UliTank

Vers. 2.3

User's Manual

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UliTank_2.3.exe was compiled with the Intel® Fortran compiler for Windows. When you start it for the first time, new OS (Windows 8 and 10) will block the execution and display a message that UliTank might contain a risk to your computer. The reason for this message is the fact, that UliTank comes without a certificate and Microsoft tries to enforce its own certification process. Since UliTank is free software, it is impossible to buy every year an expensive new certificate. You can click on the information button in the message, “accept the risk” and run the program. If you don’t trust me, you can check the program with Malwarebytes or with your own anti-virus software before running it.

Contents

1. INTRODUCTION

My work in yacht research is centered on the extended use of the computer in the design spiral. The computer is an ideal tool when it comes to multiple iteration loops as in the optimization process for the design of a sailing yacht. A detailed description of the idea can be found in [1]. The first module in the automated design process is the program UliLines [2]. With only a few input variables UliLines creates the complete hull form of a sailing yacht and provides a table of offsets as output. The next module in the workflow is the program UliTank. Based on a regression analysis of towing tank results, UliTank estimates the resistance of the hull for a given speed. In the version UliTank 2.3 the resistance is restricted to the bare or appended hull of a sailing yacht in the heeled condition but without leeway. The inclusion of the influence of leeway is planned for the future. The table of offsets that is required as input to UliTank can come from any CAD-system, the origin of the lines-plan is not restricted to UliLines. Several different input formats are allowed.

Since UliTank 2.1 the raw data as published by TU Delft are corrected for the blockage effect of the towing tank. Compared to UliTank 2.0 the correction can be as large as 10%. The predicted resistance is therefore the value for unrestricted waters of infinite depth. UliTank 2.3 uses a few different parameters for the linear regression and gives slightly more robust results than UliTank 2.2.

UliTank 1.0 was based on a regression analysis that used the towing tank tests, conducted at the Delft University of Technology. The tests covered a wide range of hull forms for sailing yachts, called the Delft Systematic Yacht Hull Series (DSYHS). My work was only possible because the researchers at TU Delft decided in a really generous act to make the entire experimental data sets of all hulls that were tested over the last 40 years available to the public. Since the beginning of 2013 the data is online [3]. In 2015 the Sailing Yacht Research Foundation (SYRF) published results of a tank test program from 2003 that was until then not available in the open literature. The tested fleet is called the US Sailing Nine Model Series [4]. This was a great opportunity to extend the database for the regression analysis. UliTank 2.3 uses now the combined test results of the DSYHS and the data from the SYRF in the upright as well as the heeled condition, with bare and appended hulls. As a result of this significant increase in the data, there are now 250 independent tank runs available at each Froude-number in the medium speed range. This is the regression analysis with the largest database in the open literature.

The theoretical background of the regression analysis and the choice of the relevant hull parameters for UliTank 2.3 are described in [5], reading is recommended. It is also recommended to study the description [3] of the DSYHS and [4] of the Nine Model Series, because the quality of the resistance prediction will deteriorate for hull forms that are outside of the database. The regression applies only to hull forms with a transom, not to double-enders.

2. INSTALLATION OF THE PROGRAM

The zipped file that you downloaded contains the executable file UliTank_2.3.exe, this manual UTman_2.3.pdf, five subdirectories and the excel-file Exampl.xlsx. You should unpack the zipped file into a folder of your own choice that you have named appropriately (e.g. UliTank). You can execute the program directly in this folder by clicking on the file UliTank_2.3.exe. The input files are stored in the subdirectories named OFFSETS, APPEND and INPUT and the output files will be stored in DRAG and UTANK. These five subdirectories should not be renamed ore deleted. The file Exampl.xlsx contains several sheets with diagrams that compare the predicted resistance to the test results. If you want to uninstall the program, you just need to delete the complete folder UliTank.

3. THE INPUT FILES

The offsets of the hull are stored in the folder OFFSETS. The name of the file must be OFFS_###.txt. The additional hull- and control- parameters are stored in the folder INPUT. The name of this file must be UT_###_in.txt. The ### stands for three digits or three characters that can be chosen by the user to distinguish between different projects. The three digits or characters will also be used in the names of the output files. The folder APPEND contains the file that describes the keel and rudder of the yacht. The name of this file is specified in UT_###_in.txt and must be in the form ########.txt, containing eight characters. The structure of the input files can best be understood by examining the examples OFFS_s01.txt, UT_s01_in.txt and AP_DSYHS that are contained in the downloaded folders. These three files describe the model Sysser 01 of the DSYHS.

3.1 The offset-file

It is mandatory to describe the hull surface in the form of offsets. Other descriptions of the surface (e.g. an IGES-file) are not supported. The hull offsets are the x,y,z-coordinates of the surface points along the sections from keel to deck level. Each section can have different z-values. The x-axis lies in the symmetry-plane in the fore and aft direction. The y-axis has its origin in the symmetry-plane and runs at right angles to it. The z-axis is vertical. The positive directions of the x- and z-axis must be specified in UT_###_in.txt. The origins of the x- and z-axis are automatically determined by the program. When the sections are fixed in the CAD-model, the transom and some stations forward of the designed waterline should be included, since the size of the transom- and bow- overhang has an influence on the resistance. There are three different formats that can be read by the program. The chosen format must be declared in UT_###_in.txt.

