length and draft, Michlet adjusts the beam by uniform scaling of the non-dimensional offsets given by the above formula, so as to achieve the desired displacement.

In the above formulation, the first parameter, f_0, controls the shape of the waterlines, the second parameter, f_1, determines the cross-section shape, and the third parameter, f_2, controls the shape of the keel-line. If, for example, $f_0 = 0.0$, then the waterline shape is rectangular, if $f_0 = 0.5$ the waterline is elliptical and if $f_0 = 1.0$, the hull will have parabolic waterlines. And similarly for cross-sections and keel-lines.

The shape parameters for some common shapes are given below. Remember that you can toggle the view from sections to waterplanes by pressing the v key once the new hullform has been displayed.

PEP: This is a canoe-like hull with Parabolic waterlines, Elliptical cross-sections, and a Parabolic keel-line. It can be formed by using 1.0, 0.5 and 1.0 for the three shape parameters.

Parabolic strut (PRR). This hullform has Parabolic waterlines, Rectangular cross-sections, and a Rectangular sideview. Use the values 1.0, 0.0 and 0.0, respectively, for the three required shape parameters.

Wigley hull (PPR). Use the values 1.0, 1.0 and 0.0 for the three required parameters.

Spheroids (EEE): Use the values 0.5, 0.5 and 0.5.

Parameter values other than 0.0, 0.5, and 1.0 can be used. For example, the hull defined by the three parameters 0.25, 0.25, 0.25 is somewhere between a spheroid and a rectangular block.

Note: From version 9.32 onwards, cusped waterplanes and buttocks are allowed in this hull series. You can now use $f_0 \leq 3.0$ and $f_2 \leq 3.0$. Be aware that the hulls could be impractical!

8.2.2 Series 2 (Unavailable)

This hull series takes five shape parameters. The LL4 hullform in the Weinblum example input file is an interesting member of this family.

8.2.3 Series 4

This hull series takes four parameters to produce bodies with elliptical cross-sections, and possibly with some parallel middle body.

Minimum and maximum values for each parameter are given in brackets below.

- f_0: Forebody shape (min. 0.0, max. 3.0)
- f_1: Afterbody shape (min. 0.0, max. 3.0)
- f_2: Forebody relative length (min. 0.0, max. 1.0)
- f_3: Afterbody relative length (min. 0.0, max. 1.0)

The first parameter, f_0, is the same as for Series 1, but is relevant to the forebody only. The second parameter, f_1, defines the shape of the afterbody in the same way.

Cross sections are elliptical (i..e the shape factor is equal to 0.5). The displacement of the vessel will ultimately determine if the cross-section is elliptical or circular.

The last two parameters specify the relative lengths of the forebody and the afterbody. If the sum of the last two parameters is less than 1.0, then the two bodies will be joined by a length of parallel middle body. Note that if the sum of the last two parameters is greater than one, then there is no parallel middle body, and the length of the afterbody is reduced so that the total is exactly equal to 1.0.

8.2.4 Series 7

This hull series takes the following seven shape parameters; minimum and maximum values for each are given in brackets.

- f_0: Forebody waterplane shape (min. 0.0, max. 3.0)
- f_1: Forebody cross-section shape (min. 0.0, max. 3.0)

- f_2: Forebody sideview shape (min. 0.0, max. 3.0)
- f_3: Afterbody waterplane shape (min. 0.0, max. 3.0)
- f_4: Afterbody sideview shape (min. 0.0, max. 3.0)
- f_5: Forebody relative length (min. 0.0, max. 1.0)
- f_6: Afterbody relative length (min. 0.0, max. 1.0)

This hull series includes and extends the first series. The first three parameters (f_0, f_1 and f_2) are the same as for Series 1, but are relevant to the forebody only; the next two parameters are for the afterbody. A cross-section parameter is not required for the afterbody because the two bodies must have the same cross-section for a clean join. The maximum value of the first five parameters is 3.0; cusped shapes are possible with this series.

The last two parameters specify the relative lengths of the forebody and the afterbody. If the sum of the last two parameters is less than 1.0, then the two bodies will be joined by a length of parallel middle body. Note that if the sum of the last two parameters is greater than one, then there is no parallel middle body, and the length of the afterbody is reduced so that the total is exactly equal to 1.0.

8.2.5 Series 8

This hull series is the same as Series 7 with one additional parameter.

f_7: Afterbody cut-off ratio (min. 0.0, max. 1.0).

The cut-off ratio determines how much of the afterbody will be removed. If $f_7 = 0$, then nothing is removed and the hull has a pointed stern with stern offsets all equal to zero. If $f_7 = 1$, then all of the afterbody is removed and the hull has a transom stern which has the same cross-section as the forebody (or parallel middle section). If f_7 is between 0.0 and 1.0 then the hull will have a transom stern smaller in area than the forebody.

Note that the parameters for this hull series cannot be changed on-screen in the current version of Michlet.

