

A Quick Introduction to MAAT Hydro's NURBS++ Hull Modeling

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NURBS++ MODELING:

1. Why Modeling ?

MAAT Hydro is a versatile hydrostatic solver designed for working in synergy with most of the existing 3D surface / BREP modelers.

Nevertheless, among the last decade, it became obvious that a significant part of the hydrostatic works were still starting from paper drawings instead of 3D BREP models, so that an easy and direct input of these ship lines in MAAT Hydro was more and more awaited, especially for transforming and / or checking the compliance of old ships.

Moreover,in its earliest stages, the hull design work is so inextricably linked to the hydrostatic analysis that integrating a set of highly specialized hull modeling tools within MAAT Hydro also became a growing need.

At last, the MAAT 2000 users will also appreciate recovering their favorite NURBS++ hull modeling tools within the user-friendly MAAT Hydro environment, which allows creating very compact models and, therefore, dramatically shorten the response times !

2. From NURBS to NURBS^{++}:

NURBS modeling has now become the standard technique for lofting free forms. Nevertheless, although it is extremely easy and intuitive to control 3D lines and surfaces geometry by moving their NURBS control points / vertices, it may become surprisingly time consuming, especially for creating ship's manufacturing master model or, more simply, any time accurate geometric constraints must be combined with free forms, which is unfortunately so common in the marine field.

On this basis, Sistre has specially implemented the NURBS mathematics into a 'NURBS^{++}' mathematics in order to allow exploiting fully the greatpotential of NURBS in the hull design field, from the first hull sketch to its final master model.

Any NURBS^{++} model is, therefore, as portable as a NURBS model, the only difference being how you can control model's geometry:

NURBS^{++}modeling simply provides much more than control points and vertices for controlling hull's geometry faster, intuitively and more accurately.It combines 3 distinct modeling tools:

- NURBS^{++} Line modelling
- NURBS^{++} Surface modeling

- NURBS^{++} Strip* modelling

As a result of more than 30 years experience in the hull design field, Sistre's NURBS^{++} modelling provides one of the most sophisticated combinations of hull design specific know how with the well-knownNURBS industry standard.

* Strips are hybrid entities specially introduced by Sistre to make the link between Lines and Surfaces easier and more intuitive.

3. NURBS^{++} Line Modeling:

3.1 Preliminary:

Although you can skip this part if you are already familiar with 3D modelling, it is important to clarify the concept of continuity before drawing any line.

Any line you may have to draw is generally a piecewise object (i.e. an assembly of simple geometric elements sharing common extremity constraints) although it isconnex:

By example, a polygon is an assembly of simple segments sharing common extremities on which direction changes: The polygon vertices.

As polygon legs only share the position of their common extremities (without sharing a common tangent), this continuity is said to be positional and noted G0, C0 or D0, according to the order of the common derivative.

The corners of a rectangle therefore typically have a positional continuity… but 'rounding' these corners will also allow sharing a common tangent, so that such 'rounded' joints will be said to be tangent continuous and noted G1, C1 or D1, according to the order of the common first derivative.

Moreover, according to the continuity of bending moments on spline supports, spline arcs also share common curvatures on their extremities, in addition to common tangents and positions, so that spline arcs are said to be curvature continuous and noted G2, C2 or D2, according to the order of the common second derivative.

In MAAT Hull, line continuities are simply represented by their color and associated to shortcuts:

- Continuity: Positional ([P] shortcut)
- Continuity: Tangent ([T] shortcut)
- Continuity: Curvature ([K] shortcut)

Although higher continuity orders would be easily managed, the Positional, Tangent and Curvature continuities are, in practice, the only ones currently necessary for NURBS^{++} modelling.

At last, in connexion with the continuity concept discussed above, it is also important to notice that using piecewise geometric objects provide an efficient way to control the incidence of local modifications on the complete line.As this topic will be extensively illustrated below, we will just give a few examples:

- Moving a polygon vertex only modifies the linked legs.
- Moving a spline knot only modifies the surrounding arcs.
- Moving aBézier arcvertex modifies it completely.
- Depending on knot's multiplicity orders, moving a NURBS control point may modify more than the linked arcs.

3.2 Presentation of the NURBS^{++}Line Modes and Tools:

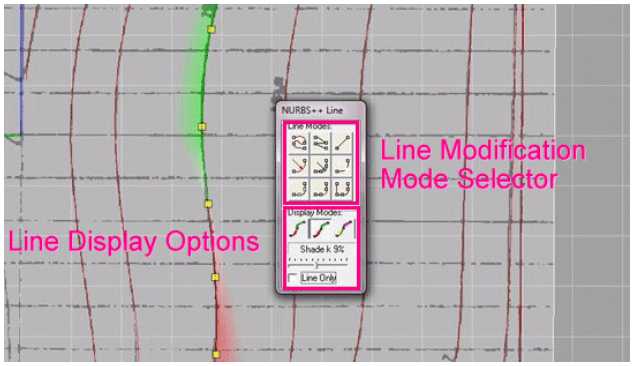
NURBS modeling provides a single unified way to represent polygons, splines, circles and Bézier arcs.

Nevertheless, in practice, accessing fully to this NURBS versatility is not always easy, so that you may often have to strugglewith knot's weights, multiplicity orders, etc... for obtaining the geometry you are looking for…

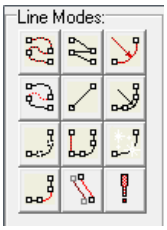
3D modeling software therefore generally provide various utilities for hidingthis powerful but abstract mathematics, in orderto make it easier to control in the concrete cases.

In MAAT Hydro, the 'NURBS^{++} Line'toolbox provides such tools, according to ship designer's most usual needs.

When a line is activated (i.e. double clicked in the 3D browser or in any 3D viewport), its knots color represent their associated continuity and the 'NURBS^{++} Line' toolbox pops up, providing the NURBS^{++} line drawing tools (button's popup hints will make you familiar with their shortcuts):



The upper frame contains theline modification mode selector, which allows choosing how tomodifycurrent arc's geometry:



Notice that line's last modification mode and active arc is automatically pre-set when it is re-modified, unless it has never been modified yet:In this case, the 'Default'line modification mode is set, so that the line will remain frozen until a modification mode will be selected.

The available 'Line Modes' buttons are the followings (when possible, their shortcut correspond to their image):

- ([s][Enter]) This button allows entering in the ‘Spline’modification mode, which allows setting the current arc as a spline arc. Associated options will be discussed below

-  ([z][Enter]) This button allows entering in the ‘Polygon’ modificationmode, for setting the current arc as a polygon arc.

-  ([c][Enter]) This button allows entering in the ‘Circle’ modificationmode, which allows setting the current arc as a circle arc.

- ([&][Enter]) This button allows blending the current arc ‘naturally’ (i.e. without passing through its intermediary knots).

-  ([/][Enter]) This button allows entering in the ‘Segment’ modificationmode, which allows setting the current arc as a segment.

- ([r][Enter]) This button allows entering in the ‘Fillet’modification mode, for setting the current arc as a fillet (bi-tangent circle) arc.

- ([a][Enter]) This button allows ‘Approximating’ the current arc, which means removing unnecessary knots and re-approximating the concerned arcs according to a given tolerance. By defaut this approximation tolerance is 1mm, but it can be specified after the ‘a’ shortcut if necessary (i.e. type [a][0][.][0][1][Enter] for re-approximating the line with a 0.01m tolerance).

-  ([+][Enter]) This button allows ‘Appending’ additional legs to the the current line, which means clicking additional knots before the first one or after the last one (right click to end). The first or the last knot must therefore be selected before appending additional legs, otherwise a warning box will popup..

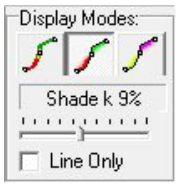
-  ([*][Enter]) This button allows entering in the ‘Fairing’ modificationmode, which allows setting current arc’s fairness, in terms of curvature variation.

-  ([-][Enter]) This button allows ‘Trimming’ the current arc, which means splitting the current line in 3 adjacent arcs according to the currently selected arc (useless when no arc is selected).

-  ([“][Enter]) This button allows Cloning the x, y and / or z coordinated of any external line into the current arc.

- ([!][Enter])This button allows resetting the line to its initial state.

At last, the lower ‘Display Mode’ frame allows selecting the most appropriate fairness control mode for the current line:



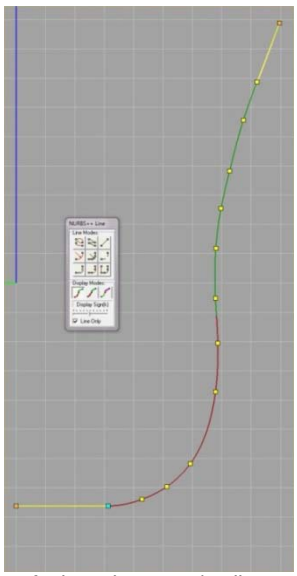
The 3 upper buttons allow selecting how the curvature distribution will be rendered:

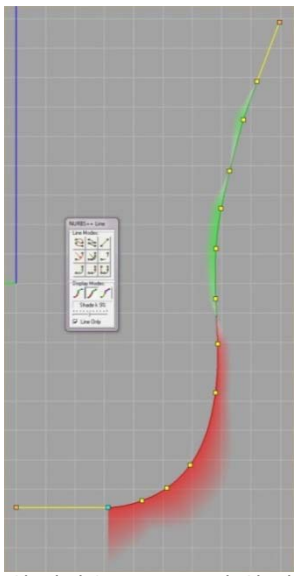
- Displays the active line in the red-convex / yellow – straight / green – concave mode.
-  Displays the active line with its curvature shading (shaded porcupine), according to the current sensivity set on its track bar (see below).
- Displays the active line with its curvature variation(∂k/∂s)shading, according to the current sensivity set on its track bar (see below).
- 

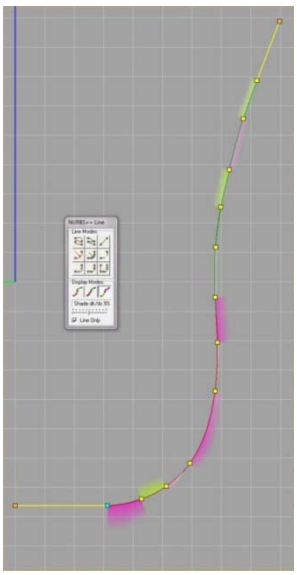
Allows setting the scanning sensivity and is, therefore, frozen for the default red-yellow-green mode. Moreover, in order to cover a wider strength range, slider’s scale is not linear.
- 

Allows showing the active line with or without the others, according to its status.

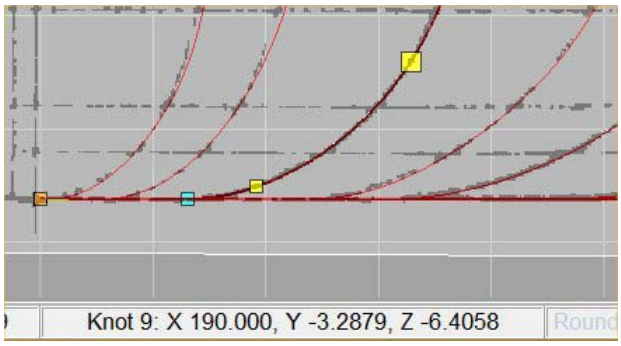
These display modes look like this:


Default Red-convex / Yellow–straight / Green–concave mode


Shaded Curvature Mode


Shaded Curvature Variation (∂k/∂s) Mode

Once these line toolbox is displayed, you can click on any knot to select it: It will be magnified and its number / coordinates will be displayed in the status bar:



Knot's color code is the following:

- Positional Continuity
- Tangent Continuity
- Curvature Continuity
- Natural Extremity (zero curvature spline extremity)

Notice that you can also type directly knot's number followed by [Enter] to select it directly from the keyboard keyboard (i.e. type [1] [Enter] to select knot [1] directly)and that it can be de-selected by clicking in any void area (in a 3D viewport or in the 3D browser).

Moreover, once a line knot is selected, you can keep the [Shift] key pressed while clicking another knot in order to restrain line's active arc on which the selected functions will operate. Notice that this can also be done from the keyboard, by typing arc limit's numbers separated by [,] and followed by [Enter] to select the arc directly from the keyboard (i.e. type [1][,][5][Enter] to select line's arc [1, 5]).

Conversely, hitting the [Backspace] key will reset line's active arc to the full line (this will be discussed and illustrated in the following example).

3.3 Copying Ship’s Stations from a Background Bitmap:

Copying ship’s stations from a paper body plan seemed to be the most useful way to illustrate how simply the various ‘NURBS^{++}Line’ tools can answertomost of ship designer’sline drawing, copying and fairing needs.

We will therefore start by importing and calibratinga scanned body plan in the MAAT project before copying the stations.

3.3.1Loading and calibrating the Background Bitmap:

Assuming that ship's body plan has been preliminarily scanned in a bitmap file, we will import it in the MAAT project as '3D Bitmap' object, which will be calibrated and associated to a 3D quadrangle.

Such '3D Bitmap' objects can be created by selecting a parent folder in the 3D browser and 'New Bitmap' in the right click popup menu.

A 'bmp' file must, then, be selected (the 'bmp' format is the only one supported for the moment), before anchoring, stretching and orienting bitmap's final 3D quadrangle.

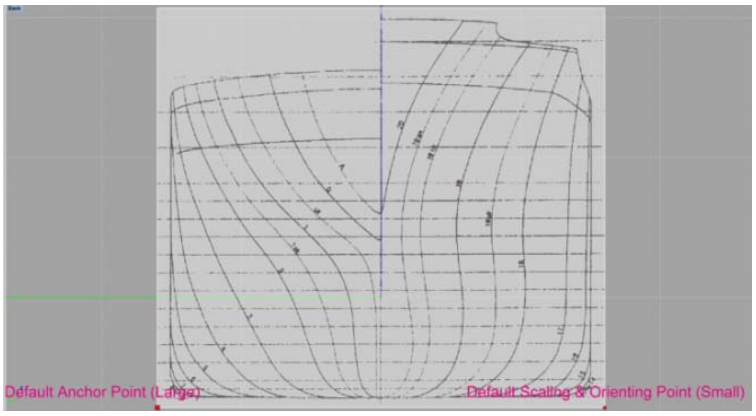
Bitmap's initial dimensioning is not important, given that an accurate calibration will be done right after, by clicking 2 remarkable pixels whose 'world' coordinates are known and will be entered.

The following procedure will illustrate this operation and initializethe ship lines copy:

- Run MAAT andmaximize the 'Back' viewfrom its title menu to display the body plan view only.
- Select 'My Project' as bitmap's parent in the 3D browser, right click and select 'New Bitmap' in the popup menu.
- Select the '/Bitmaps/BulkCarrierBodyPlan.bmp' file in the file selection dialog box ('bmp' format is the only one available for the moment. Please notice that the bitmap data will be encoded in the MAAT Hydrofile so that, although they will be compressed,project's file size may significantly increase when the bitmap is heavy).
- As soon as the bitmap file is loaded, enter bitmap's lower left corner by clicking a roughly estimated point in lower left part of the 'Back' viewport. Once entered, this lower left point becomes the anchor point from which bitmap's initial size will be stretched by entering a second point.
- Enterthis second pointby clicking in the 'Back' viewport in order to pre-set body plan's size roughly.
- This new initial and roughly sized bitmap appears in the 3D browser and the 'Back' viewport. Please, notice that this 3D object can be viewed in any other viewport.
- Click on this newly created bitmap in the 3D browserto selectit (or click on its frame in any 3D viewport): Two red points will then appear:

- The large (lower left) red point is bitmap's anchor point.

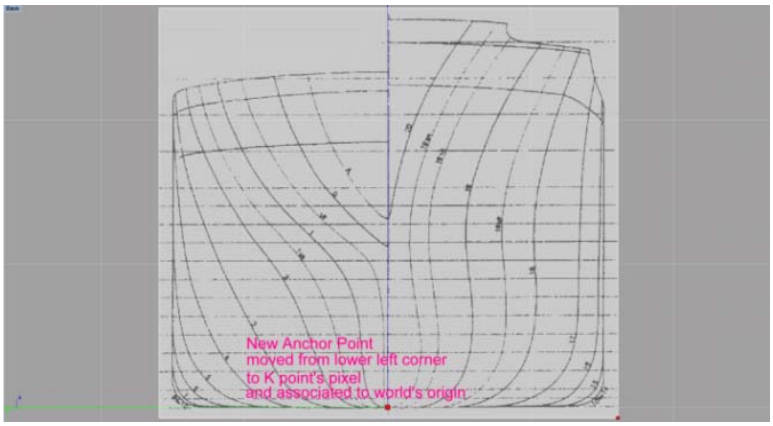
- The small (lower right) red point is bitmap's scaling / orienting point.