The simplest format (`FORMAT` = 1) is just a list of points. Each point starts at a new line and the x-, y- and z-coordinate are separated by a blank, a comma or a tab stop. Make sure that a decimal point is used inside the numbers and no comma. All points that belong to the same section have the same x-coordinate and have to be listed consecutively. A change in the x-value will indicate the beginning of a new section. The files OFFS_s01.txt to OFFS_s71.txt and OFFS_us5.txt use this format and can be regarded as examples. The files for the Sysser-models were copied from [3], where they are called “points file”. The file for model us5 was created from an IGES-file in [4] using Rhino.

The format with the code `FORMAT` = 2 is used when the offsets are written by the program DELFTship. Use the export option "stations". Since DELFTship exports only 3 decimal places the accuracy might not be sufficient for small models. OFFS_dsh.txt is an example of this format.

The third possibility to import offsets is `FORMAT` = 3, which specifies the GHS-format. Many CAD-programs offer this export format. An example is the file OFFS_ghs.txt. UliTank starts reading the file at the line with the asterisk. All the lines above are ignored and can be used for comments. Some programs like DELFTship add additional points at deck-level. In this case the usage of GHS is not possible because UliTank can only identify points on the hull-surface or on the symmetry-plane. If there is no other possibility to export the sections, then the deck-points must be deleted manually.

3.2 Hints to create an offset file

The easiest way to create an offset file is to run UliLines-3.3 or UliLines-4.4 with the parameter CADOUT = 4. One only has to move the output file from UliLines to the folder OFFSETS.

If you have created the hull in Rhino, you should define between 30 and 50 vertical planes. You might want to use a closer spacing at bow and stern. Create the intersections between these planes and the hull surface. Define points on these intersection-curves: go to Curve – Point object – Divide curve by – Number of segments, type "40" and use the option "mark ends = yes". Make sure that there are no other, previously created points on this layer, switch all other layers off and use the command: Save as – Points (*.txt). Transfer this file into the folder OFFSETS and rename it OFFS_###.txt.

A hull that was created in ProSurf can be exported using the option Data File Output – GHS Output. Prior to that you have to define between 30 and 50 stations using the command: PlaneCuts – Initialize Lines. Many CAD-programs convert the units into feet and change the positive x-direction when the export option GHS is chosen. ProSurf does not do that; the coordinates are exported as drawn. In case the offsets are measured in feet, a value of 3.2808 should be entered for SCALE (see below).

If you use DELFTship to design a hull, then make sure that you export a model of sufficient length. The model in the example OFFS_dsh.txt has originally a length of 3 meters. If this model is exported using "stations", the accuracy of 3 decimal places is not sufficient. The execution time of UliTank would be extremely long and spurious convergence might occur. The model was therefore scaled up by a factor of 10 in all three directions, i.e it was created with a length of 30 meters. In the next step you should define 30 to 50 stations using the command: Intersections – Stations. Select the medium Precision and write a .txt file via File – Export – Stations. Transfer the file into OFFSETS and rename it into OFFS_###.txt.

3.3 The file UT_###_in.txt

The purpose of this file is the collection of the control parameters and the input of the test conditions. The input file is built by a sequence of line-pairs. The first line always contains an explanation and the second line the numerical value of the parameter. The program reeds only every second line and in that line only the first number until the first blank behind this number. The rest of the line is ignored. This is convenient if you want to test different values for a parameter and you want to memorize what has been tested: just move it to the right and type the new value in the left-most position.

Now let's inspect the file UT_s01_in.txt line by line

```
Headline:
*    DSYHS parent model Sysser 1   *
FORMAT specifies data format in the offset-file: 1= point coordinates; 2= DelftShip; 3= GHS
   1
```

In the second line, the user can type a description of the yacht or of the project. This headline will also appear in the output files. The third line is a description of the possible offset formats, as described in chapter 3.1. In the fourth line the chosen integer value is submitted.

```
XAXIS   positive x-direction in offset-file: 1= from stern to bow; 2= from bow to stern
   1
ZAXIS   positive z-direction in offset-file: 1= from keel to deck; 2= from deck to keel
   1
SCALE   = numerical value of distance in offset-file / distance at tank-model in meters
  1000.
```

`XAXIS` and `ZAXIS` tell the program in which direction the values of the coordinates in the offset file increase. The parameter `SCALE` allows the definition of any desired model size, be it a small towing tank model or a full size ship. UliTank requires all dimensions in meters. In this example the numbers in the offset file are millimeters. The length of the waterline L_{WL} in the offset file is 1600. The model in the towing tank has an L_{WL} of 1.6 m. The scale factor is therefore 1600/1.6 = 1000.

```
VOLUME = immersed volume of the canoe body (w/out appendages) of the tank model in m3
  0.0376136
ZTOW  = height of towing point above still water surface in mm
   255.
XTOW  = distance of towing point from forward end of DWL (FP) in m
   0.301
```

