

UliTank

Vers. 3.3

User's Manual

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UliTank_3.3.exe was compiled with the Intel[®] Fortran compiler for Windows. When you start it for the first time, new OS (Windows 8 and 10) can 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 your anti-virus software before running it.

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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 3.3 there are no restrictions any more and the resistance can be predicted for the bare or appended hull of a sailing yacht, in the heeled condition and with leeway and sideforce, in the complete speed range up to the Froude-number of 0.8. 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 2.4 uses a few different parameters for the linear regression and gives more robust results than UliTank 2.2 and UliTank 2.3.

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 3.3 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, with and without leeway. As a result of this significant increase in the data, there are now more than 400 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 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. New additional information about the Nine Model Series is described in [8]. The regression applies only to hull forms with a transom, not to double-enders. Predictions are reliable up to a Froude-number of 0.8. The effects of planing are not covered.

2. INSTALLATION OF THE PROGRAM

The zipped file that you downloaded contains the executable files UliTank_3.3-x64.exe, UliTank_3.3-Win32.exe, this manual UTman_3.3.pdf, five subdirectories and the excel-file Examp1.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_3.3.exe. Depending on your Computer, you should use either the 64-bit or the 32-bit version of the program. If x64 doesn't run, try Win32. 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 or deleted. The file Examl.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 the user can chose 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 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 0.3048 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 reads 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  = distance at tank-model in meters / numerical value of this distance in offset-file
1e-3
```

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 numerical value of 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 $1.6/1600 = 0.001 = 1e-3$

```
ZDWL   z-coordinate of the DWL, in the dimension and coordinate-system of the offset-file
124.4
LEK    = x-coordinate of LE keel, in the dimension and coordinate-system of the offset-file
1083.
LER    = x-coordinate of LE rudder in the waterplane, coordinate-system of the offset-file
124.
XFVERT = x-coordinate of additional vertical weight FV, coordinate-system of the offset-file
1120.
```

ZDWL is the z-coordinate of the designed waterline in the offset-file. It is necessary to indicate the position of the DWL, because the rudder-span is defined relative to the DWL. LEK and LER define the position of the leading edge of the appendages. The x-coordinates of these points in the coordinate system of the offset-file must be submitted. For a swept keel or rudder, the uppermost point of the leading edge is taken. XFVERT is the x-coordinate of the position of an additional vertical weight, which is added to the model in the towing tank. For the full size yacht, it is the position of the center of effort of the sails. These four values will be converted in the same way as the coordinates in the point-file OFFS_###.txt, by applying XAXIS, ZAXIS and SCALE.

```
VOLUME = immersed volume of the canoe body (w/out appendages) of the tank model in (m^3)
0.0376136
WATER   1 = fresh water, 2 = seawater with 3.5% salinity
1
ZTOW    = height of towing point in Tank above still water surface in (m)
0.255
XTOW    = distance of towing point in Tank 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} . WATER is an integer number that indicates whether the ship floats in freshwater or in seawater. For a given VOLUME the weight of the model will be larger in seawater. ZTOW is the vertical distance of the towing point above the still water level, measured in meters. The positive distance from the forward end of the designed waterline (forward perpendicular FP) to the towing point in x-direction in meters is named XTOW. For the full size yacht, ZTOW would be the vertical height of the center of effort of the sails above the water-plane, XTOW would describe the same location as XFVERT.

```
VSECTN = factor determines sharpness of the fore-section with keel 0 - 2
2.0
SIDEFR  = factor determines sideforce for bare hull when heeled and pitched 0.1 - 1.0
0.65
RDFLOW  = factor determines changing rudderflow-angle when heeled 0.3 - 0.6
0.24
```

These three factors describe the influence of the hull form on the creation of side-forces. The theory of wing sections [10] offers a straightforward method to calculate the side-forces created by keel and rudder. Since a similar generalized theory for the complex flow around the hull is lacking, empirical correction factors must be used. *VSECTN* modifies the sideforce created by the forebody of the appended hull, depending on the form of the section. A pointed V-section will require a value of two to match the measured force, whereas for a rounded forebody a value of zero could be appropriate. The US Sailing models #1 - #6 are best simulated with *VSECTN* = 1, only the models #7 - #9 with a large area coefficient of the main section require values around 0.2.