When these scaling points are displayed (notice that you can pan and zoom the bitmap before and during its calibration):

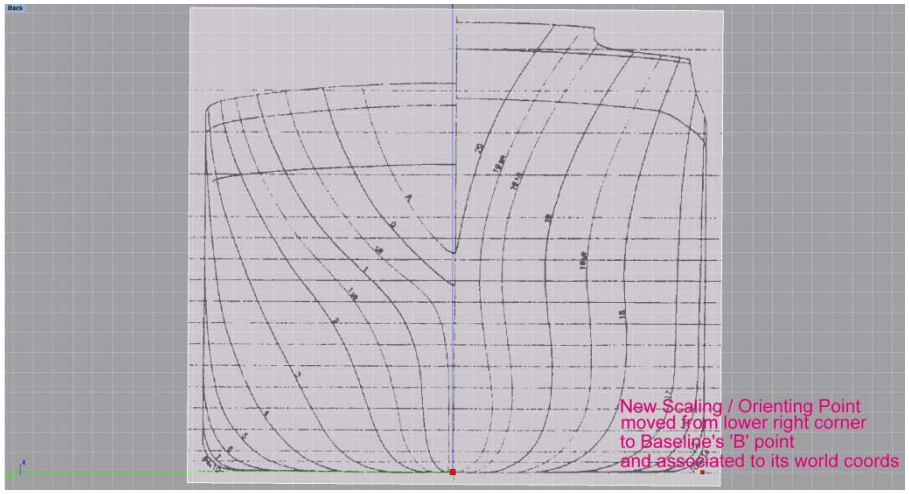
- Click on the large lower left point (anchor point) and, while keeping the left mouse button pressed, drag it onto theK point pixel, whose 'world' coordinates are known (0,0,0). It is important to stress that keeping the left button pressed allowsdragging the anchor pixel onto another pixel, whilereleasing the button allowsentering its associated world coordinates. Then, without keeping the left mouse button pressed, bitmap's anchor pixel will not be dragged to its desired position (K point's pixel), so that it will remain on its initial (lower left) pixel.

- Once the mouse button is released, anchor point's new pixel is registered, and follows cursor's 'world' coordinates in real time to offset the bitmap, until you click again or type its "world" coordinates directly. In this case, we will simply type [0][,][0][,][0][Enter] to offset the selected bitmap pixel to the world origin:



- Once bitmap's anchor point is correctly set, click on the small lower right point (scaling / orienting point), and, while keeping the left mouse button pressed, drag it onto baseline's 'Bmax' pixel, whose 'world' coordinates are known (0,-12.5, 0). Like for bitmap's anchor point, it is important to notice that keeping the left button pressed allows moving the point onto another pixel before entering its associated world coordinates, otherwise it will remain on its initial (lower right) pixel.

- Once the left mouse button is released, scaling / orienting point's new pixel is registered, so that its 'world' coordinates will follow the mouse cursor in real time, until you click or type its 'world'position. In this case, we will simply type [0][,][-][1][2][.][5][,][0] [Enter] to offset the selected bitmap pixel to these world coordinates. The bitmap is now fully calibrated and we can move mouse's cursor on it to control the word coordinates of any pixel in the status bar:



- Once calibrated, rename the bitmap 'Body Plan' in the 3D browser.

- Please notice that, when anchor or scaling point's pixel doesn't need to be modified, you just have to brieflyclick on it(don't keep the left button pressed) to set its 'world' coordinates directly.

- You can repeat this bitmap calibration procedure as often as necessary. Moreover, 3D bitmaps can also be transformed as any geometric object thanks to menu bar's '/Transform' functions.

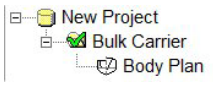
- You can create as many bitmaps as necessary, on any canonicview,and switch them 'on' or 'off' by a double click in the 3D browser.

- At last, abitmap can also be immediately reversed by selecting it in the 3D browser and typing [-][Enter] (useful for entering fore and aft stations on the same view, as shown below).

If necessary, this calibrated bitmap can be loaded directly from the '\DemoFiles\Bulk Carrier Example 0.m2a' demo file.

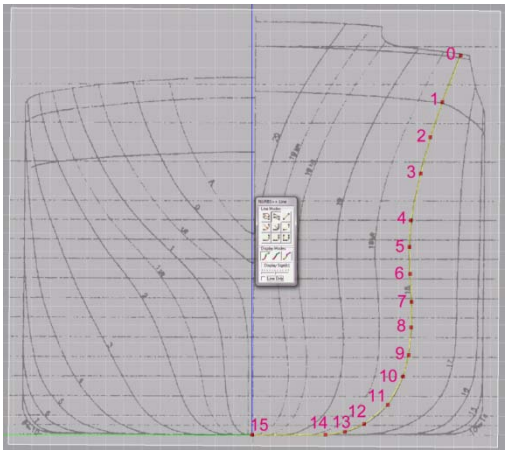
3.3.2Drawing a polygonal Station:

Ship's body plan bitmap now appears as a planar object in the 3D viewports, while the 3D browser contains a 'Bitmap' object named 'Body Plan':



Let us now start by copying station 18, whose composite geometry is a good starting point:

- Select '/Line/Polygon' in the menu bar.
- Left click on station 18's upper extremity pixel (remember that you can simultaneously zoom with the mousewheel and pan with the right button when the viewport has the focus). Once done, the clicked extremity becomes the anchor vertex of a 'rubber polygon'.
- Similarly, from top to bottom, enter as manyvertices as necessary for copying the station accurately (16 vertices numbered from 0 to 15 in our example), until the final keel point has to be entered.
- Finally, in order to insure that keel point's coordinates are appropriate, we can type [0][,][0][,][0][Enter] directly instead of left clicking this last point.
- Once done, right click to finish polygon's acquisition. Here are the16 polygon knots wehave entered:



Once the polygon knots have been entered, the 'NURBS^{++}Line' tool box pops up and the line automatically enters into the Polygon Modification Mode ('Polygon Mode' is displayed in the command line and toolbox's polygon button is pushed).

Clicking on a knot, as well as entering its number,willmagnify it to show that it is selected (its coordinates are displayed in the status bar), while clicking in a void area will de-select it, as explained above.

If necessary, the knotselection can also be incremented by pressing the [↑] key or decremented by pressing the [↓] key.

Selecting a knot is therefore the simplest way of controlling its coordinates in the status bar, butit also allows ofsetting them in various ways:

- In the ‘Polygon’, ‘Spline’, ‘Segment’ or ‘Circle’ mode, you can keep the left button pressed for draggingthe selected knotto a new position: The polygon, spline or circle will will be updated in real-time.

- Enter knot’s coordinatesdirectly in the *x*[,]*y*[,]*z*[Enter] format, like we did previously for the keel point or the bitmap calibration ([0][,][0][,][0][Enter] by example).

- Fix any knot coordinate individually in the [x]x[Enter], [y]y[Enter] or [z]z[Enter] format ([z][0] [Enter] by example).

- Reverse any knot coordinate in the [-][x][Enter], [-][y][Enter] or [-][z][Enter] format ([-][y] [Enter] by example).

- Scale any knot coordinate in the [x][*]xratio[Enter], [y][*]yratio[Enter] or [z][*]zratio[Enter] format ([y][*][-][1] [Enter] by example).

- Offset any knot coordinate in the [x][+]xoffset[Enter], [y][+]yoffset[Enter] or [z][+]zoffset[Enter] format. Please, notice that you cannot type negative offsets directly: [x][-][1][Enter] would fix x coordinate to -1, as explained above, so that you would have to type [x][+][-][1][Enter] for offsetting x by -1.

- Get the best knot coordinate (in terms of energy) in the [x][?][Enter],[y][?][Enter] or [z][?][Enter] format([y][?][Enter] by example).

- Drag the knot inthe line to a specific coordinate in the [2][x]xcoord[Enter], [2] [y]ycoord[Enter] or [2] [z]zcoord[Enter] format([2][z][7][Enter] by example). Please, notice that the dragging area is limited by the previous and following knot, if any.

Moreover, the selected knot can also be ‘slided’in the line by hitting the [←] / [→] keys (like everywhere, keeping the [Shift] key simultaneously pressed makes larger increments end keeping the [Ctrl] key pressed makes smaller increments).

At last, any selected knot can be removed by hitting the [Delete] keyand new knotscan be inserted by keeping the [Insert] key pressed while clicking the line on knot’s target position.

Most of these knot operations will be used thereafter in order to illustrate how easily they can help solvingany fairing problem.

If necessary, this initial polygon can be loaded directly from the ‘\DemoFiles\Bulk Carrier Example 1.m2a’ demo file.

2.3.3 Fairing the polygonal station:

After having briefly presented how the NURBS^{++} knots can be set, let us now-put this into practice forfairing this raw polygonal model.

Then, let us click first on the Spline button (or type [s][Enter]) to switch from the initial ‘Polygon’ mode to the ‘Spline’ Mode and transform this raw polygon into a smooth curve.

You can notice that the original line remains displayed in white behind the current line, providing a comparison reference as long as the modification is not finished.

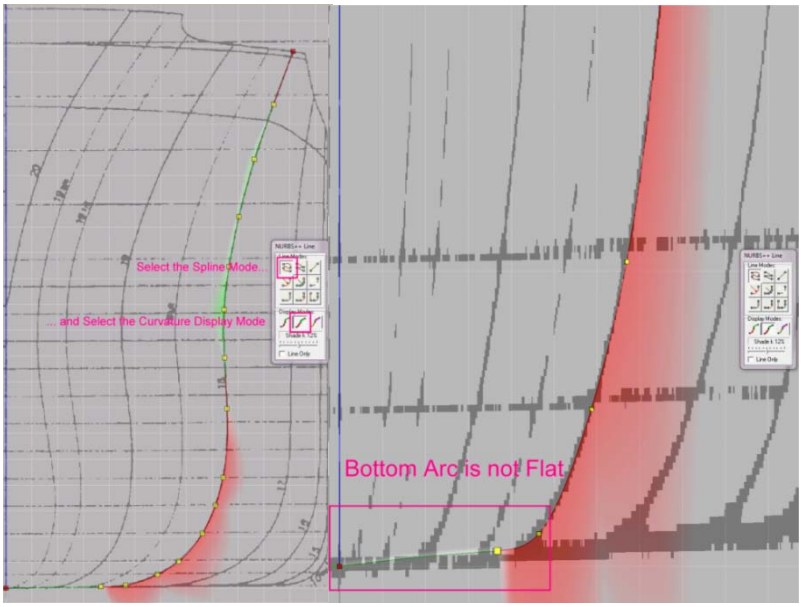
Moreover, polygon’sinternal red knots havealso become yellow, showing that spline’s internal knots have a curvature continuity instead of the original positional continuity.

If necessary, hitting the [Esc] key cancels the current line modifications, while the [Enter] key validates them.

In addition, let us also select the ‘curvature shading’ mode in the ‘Display Mode’ frame and, if necessary,adapt the scanning sensivity with the track bar located below the button.

This line is obviously smoother than the initial.

Nevertheless, moving the cursor in the viewport with mouse’s right button and [Alt] key pressed will shorten line’s isotropic view in order to magnify bottom’s unfairness:



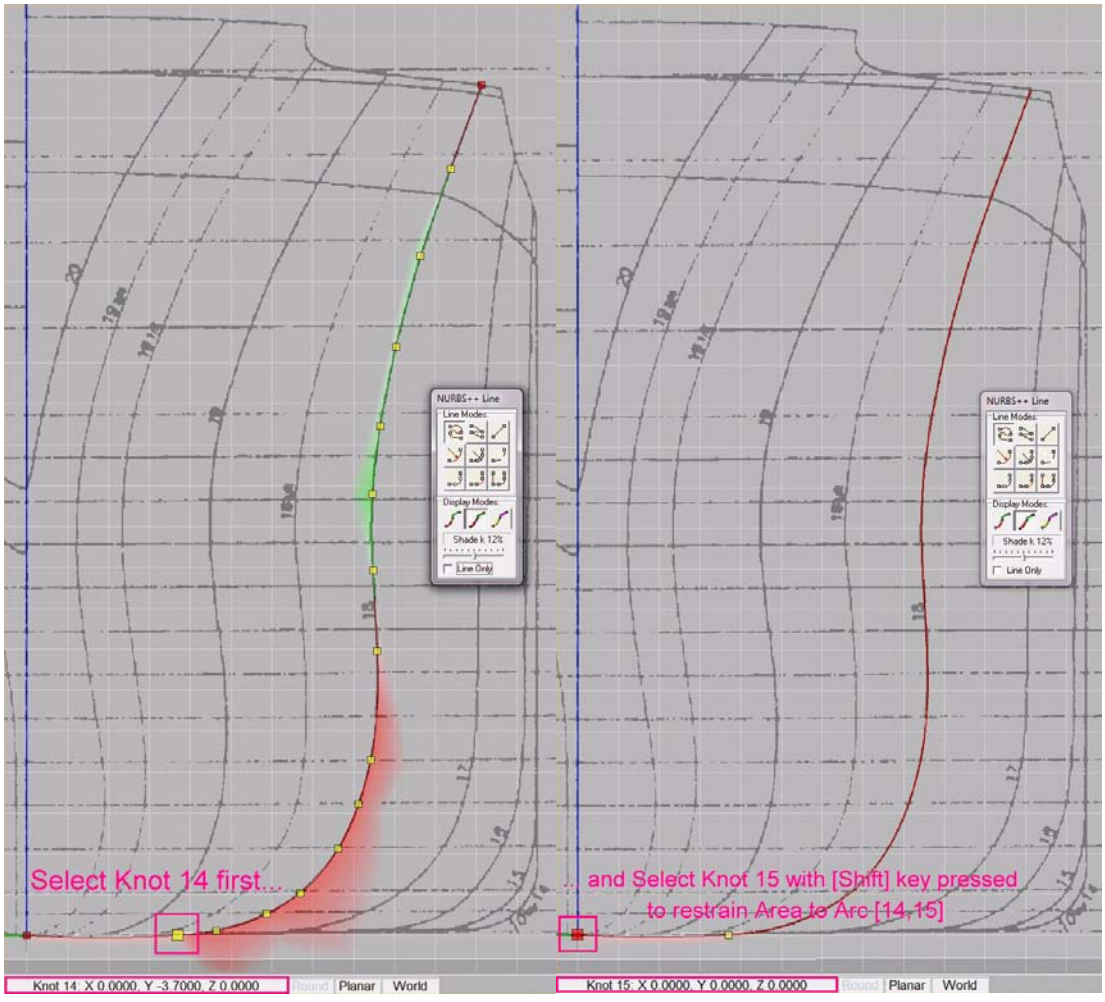
We can set spline’s knot 14 in anyposition by dragging it freely with mouse’s left button down (or, by example, directly type [0][,][-][3][.][7][,][0][Enter]) but, in no case,this will allow us to flatten the bottom arctotally, as expected.

Once this problem is clearly identified, re-select the ‘Back’ view in viewport’s menu, for returning to the isotropic view.If not done yet, wecan now understand that the line we are looking for is composite, i.e. made of 2 distinct areas which must therefore be defined separately,in 2 distinct steps:

- Define the flat bottom area.
- Blend the upper arcwiththis flat area with a tangent continuity.

We will therefore start byflattening the bottom arc [14, 15].

For restraining line’s active area to arc [14, 15], we will first click on knot 14 to select it and, while keeping the [Shift] key pressed, click on knot 15:Line’s active area is immediately restrained to arc [14, 15] (shaded area is restrained to arc [14, 15] and all the other knots are hidden):



Remark: The same resultwould have been obtained by selecting knot 15 before knot 14.

Now that only the [14, 15] bottom arc is active, the simplest way to flatten it is to constrain its z coordinate to 0 by typing [z][0][Enter].

Let us here notice that, if any knot was selected when typing [z][0][Enter], it would have been only modified instead of the current arc. It is therefore a good habit to check this point before executing such a command, or keep the [Shift] key simultaneously pressed for modifying the current arc unconditionally.

Alternatively, it would also have been possible to enter in the ‘Polygon’ mode by clicking on the button before setting knot 14’s height to 0.

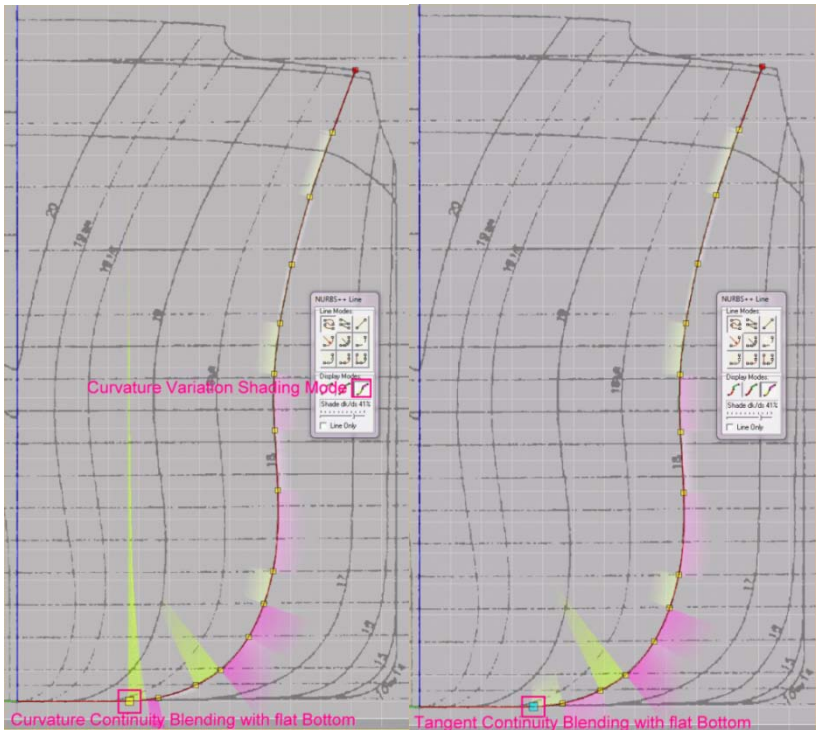
At last,entering in the ‘Segment’ mode by clicking on the button or typing [/][Enter], would also have been equivalent in this case: Once segment’s pivot is selected, you can directly type [0][Enter] to set its slope to 0° or hit the [Page Up] / [Page Down] keys to increment / decrement segment’s slope (like usual, keeping the [Ctrl] or [Shift] key simultaneously pressed will provides smaller or larger increments).