The input of the immersed volume in m^3 is used to calculate the draft and the position of the L_{WL}. `ZTOW` is the vertical distance of the towing point above the still water level, measured in millimeters. The positive distance from the forward end of the designed waterline (forward perpendicular) to the towing point in x-direction in meters is named `XTOW`.

```
APPEND = name of the file, that contains the description of the appendages: AP_XXXXX.txt
   AP_DSYHS.txt
LEK    x-distance LE keel to origin x=0, origin defined in offset-file (m)
     1.083
LER    distance LE rudder to origin x=0 (m) in the waterplane
     0.124
```

`APPEND` is the name of the text-file in the folder APPEND that contains the description of keel and rudder. The name must consist of eight characters plus the extension .txt. `LEK` and `LER` define the position of the leading edge of the appendages, relative to the origin x = 0 of the coordinate system. This coordinate system is the one that is used in the offset-file. For a swept keel or rudder, the uppermost point of the leading edge is taken.

```
HTRIP  = height of trip (sandgrain or pin), canoe-body in mm
   1.0
DPIN  = diameter of pin, if pin used for tripping, canoe-body in mm
   0.
NPIN  = number of pins, canoe-body, use 0 for sandgrain with Delft-method
   0
XTRIP  = average distance of pins or sand strips from FP in mm, canoe-body
   260
```

`HTRIP` is the height of the sand grains that form the boundary-layer trip in the DSYHS. If there is no trip, then `HTRIP` = 0. In some towing tanks pins or studs are used as tripping device. In this case `HTRIP` indicates the pin-height, `DPIN` describes the diameter of the pins and `NPIN` is the number of submerged pins. The positive distance from the forward perpendicular to the pins or sand strips is named `XTRIP`. It should not be mixed up with the actual transition point. If the Delft-method is employed, the resistance of the sand strips is already subtracted from the measured resistance and only these corrected values are published. In this case `NPIN` must be set to zero. If `NPIN` is different from zero, the program calculates the pin-drag and uses this additional force in the equilibrium of forces and moments.

```
HATRIP = height of trip (sandgrain or pin), appendages in mm
   1.0
DAPIN  = diameter of pin, if pin used for tripping, appendages in mm
   0.
NPINKL = number of pins for b.l.-trip keel, use 0 for sandgrain with Delft-method
    0
NPINRD = number of pins for b.l.-trip rudder, use 0 for sandgrain with Delft-method
    0
```

`HATRIP`, `DAPIN`, `NPINKL` and `NPINRD` describe the equivalent parameters for the appendages. The meaning is the same as for the canoe-body.

```
REGRES Specifies the regression model used for prediction: 1= linear; 2= quadratic
   1
```

UliTank 2.3 offers two different regression models. The quadratic regression model gives better predictions in the range between Froude-number 0.3 and 0.6, as long as the model is within the parameter-range of the database. For models slightly outside of the database the linear regression should be used. It is good practice to run both models and check for plausibility. In the linear case a slight extrapolation beyond $Fn = 0.8$ is possible.

The following values describe the test conditions in the towing tank.