8.2.6 Series 9

This hull series is the same as Series 8 with one additional parameter.

f_8: Hull section cut-off ratio (min. 0.0, max. 0.999).

The hull section cut-off ratio determines how much of the section shape is used below the waterline. This does not mean that the section is actually raised with respect to the baseline, only that it defines where the section shape is cut off. If f_8=0, then the sections are wall-sided at the waterline. If f_8 is greater than 0, then the section shape is cut off below the water and, consequently, the sections are flared at the waterline.

The best way to think of the effect of the section cut-off ratio is to imagine a hemisphere floating so that its equator is at the waterplane, a situation that corresponds to f_8=0. If the hemisphere was floated at a level where the equator was above the water, then the portion below the water would be more like a circular dish. Note, that Michlet re-scales offsets so that the underwater displacement, length and draft are equal to the values given in the input file.

The parameters for this hull series cannot be changed on-screen in the current version of Michlet.

Note that Series 1, 7, and 8 are subsets of Series 9 and it could be reasonably argued that they are redundant. An equally legitimate counter-argument is that there is often no need for the greater range of hulls available in Series 9, and it will only slow down optimisation runs.

See Michlet example s9in.mlt for more details.

8.2.7 Series 20

This hull series has 20 parameters that define the location and shape of five vertical control sections. The first control section (0) is at the bow, the last control section (4) is at the stern. Note that the hull surface will be defined using many more stations based on these five control sections.

- f_0: Section 1 spacing (min. 0.0, max. 1.0)
- f_1: Section 2 spacing (min. 0.0, max. 1.0)
- f_2: Section 3 spacing (min. 0.0, max. 1.0)

The first three parameters define the spacing between control sections. f_0 defines the distance of control section 1 from the bow (which is defined as control section 0). f_1 defines the distance of control section 2 from control section 1. f_2 defines the distance of control section 3 from control section 2. The last control section (number 4) is at the stern. The distance from the stern to the previous control section does not need to be defined: it is equal to
1 - (f_0+f_2+f_2).

During optimisation runs, the actual spacing of the control sections can sometimes be clipped so that they do not extend beyond the stern and to ensure that they are not too close together.

- f_3: Keeline depth at control section 0 (min. 0.0, max. 1.0)
- f_4: Keeline depth at control section 1 (min. 0.0, max. 1.0)
- f_5: Keeline depth at control section 2 (min. 0.0, max. 1.0)
- f_6: Keeline depth at control section 3 (min. 0.0, max. 1.0)
- f_7: Keeline depth at control section 4 (min. 0.0, max. 1.0)

The next five parameters (f_3 to f_7) define the depth of the keelline at each control section. If the value is equal to 0, then the keelline is at the waterplane. If the value is equal to 1, the keelline at that control point coincides with the baseline.

- f_8: Waterline offset at control section 1 (min. 0.0, max. 1.0)
- f_9: Waterline offset at control section 2 (min. 0.0, max. 1.0)
- f_{10}: Waterline offset at control section 3 (min. 0.0, max. 1.0)
- f_{11}: Waterline offset at control section 4 (min. 0.0, max. 1.0)

The next four parameters (f_8 to f_{11}) define the hull beam (as a fraction of the maximum beam) at the waterline of control sections 1 to 4. There is no need to define the offset at the bow because it is assumed to be equal to zero.

- f_{12}: Section shape of control section 1 (min. 0.0, max. 1.0)
- f_{13}: Section shape of control section 2 (min. 0.0, max. 1.0)
- f_{14}: Section shape of control section 3 (min. 0.0, max. 1.0)
- f_{15}: Section shape of control section 4 (min. 0.0, max. 1.0)

Parameters f_{12} to f_{15} define the shapes of the control sections. As with Hull Series 1,7,8, and 9, the sections are rectangular if the parameter is equal to 0.0, elliptical if it is equal to 0.5, and parabolic if equal to 1.0. Other values will create shapes intermediate between rectangular and elliptical, or between elliptical and parabolic. The shape of the control section at the bow (i.e control section 0) is not defined by the user: it is assumed to be parabolic (i.e shape parameter equal to 1.0), but with offsets all equal to zero.

- f_{16}: Control section 1 cut-off ratio (min. 0.0, max. 1.0)
- f_{17}: Control section 2 cut-off ratio (min. 0.0, max. 1.0)
- f_{18}: Control section 3 cut-off ratio (min. 0.0, max. 1.0)

- f_{19}: Control section 4 cut-off ratio (min. 0.0, max. 1.0)

Parameters f_{16} to f_{19} define control section cut-off ratios. These four parameters play the same role as the section cut-off ratio in Series 9. In Series 9, one parameter is used for all sections; here it is used separately for the last four control sections. The bowmost control section (0) is assumed to have a cut-off ratio of 0.0, i.e. it is wall-sided at the waterline.

Series 20 can be used to create some very unusual hulls. For more information, see Example gs20.mlt in the GODZILLA manual.

8.2.8 Series 32

This hull series has 32 parameters that define the location and shape of 7 vertical control sections.