Once the bottom arc is flattened, we can return to the complete line by hitting the[Backspace] key and, then, select arc [1, 14] like we did for arc [14, 15] (click on knot 1 and, then, on knot 14 while keeping the [Shift] key pressed).

In order to magnify the incidence of blendingknot’s continuity on spline’s arc, we will first turn the line shading mode to’Curvature Variation’ (∂k/∂s), which is the hardest criterion.

The default curvature continuityof knot14 (yellow dot □)obviously causes a strong curvature variation in arc [13, 14].

We can therefore click on knot 14 to select it and type [t][Enter] to turn its blending continuity to tangent (blue dot □): The curvature variation in arc [13, 14] becomes significantly lower, which normally corresponds to a smoother geometry.



Just for practice, you can also control the incidence of various continuities on this blending arc:

Type [P][Enter] fora Positional Blending (■)
Type [N][Enter] for a ‘Natural' Extremity (■)
Type [T][Enter] for a Tangent Blending (■)
Type [K][Enter] for a Curvature Blending (■)

Notice that setting the continuity of the internal knots is ignored, as spline arc-sare necessarily curvature continuous (C2).

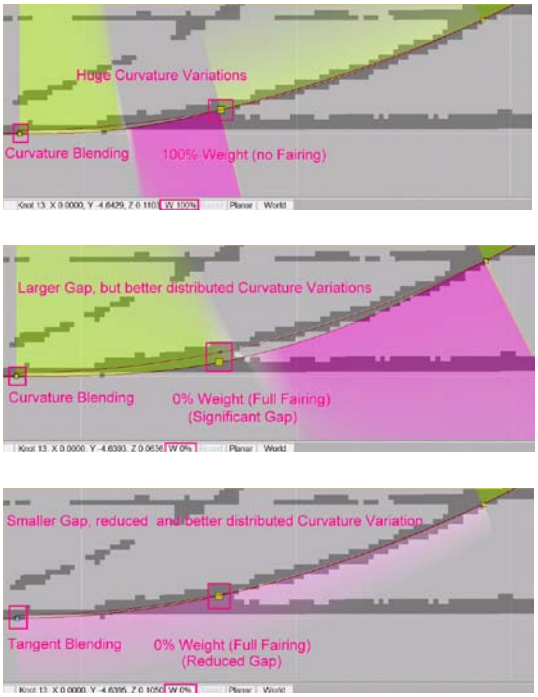
If necessary, you can also select this blending knot and hit the [←] / [→] keys for ‘sliding’ it incrementally in the line (like usual, keeping the [Ctrl] or [Shift] key si-multaneously pressed will provides smaller or larger increments).

Moreover, assuming that the blending knot must reach line’s y = -3.5 point, we would simply type [2][y][-][3][.][5]to do it.

Although we have seen that it is not the best option, we willselect the blending knot and type [k][Enter] to set its continuity to‘curvature’.

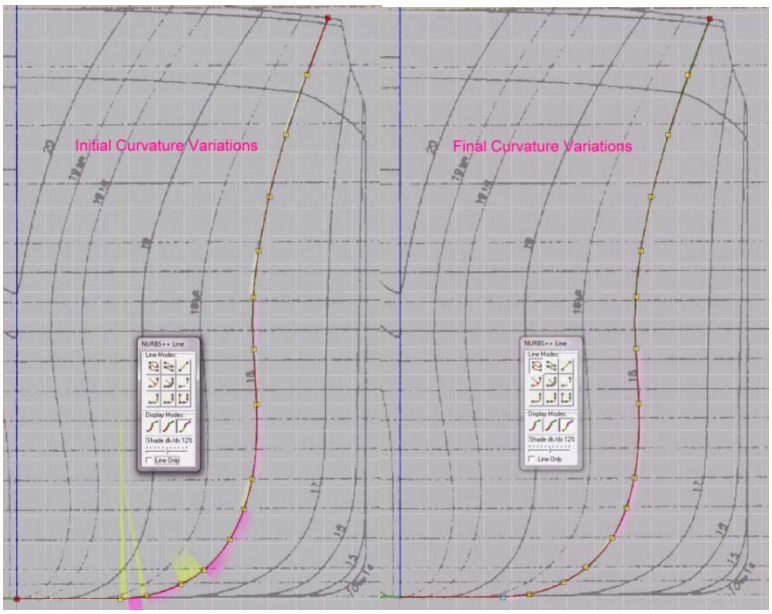
In order to spread thegreater curvature variation on a larger area (assuming that we are still in the ‘Spline’ mode), we will click on knot 13 to make it selected, then zoom in this area and hit the [Page Down] key several times to decrease knot 13’s weight, as shown in the status bar (like usual, keeping the [Ctrl] or [Shift] key simulta-neously pressed will provide smaller or larger increments).

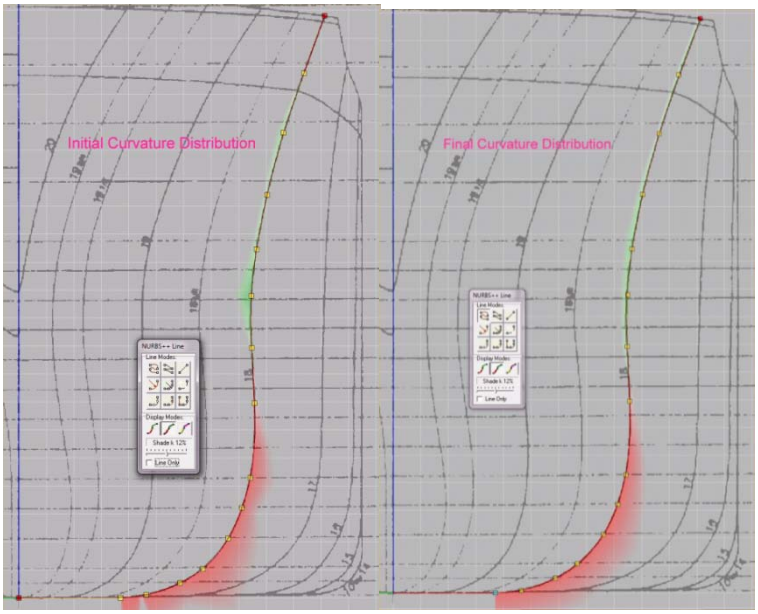
Finally, according to the excessive gap between this faired curvature blending and bitmap’s original line, we will click again on knot 14 to select it and type [t][Enter] to return to the previous tangent continuity.Blending now looks fair and matches more tightly with the bitmap line:



Now that the flat area / curved area transition seems to be smooth enough, we might also want to adjust certain upper knots in order to fair the rest of the line.

But, in order to see how MAAT Hull can do thisautomatically, let us release similarly the weight of knots 9, 5, 3 and 1 to 0% (full fairing). To do this, select each of these spline knots and hit the [Page Down] key until knot's weight reaches 0% in the status bar:Once done, line's fairnessshould be significantly improved, while staying fairly close to the original drawing. Getting a better result by dragging the knots manually mightcertainly be longer and more difficult.





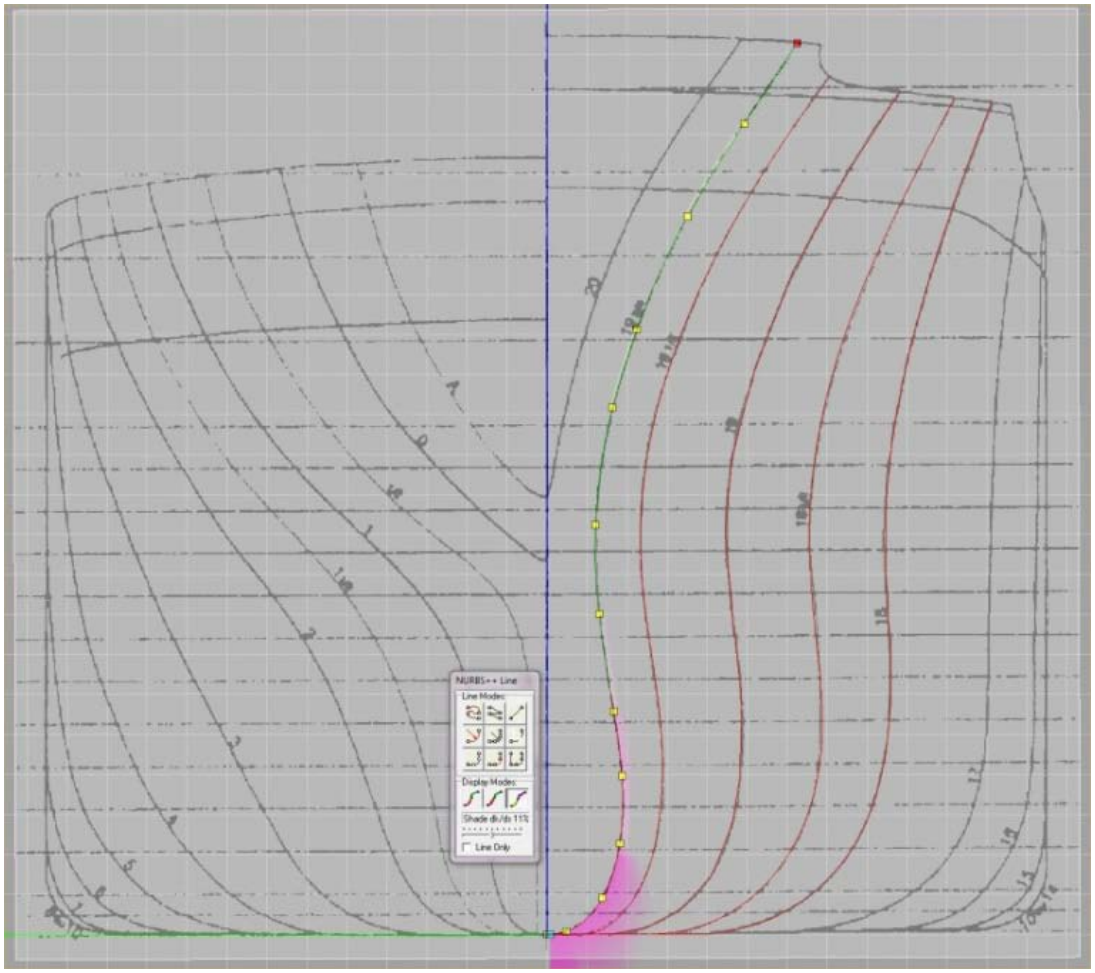
Assuming that this station is now satisfactory, we can hit the [Enter] key to validate it, and rename it 'Sta 18' in the 3D browser.

If necessary, this first line can be loaded directly from the '\DemoFiles\Bulk Carrier 2.m2a' demo file'.

2.3.4 Entering Stations 18.5, 19, 19.5 and 19.75:

Finally, we can now repeat this procedure as a training for copying stations 18.5, 19, 19.5 and 19.75 similarly.

Once these stations will be entered and faired, the lines should look like this:



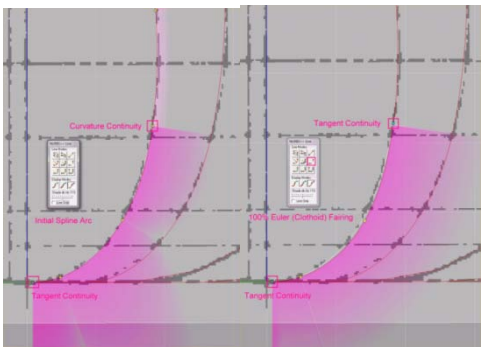
If necessary, these lines can be loaded directly from the '\DemoFiles\Bulk Carrier 3.m2a' demo file'.

2.3.5 Additional Fairing of Station 19.75's foot:

Because of its locally strong curvature, the spline fairing of Station 19.75's foot may need to be improved, so that we should have to use a stronger fairing tool: The Euler / Clothoid Fairing.

As this fairing tool is strong, we will only use it for station's foot and select thisarc before clicking on the fairing button or typing [*][Enter].

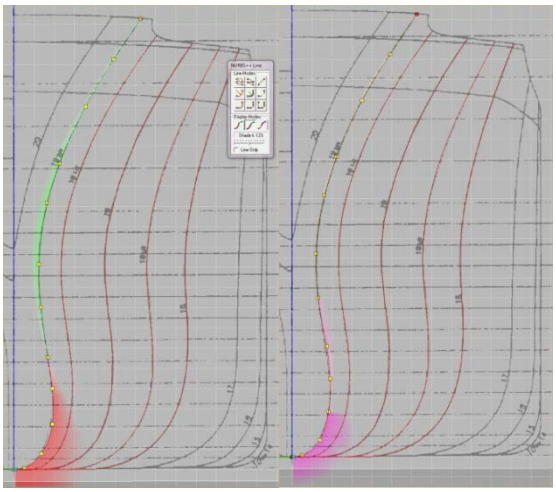
Once selected, the [Page Up] [Page Down] keys allow increasing or decreasing the Euler fairing strength (as everywhere, keep the [Shift] or [Ctrl] key pressed for larger or smaller increments in necessary).



Nevertheless, this higher quality fairing has a cost: According to Euler fairing's nature, only the tangent continuity can be maintained at the extremities.

Once station foot's arc has been faired, we can hit the [Back Space] key to return to the complete line and control the result.

Then, we will just have to select station's upper arc and click on the Spline button (or type [s][Enter]) to return to the 'Spline' Mode and blend the upper area with the lower faired area:



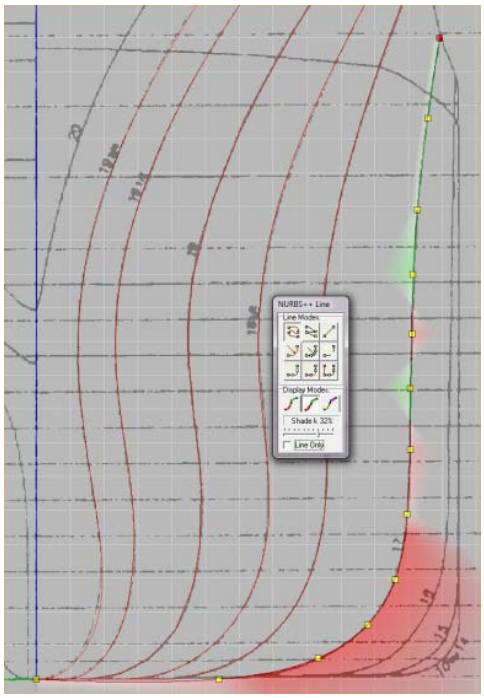
If necessary, these lines can be loaded directly from the '\DemoFiles\Bulk Carrier 4.m2a' demo file'.

2.3.6 Copying and Fairing Station 17:

Although station 17 would have been copied like the previous ones, we will do it here in another way,just forintroducing other fairing possibilities:

This time, we will start by selecting '/Line/Spline' in the menu bar, instead of '/Line/Polygon' and click a dozen of spline knots on station's bitmap, from top to down. Once the last point has been entered, right click to exit the knot acquisition mode and enter directly in the spline modification mode.

Depending on the knots you have entered, line's curvature shading should more or less look like this:



A first glance shows that spline's curvature alternates above and below 0 in the upper area and that the flat bottom arc is not flat.

First of all, we will therefore select the keel point and type [0][,][0][,][0][Enter] to fix its coordinates accurately, if not done yet.

Afterwards, while keeping the [Shift] key pressed, we will click on the other bottom knot, in order to restrain the active area to the bottom arc, like done previously.

Once done, we will switch to the 'Segment' mode by clicking on the button or typing [/][Enter]: The bottom arc immediately becomes straight.

After having selected the keel point as pivot, we can press the [Page Up] / [Page Down] keys up and down to rotate the current segment around this pivot (like everywhere, keep the [Shift] or [Ctrl] key pressed for larger or smaller increments).

Alternatively, you can also type [0][Enter] to set segment's slope directly to 0°.

Notice that the adjacent blending of current segment will follow its slope according to the current continuity, which can be modified whenever.

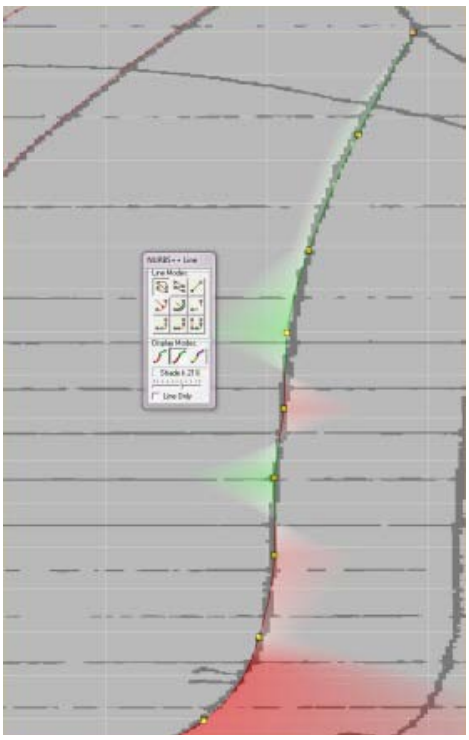
This can be verified by selecting this blending knot and typing [k][Enter] for a curvature continuity, [t][Enter] for a tangent continuity, or [p][Enter] for a positional continuity.