The integer number `NTEST` is identical to the number of rows that contain speed values. Each line represents a test run in the towing tank. The first column indicates the towing speed in m/s. Next column is the trimming moment caused by movable weights in Nm. The applied moment is positive, if the bow is moved down, otherwise it is negative. Next is the fresh water temperature in the tank, recorded in degrees Celsius. The fourth column shows the turbulence level in %. For the definition of `Tu` and a recommendation of its value see [6]. In the next column we find the distance from the forward perpendicular to the active boundary-layer trip in millimeters. When there are several trips, this distance can vary, depending on which of the trips is active. If natural transition is assumed, then `Xtrip` should be larger than the total length of the model. A subroutine in the program will always check, if natural transition occurs, before the prescribed trip is reached. The actual position of the switch in the computation to the turbulent regime will be printed on the screen during the execution. The heel-angle in degrees is given in the next column. The last column indicates, whether the hull is appended or not. Integer 1 stands for hull with keel and rudder, 0 indicates bare hull only.

```
NTEST  = number of rows, each row simulates a test point
   41
IROWBL = row-number for which boundary-layer data will be printed
   5
one row per testpoint. Speed in m/s, external trimming moment in Nm - bow down is positive,
fresh water temperature in degrees Celsius, turbulence level in %,
distance of trip from FP in mm, heel angle in degrees, appended yes=1
 speed          Trimmoment     Ttank    Tu%    Xtrip   heel  append
0.398069        0.000000        17.3   2.06     500      0      0
0.597122        0.000000        17.3   1.20     260      0      0
0.796200        0.000000        17.3   0.82     260      0      0
0.995311        0.000000        17.3   0.61      20      0      0
1.195471        0.000000        17.3   0.48      20      0      0
1.394681        0.000000        17.3   0.39      20      0      0
1.593961        0.000000        17.3   0.32      20      0      0
1.793328        0.000000        17.3   0.28      20      0      0
1.992809        0.000000        17.3   0.24      20      0      0
2.192474        0.000000        17.3   0.21      20      0      0
2.392537        0.000000        17.3   0.19      20      0      0
0.995311        1.432250        17.3   0.61      20      0      0
1.195471        2.864500        17.3   0.48      20      0      0
1.394681        4.296750        17.3   0.39      20      0      0
1.593961        8.593500        17.3   0.32      20      0      0
1.793328        17.187000       17.3   0.28      20      0      0
```

```
1.992809        28.645000       17.3   0.24      20       0      0
2.192476        38.670751       17.3   0.21      20       0      0
2.392546        42.967501       17.3   0.19      20       0      0
0.398069        0.000000        17.3   1.50    2000      20      0
0.597122        0.000000        17.3   0.20     500      20      0
0.796200        0.000000        17.3   0.82     260      20      0
0.995311        0.000000        17.3   0.61     260      20      0
1.195471        0.000000        17.3   0.48      20      20      0
1.394681        0.000000        17.3   0.39      20      20      0
1.593961        0.000000        17.3   0.32      20      20      0
1.793328        0.000000        17.3   0.28      20      20      0
0.502620        0.000000        20.0   4.00     260       0      1
0.603155        0.000000        20.0   3.00      20       0      1
0.703696        0.000000        20.0   2.00      20       0      1
0.804244        0.000000        20.0   1.38      20       0      1
0.904801        0.000000        20.0   1.22      20       0      1
1.005368        0.000000        20.0   1.10      20       0      1
1.105946        0.000000        20.0   1.00      20       0      1
1.206536        0.000000        20.0   0.92      20       0      1
1.307141        0.000000        20.0   0.85      20       0      1
1.407763        0.000000        20.0   0.79      20       0      1
1.508402        0.000000        20.0   0.73      20       0      1
1.609061        0.000000        20.0   0.69      20       0      1
1.709743        0.000000        20.0   0.65      20       0      1
1.810450        0.000000        20.0   0.61      20       0      1
```

If additional information about the boundary-layer is of interest, then `IROWBL` will specify the tank run for which additional data will be printed in OUT_###.txt. In this example the 5th row with the speed of 1.195 m/s will trigger the printout of the boundary-layer data.

3.4 The file AP_#####_in.txt

The appendages are defined in this file. The general structure is the same as in UT_###_in.txt. The file for the Delft-models is named AP_DSYHS.txt. An explanation line by line follows:

```
*  Standard keel DSYHS, all dimensions at tank model scale  *
   DXCOGK distance COG to LE keel (m)
     0.2582
   ACOFFK section area coefficient
     0.6581
   TFIN   draft of fin-keel from root to tip, at right angle to waterplane (m)
     0.219
```

The first line is just comments, that will not be read. `DXCOGK` is the positive distance in x-direction of the center of gravity of the keel to the uppermost point of the leading edge. `ACOFFK` is the section area coefficient, it is defined as the section area divided by chord and max. thickness. `TFIN` is the draft of the fin-keel from the bottom of the canoe-body to the lowest tip of the keel, measured at a right angle to the designed waterplane.

The following table is a description of the geometry of the keel:

```
   Chord (m), thickness ratio, for the given vertical position
   0.4140     0.15             at fin-root, close to canoe body
   0.3843     0.15             at 19.51% TFIN down from root
   0.3558     0.15             at 38.27% TFIN down from root
   0.3295     0.15             at 55.56% TFIN down from root
   0.3065     0.15             at 70.71% TFIN down from root
   0.2876     0.15             at 83.15% TFIN down from root
   0.2736     0.15             at 92.39% TFIN down from root
   0.2649     0.15             at 98.08% TFIN down from root
```

For a given distance vertically downward from the root, the chord and the thickness ratio of the section must be given. The thickness ratio is the maximum thickness of the foil-section divided by the chord. This method of describing the geometry allows for a large variety of keel-forms that need not to have straight contours.

```
*  Standard rudder DSYHS            *
   DXCOGR distance COG to LE rudder (m)
     0.0613
   TRUD   draft of rudder from z=0 (DWL) to tip, at right angle to waterplane (m)
     0.266
   CURUD  upper chord at waterplane-level (m), if necessary extended inside the cb to the LE
     0.124
   CLRUD  lower chord at tip (m), parallel to waterplane
     0.096
   TCURD  thickness ratio of upper section at top (-)
      0.1193
   TCLRD  thickness ratio of lower section at tip (-)
      0.1193
   ACOFFR section area coefficient
     0.6786
```

The description of the rudder is similar to the keel. The first line is again just a comment. Since the upper part of the rudder follows normally the contour of the hull, the chord at the waterplane-level is not uniquely defined. To overcome this, the leading edge of the rudder is extended upwards to the waterplane, if necessary even inside the canoe-body. The upper chord length `CURUD` is then defined as the distance from the extended leading edge to the trailing edge in the waterplane. The other parameters are analogous to the keel-parameters.