The first control section (0) is at the bow, the last control section (6) is at the stern. Note that the hull surface will be defined using many more stations based on these control sections.

- f_0: Section 1 spacing (min. 0.0, max. 1.0)
- f_1: Section 2 spacing
- f_2: Section 3 spacing
- f_3: Section 4 spacing
- f_4: Section 5 spacing

The first 5 parameters define the spacing between control sections. f_0 defines the distance of control section 1 from the bow (which is defined as control section 0). f_1 defines the distance of control section 2 from control section 1. f_2 defines the distance of control section 3 from control section 2. The last control section (number 4) is at the stern. The distance from the stern to the previous control section does not need to be defined as it is the remainder after other spacings have been deducted from 1.

- f_5: Keeline depth at control section 0 (min. 0.0, max. 1.0)
- f_6: ditto section 1
- f_7: ditto section 2
- f_8: ditto section 3
- f_9: ditto section 4
- f_{10}: ditto section 5
- f_{11}: ditto section 6

The next parameters (f_5 to f_{11}) define the depth of the keelline at each control section. If the value is equal to 0, then the keelline is at the waterplane. If the value is equal to 1, the keelline at that control point coincides with the baseline.

- f_{12}: Waterline offset at control section 1 (min. 0.0, max. 1.0)
- f_{13}: ditto section 2
- f_{14}: ditto section 3
- f_{15}: ditto section 4
- f_{16}: ditto section 5
- f_{17}: ditto section 6

The next parameters (f_{12} to f_{17}) define the hull beam (as a fraction of the maximum beam) at the waterline of control sections 1 to 6. There is no need to define the offset at the bow (section 0) because it is assumed to be equal to zero.

- f_{18}: Section shape of control section 0 (min. 0.0, max. 1.0)
- f_{19}: ditto section 1
- f_{20}: ditto section 2
- f_{21}: ditto section 3
- f_{22}: ditto section 4
- f_{23}: ditto section 5
- f_{24}: ditto section 6

Parameters f_{18} to f_{24} define the shapes of the control sections. As with Hull Series 1,7,8,9, and 20, the sections are rectangular if the parameter is equal to 0.0, elliptical if it is equal to 0.5, and parabolic if equal to 1.0. Other values will create shapes intermediate between rectangular and elliptical, or between elliptical and parabolic. Unlike series 20, here we can specify the shape of the control section at the bow (i.e control section 0). Of course, the offsets at the bow will all be equal to zero, but the shape does not have to be parabolic as with series 20.

- f_{25}: Control section 0 cut-off ratio (min. 0.0, max. 1.0)
- f_{26}: ditto section 1
- f_{27}: ditto section 2
- f_{28}: ditto section 3
- f_{29}: ditto section 4
- f_{30}: ditto section 5
- f_{31}: ditto section 6

Parameters f_{25} to f_{31} define control section cut-off ratios. Unlike series 20, here we can specify the cut-off ratio for the bowmost control section (0). Series 32 can be used to create some very unusual hulls. For more information, see Example gs32.mlt in the GODZILLA manual which can be used as a template for your own work.

8.2.9 Series 42

This hull series has 42 parameters that define the location and shape of 9 vertical control sections. It is identical to series 32, but with 2 additional sections. If you do not understand the method for the previous hull series, skip to the next part of this manual.

The first control section (0) is at the bow, the last control section (8) is at the stern. Note that the hull surface will be defined using many more stations and based on these control sections.

- f_0: Section 1 spacing (min. 0.0, max. 1.0)
- f_1 to f_6: Other spacings.

The first 7 parameters (f_0 to f_6) define the spacing between control sections. f_0 defines the distance of control section 1 from the bow (which is defined as control section 0). f_1 defines the distance of control section 2 from control section 1. f_2 defines the distance of control section 3 from control section 2. The last control section (number 8) is at the stern. The distance from the stern to the previous control section does not need to be defined as it is the remainder after other spacings have been deducted from 1.

- f_7: Keeline depth at control section 0 (min. 0.0, max. 1.0)
- f_8: ditto section 1
- f_{15}: ditto section 8

The next parameters (f_7 to f_{15}) define the depth of the keelline at each control section. If the value is equal to 0, then the keelline is at the waterplane. If the value is equal to 1, the keelline at that control point coincides with the baseline.

- f_{16}: Waterline offset at control section 1 (min. 0.0, max. 1.0)
- f_{17}: ditto section 2
- f_{23}: ditto section 8

The next parameters (f_{16} to f_{23}) define the hull beam (as a fraction of the maximum beam) at the waterline of control sections 1 to 7. There is no need to define the offset at the bow (section 0) because it is assumed to be equal to zero.