We will finally type [t][Enter] for a tangent continuity and re-select the keel point before typing [0][Enter] for settingan horizontal bottomarc and blending it with a tangent continuity.

Once done, we can hit the [Backspace] key to return to the complete line and notice, in the tool box, that this has also reset the modification mode to the default one, which freezes the line as long as no mode is selected.

Now that the bottom arc is accurately defined, we want to remove the upper curvature oscillations. We will therefore, like previously, select the upper arc by clicking its knot limits and, then, click on the button (or type [s][Enter]) to return to the spline mode in which the line will no longer be frozen.

In order to magnify these oscillations in an anisotropic view, we can keep the [Alt] keypressed and mouse's right button down while moving the cursor up:



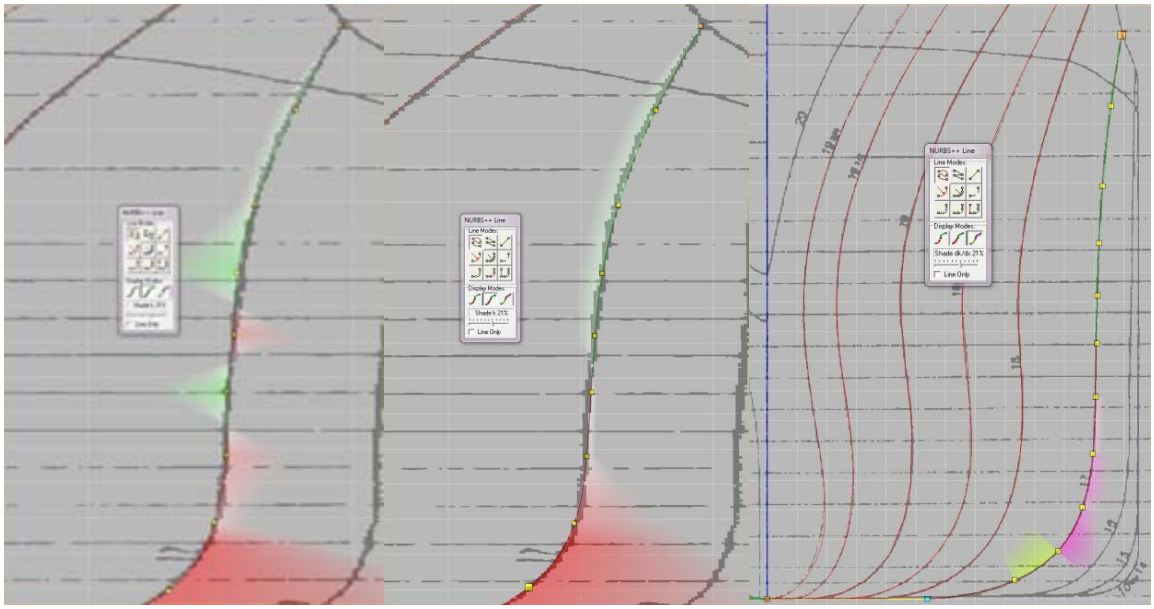
Although we mightfair this area by decreasing spline knot's weight like previously, we will illustrate alternative procedures here:

The first alternative consists in selecting the upper knot located on the largest bump andtyping [y][?][Enter] to get its best y coordinate in terms of bending energy.

Once done, the curvature distribution should be improved on the ‘released’ knot and you can repeat this operation on other ‘bumped’ knots until you get the fair curvature distribution you are looking for.

We may also have to repeat this operation on lower knots where, if necessary, typing [z][?][Enter] will allow releasing the z coordinate instead of y.

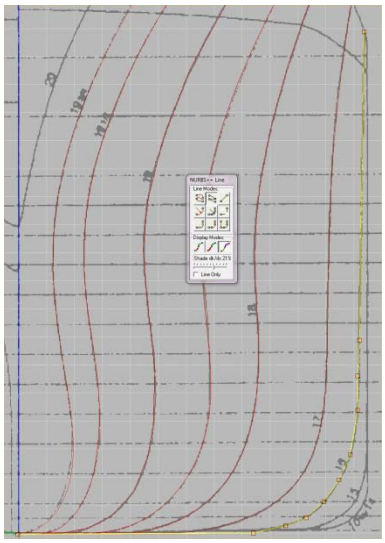
Comparing the final curvature distribution with the initial one shows a significant improvement (select the ‘Back’ view in 3D viewport’s menu for returning to the isotropic view):



If necessary, these lines can be loaded directly from the ‘\DemoFiles\Bulk Carrier 5.m2a’ demo file’.

2.3.7 Copying and Fairing Station 16 and 15:

Station 16 has a straight upper area and a large flat bottom, so that we will select '/Line/Polygon' to sketch it as a 11 knots polygon (first and last polygon legs will, then,directly define the straight areas).



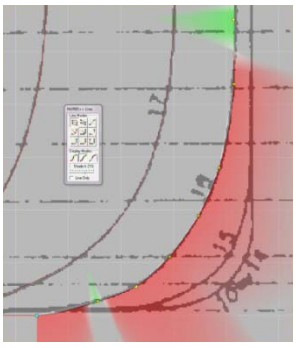
Once done, we will select the bottom arc [9, 10] and type [z][0][Enter]to flatten it in the z=0 plane.

When done, hit the [Backspace] key to re-activate the full line, select arc [1, 9] and click on the button (or type [s][Enter]) to switch to the spline mode for fairing the bilge arc.

As the default blending continuities still remain positional (red knots), we click on knot 1 and type [k][Enter] to turn it to a curvature continuity (yellow knot).

Similarly, we also click on knot 9to select it and type [t][Enter] to turn it to a tangent continuitycontinuity (blue knot).

.



Before starting bilge's fairing process, let us assume that we first want to:

- See if the bilge arc may have a circular part or not.
- Fix the bilge limits (i.e. knots 1 and 9) more accurately.

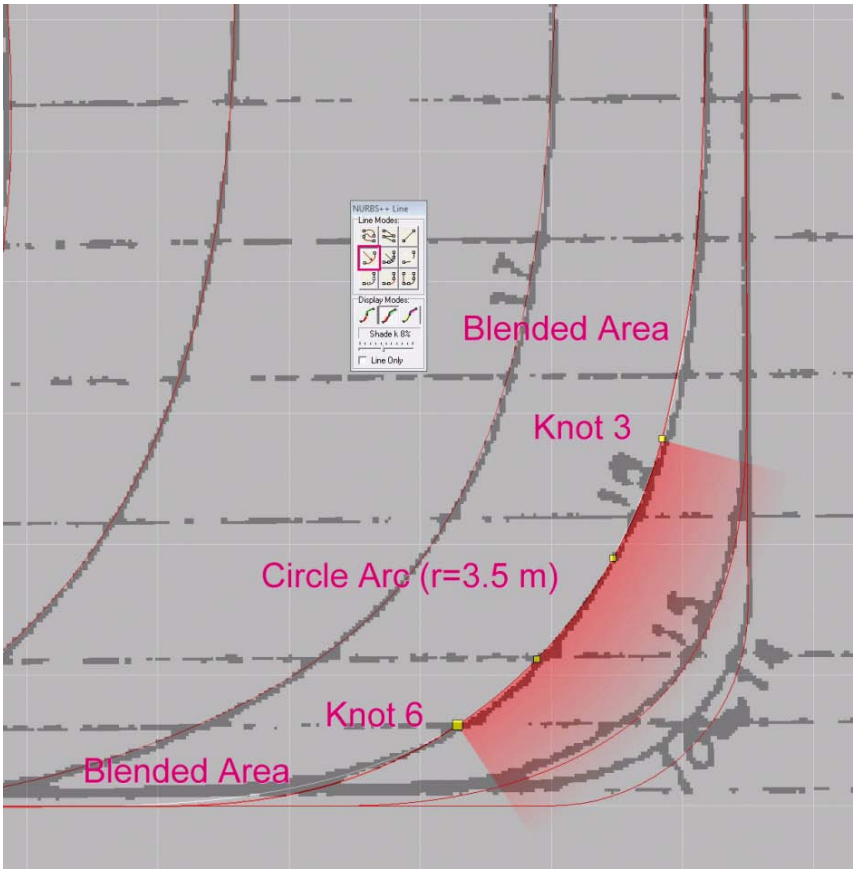
In order to see if the bilge can be approximated by a circle (mostly for introducing the ‘Circle’ modification mode), we will select arc [4, 7] like we did for the previous arcs and click on the  button (or type [c][Enter]) to switch to the ‘Circle’ mode.

Arc’s circle approximation is thendisplayed, so that it can be compared with the background bitmap and the white original line (current radius and tangents are displayed in the status bar).

In this ‘Circle’mode, you can drag any arc knot to set its radius in real time, hit the [Page Up] / [Page Down] keys to increment / decrement it(like everywhere, keep the [Shift] or [Ctrl] key pressed for larger or smaller increments).

Moreover, you can also type the radius or curvature directly on the keyboard whenever necessary.By example, type [r][3][.][5][Enter] to set a 3.5 m radius or or [k][0][Enter] to set a straight (zero curvature) arc.

While setting arc’s radius, you will notice that the adjacent arcs are blended in real time according to the current blending continuities (curvature), which can also be modified like previously whenever necessary.



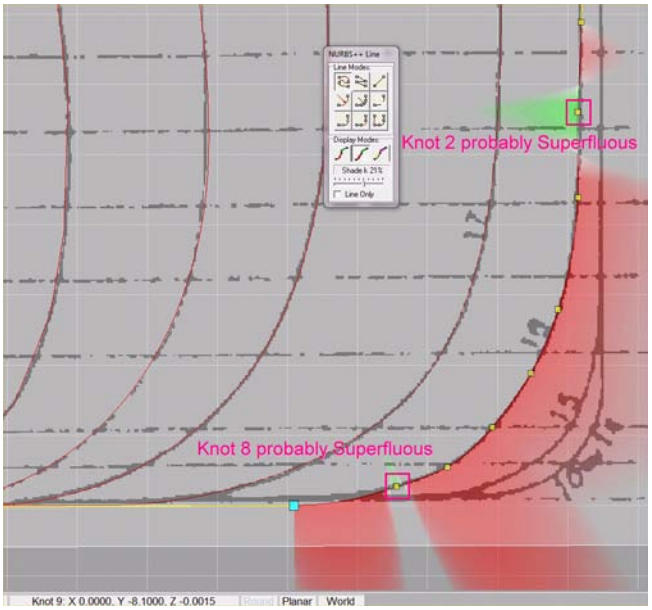
Assuming that this circle approximation is not satisfactory, we will hit [Ctrl][z] as many times as necessary to undo these circle operations and return to the initial spline arc [1, 9].

For moving the bilge limits, just hit the [Backspace] key to re-activate the full line, and select arc [1, 9] again.

Once done, click on knot 1 to select it, notice its coordinates in the status bar and hit the [←] / [→] keys to drag knot 1in the line (keep [Shift] or [Ctrl] key pressed for larger or smaller increments).

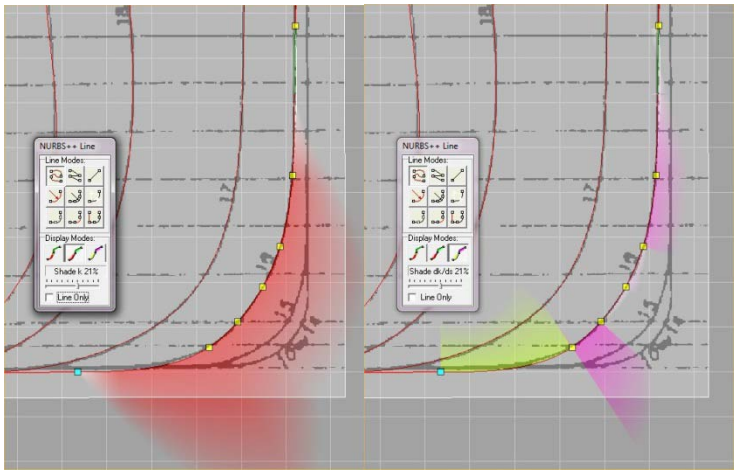
Assuming that we finally want to drag knot 1 to a specific height (let's say z=7m), type: [2][z][7][Enter] when knot 1 is selected.

Similarly, select knot 9 and drag it to y=-8m by typing: [2][y][-][8][Enter].

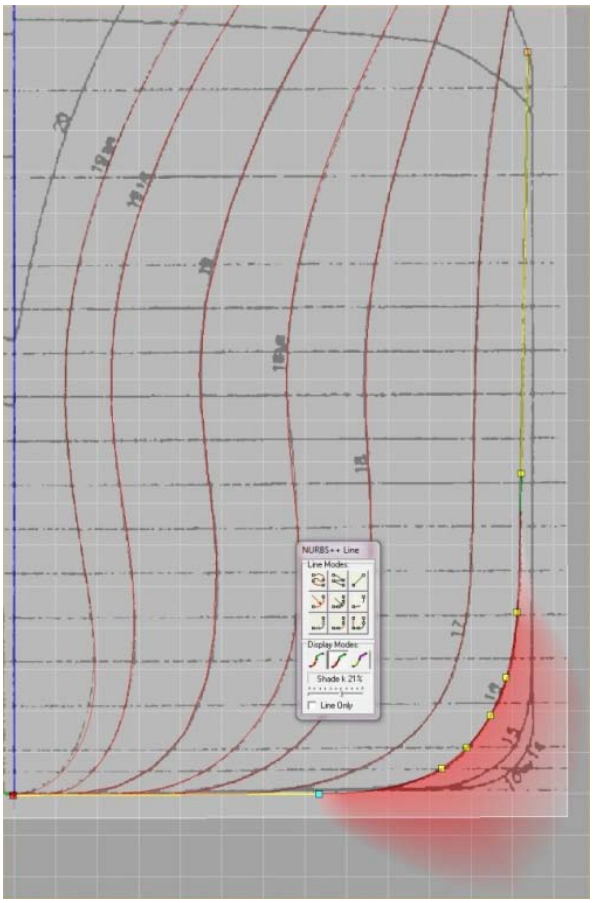


As the curvature distribution shows that knots 2 and 8 seem to be useless, let us select knot 8 first, hit the [Delete] key to remove it and repeat this operation on knot 2.

Assuming that the bilge arc (now [1, 7]) is always selected,click on the  button or type [s][Enter] to refresh the blending arc:



At last, we can decrease knot's weights and release their coordinates like previously to removebilge's residuaryunfairnesses:

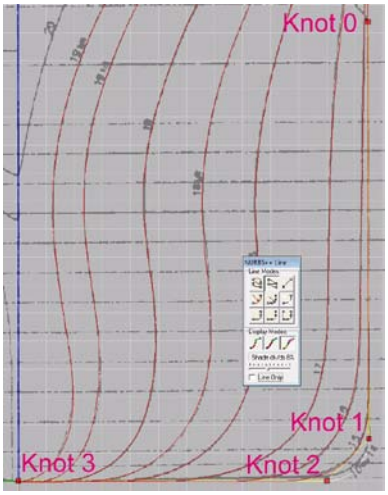


Finally, this procedure can be repeated for copying station 15 in a similar way, except that its vertical side arc will be flattened to y = -12.5 by selecting arc [0, 1] and typing [y][-][1][2][.][5].

If necessary, these lines can be loaded directly from the '\DemoFiles\Bulk Carrier 6.m2a' demo file'.

2.3.8 Copying and Fairing Station 14:

Station 14 has a so simple definition (vertical side + constant 1.5 m radius bilge + horizontal bottom) that it can be created very directly.Entering a 4 knots polygon,from top to down, will therefore be only necessary here. Once these 4 knots are entered, right click to exit the input loop and get the line modification toolbox:



Once displayed, select arc [0, 1] by clicking on knot 0 and, then, on knot 1 while keeping the [Shift] key pressed and type [y][-][1][2][.][5][Enter] to flatten this side arc in the y = -12.5 plane.

Press the [Backspace] key to return to the complete line and select arc [2, 3] by clicking on knot 2 and, then, on knot 3 while keeping the [Shift] key pressed. Similarly, type [z][0] [Enter] to flatten this bottom arc in the z = 0 plane.

Once displayed, press the [Backspace] key to return to the complete line, select arc [1, 2] by clicking on knot 1 and, then, on knot 2 while keeping the [Shift] key pressed.

Click on the  button or type [s][Enter] for switching to the spline mode, but the straight arc will not change as long as the adjacent continuities remain positional (■red knots).

In order to set a curvature (□ yellow knot) bilge-side continuity, we will click on knot 1 to select it and type [k][Enter]: The bilge arc is now curvature blended (C2) with the vertical side.

Similarly, we will set a tangent bilge-bottom continuity (□ blue knot) by selecting knot 2 and typing [t][Enter].

The fairness of resulting bilge arc now depends on position of knots 1 and 2.

In order to use an additional knot to control bilge's geometry, keep the [Insert] key pressed while clicking the bilge arc in the middle: An intermediary knot is inserted, which you can drag for controlling bilge's camber.