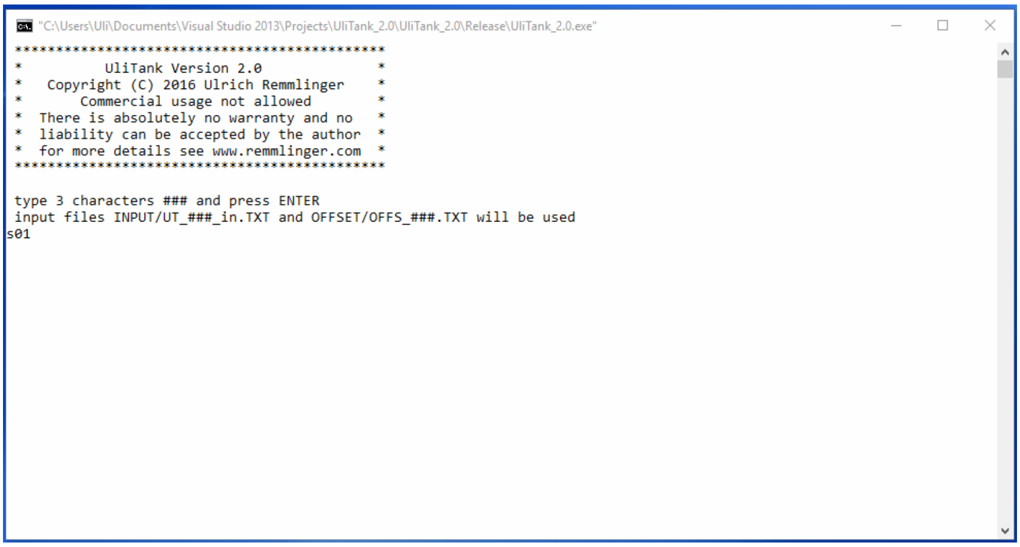
```
*  foil section shapes, thickness will be adjusted
   SSHAPE  1= NACA 63(2)A015 as in DSYHS, 2= NACA 64(2)A013 as in USSAIL
     1
```

`SSHAPE` defines the section-shape. Integer 1 defines the sections as used in the DSYHS. The keel employs a NACA 63_2A015 section and the rudder is made of NACA 0012. Integer 2 is appropriate for the models of the US Sail series. Keel and rudder both have sections of the form NACA 64_2A013. The drag coefficient for each foil section is calculated with the program XFOIL [7] as a function of the Reynolds-number and the thickness ratio.

It is advisable to save one of the downloaded input files without altering it. It can be used as a template for further input files in the future.

4. RUNNING THE PROGRAM

When opening UliTank_2.3.exe the following window will appear and will ask you for the identifiers of the input file (depending on the setting of your command prompt options, the background color might be black):



```
*********************************************
*          UliTank Version 2.0              *
*   Copyright (C) 2016 Ulrich Remmlinger    *
*       Commercial usage not allowed        *
*  There is absolutely no warranty and no   *
*  liability can be accepted by the author  *
*  for more details see www.remmlinger.com  *
*********************************************

 type 3 characters ### and press ENTER
 input files INPUT/UT_###_in.TXT and OFFSET/OFFS_###.TXT will be used
s01
```

If you want to execute the program with the input file UT_s01_in.txt in the folder INPUT then type s01 and press enter. The offsets will be taken from the file OFFS_s01.txt in the folder OFFSET. The program is not case sensitive if characters replace ###. The program will display diagnostic messages and will indicate the termination.

The towing force at a given distance above the water level will exert a bow down moment around the y-axis. This and any additionally applied trimming moment will change the sinkage and trim of the model. The sinkage and trim-angle are determined in an iterative search for the hydrostatic equilibrium of forces and moments. The resulting attitude of the hull at rest must not be confused with the trim and sinkage at speed, these values are unknown. If the definition of the hull surface is not smooth, but wavy or stepped, it can happen that an infinitesimal change of the sinkage or trim will result in a large jump of the forces or moments. In such a case the true equilibrium can not be found, spurious convergence is detected and a message is displayed. If the remaining error is less than 0.1% of the required forces or moments, the values are accepted as a valid solution. If you use an offset file of a small model that was produced with DELFTship, such a situation can occur, because the restricted accuracy of only three decimal places in the coordinates will cause a stepped keel line that is constantly flat across several stations but with occasional jumps of the last digit. In such a situation a very small change in the trim-angle will cause a large change in L_{WL}.

Depending on the clock-speed of your computer, the operating system and on the smoothness of the model, it can take anything from milliseconds to minutes for the computation to converge. If the run was not successful and an error occurred, you might be able to adjust your parameters or offsets based on the displayed message. After termination press Enter and the window will close and you can inspect the output files in two program folders.