- f_{24}: Section shape of control section 0 (min. 0.0, max. 1.0)
- f_{25}: ditto section 1
- f_{32}: ditto section 8

Parameters f_{24} to f_{32} define the shapes of the control sections. As with Hull Series 1,7,8,9,20, and 32, the sections are rectangular if the parameter is equal to 0.0, elliptical if it is equal to 0.5, and parabolic if equal to 1.0. Other values will create shapes intermediate between rectangular and elliptical, or between elliptical and parabolic. As with series 32, here we can specify the shape of the control section at the bow (i.e control section 0). Of course, the offsets at the bow will all be equal to zero, but the defined shape does not have to be parabolic.

- f_{33}: Control section 0 cut-off ratio (min. 0.0, max. 1.0)
- f_{34}: ditto section 1
- f_{41}: ditto section 8

Parameters f_{33} to f_{41} define control section cut-off ratios. As with series 32, here we can specify the cut-off ratio for the bowmost control section (0). For more information, see Example gs42.mlt in the GODZILLA manual.

8.2.10 Series 58

This series produces axi-symmetric submarine-like bodies studied by Gertler [1].

The radii of the hulls are given by a 6 term polynomial. The first 6 parameters are used to determine the square of the radius:

$$r^2 = f_0 x + f_1 x^2 + f_2 x^3 + f_3 x^4 + f_4 x^5 + f_5 x^6. \tag{4}$$

The last parameter (i.e. f_6) is reserved for future purposes.

8.2.11 Series 5470

This hull series takes two parameters to produce a mathematically-defined submarine body.

Minimum and maximum values for each parameter are given in brackets below.

- f_0: Forebody relative length (min. 0.0, max. 1.0)
- f_1: Afterbody relative length (min. 0.0, max. 1.0)

These parameters determine the amount of parallel middle body, as discussed for Series 4 and 7.

The special choices $f_0 = 0.233236$ and $f_1 = 0.255102$ will produce the shape of the DARPA SUBOFF bare hull. (The length, draft and displacement of the hull will ultimately determine if the cross-section is elliptical or circular.) See Michlet Example s5470.mlt to see how this is achieved for the DARPA SUBOFF body.

8.2.12 Krein's Caravans

These vessels are hydrodynamic oddities which have been used for theoretical investigations into bodies with zero wave resistance. The hull shape can only be accessed through the lines drawing screen. There is only one shape parameter for this hull series, namely the number of satellite hulls. This can be between 0 and 7 inclusive in the current version of Michlet. Because of the requirement of evenly-spaced stations in Michlet, best results for Krein's caravans are obtained if the number of stations is chosen carefully.

8.3 Spline Formats

The offset definition methods described above all use equally-spaced sections and waterlines. The spline format method allows offsets to be defined at unequally-spaced sections and waterlines.

The following is a short example of the spline format. Comments in the file begin with the # character in the first column. The file must not contain blank lines.

```
# Example of Spline format
3
BEGIN
0.0
0.00, 0.0
0.10, 0.0
0.50, 0.0
0.95, 0.0
1.00, 0.0
END
BEGIN
0.15
0.00, 0.0
0.25, 0.16
0.33, 0.19
0.60, 0.28
0.75, 0.35
0.87, 0.36
1.00, 0.37
END
BEGIN
0.45
0.00, 0.0
0.20, 0.21
0.45, 0.37
0.85, 0.48
1.00, 0.50
END
BEGIN
0.70
0.00, 0.0
0.26, 0.13
0.51, 0.23
0.66, 0.32
0.88, 0.36
1.00, 0.38
END
BEGIN
1.0
0.00,0.0
0.15,0.0
0.45,0.0
```

0.95,0.0
1.00,0.0
END
#The last line must be EOF
EOF

The first number (3 in the example above) signifies that Michlet will use cubic splines (the only valid option in the current version).

The last line of the file must be EOF.

Data for each station is enclosed between BEGIN and END statements. (They do NOT have a # symbol before them.) The first number on its own is the station ordinate. 0.0 is the bow. Always use 0.0 for the first station, and always include at least 5 pairs of ordinates for any station.

Stations must be in ascending order starting at the bow and ending with the stern.

The pairs of numbers (separated by a comma) are the z-ordinate (0.0 = baseline), and the offset at that z-ordinate. The waterlines must be in ascending order from baseline to the top of hull. Values can be in dimensional, or non-dimensional form. Michlet will scale the hull to the length, draft and displacement that you specify in the in.mlt file.

Negative offsets resulting from interpolation are clipped to 0.0. Any offset greater than 99999.9 is set to 99999.9.

To use your own spline offset file, save it to sploff1.csv and use -2 for the Offset Type in the in.mlt file. That is, use:
Offsets
-2

Hull offsets for the NPL hulls in the examples use the cubic spline format. See the npl_sploff1.csv file in the example directory.

For multihulls, use sploff1.csv for the first hull, sploff2.csv for the second hull, etc.

Note that an injudicious spacing of nodes can lead to unusual bulges in the hull surface when using the spline method. It is often best to use an equal spacing of nodes, but even then some problems can arise. (This is why CAD programs use B-splines or other methods, not simple Hermite cubic splines as in Michlet!) For flat horizontal surfaces, or sharply-curved portions use a larger number of nodes than you would for vertical surfaces.