When the bare hull heels and pitches, the asymmetry of the submerged body creates a sideforce. The factor *SIDFR* takes this into account, values between 0.1 and 1.0 apply. Another effect of the hull form is the change of the flow angle around the rudder, when the boat heels. In [9] the effect is described, it can even lead to the situation that the flow over the rudder is coming from the “wrong” side. The factor *RDFLOW* shifts the rudder flow to the negative side. In real life, it is not important to know this effect, because the helmsman will automatically position the rudder at the correct angle to get the desired sideforce.

```
APPEND = name of the file that contains the description of the appendages: AP_XXXXX.txt
        AP_DSYHS.txt
ASCALE = Scale of appendages = TFIN at tank-model in meters / value TFIN in AP_XXXXX.txt
        1.
```

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*. The content of this file is described in paragraph 3.4. *ASCALE* allows the scaling of the appendages in the same way as *SCALE* does it for the canoe-body.

```
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. The Nine Model Series uses pins or studs 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.

```
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. The program always calculates the drag of the sand strips or pins and uses these additional forces in the equilibrium of moments.

The drag forces for hull and appendages in the output do not contain the drag of the tripping devices, these are separately listed as *Rvisc-trip*. If the predicted resistance is compared to the measured data of the towing tank, *Rvisc-trip* must be subtracted from the test data, if the raw data is used as in the case of the Nine Model Series. This is not necessary for the DSYHS, as these values are supposedly already corrected.

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. Insert zero for the full size yacht. Next is the 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 in the towing tank see [6], values in the open ocean see [11]. 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 follows. The next column indicates, whether the hull is appended or not. Integer 1 stands for hull with keel and rudder, 0 indicates bare hull only. The leeway angle *delta* and the *rudderangle* are supplied next in degrees. The last parameter is the vertical force *FV* that is additionally applied to the model when heeled with leeway. The positive direction is downward. For the full size yacht with a side force $F_{sail,y}$ and a heelangle φ the vertical force is $FV = \sin(\varphi) \cdot F_{sail,y}$ and the horizontal component of the side force would be $FH = \cos(\varphi) \cdot F_{sail,y}$. The force *Fside*, created by the appendages and listed in the output file, balances this force *FH*.

```

NTEST = number of rows, each row simulates a test point
49
PRINT print forces in Newton = 1; drag area in m^2 = 2; coefficient based on wet surface = 3;
                                           Delft regression = 4
1
one row per testpoint. Speed in m/s; external trimming moment in Nm - bow down is positive;
water temperature in degrees Celsius; turbulence level in %; additional vertical weight FV
                                           in N - down is +
Xtrip= distance of active trip from FP in mm; heel, delta and rudderangle in degrees; appended
                                           yes=1

```

Speed	Trimmoment	Ttank	Tu%	Xtrip	heel	append	delta	rudderang.	FV
0.39807	0	17.3	2.00	500	0	0	0	0	0
0.59712	0	17.3	1.20	260	0	0	0	0	0
0.79620	0	17.3	1.88	260	0	0	0	0	0
0.99531	0	17.3	1.51	20	0	0	0	0	0
1.19547	0	17.3	1.25	20	0	0	0	0	0
1.39468	0	17.3	1.08	20	0	0	0	0	0
1.59396	0	17.3	0.94	20	0	0	0	0	0
1.79333	0	17.3	0.84	20	0	0	0	0	0
1.99281	0	17.3	0.75	20	0	0	0	0	0
2.19247	0	17.3	0.68	20	0	0	0	0	0
2.39254	0	17.3	0.63	20	0	0	0	0	0
0.99531	1.4	17.3	1.51	260	0	0	0	0	0
1.19547	2.9	17.3	1.25	20	0	0	0	0	0
1.39468	4.3	17.3	1.08	20	0	0	0	0	0
1.59396	8.6	17.3	0.94	20	0	0	0	0	0
1.79333	17.2	17.3	0.84	20	0	0	0	0	0
1.99281	28.6	17.3	0.75	20	0	0	0	0	0
2.19248	38.7	17.3	0.68	20	0	0	0	0	0
2.39255	43	17.3	0.63	20	0	0	0	0	0

The parameter PRINT specifies the form in which the data will be printed in the file DRAG_####.txt. The resistance R can be put out directly in Newtons (1) or in form of a drag area DA (2) with the dimension m^2 or as a dimensionless coefficient C (3). PRINT = 4 replaces the regression method of UliTank with the Delft regression [3]. The computations of the resistance- and sideforce-values according to the Delft method are supplied to enable a comparison with the UliTank-method.