5. THE OUTPUT FILES

The result of the computations is a table of resistance values vs. speed. It can be found in the folder DRAG in the file DRAG_###.txt. The values are separated by commas and you need to use the import-assistant to convert this text-file into an excel-file. The table on the next page is the output for Sysser 1, identified as DRAG_s01.txt. In the first column you will find the value of the Froude-number, based on the actual trimmed L_{WL}. The next five columns show the viscous-, keel-, rudder-, residuary- and total-resistance values in N, calculated with the new regression formula. If sand strips, studs or pins are used to trip the boundary-layer, then Rvisc-trip is the calculated viscous resistance of these strips or pins. This value is not contained in Rtotal and must be subtracted from the measured resistance in the tank, to make the test results comparable with the prediction. The measured resistance values for the DSYHS are already corrected for the parasitic drag of the sand strips, no additional correction is necessary. Column 8 and 9 contain the predicted resistance for the bare hull using the Delft-method. The definition of these resistance components is explained in [5]. In the next six columns the resistance values are converted into dimensionless coefficients. The forces are divided by the dynamic pressure and the wetted surface according to:

$$C = \frac{R}{\frac{1}{2} \cdot \rho \cdot U^2 \cdot A_{wet}}$$

*   DSYHS parent model Sysser 1   *

Resistance values calculated with UliTank - linear regression model

for details see www.remmlinger.com

FN	Rvisc-cb (N)	Rkeel (N)	Rrudder (N)	Rresidu (N)	Rt (N)	Rvisc-trip(N)	Rvisc-delft	Rt delft (N)	C visc-cb	C appendgs	C residu	C t	Cvisc-delft	Ct delft
0.10022	0.24984	0.0	0.0	0.01417	0.26401	0.00932	0.29312	0.30030	0.00487	0.0	0.00028	0.00515	0.00572	0.00586
0.15034	0.56813	0.0	0.0	0.05349	0.62161	0.02100	0.59981	0.62456	0.00492	0.0	0.00046	0.00539	0.00520	0.00541
0.20047	0.96060	0.0	0.0	0.16386	1.12446	0.03738	0.99958	1.14753	0.00468	0.0	0.00080	0.00548	0.00487	0.00559
0.25061	1.51585	0.0	0.0	0.41031	1.92616	0.05956	1.48761	1.93821	0.00473	0.0	0.00128	0.00601	0.00464	0.00605
0.30101	2.12763	0.0	0.0	1.00529	3.13292	0.08726	2.06359	3.18878	0.00460	0.0	0.00217	0.00677	0.00446	0.00690
0.35119	2.79376	0.0	0.0	2.26371	5.05747	0.12012	2.71912	5.30462	0.00444	0.0	0.00360	0.00804	0.00432	0.00843
0.40142	3.58003	0.0	0.0	6.64577	10.22580	0.16152	3.45483	10.69484	0.00435	0.0	0.00808	0.01244	0.00420	0.01301
0.45172	4.53523	0.0	0.0	15.74657	20.28180	0.21272	4.26904	20.87620	0.00436	0.0	0.01513	0.01949	0.00410	0.02006
0.50211	5.59813	0.0	0.0	28.26502	33.86315	0.27125	5.16044	35.10260	0.00436	0.0	0.02200	0.02635	0.00402	0.02732
0.55255	6.78040	0.0	0.0	39.81274	46.59314	0.33632	6.12814	47.73493	0.00436	0.0	0.02560	0.02996	0.00394	0.03069
0.60306	8.04102	0.0	0.0	45.44221	53.48322	0.40517	7.17233	54.68771	0.00434	0.0	0.02453	0.02888	0.00387	0.02953
0.25064	1.51434	0.0	0.0	0.42781	1.94215	0.06012	1.48761	1.93053	0.00472	0.0	0.00133	0.00606	0.00464	0.00602
0.30109	2.11816	0.0	0.0	1.02515	3.14331	0.08880	2.06359	3.17013	0.00458	0.0	0.00222	0.00680	0.00446	0.00686