8.4 Multiple Offset Formats

For multihulls, you can use any combination of offset tables, shape function and parameters, offsets from separate files, or spline input files.

9 OUTPUT FILES

When Michlet is run, one of the first things it does is to clear its output files by placing the character string # Blank in each file. If you have not copied the files to a safe directory before running Michlet, previous output will be over-written. It can be very useful to create some small batch files (or scripts in Unix) that copy data to safe directories or to disc.

9.1 out.mlt

This comma-separated text file is created when you exit from Michlet. The file contains, among other output quantities, details of the hullforms, tables of resistance, and an array of (dimensionalised) hull offsets. If drag was not calculated before exiting Michlet, all resistances in this file will be equal to zero.

9.2 Hull Data

- off1.mlt, ..., off5.mlt : dimensional hull offsets for hull 1, ..., hull 5.

- fsoff1.txt, ..., fsoff5.txt : dimensional hull offsets for hull 1, ..., hull 5 in a format that can be read by FREEShip and DELFTship. Note that the offsets are saved section by section from the aftmost to the bowmost. This is opposite to Michlet's convention in which the first station is the bowmost.
- hsecarea.mlt : section areas
- hwparea.mlt : waterplane areas

9.3 Speed Dependent Vectors and Arrays

9.3.1 ship_output_by_speed.mlt

This file contains the information in the out.mlt file in a more convenient form for use by other programs such as gnuplot, Open Office and Excel.

9.3.2 drag.mlt

Some users do not need the detailed output of ship_output_by_speed.mlt. The drag.mlt file contains only the speed, viscous drag, wave drag, and transom stern hydrostatic drag. The total drag is the sum of the components.

9.4 Theta-Dependent Vectors And Arrays

- drdth.mlt : θ (degrees) and $dR/d\theta$ (kN).

9.5 Wave Elevation Output Files

Resistance graphs, wave elevation contour plots and free wave spectrum graphs can be saved as .pcx files. Wave elevations and free wave spectra can also be saved as text (.mlt) files. Press s to save the data for wave elevations. A prompt will appear asking for a filename (maximum 8 letters). The extension .mlt will be appended automatically. Press S to save a resistance, wave elevation or free wave spectrum plot as a .pcx file. The .pcx extension will be added automatically.

It is very important to note that wave elevation data is not saved automatically on exit. After you display wave patterns or wave cuts you should save the data, or the graphic, or both.

The table below is an example output file of wave elevations for a small rectangular patch using a 5×5 grid. Of course, for real work, the size of the output file will be much larger. Also, the elevations will not always be symmetric around y=0.0 for all ships and all rectangular patches. Output is comma-separated, and can be pasted into Excel spreadsheets.

```
RECTANGULAR PATCH
Speed
6.0000
x0,x1,nX
20.0000,40.0000,5
y0,y1,nY
-10.0000,10.0000,5
x_zmin,y_zmin,zmin
40.0000,-5.0000,-0.0227
x_zmax,y_zmax,zmax
20.0000,-5.0000,0.0139
ELEVATIONS
z,20.0000,25.0000,30.0000,35.0000,40.0000,
10.0000,0.0011,-0.0002,-0.0012,0.0033,-0.0032
5.0000,0.0139,-0.0166,-0.0002,0.0095,-0.0227
0.0000,0.0028,-0.0033,0.0015,0.0001,0.0011
-5.0000,0.0139,-0.0166,-0.0002,0.0095,-0.0227
-10.0000,0.0011,-0.0001,-0.0012, 0.0033,-0.0032
```

Speed is in ms^{-1}. x0, x1, y0, and y1 are the ordinates (in metres) of the corners of the patch. nX and nY are the number of grid nodes in the X- and Y-directions.

x_zmin and y_zmin are the co-ordinates (in metres) of the minimum wave elevation in the rectangular patch. zmin is the minimum wave elevation. x_zmax and y_zmax are the co-ordinates (in metres) of the maximum wave elevation in the rectangular patch. zmax is the maximum wave elevation.

Wave elevations, z, are given as a table of values. The first row contains the x-ordinates of the grid points of the rectangular patch; the first column contains the y-ordinates for the patch.

This file can be used as an input file for the ship-identification objective in GODZILLA by renaming it as userrecp.mlt. No other changes to the file are necessary, making it easy to use with DOS batch files or Unix scripts.

Output files for the sectorial patch and the wave cuts have a very similar format to the above table.

9.6 Output Formats

The variety, type, and format of output files is controlled by the values of the two input variables Output File Type and Output File Subtype in the in.mlt input file. For example, in addition to the files described above, Michlet can output files that make it easy to create lines drawings using public domain programs like gnuplot, or to automatically generate text and tables using LaTeX. Description of the many different possibilities is beyond the scope of this manual. Customised versions and documentation can be made available... for a price!