Nevertheless, using a spline blending for approximating a circle arc is somewhat dissatisfying, as it is inaccurate and time consuming.

Clicking on the button for switching to the ‘Circle’ mode would directly create a circular area, as seen previously, but the adjacent arcs would be modified according to the current arc tangents, so that it wouldn’t be finally easier to use…

This is therefore thereason why ‘Fillet’ mode has been included in the ‘NURBS^{++} Line’ toolbox:

Once the fillet arc [1, 3] is selected, you can therefore click on the button or type [f] [Enter] to switch to the ‘Fillet’ mode:The current arc is immediately approximated by a tangent circle arc, whose points of tangency are automatically updated according to the current radius, which is displayed in the status bar with the associated tangents.

Like for the ‘Circle’ mode, you can hit the [Page Up] / [Page Down] keys to increment / decrement the radius (keep the [Shift] or [Ctrl] key pressed for larger or smaller increments) and you can also type the radius or curvature directly on the keyboard whenever necessary.

Nevertheless, it is important to notice that, depending on the starting data, creating a fillet arc approximation is not always possible.

Concerning this station, whose bilge radius is 1.5 m, we will simply have to type [r][1][.][5][Enter] to get the expected arc (notice that we might have simply typed[1][.][5][Enter]).

Once done, we can hit the [Backspace] key to reset station’s active area.

Finally, as the inserted knot 2 is now useless, we would be able to select it and hit the [Delete] key to remove it, like explained above.

But, nevertheless, it must be noticed that, alternatively, MAAT Hull can automatically detect and remove such useless knots by clicking on the  approximation button, which is convenient when such knots are numerous (especially for re-approximating heavy imported lines).

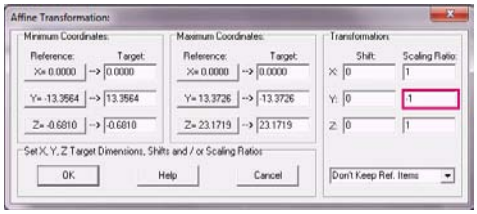
The default approximation tolerance is 0.1 mm, but you can specify any other value whenever necessary, by typing [a]tolerance[Enter] (the zero tolerance is ignored).

If necessary, these lines can be loaded directly from the ‘\DemoFiles\Bulk Carrier 7.m2a’ demo file’.

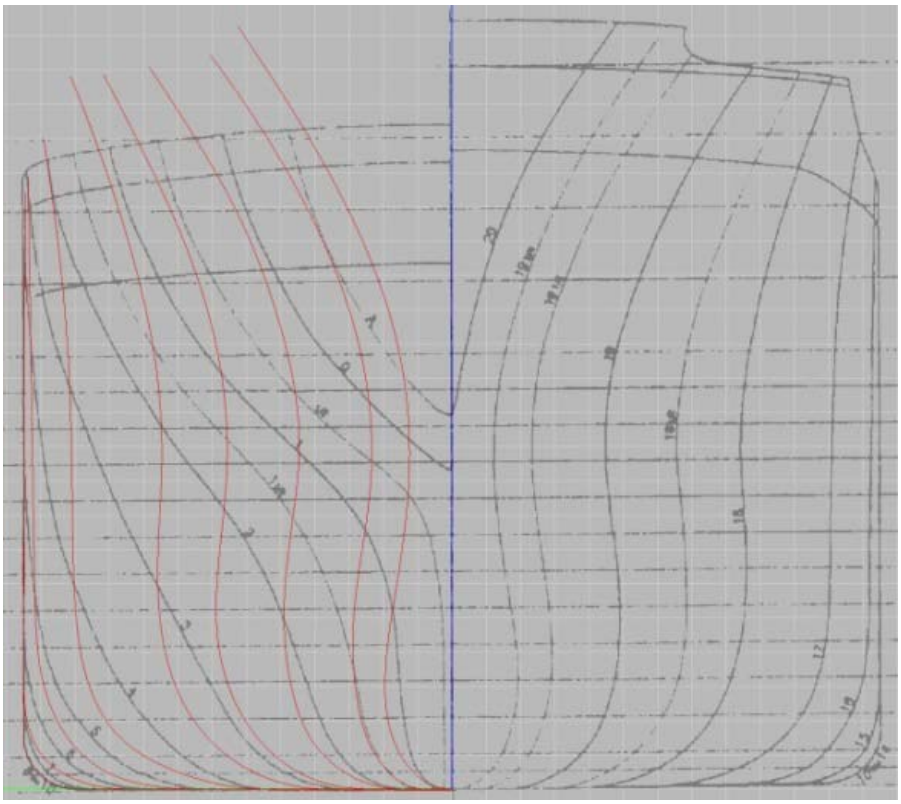
2.3.9Preparing to Copying the after Stations:

We have now introduced MAAT Hydro's most usual line drawing tools, so that copying the after stations won't require anything really new.

As the fore stations have been entered with negative breadths, we will first select '/Transform/Resize Shift Scale' in the menu bar and set a -1 coefficient in the y scaling field before clicking [OK] in order to reverse the current model.



Once done, select the 'Body Plan' bitmap in the 3D browser and type [-][Enter] to return to its original orientation:



The after lines we will now copy on the body plan bitmap will have the same positive half-breadths than the fore stations.

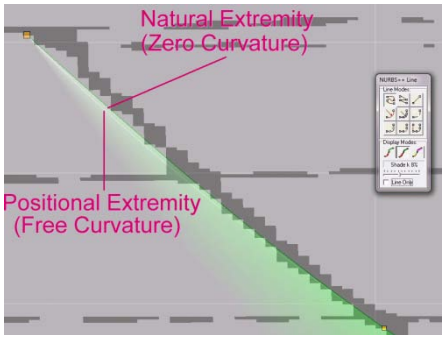
2.3.10 Copying Station 0:

We will therefore select '/Line/Spline' in the menu bar and input 6 spline knots on the bitmap to copy station 0. Once entered, right click to exit spline's knot input loop.

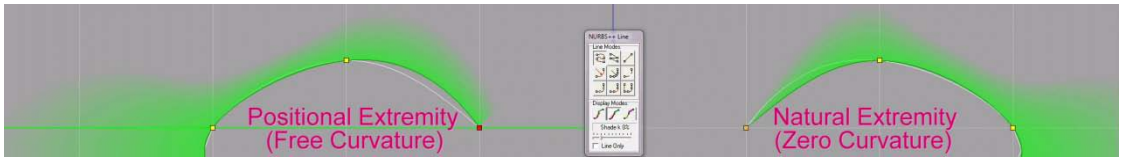
Let us select the first extremity knot and type [n][Enter] to turn it from Positional to Natural (the red knot becomes orange and the curvature shading changes around it).

With the default Positional extremity, the curvature takes a free value at the extremity while the Natural extremity replicates the 'flat' zero curvature extremity of a real spline (no bending moment).

Stretching and zooming the display at the modified extremity allows comparing the effect of both options. The initial Positional extremity looks 'fat' (non-zero curvature) compared with the Natural 'flat' (zero curvature) extremity:



This extreme example magnifies this difference:



Notice that the natural [n] extremity option is only accepted on spline extremities, while the positional [p], tangent [t] and curvature [k] options are accepted in any case.

Now that these spline options have been presented, simply click on the  fairing button or type [*][Enter] to switch to the 'Fairing' mode for a final smoothing, which will directly provide the fair line we are looking for.

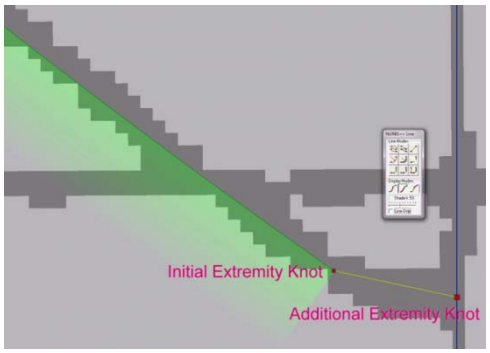
Although it is only for demonstration purpose, let us now round station 0's foot, assuming that we must add it an additional arc for this purpose.

We will therefore click online'slast knotto select the extremity where additional knot(s) have to be added (we would have selected the first knot for appending arcs to the other extremity).

Once the last knot is selected, zoom station 0's foot, click the  'Append'

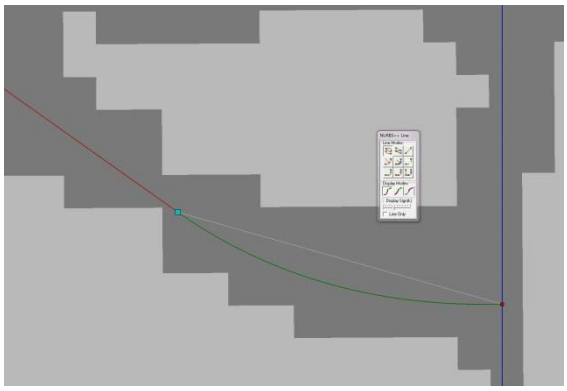
button or type [+][Enter] and enter the additional extremity knot in the center line.

Although the number of additional knots is not limited, we will right click immediately after having added this center line point.

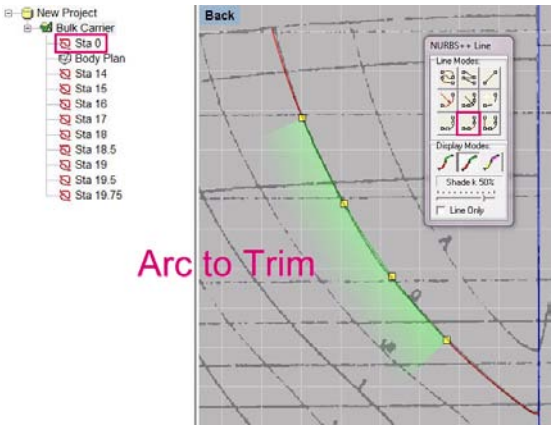


Select this additional arc by clicking its extremity knots and click on the  button or type [s][Enter] for switching to the spline mode.

Select arc's initial knot, type [t][Enter] to turn its continuity to 'Tangent' and drag spline's last knot in the center line until spline's tangent becomes horizontal (if necessary, you can type [y][0][Enter] to fix the knot in the center line):

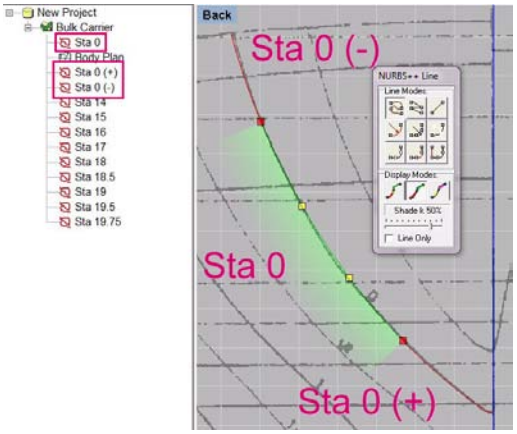


Hit the [Backspace] key to return to the full line and, just for demonstration, select this station arc:



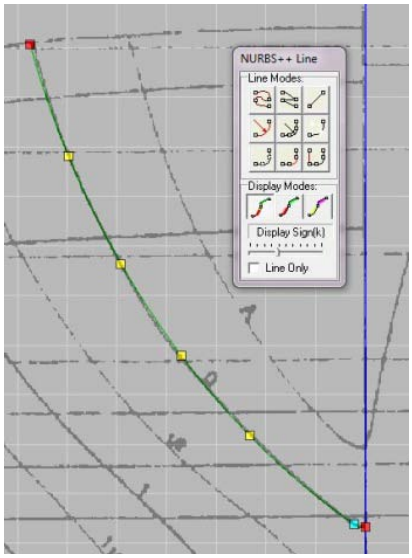
Now, click on the  'Trim' button or type [-][Enter] to trim the current arc.

Once trimmed, the color of arc's extremity knots becomes red andthe 3D browser shows that new lines 'Sta 0 (-)' and 'Sta 0 (+)' have been added to the original 'Sta 0'.



Moreover,selecting these lines in the 3D browser will show that the original line has been splitted in 3 independent lines, according to the currently selected arc (this function has therefore no effect when the full line is selected and only 1 line is created in other cases).

Finally, hit [Ctrl][z] to undo this operation and return to the original connex line, hit [Enter] to validate it and rename it 'Station 0' in the 3D browser.



If necessary, these lines can be loaded directly from the '\DemoFiles\Bulk Carrier 8.m2a' demo file'.

2.3.11 Copying Station 0.5:

We can now start copying station 0.5 similarly, by entering 8 spline knots, numbered from 0 to 7.

Station's keel point coordinates has to be entered directly by typing [0],[0][.][2][5][,][0][Enter] and, once done, right click to exit spline's knot input loop and follow these steps:

1) Select the vertical keel arc [6, 7] and flatten it in the vertical y=0.25 plane, by typing [y][0][.][2][5][Enter].

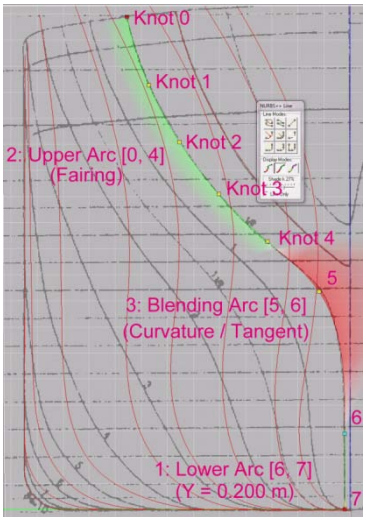
(2) Hit [Backspace] to return to the full line and select upper arc [0, 4], click on the  button or type [*][Enter] to switch to the 'Fairing' mode and hit the [Backspace] key to set the 100% fairing strength.

(3) Alternatively, you can also click on the button or hit [c][Enter] for entering in the 'Circle' mode and adjust arc's radius by 17.0 m.

(4) Hit [Backspace] again to return to the full line, select blending arc [4, 6] and, click on the on the button or type [s][Enter] to switch to the 'Spline' mode.

(5) Select knot 4, type [k][Enter] to set itscontinuity to 'curvature' (■ yellow knot), select knot 6 andtype [t][Enter] to set itscontinuity to 'tangent' (■ blue knot).

(6) Adjust knot 5's position and weight if necessary to get the smoothest blending and finally hit [Backspace] again to return to the full line:



Finally, hit [Enter] to validate the line and rename it 'Sta 0.5' in the 3D browser.

If necessary, the final 2D lines we have obtained can be loaded directly from the '\DemoFiles\Bulk Carrier 9.m2a' demo file'.

2.3.12 Copying Station 1:

Let us now start copying station 1 similarly, by entering 14 polygon knots, numbered from 0 to 13.

Like usual, station's keel point coordinates will be entered directly by typing [0],[0][,][0][Enter] and, once done, right click to exit spline's knot input loop and follow these steps:

1) Select the small horizontal arc [12, 13] and flatten it in the horizontal z=0 plane, by typing [z][0][Enter].

(2) Hit [Backspace] to return to the full line and select upper arc [0, 3], click on the button or hit [c][Enter] for entering in the 'Circle' mode and adjust arc's radius by 18.0 m.

(4) Hit [Backspace] again to return to the full line, select blending arc [3, 12] and, click on the on the button or type [s][Enter] to switch to the 'Spline' mode.

(5)Select knot 3, type [k][Enter] to set itscontinuity to 'curvature' (■ yellow knot), select knot 12 andtype [t][Enter] to set itscontinuity to 'tangent' (■ blue knot).

(6) Set and / or weight knots 4 to 11 in order to get the smoothest blending between the upper arc and the flat bottom.

Finally, hit [Enter] to validate the line and rename it 'Station 1' in the 3D browser.