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
SWEEP sweep angle of fin-keel at 1/4-cord-line in degrees
  45.0
```

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, which is defined as the section area divided by chord and max. thickness. This coefficient can be calculated from the data in [10], but for the input in UliTank the numbers were slightly tweaked to match the given volumes of the tank-models. TFIN is the draft of the fin-keel from the bottom of the canoe-body to the tip of the keel at the trailing edge, measured at a right angle to the designed waterplane. SWEEP is the sweep angle of a straight line 25% behind the leading edge of the keel, measured against the vertical.

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 inserted. 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.

```
KSTYPE keel foil section type: 63 = NACA 63(2)A015, 64 = NACA 64(2)A013, 00 = NACA0012
63
```

KSTYPE defines the section-shape of the keel. Integer 63 defines the section NACA 63₂A015 as used in the DSYHS. Integer 64 refers to the form NACA 64₂A013, which is used by the US Sail series and 00 designates the NACA 0012 profile. The lift and drag coefficients for these foil sections were calculated with the program XFOIL [7] as a function of the Reynolds-number for the given thickness ratio. The position of the trip at model size as described in the raw-data files of the tank tests was inserted into XFOIL. For HATRIP = 0, a full size ship is assumed with no tripping device and XFOIL was calculated with natural transition. If the

thickness ratio at full size differs from the one of the above profiles used in the tank tests, then a correction is applied to the lift and drag coefficients of the original tank section profiles.

```
* Standard rudder DSYHS *
DXCOGR distance COG to LE rudder (m)
0.0613
TRUD draft of rudder from DWL (as defined by ZDWL) to tip, at right angle to w.plane (m)
0.266
SWEEPR sweep angle of rudder at 1/4-cord-line relative to waterplane in degrees
5.5
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
RSTYPE rudder foil section type: 63 = NACA 63(2)A015, 64 = NACA 64(2)A013, 00 = NACA0012
00
```

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 (which is defined by the parameter ZDWL), 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.

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_3.3.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):

```
"C:\Users\Uli\Documents\Visual Studio 2013\Projects\UliTank_2.0\UliTank_2.0\Release\UliTank_2.0.exe"
*****
* 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. 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. In the file `EXAMPL 3.3.xlsx` you will find the converted version of `DRAG_s01.txt`. For your convenience I have added in the upper part of the excel-file the input data that can be copied and inserted into the input file `UT_s01_in.txt`. In the first column of the output is the value of the Froude-number, based on the actual trimmed L_{WL} . If `PRINT` is set to 1, the next five columns show the viscous-, keel-, rudder-, residuary- and total-resistance values in Newtons, 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 raw data of 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. The definition of the above resistance components is given in [5].

New in `UliTank 3.2` was the addition of `Fside` and pitch-angle. Depending on heel and leeway the flow around hull and appendages creates a sideforce. `Fside` is its horizontal component at right angle to the direction of travel. The pitch-angle in degree is predicted from a separate regression analysis. It should be regarded as a first estimate, bow down is negative.

When `PRINT` is set to 2, the dragarea DA in m^2 is printed instead of the resistance forces. For `PRINT = 3` dimensionless coefficients C are printed. With boatspeed V , water density ρ and wetted surface A_{wet} the definitions are:

$$DA = \frac{R}{\frac{1}{2} \cdot \rho \cdot V^2} \qquad C = \frac{R}{\frac{1}{2} \cdot \rho \cdot V^2 \cdot A_{wet}}$$

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 “Exempl” in the folder.