10 ON-SCREEN OPTIONS

Note that the keys used to operate Michlet are case sensitive, i.e. pressing a will give a different result to pressing A.

Also note that Michlet doesn't often ask for confirmation when you press a key to request an action. This can be a bit bewildering for a start, but it is often better than being asked to confirm everything you want to do.

10.1 Lines Drawings

This screen shows lines drawings of the vessel as well as geometric and other details.

To see what options are available, press ?. (You must press the Esc key to return to the Lines Drawing screen before using the listed options).

The panel at the right of the screen shows the following quantities:

- Hull displacement volume D in cubic metres
- Length L in metres
- Draft T in metres
- Beam B in metres
- Wetted surface area S in square metres
- Waterplane area A_{wp} in square metres
- Transom area A_t in square metres
- Block coefficient C_b
- Prismatic coefficient C_p
- Longitudinal centre of buoyancy LCB in metres
- Vertical centre of buoyancy VCB in metres
- Longitudinal centre of flotation LCF in metres

- Longitudinal hull offset distance s in metres
- Lateral hull offset distance w in metres
- Overall length LOA in metres
- Overall width WOA in metres
- Total displacement volume D_{tot} in cubic meters
- Total wetted surface area S_{tot} in square meters
- Skin friction type
- Form factor type
- Wave drag N_θ

Note that LCB is given as (metres) from the centre of the hull. Negative LCB means that the LCB is aft of centre.

10.2 Individual Hull Plots

If there is more than one hull, press the number corresponding to the hull you want to display.

10.3 Other Menus

Other menus are available from the Lines Drawing screen. Remember to use upper case letters to invoke these menus:

- M : Ship Motions (sinkage and trim only at this stage)
- P : Pressure Signatures
- R : Resistance graphs
- W : Ship waves and free wave spectra

The options available from these menus will be described in detail later in this section.

10.4 Section Areas and Waterplane Areas

- a : Section areas
- A : Waterplane areas

If there is more than one hull in the vessel or ensemble, press the number corresponding to the hull to see the area curve for that particular hull. You can return to the Lines Drawing screen by pressing the Esc key.

10.5 Views

There are several views of the vessel available from the Lines Drawing screen. To change the current hull, press the appropriate hull number. E.g. to see details for the second hull, press 2.

- e : (enlarged) true scale view of the hull arrangement in the waterplane
- h : (horizontal) waterlines of all hulls. (Non-dimensional)
- H : (horizontal) waterlines of current hull. (Non-dimensional)
- v : vertical sections of all hulls. (Individually true-scale)
- V : vertical sections of current hull. True-scale

Non-dimensional plots are used for the horizontal views because too much detail is lost for thin hulls.

When the vertical sections of more than one hull are displayed, each plot is shown true-scale for that hull only. Thus a small outrigger can look much deeper than a hull with a larger draft.

10.6 Editing Parameters

Some of the parameters describing the hulls can be changed from the Lines Drawing screen. Pressing the following (lower case) letters will bring up a prompt for you to key in a value and then to press the Enter key. To abort the input, press the Esc key.

- l : Hull length.
- s : Hull longitudinal separation distance.
- t : Hull draft.
- w : Hull lateral separation distance.

If you key in a value that is out of range for a particular parameter, the original value of that parameter will be retained. No warning that this has occurred is given in the current version. Always check that the value you have entered has been accepted.

You cannot change the longitudinal or the lateral separation distance for hull 1: its centre is always located at the co-ordinate origin. (Refer to Figure 1).

10.7 Editing Offsets

Please note that offsets cannot be edited on-screen if the trim or sinkage have been set to non-zero values.

When the lines drawing of a hull is displayed, one section is highlighted; it is in white while all other sections are in another colour. Also, a small light-red cross is located at one of the waterlines along the highlighted section. To move the highlighted section, use the x and X keys to move backwards or forwards, respectively, through the hull sections. Note that the bowmost section will never be highlighted as it cannot have other than all zero offsets. The sternmost section can be highlighted as that section can have non-zero offsets. (The only signal to Michlet that a hull has a transom stern is the existence of non-zero stern offsets.) To move the red cross from one waterline to the next, use the z and Z keys.

There are two ways to change the value of an offset at the location of the red cross. The first is to press y or Y which decreases or increases (respectively) the highlighted offset by a (non-dimensional) increment. This increment can be changed by pressing I and entering the desired increment. The second method is to input the (non-dimensional) offset directly. To do this press i and then enter the value.

(I've never tried to input an entire hull this way myself. I use these options to fiddle around with bulbs or to do some quick fairing of lines.)

10.8 Editing Mathematical Offset Series

Some hull formulae can be specified on-screen. To begin specification of the new (mathematical) hull series, press n. You will prompted to input the appropriate parameters.

On-screen choices include:

- 1 : Series 1. Simple three parameter family
- 7 : Series 7. Seven parameter extension of Series 1
- k : Krein's Caravans

Details for these hull series are given in another section of the manual.