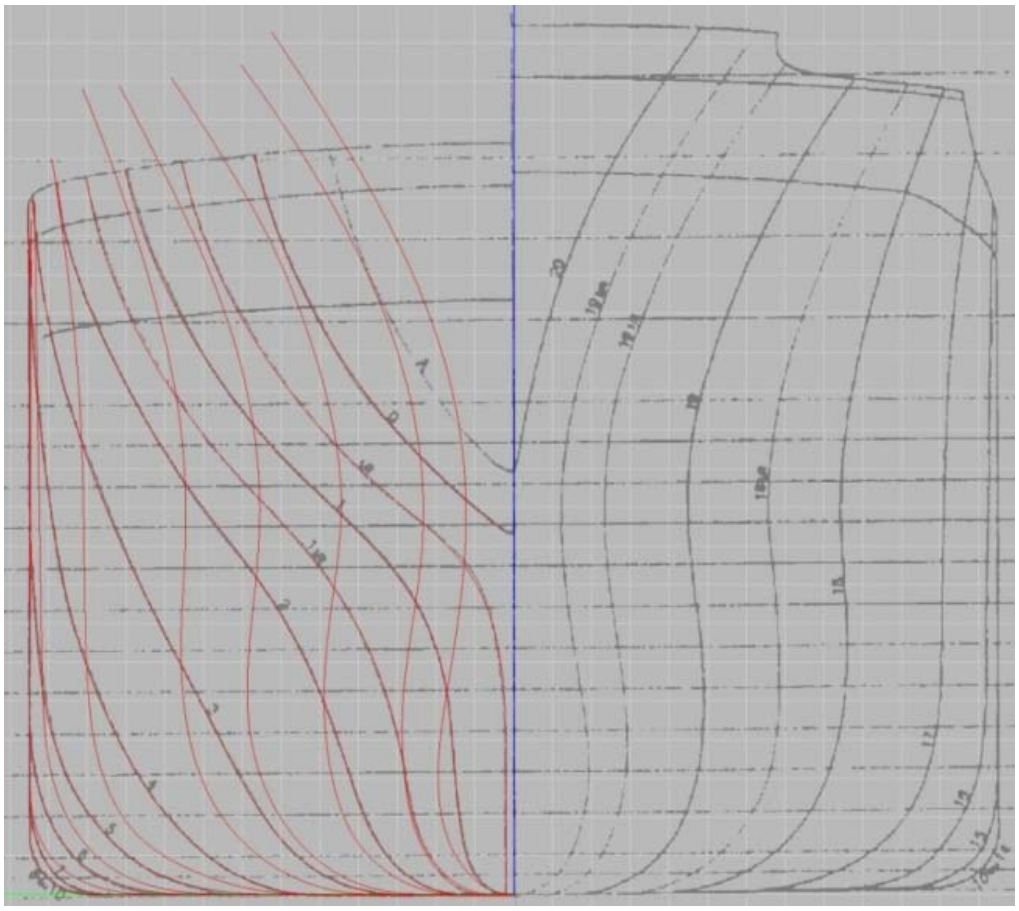
If necessary, the final 2D lines we have obtained can be loaded directly from the '\DemoFiles\Bulk Carrier 10.m2a' demo file'.

2.3.13 Copying the other after Stations:

Now that you have seen how to use most of MAAT's line drawing and fairing tools, we will let you put what you have learnt into practice for copying the last after stations.

When lines are becoming numerous, don't forget that you can hide or show the other lines whenever necessary by checking / unchecking the 

checkbox.

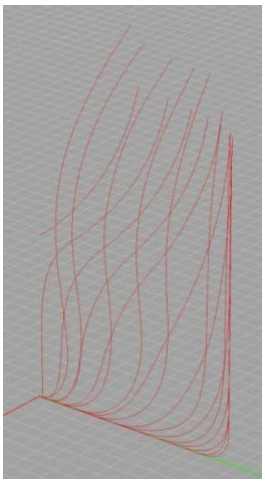


If necessary, these final 2D lines can be loaded directly from the '\DemoFiles\Bulk Carrier 11.m2a' demo file'.

2.3.14Putting the Stations in their final Position:

Now that all the stations have been copied from the bodyplan bitmap, we can double click it in the 3D browser in order to turn it off and view these lines only.

Moreover, we can also double click on viewport's title to return to the initial multi-view display and see, in the perspective view, that the stations must now be moved to their final x position:



As station 0 will remain in its x=0 position, we will directly double click on 'Sta 0.5' in the 3D browser to make it active: When its knots and toolbox are displayed, hit the [Backspace] key to return to the full line if necessary. We must indeed recall here that coordinate transformations:

- Only operate on the current knot, if any knot is selected.
- Operate on the current arc if no knot is selected (or, in any case, if the [Shift] key is pressed).

We must therefore insure that the full line is active before modifying its x position and keep the [Shift] key pressed before validating if any knot is currently selected.

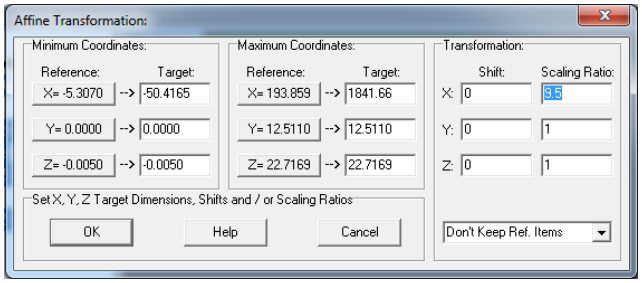
As we may have to use them very often, please print a copy of 'Annex 1: Line Modeling Reminder' and refer to it until you will remember alltheavailable coordinate transformation shortcuts.

Then, in this case, once the full line is active without any knot selected, type [x][0][.][5][Enter] to flatten it in the x = 0.5 plane (for convenience, we enter relative positions instead of the real ones, provided that we will transform them globally at the final stage).

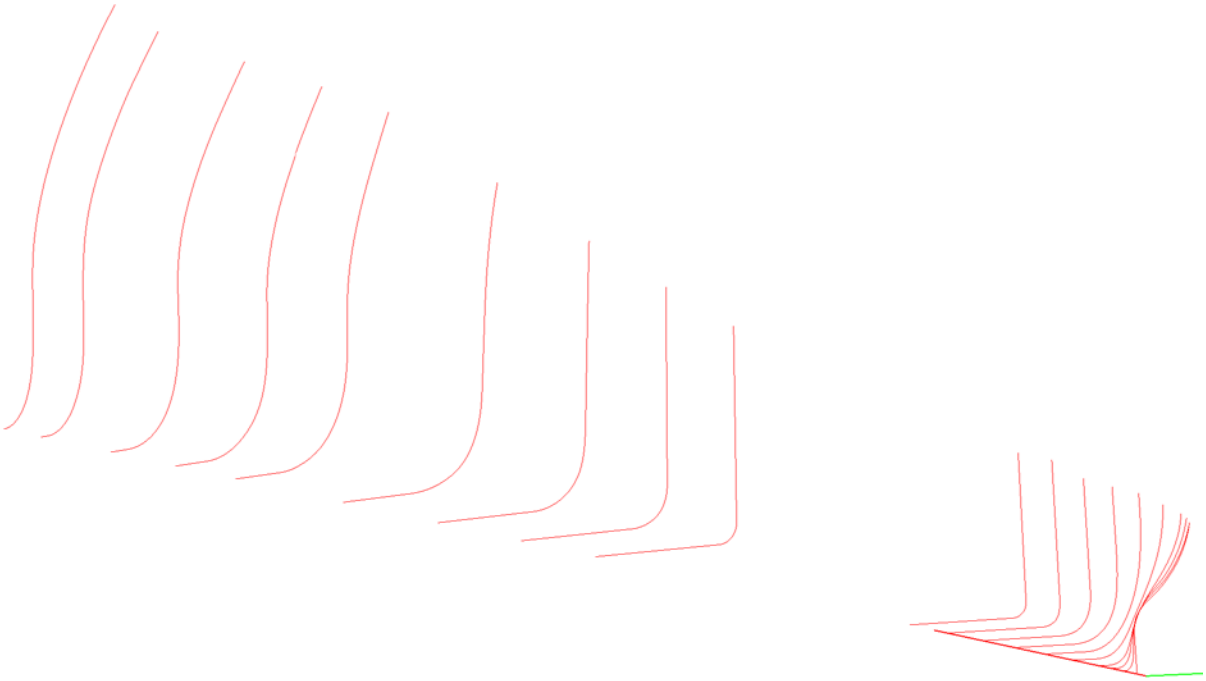
Hit [Enter] to validate this x modificationand repeat this operation for each station with its relative coordinate.

When all the stations have been moved to their relative position, select all of them in the 3D browser, right click and select '/Transform Resize Shift Scale' in the popup menu.

In the transformation dialog box, enter 9.5 in the x ‘Scaling Ratio’input field and let the other ratios to 1, although you might enter the values that you want.



Once the [OK] button is clicked, the selected stations are scaled longitudinally and finally look like this:



If necessary, these final data can be loaded directly from the ‘\DemoFiles\Bulk Carrier 12.m2a’ demo file’.

2.3.15Drawing the Stem Line:

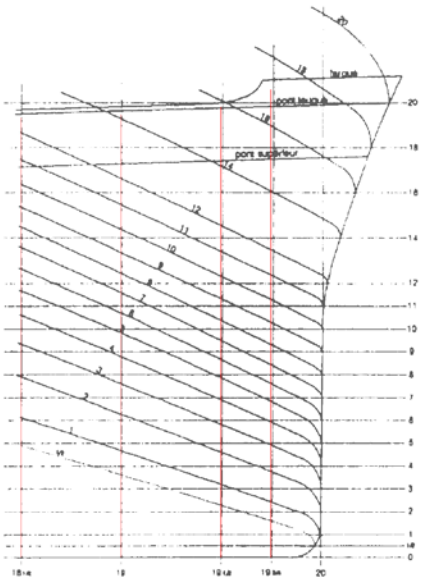
Now that all the stations have been copied from the body plan bitmap, let us import a stem bitmap for copying this line similarly:

Maximize the [Right] viewport by double clicking on its title, select the ‘Bulk Carrier’ folder in the 3D browser, right click, select ‘New Bitmap’ in the popup menu and select the ‘\Bitmaps\Bulk Carrier Stem.jpg’ bitmap file.

Click the anchor point approximately on Sta 19’s base and click the scaling point so that bitmap’s height roughly corresponds to the stations heights.

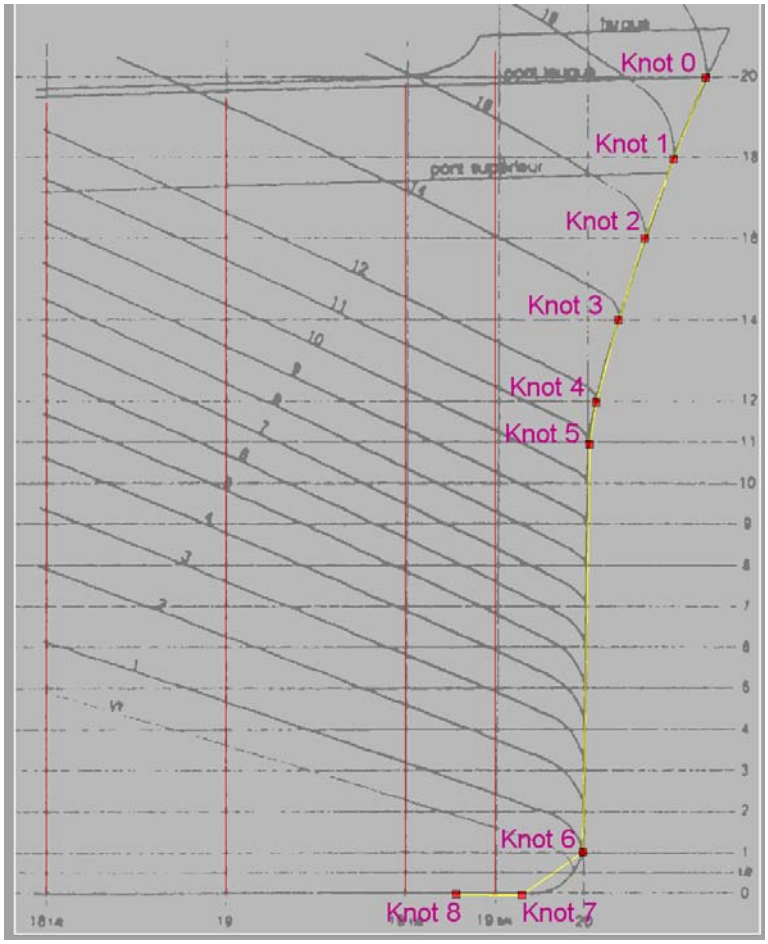
Once done, rename this bitmap ‘Stem Bitmap’ in the 3D browser and scale this bitmap accurately as follows:

- Zoom the right view in order to display the bottom of stations 18.5 to 20 at the bottom of the viewport.
- Click on the bitmap to select it: Its red scaling points are then displayed.
- Keep the left mouse button pressed on the (lower left) anchor point and drag it onto station the pixel of 18.5’s foot.
- Release the mouse button when done and click when this anchor point has been brought onto the foot of the line ‘Sta 18.5’ (alternatively, you can also enter its coordinates directly on the keyboard: 175.75 , 0, 0).
- Notice that you can zoom and pan with the mouse during this setting.
- Click again on the bitmap to re-select it and re-display its red scaling points.
- Keep the left mouse button pressed on the (lower right) scaling point and drag it ontothe pixel of station 19.75’s foot.
- Release the mouse button when done and click when the scaling point has been brought onto the foot of the line ‘Sta 19.75’ (alternatively, you can also enter its coordinates directly on the keyboard: 187.625 , 0, 0).



The stem bitmap is now scaled and we can use it for entering the stem line:

- Select '/Line/New Polygon' in the menu bar.
- Enter the 9 stem knots on the stem bitmap as shown below.

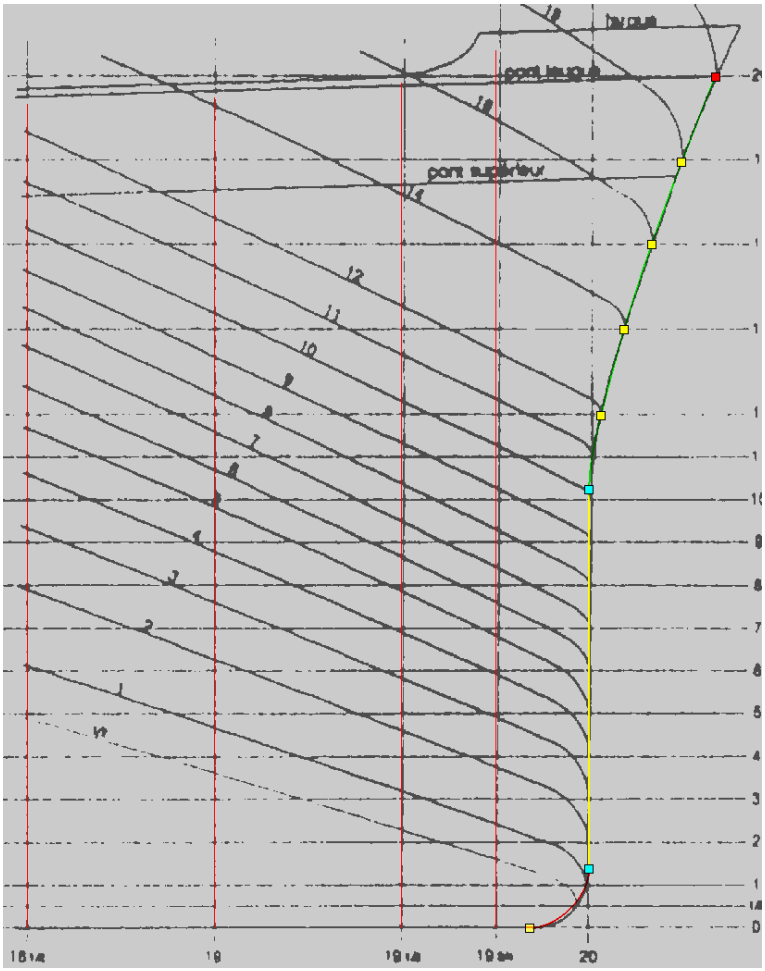


- Select arc [5, 6] by clicking the corresponding knots (keep [Shift] key pressed while selecting the second knot). Alternatively, you can also simply type [5][,][6][Enter].
- Type [x][1][9][0][Enter] to put this arc in the x=190 m plane.
- Hit the [Home] key to reset the arc.
- Select arc [7, 8] similarly and type [z][0][Enter] to put this arc in the z=0 plane (Alternatively, you can also simply type [7][,][8][Enter]).
- Hit the [Home] key to reset the arc.
- Select arc [6, 7] and type [s][Enter] to draw a spline blending in this arc.
- Type [r][1][.][5] [Enter] to set a 1.5 m circular arc [6, 7].
- Hit the [Home] key to reset the arc.
- Select arc [0, 5] and type [s] so draw a spline on knots 0 to 5.
- Select knot 5 and type [t][Enter] to set a tangent blending on this knot.
- If necessary, use the [←] /[→] keys,while knot 5 is selected, to find the best tangency point. You can also select other knots and set their

weight with the [Page Up] / [Page Down] keys to fair the upper part of the line where necessary (the zero weight knots can be removed by hitting the [Delete] key).

- Hit the [Home] key to reset the arc, select the last knot and hit the [Delete] key to remove knot 8, which is no longer necessary.

The final stem line now looks like this:



We can therefore press [Enter] to validate this line and rename it ‘Stem’ in the 3D browser.

If necessary, these data can be loaded directly from the ‘\DemoFiles\Bulk Carrier 13.m2a’ demo file’.