0.35132	2.77480	0.0	0.0	2.27075	5.04556	0.12310	2.71912	5.20455	0.00441	0.0	0.00361	0.00802	0.00432	0.00827
0.40170	3.53164	0.0	0.0	6.65142	10.18307	0.16904	3.45483	10.46839	0.00430	0.0	0.00809	0.01239	0.00420	0.01273
0.45249	4.38088	0.0	0.0	16.53398	20.91487	0.23142	4.26904	21.30568	0.00421	0.0	0.01589	0.02010	0.00410	0.02047
0.50319	5.29018	0.0	0.0	30.81847	36.10865	0.30990	5.16044	37.13894	0.00412	0.0	0.02398	0.02810	0.00402	0.02890
0.55425	6.27860	0.0	0.0	42.72720	49.00581	0.39905	6.12815	50.69837	0.00404	0.0	0.02747	0.03151	0.00394	0.03260
0.60522	7.41614	0.0	0.0	49.02797	56.44411	0.48903	7.17237	57.17621	0.00400	0.0	0.02647	0.03047	0.00387	0.03087
0.10182	0.17078	0.0	0.0	0.01428	0.18506	0.00948	0.28919	0.29638	0.00333	0.0	0.00028	0.00361	0.00564	0.00578
0.15274	0.47139	0.0	0.0	0.04386	0.51525	0.02134	0.59178	0.61653	0.00409	0.0	0.00038	0.00447	0.00513	0.00534
0.20367	0.96871	0.0	0.0	0.12069	1.08940	0.03805	0.98619	1.13414	0.00472	0.0	0.00059	0.00531	0.00481	0.00553
0.25461	1.46739	0.0	0.0	0.35319	1.82058	0.06077	1.46768	1.91828	0.00458	0.0	0.00110	0.00568	0.00458	0.00598
0.30583	2.13964	0.0	0.0	1.07208	3.21172	0.08888	2.03595	3.16113	0.00463	0.0	0.00232	0.00695	0.00440	0.00684
0.35682	2.82111	0.0	0.0	2.47834	5.29945	0.12262	2.68269	5.26819	0.00448	0.0	0.00394	0.00842	0.00426	0.00837
0.40787	3.63897	0.0	0.0	6.67509	10.31406	0.16494	3.40854	10.64856	0.00443	0.0	0.00812	0.01255	0.00415	0.01295
0.45899	4.62342	0.0	0.0	15.99221	20.61563	0.21687	4.21185	20.81901	0.00444	0.0	0.01537	0.01981	0.00405	0.02001
0.12655	0.41656	0.13632	0.05842	0.03001	0.64131	0.07235	0.43510	0.44955	0.00510	0.00238	0.00037	0.00785	0.00533	0.00550
0.15186	0.60170	0.20078	0.08130	0.05319	0.93698	0.10421	0.60093	0.62861	0.00511	0.00240	0.00045	0.00796	0.00511	0.00534
0.17718	0.78789	0.27680	0.10706	0.09861	1.27035	0.14187	0.79012	0.87007	0.00492	0.00240	0.00062	0.00793	0.00493	0.00543
0.20250	1.00288	0.36343	0.13330	0.17155	1.67116	0.18537	1.00201	1.15735	0.00479	0.00237	0.00082	0.00799	0.00479	0.00553
0.22782	1.24755	0.46019	0.15971	0.26535	2.13279	0.23506	1.23607	1.51461	0.00471	0.00234	0.00100	0.00806	0.00467	0.00572
0.25315	1.51950	0.56652	0.19442	0.44164	2.72208	0.29095	1.49184	1.96419	0.00465	0.00233	0.00135	0.00833	0.00456	0.00601
0.27848	1.81966	0.68188	0.23167	0.74867	3.48189	0.35302	1.76894	2.52433	0.00460	0.00231	0.00189	0.00880	0.00447	0.00638
0.30382	2.12741	0.80574	0.27186	1.20131	4.40633	0.42039	2.06702	3.22952	0.00452	0.00229	0.00255	0.00936	0.00439	0.00686
0.32916	2.44879	0.93760	0.31520	1.74232	5.44392	0.49387	2.38578	4.07507	0.00443	0.00227	0.00315	0.00985	0.00432	0.00737
0.35454	2.79224	1.07710	0.36185	2.84469	7.07589	0.57405	2.72495	5.49966	0.00436	0.00225	0.00444	0.01104	0.00425	0.00858
0.37988	3.17304	1.22410	0.41183	4.92027	9.72924	0.66110	3.08428	7.82972	0.00431	0.00222	0.00669	0.01322	0.00419	0.01064
0.40527	3.58897	1.37853	0.46513	8.24960	13.68223	0.75522	3.46356	11.25118	0.00429	0.00220	0.00985	0.01634	0.00414	0.01344
0.43068	4.05011	1.54041	0.52169	13.06976	19.18196	0.85662	3.86260	15.99149	0.00428	0.00218	0.01382	0.02029	0.00409	0.01692
0.45611	4.55094	1.70942	0.58135	18.88807	25.72977	0.96517	4.28121	21.94993	0.00429	0.00216	0.01782	0.02427	0.00404	0.02071