10.9 Copying Offsets

If there is more than one hull loaded, you can copy offsets from other hulls to the currently displayed hull. Press C and then the number corresponding to the hull you wish to copy from. Other parameters such as displacement, length, draft, trim etc., will not be copied.

For example, suppose that there are three hulls loaded and that the current hull is Hull 2. To copy offsets from Hull 3, press C, and then press 3. Hull 2 will now have the same (non-dimensional) offsets as Hull 3.

This feature of Michlet can be very useful for “evolving” good hull shapes. For example, suppose you have five hulls loaded. You can make small changes to one of the hulls, assess and compare the drag of all hulls, and then replace the worst hull in the collection with the best hull. You could then make further small changes to one of the hulls. Continuing this process should result in a hull “better” than we started with.

The optimisation module, GODZILLA, is an attempt at automating this evolutionary design process, and is described later in another manual.

10.10 Resistance Graphs

There are two main categories of resistance graphs in Michlet, namely hull drag plots, and ship drag plots. Hull drag plots are for each hull considered as if it were the only hull in the ensemble, i.e. wave interference effects between hulls are not relevant. Ship drag plots include wave interference effects between the hulls that comprise the entire ensemble. Of course, for monohulls there is no such interference.

10.10.1 Hull Resistance Graphs

- t : Total resistance components.
- v : Viscous drag components.
- w : Wave resistance components.
- c : Total resistance comparison of all hulls.

If there is more than one hull, you can see results for other hulls by pressing the appropriate number when a plot is displayed.

10.10.2 Ship Resistance Graphs

- T : Total resistance.
- W : Wave resistance.
- I : Wave resistance interference components.
- C : Total resistance components.

When any resistance plot is displayed, you can save the plot as a .pcx file. Press S, then enter a filename. The .pcx extension will be appended by Michlet. You cannot save hull resistance data (e.g. by using lowercase s) as can be done in some other Michlet plots. Resistance is saved on exit from the program.

10.11 Wave Analysis Plots

Pressing W in the Lines Drawing screen brings up the Wave Analysis module. From here you can edit parameters that control the location at which wave elevations are calculated and also the speed for which the plots will be calculated. The initial values of these parameters are input via the in.mlt file.

To change the speed at which the wave pattern will be calculated, press u and then enter a value. The value entered must lie between the minimum speed and maximum speed specified in the in.mlt file.

In Figure 10, the co-ordinate origin is at the centre of Hull 1.

Available plots are:

- B : β as a function of θ. The maximum value of β is the Kelvin angle. (Neither the .pcx file nor the data can be saved from this plot).
- F : Free wave spectrum (herein defined as $dR_w/d\theta$)
- S : Sectorial contour plot of wave elevations behind the vessel. The size and location of the patch are controlled by the values of R_0, R_1 and β defined earlier.

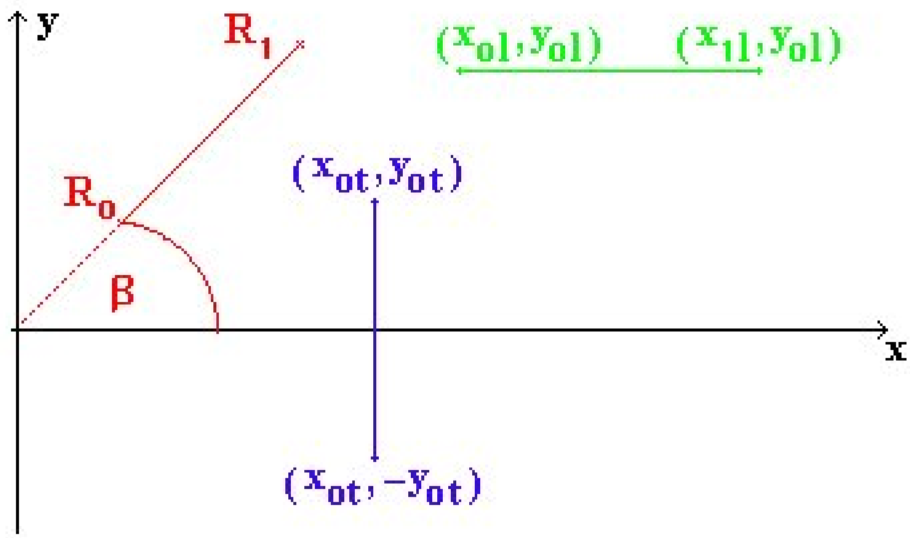

Figure 10: Polar, longitudinal and transverse wave cuts

- P : (Polar) cut along a radial line defined as emanating at an angle, β, from the centre of hull 1.
- R : Rectangular contour plot of wave elevations behind the vessel. The size and location of the patch are controlled by parameters defined earlier in this manual. Clearly, the patch should be a square if you want a correct on-screen aspect ratio.
- L : Longitudinal cut along a line extending from x_{0l} to x_{1l} from the centre of hull 1 and at a distance y_{0l} from the track of hull 1.
- T : Transverse cut along a line perpendicular to the ship's track and at a distance of x_{0t} metres from the centre of hull 1.