2.3.16 Drawing the Stern Line:

We will now enter the stern line exactly as we have entered the stem line:

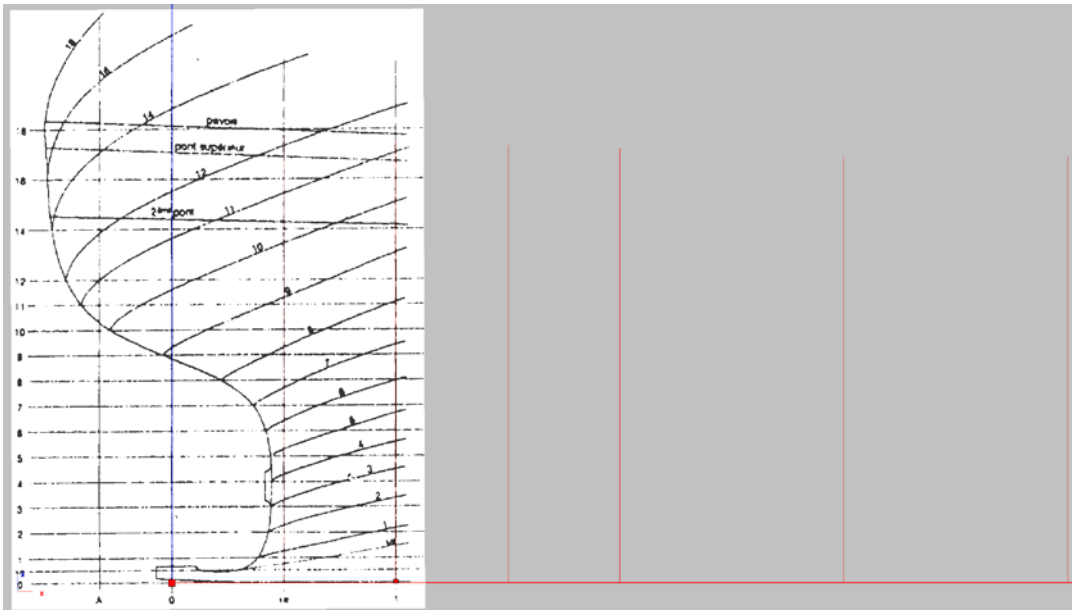
Keep the [Right] viewport maximized, select the ‘Bulk Carrier’ folder in the 3D browser, right click, select ‘New Bitmap’ in the popup menu and select the ‘\Bitmaps\Bulk Carrier Stern.jpg’ bitmap file.

Click the anchor point approximately on Station0’s base and click the scaling point so that bitmap’s height roughly corresponds to the stations heights.

Once done, rename this bitmap ‘Stern Bitmap’ in the 3D browser and scale it accurately as follows:

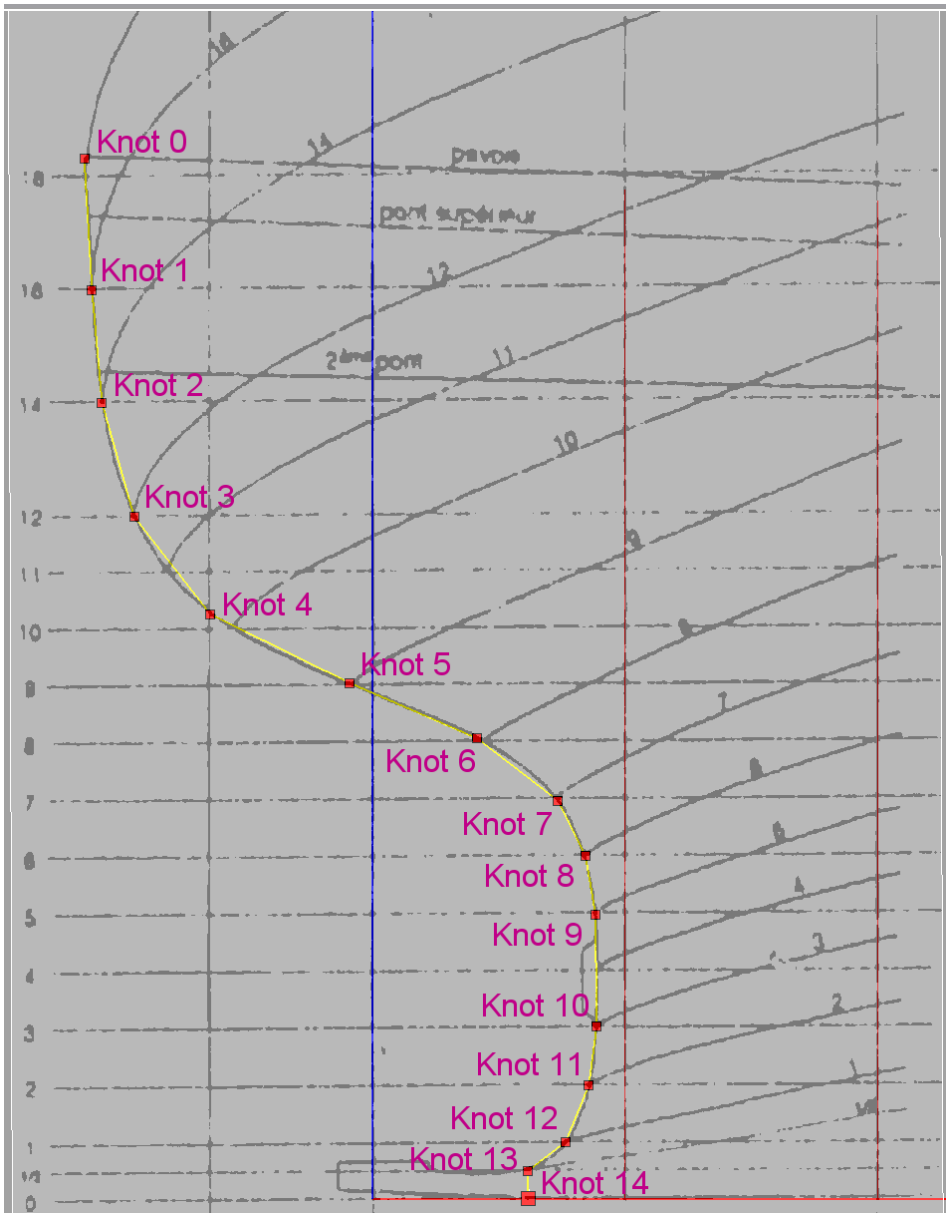
- Zoom the right view in order to display the bottom of stations 0 to 1 at the bottom of the viewport.
- Select the bitmap in the 3D browserto displayits red anchor and scaling points.
- Keep the left mouse button pressed on the (lower left) anchor point and drag it onto the pixel of station 0’s foot.
- Release the mouse button when done andshift this pixel onto the foot of the line ‘Sta0’ (alternatively, you can also enter its coordinates directly on the keyboard: 0 , 0, 0).
- Notice that you can zoom and pan with the mouse during this setting.
- Select the bitmap again in the 3D browserto re-display its red anchor and scaling points.
- Keep the left mouse button pressed on the (lower right) scaling point and drag it ontothe pixel of Station 1’s foot.
- Release the mouse button when done and shift this pixel onto the foot of thethe line ‘Sta 1’ (alternatively, you can also enter its coordinates directly on the keyboard: 9.5 , 0, 0).

The scaled bitmap should now look like this:



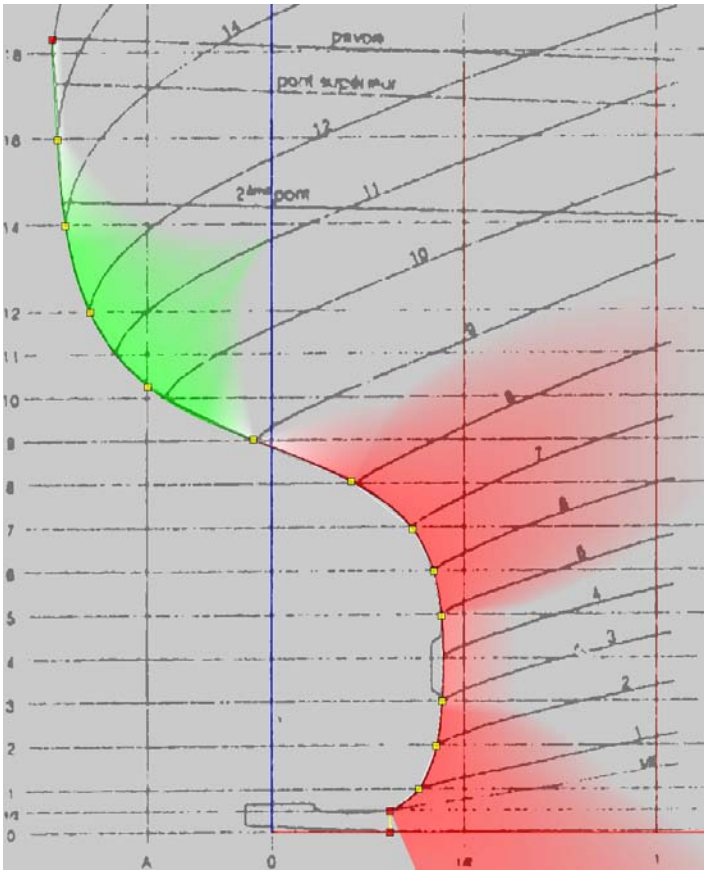
The stern bitmap is now scaled and we can use it for entering the stern line:

- Select '/Line/New Polygon' in the menu bar.
- Enter the 15 stem knots on the stem bitmap as shown below.



- Select arc [0, 13] by clicking the corresponding knots (keep [Shift] key pressed while clicking the second knot).
- Type [s][Enter] to draw a spline on arc [0, 13].
- If necessary, you can fair the line by selecting knots and setting their weight with the [Page Up] / [Page Down] keys (the zero weight knots can even be removed by hitting the [Delete] key). Turning the curvature scanning mode on can be helpful for controlling the fairness accurately.
- Hit the [Home] key to reset the arc.

The final stem line now looks like this:

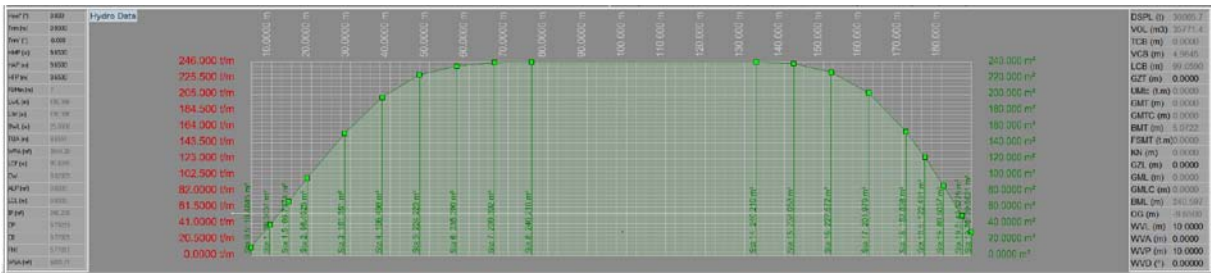


We can therefore press [Enter] to validate this line and rename it ‘Stern’ in the 3D browser.

If necessary, these data can be loaded directly from the ‘\DemoFiles\Bulk Carrier 14.m2a’ demo file’.

2.3.17 Hydrostatic !:

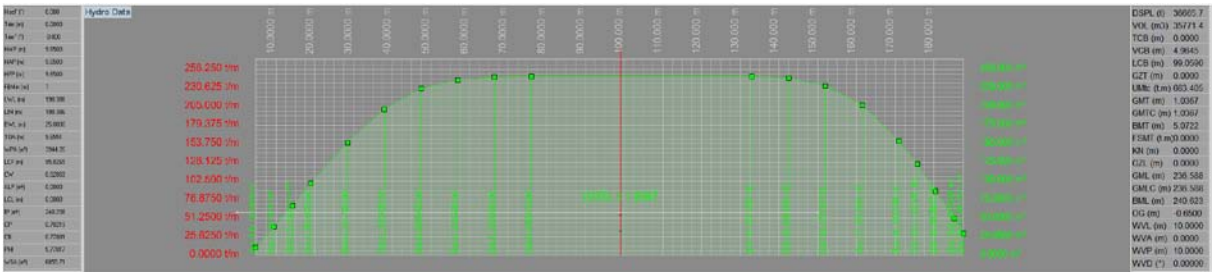
Although you have not yet created or imported any BREP solid, you can click on the [Hydro] button for opening the Hydrostatic viewport: MAAT Hydro will automatically calculate the immersed areas of the stations identified in the active folder (notice that the SAC is only accounted between stations, which are automatically symmetrized):



All the [Hydro Data] functions of the [Hydro] viewport can be used with these stations as well as with solids,which can even be combined together for modeling any additional item if necessary(in fact, MAAT Hydro's hydrostatic engine is an 'hybrid' engine and the [Hydro Data] menu provides distinct 'Integrate Solids'and 'Integrate Stations' options to control it).

Moreover, most of the hydrostatic tools of the menu bar can also operate directly on such stations:

Let us first select '/Mass/Dwl Displacement' in the menu bar and type [9][Enter] to create directly a Dwl's displacement masswith a 9m VCG. The SAC becomes highlighted, as it now corresponds to ship's equilibrium:

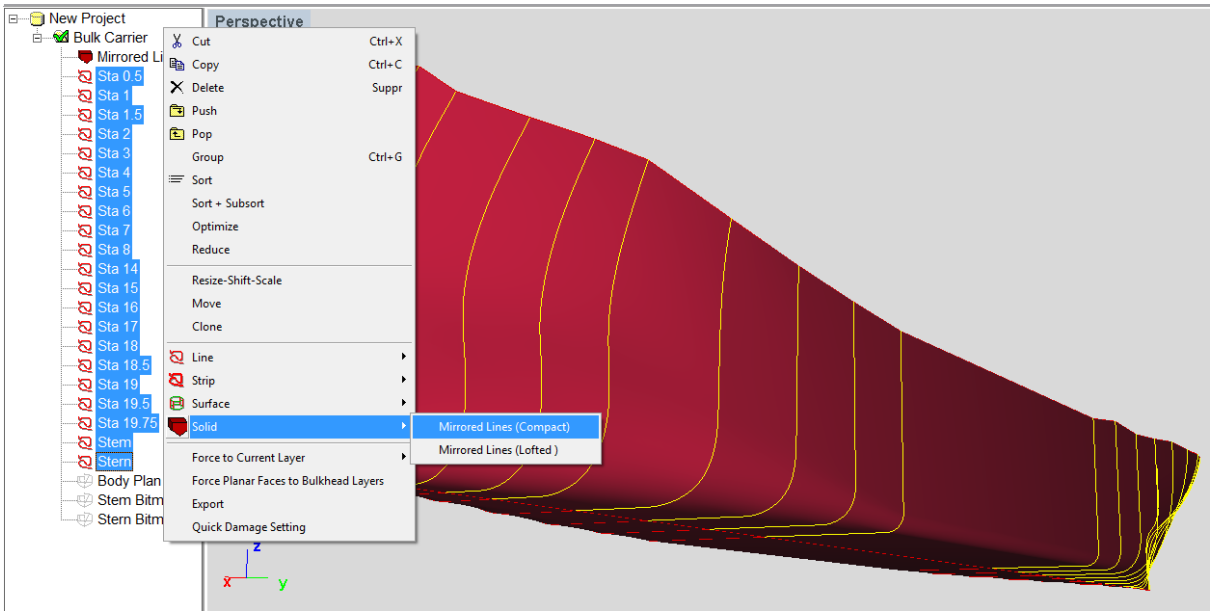


As ship's buoyancy is now counterbalanced by a reasonable weight, we can select '/Tools/Transverse Stability' in the menu bar and directly validate the default range to get ship's stability features. Hydrostatic Curves, Floatation's Analysis, Cross Curves, etc… can also be immediately obtained in a similar way if necessary.

In fact, compartment and tank definitions are the only things we cannot do on such a model, which is therefore only suitable for preliminary calculations.

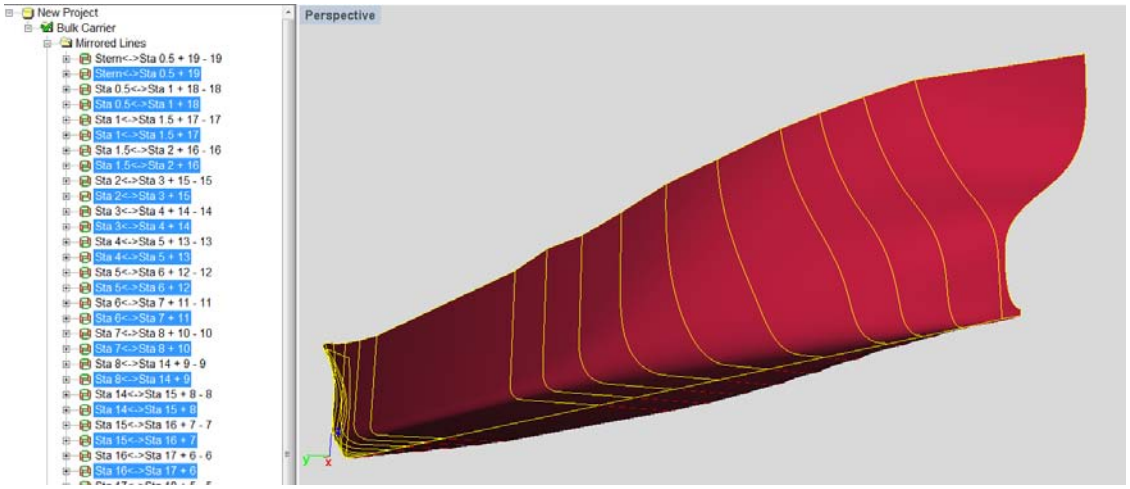
MAAT Hydro therefore also allows transforming these lines immediately into a BREP solid which can be divided into compartments if necessary and can contain as many tanks as needed:

-Select the stations, stem and stern lines in the 3D browser.
- Right click to display 3D browser's popup menu.
- Select '/Solid/Mirrored Lines (compact)'.
- The selected lines are then sorted and mirrored for creating the corresponding BREP solid.