For PRINT = 4 the program circumvents the UliTank-modul and calculates the forces by the Delft-method. As the Delft-method does not consider the deflection of the rudder, a line in the program was added to calculate the additional sideforce of a deflected rudder, following classical wing theory. This sideforce FS rudder is listed separately and the user can decide on the inclusion.

A second output file OUT_###.txt is contained in the folder UTANK. It lists several useful hull dimensions and dimensionless parameters for the upright hull at rest, without additional trimming moment. The file OUT_s01.txt looks like this:

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

Hull properties calculated with UliTank 3.3
for details see www.remmlinger.com

values upright at rest, without trim in fresh water
immersed volume canoe body (m3) = 0.376136E-1
immersed volume fin keel (m3)   = 0.25484E-2
immersed volume rudder (m3)    = 0.23290E-3
total mass of the yacht (kg)   = 40.341
wetted surface canoe body (m2) = 0.647777
waterplane area (m2)          = 0.558297
waterline length (m)          = 1.608
maximum beam in waterplane (m) = 0.513
maximum draft canoe body (m)  = 0.127
maximum draft with keel (m)   = 0.346
Cx                             = 0.6394
Cp                             = 0.5623
Cwp                            = 0.6780
LCB in % Lwl behind FP        = 52.128
LCF in % Lwl behind FP        = 53.152
Rocker angle aft end DWL (deg) = 19.378
```

6. EXAMPLES

Several sheets in the file Examlp 3.3.xlsx compare the predicted and measured resistance values. The corresponding input files are available in OFFSETS and INPUT. The sheet Sysser#1 compares the results for the DSYHS-model Sysser 01.

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 sand strips on the appendages increases linearly with the width of the strip. Based on this, they measure at Delft the resistance with sand strips of 40mm width and again with 20mm width and extrapolate the resistance to zero strip width. Close to the nose of the foil with the steep velocity gradient close to the stagnation point, a linear extrapolation is not possible. The parasitic drag is underestimated und the value of the published total drag is too high. The curve “DA trip” in the diagram for the appended hull in the excel-sheet “Sysser#1” shows, that the “error” in the prediction is about a quarter of the resistance of the sand strips, which matches the higher velocities around the nose of the foil. Most likely the predicted total resistance is closer to reality than the measured and “corrected” value. With Sysser#25 one can even observe a flow separation at the strips for the large leeway angles. This is a well-known phenomenon from

wind-tunnel tests with ice accretion on airfoils. For the sand strips on the hull a linear assumption is allowed, because the velocity gradient along the hull is small.

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 excel-sheet “ghs”. Sysser#72 is the only Delft-model without sand strips and boundary-layer-transition occurs naturally. With UliTank it is easy to demonstrate that the resultant viscous resistance depends heavily on the turbulence level in the tank. Varying turbulence levels that can be caused by short and varying waiting times between test runs will lead to significantly varying test results and bad repeatability.

An example that uses DELFTship is the monohull of the catamaran Delft 372. The predictions in “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 $3/30 = 0.1$ This compensates the upscaling in DELFTship and the model is back to its original L_{WL} of 3 meters.

The sheet “USSAIL#5” shows the prediction for the parent model #M5 of the US Sailing Nine Model Series. The sheet “wlp” compares the prediction for the hull of the “Wide-Light-Project” with test results that were published by the SYRF. “USSAIL#6” is an example of the computation for a full size yacht in seawater, driven by the sailforce at the center of effort.

The sheet “C40” shows the predictions for a fictitious Class 40 yacht. A full size yacht of 12 meter length is simulated. It is a test for the robustness of the simulation/prediction, because this hull form is clearly outside of the model-series of the database that was used in the regression analysis.

The examples show in most cases that the new regression is much better than the old Delft method. UliTank will predict the forces within $\pm 10\%$ of the test results. In the excel-sheet USSAIL#5 you can find a detailed comparison with the results of the Delft-method. It is obvious, that the Delft-method is only applicable for models of the DSYHS. For US#5 the prediction fails.

If you encounter difficulties that are not covered within this manual, feel free to send me an e-mail at ulrich@remmlinger.com and I will be happy to help you. I appreciate every kind of feedback.

Good luck with your computations!

7. REFERENCES

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