To edit the parameters defining the extent of the various cuts and contour domains, press the lower case letter corresponding to the relevant cut or domain. This will bring up a small menu. To then change a particular parameter, press the letter corresponding to that parameter and enter the desired value.

Wave elevations can take quite a long time to compute. For finite depth, considerably more. These times can be reduced by using fewer grid points, but then the plot might not look as clear as for a finer grid. Using a smaller value of N_θ will reduce calculation time, but accuracy could be seriously impaired. For supercritical depth-based Froude numbers, N_θ must be very large otherwise the wave pattern will be seen to 'drop out' for large distances from the ship.

The dimensions for the wave elevation patches in the examples have been chosen in order to give a true aspect ratio (or acceptably close).

When either of the two wave elevation patches are displayed, press c to "clip" the wave pattern above and below a maximum height. For example, if the maximum wave amplitude is 1.0m, and a "clip" value of 0.5 is entered, all amplitudes above 0.5m will be in white, all elevations below -0.5m will be black. Note that the wave elevations are not re-calculated, but merely re-displayed with new colours. Some very dramatic patterns can be made by using a very small value (e.g. 0.001).

When any wave elevation plot is displayed, you can save the plot as a .pcx file. Press S, then enter a filename. The .pcx extension will be appended by Michlet. To save wave elevation data press s.

10.12 Ship Motion Graphs

The only plots available are for the experimental sinkage and trim: i.e. the values appearing in the in.mlt file. If these are not specified, plots will not be available.

- s : Sinkage vs Speed.
- t : Trim vs Speed.

10.13 Sea-bed Pressure Signature Plots

Pressing P in the Lines Drawing screen brings up the Pressure Signature module. From here you can edit parameters that control the location at which bottom pressures are calculated and also the speed for which the plots will be calculated. The initial values of these parameters are input via the in.mlt file.

The method to change the parameters controlling the plot is identical to that used to change rectangular wave elevation plots described earlier in this section.

When the pressure patch is displayed, press c to "clip" the contour plot above and below a maximum value. For example, if the maximum pressure is 1.0 Pascal, and a "clip" value of 0.5 is entered, all pressures above 0.5 Pascal will be in red, all elevations below -0.5 will be blue.

When the pressure plot is displayed, you can save the plot as a .pcx file. Press S, then enter a filename. The .pcx extension will be appended by Michlet. To save pressure data press s.

11 LINKS AND BIBLIOGRAPHY

Several papers that might be helpful can be found at the Cyberiad web site:
www.cyberiad.net/leo.htm.

There are many helpful discussions at www.boatdesign.net: the Software Forum is a good place to discuss Michlet and to share input files with other users. The new Hydrodynamics and Aerodynamics Forum is also a useful resource.

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12 RECENT MICHLET REVISIONS

Version 9.33: Released 25 May 2015:

- Fixed slow screen drawing due to changes in Windows and some NVIDIA drivers.

Version 9.32: Released 19 April 2013:

- Allow calculations to continue while in other windows, and allow multiple copies to run at the same time.
- Allowing cusped waterplanes and buttocks in Series 1. Be careful: the hulls might not be very practical!
- Box constraint. Users can now demand that hulls found during the optimisation process accommodate a box at the stern. This is useful for fitting engines, propulsors and other machinery (with room for maintenance access) close to the stern.

Version 9.31: Released May 2013:
Version 9.30: Released March 2013:
Version 9.20: Released April 2011:
Version 9.10: Released 9 January 2010:
Version 9.01: Released 5 February 2009:
Version 8.07: Released 6 November 2005.
Version 8.01: Released 5 May 2002.
Version 7.01: Released 4 October 2001.
Version 6.00-6.06b: Released 13 March 1999 to 17 March 2001.

13 COMMAND SUMMARY

The following options are available when the opening screen is displayed. Note that some options may not be available in GODZILLA mode.

- ? : Display help screen
- a : Section area graph
- A : Waterplane area graph
- c : Calculate after offsets changed on-screen
- C : Copy offsets from another hull
- e : Enlarge hull arrangement plot
- h : Show all hull horizontal cuts
- H : Show current hull horizontal cut
- i : Input non-dimensional offset
- I : Change non-dimensional Y-increment
- l : Change hull length
- M : Motions menu (i.e. for sinkage and trim)
- n : New (mathematical) hullform menu
- P : Pressure signature menu
- R : Resistance menu
- s : Change longitudinal stagger (for any hull except hull 1)
- t : Change draft
- v : Show all hull vertical cuts
- V : Show current hull vertical cut
- w : Change lateral stagger (for any hull except hull 1)
- W : Wave analysis menu
- x : Highlight previous hull section
- X : Highlight next hull section
- y : Decrease offset by y increment
- Y : Increase offset by y increment
- z : Highlight previous hull waterline
- Z : Highlight next hull waterline
- 1,2,3,4,5 : View chosen demihull