Diagrams for a graphical representation of the results can easily be drawn, using the standard excel-functions. Examples can be found in the excel-file “Exampl” in the folder.

A second output file OUT_###.txt is contained in the folder UTANK. It lists several useful hull dimensions and dimensionless parameters for the hull at rest, without additional trimming moment. If the parameter `IROWBL` is different from zero, then additional boundary-layer data will be printed at the end of the file. The file OUT_s01.txt looks like this:

```
*    DSYHS parent model Sysser 1   *
 Geometry defined in: OFFS_s01.TXT

 Hull properties calculated with UliTank
 for details see www.remmlinger.com

 values at rest, without trim in fresh water
 immersed volume canoe body (m3) =  0.376136E-1
 immersed volume fin keel (m3)   =   0.25525E-2
 immersed volume rudder (m3)     =   0.23290E-3
 total mass of the yacht (kg)    =    40.359
 wetted surface canoe body (m2)  =  0.647784
 designed waterline (m)          =    1.608
 maximum beam (m)                =    0.513
 maximum draft (m)               =    0.127
 Cx                              =   0.6394
 Cp                              =   0.5623
 Cwp                             =   0.6780
 LCB in % Lwl behind FP          =   52.128
 LCF in % Lwl behind FP          =   53.152
 half entrance angle bow (deg)   =    7.209
 Rocker angle at stern (deg)     =   19.378
 height longt. metacentre BM (m) =    1.230

boundary-layer data for FN = 0.30
 x dist.to FP  V/shipspeed      C fric    delta1 (m)
       0.000       0.0000          -        0.00000
       0.012       0.7123      0.01256      0.00012
       0.053       0.8398      0.00847      0.00022
       0.103       0.8975      0.00741      0.00032
       0.153       0.9364      0.00689      0.00042
       0.203       0.9653      0.00648      0.00052
       0.253       0.9886      0.00608      0.00061
       0.303       1.0040      0.00570      0.00070
       0.353       1.0160      0.00544      0.00080
       0.403       1.0275      0.00525      0.00089
       0.453       1.0377      0.00507      0.00098
       0.503       1.0463      0.00489      0.00107
       0.553       1.0539      0.00474      0.00117
       0.603       1.0599      0.00458      0.00127
       0.653       1.0645      0.00444      0.00138
       0.703       1.0682      0.00430      0.00149
       0.753       1.0709      0.00417      0.00161
       0.803       1.0727      0.00404      0.00173
       0.853       1.0739      0.00392      0.00187
       0.903       1.0744      0.00380      0.00201
       0.953       1.0749      0.00370      0.00216
       1.003       1.0755      0.00359      0.00232
       1.053       1.0757      0.00349      0.00249
       1.103       1.0751      0.00337      0.00270
       1.153       1.0721      0.00321      0.00297
       1.203       1.0650      0.00300      0.00335
       1.253       1.0526      0.00272      0.00390
       1.303       1.0356      0.00240      0.00472
       1.353       1.0144      0.00204      0.00598
       1.403       0.9900      0.00162      0.00799
       1.453       0.9638      0.00116      0.01146
       1.503       0.9271      0.00045      0.02075
       1.553       0.8853      0.00000      0.03481
       1.603       0.8672      0.00000      0.03481
       1.653       0.8925      0.00000      0.03481
       1.676       0.9047      0.00000      0.03481
```

The b.l.-data is arranged in four columns. The first indicates the distance of the station from the forward end of the actual waterline in x-direction, measured in meters. The next column lists the fraction of the velocity at the outer edge of the b.l. divided by the ships speed. The column `Cfric` shows the skin friction coefficient. A value of zero indicates a separated b.l. In the last column one can find the displacement thickness `delta1` of the b.l. measured in meters. The boundary-layer computation uses an integral method for the equivalent body of revolution [6].

6. EXAMPLES

There are several sheets in the file Exampl.xlsx that compare the predicted and measured resistance values. The corresponding input files are available in OFFSETS and INPUT. The sheets DRAG_s01 to DRAG_s71 compare the results for the DSYHS-models Sysser 01 to Sysser 71. For Sysser 23 the version with the cut off transom is used. This example demonstrates the influence of the transom overhang on the resistance at higher Froude numbers.

For some of the appended Sysser models the published value of the measured resistance at lower Froude-numbers is higher than the predicted resistance. The reason for this discrepancy is the assumption by the Delft-team that the resistance of the sandstrips on the appendages is independent of its position and that the resistance increases linearly with the width of the strip. Close to the nose of the foil this is not true, the parasitic drag is underestimated und the value of the published drag is too high. For the sandstrips on the hull such an assumption is valid, because the velocity gradient along the hull is much smaller than the gradient close to the stagnation point at the foil.

The files OFFS_ghs.txt and UT_ghs_in.txt demonstrate the usage of the GHS format (FORMAT = 3). Sysser 72 was loaded into ProSurf and exported as GHS-file. The resistance results are included in the sheet DRAG_ghs.

An example that uses DELFTship is the monohull of the catamaran Delft 372. The predictions in DRAG_dsh are compared to the tank data. The length of the tank model is 3 meters. Because DELFTship only exports 3 digits after the decimal point, the accuracy of the offsets would be not sufficient. Therefore the hull is modeled in DELFTship with a length of 30 meters and exported via the option “stations”. The parameter SCALE in UT_dsh_in.txt is 30/3 = 10. This compensates the upscaling in DELFTship and the model is back to its original L_{WL} of 3 meters. Even with this manipulation the predicted resistance deviates from the test results. The reason is the lofting method in DELFTship. The hullform that is created from the input data is not really smooth. If instead Rhino is used for the lofting and the creation of the table of offsets, UliTank predicts resistance values that are much closer to the test results.

The sheet DRAG_us5 shows the prediction for the parent model #M5 of the US Sailing Nine Model Series. The sheet DRAG_wlp compares the prediction for the hull of the “Wide-Light-Project” with test results that were published by the SYRF.

The examples show in most cases that the new regression is much better than the old Delft method. If you encounter difficulties that are not covered within this manual you can send me an e-mail at ulrich@remmlinger.com and I will be happy to help you.
Good luck with your computations!

7. REFERENCES

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