Let us now select the created solid in the 3D browser and select /Solid/Explode' in the popup menu to understand exactly what MAAT Hydro has done for creating this hull solid:

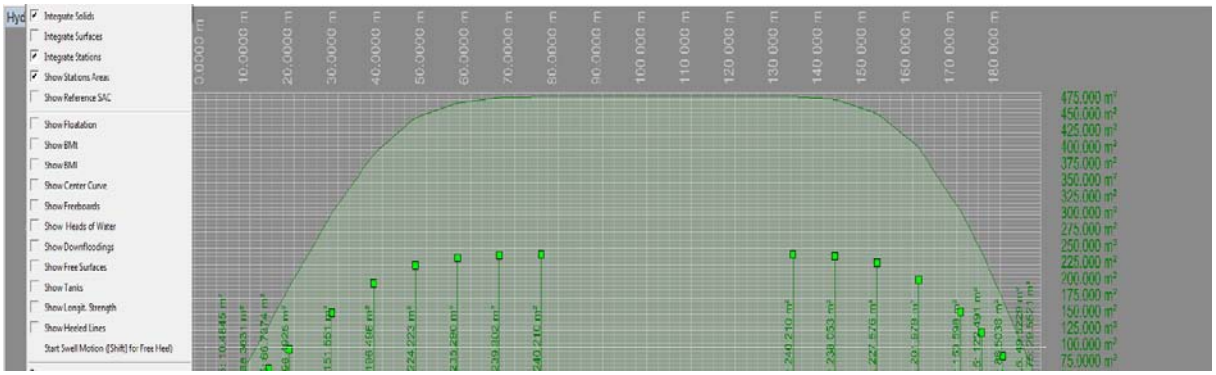
- The selected lines have been automatically sorted.
- Least energy faces have been drawn between all the consecutive lines.
- These faces have been automatically mirrored.
- A 'deck' face has been automatically added for closing the solid.
-



Let us now hit [Ctrl][z] to revert to the original (unexploded) hull solid.

Notice that selecting '/Solid/Mirror Lines (Lofted)' instead of '/Solid/Mirror Lines (Compact)' would have lofted a single smooth surface on the selected lines instead of separate least energy faces. Nevertheless, we didn't select this option as it would produce significantly heavier faces and slow down all the hydrostatic calculations for nothing. Hull fairing and smoothing are so rich topics that theywill be discussed thoroughly in the next parts of this tutorial.

Click on the [Hydro] button to open the hydrostatic viewport and notice that hull's SAC's areas are now doubled, because both stations and solids integrators are currently switched on, so that solid's buoyancy is now added to station's buoyancy.

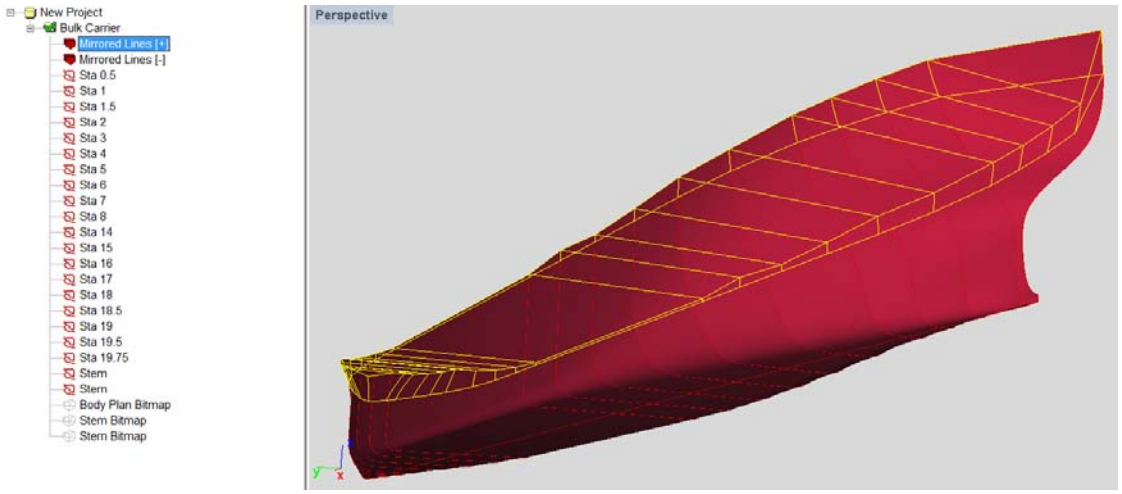


Although it might sometimes be useful to use both integration engines simultaneously (i.e. for combining additional solid volumes with an initial stations model…), we will switch off the stations integratorwhich is now useless (i.e. uncheck 'Integrate stations'in hydrostatic viewport's popup menu) for integrating the solids only:



Once done, let us close the hydrostatic viewport andsimply select the hull solid again in the 3D browser, right click and select '/Solid/Split Ortho' in the popup menu. Typing [h][1][6][Enter] will split this hull solid by a z=16m horizontal plane (this model is not intended for large heel angle calculations).

Select the upper solid [Mirrored Lines [+] in the 3D browser and hit [Delete] to remove it. The remaining solid can then be renamed ‘Hull’.

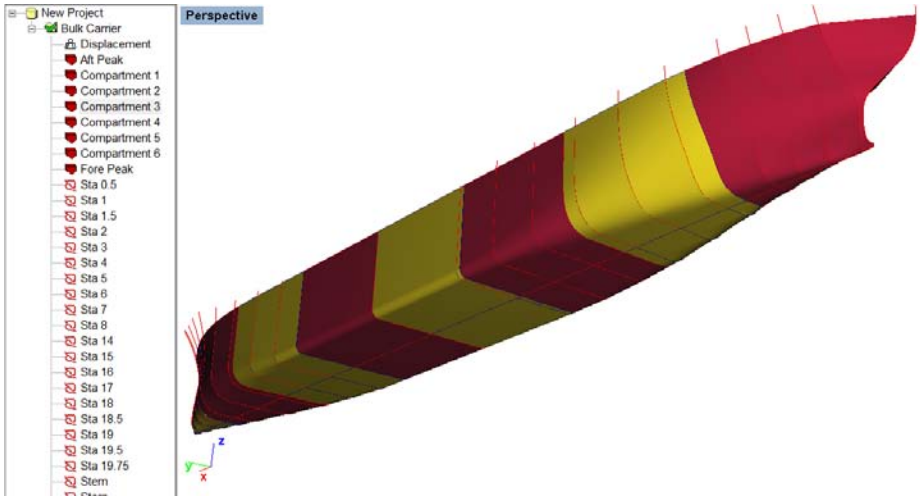


Let us now select the ‘Hull’ solid in the 3D browser, right click and select ‘/Solid/Split Ortho’ again in the popup menu. Typing [t][1][9][Enter] will split this hull solid by a x=19 m transverse plane.

We can rename [Hull [-]’ to ‘Aft Peak] and repeat this operation for these transverse planes in oder to divide the hull into compartments:

-Type [t][5][0][Enter] will split this hull solid by a x=50 m transverse plane.
-Type [t][7][5][Enter] will split this hull solid by a x=75 m transverse plane.
-Type [t][1][0][0] [Enter] will split this hull solid by a x=100 m transverse plane.
-Type [t][1][2][5] [Enter] will split this hull solid by a x=125 m transverse plane.
-Type [t][1][5][0] [Enter] will split this hull solid by a x=150 m transverse plane.
-Type [t][1][7][5] [Enter] will split this hull solid by a x=175 m transverse plane.

Rename the last fore compartment ‘Fore Peak’ and the others ‘Compartment 1’ to ‘Comparment 5’.

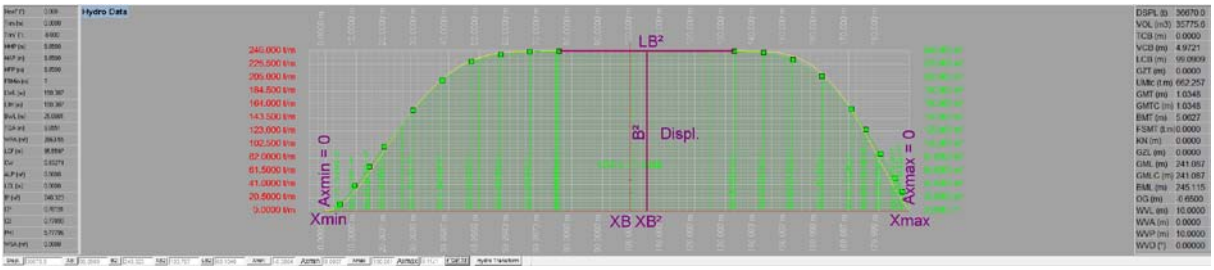


Tanks, masses, opening and silhouette descriptors, loading and damage conditions,… can also be created as explained in previous tutorials.

2.3.18 Hydrostatic Transformations:

In addition to its hydrostatic analysis tools, MAAT Hydro also provides powerful hydrostatic transformation tools allowing to reach target hydrostatic features at any stage of hull design.

Click on status bar's [Hydro] button to open the hydrostatic viewport, right click in viewport's title and check the 'Show Reference SAC' option to display the target hydrostatic data bar at the bottom of the viewport and the corresponding target SAC in yellow:



The target hydrostatic data bar allows entering ship's target hydrostatic data, which are used for creating a synthetic target SAC (displayed in yellow). Once this synthetic target SAC is correctly defined, it will remain usable for transforming the ship model accordingly, as well as stations or surfaces whenever necessary.

These target hydrostatic data can be specified with the following controls:



1: [Displ.] button presets the target displacement to its current Dwl value.
2: Target Displacement's input field (allows entering the target displacement*).
3: [XB] button presets the target LCB to its current Dwl value.
4: Target LCB's input field (allows entering the target LCB*).
5: [B2] button presets the target Max station area (B^2) to its current Dwl value.
6: Target Max station area (B^2) input field (allows entering the target B^2*).
7: [XB2] button presets the target x position of B^2 to its current Dwl value.
8: Target x position of B^2 input field (allows entering B^2's target x position*).
9: [LB2] button presets B^2'slongitudinal extent to its current Dwl value.
10: Target B^2 extent's input field (allows entering the B^2's target longitudinal extent*).
11: [Xmin] button presets SAC's minimum abscissa to its current Dwl value.
12: Target Xmin's input field (allows entering the Xmin's target value*).
13: [Axmin] button presets SAC's Area at xmin to its current Dwl value.
14: Target Axmin's input field (allows entering the target SAC area at xmin*).
15: [Xmax] button presets SAC's maximum abscissa to its current Dwl value.
16: Target Xmax's input field (allows entering the Xmax's target value*).
17: [Axmax] button presets SAC's Area at xmax to its current Dwl value.
18: Target Axmax's input field (allows entering the target SAC area at xmax*).
19: [Get All] button presets all the input fields to their current Dwl value.
20: [Hydro Transform] button transforms current model's geometry so that its hydrostatic data will reach the target hydrostatic data.

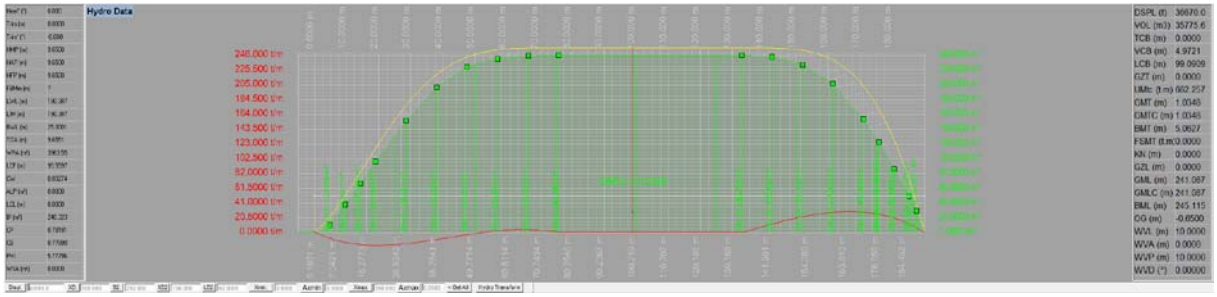
In order to illustrate this presentation, let us enter the following target values in

the transformation input fields (don’t forget to press [Enter] to validate your inputs or [Esc] to cancel):

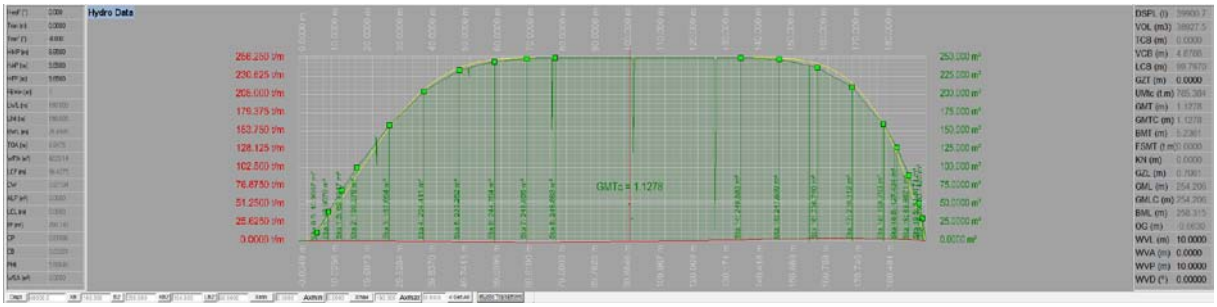
Displ: 40000 t
XB: 100 m
B2: 250 m²
XB2 : 104 m
LB2 : 60 m
Xmin : 0 m
Axmin : 0 m²
Xmax : 190 m²
Axmax : 0 m²

Once done, the corresponding target SAC is displayed in yellow,to be compared with the original green SAC. As the initial and target midship areas (B²) are different in this case, the hydrostatic transformation will first have to scale the ship transversally and verticallyin order to equal them.

After this first transformation, the original areas will simply have to be shifted longitudinally in order to reach the target SAC (this variable longitudinal shift *δx(x)* is displayed in red along the x axis and the grey vertical grid is used for showing a preview of this variable shift).



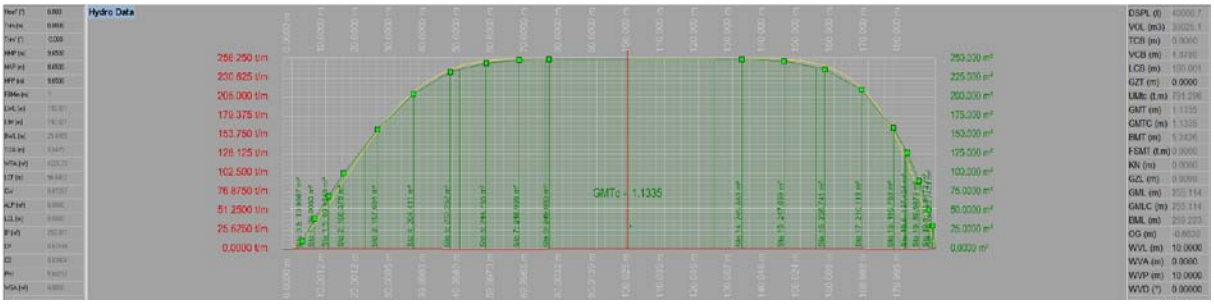
You can now click on the [Hydro Transform] button to transform model’s geometry according to these target data. Once done, the current SAC and hydrostatic data have become much closer of their targets:



By hitting [Ctrl][z] / [Ctrl][y] to undo / redo the transformation, youwill also see,in the 3D viewports, how the stations have been scaled in the transverse plane and shifted longitudinally.

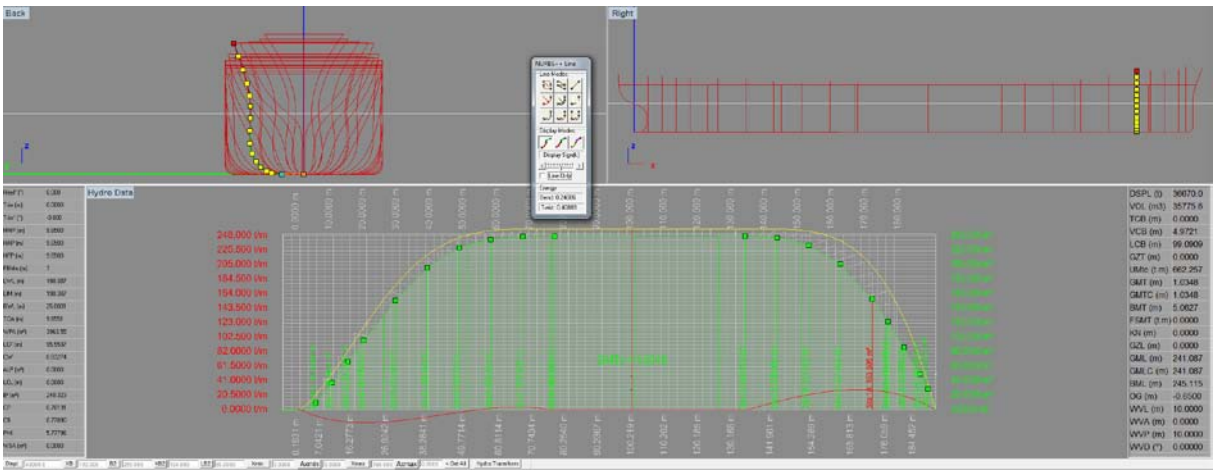
At last, you can click on this button several times to repeat this hydrostatic

transformation until ship's hydrostatic data match exactly with the target data:



In addition to this global ship transformation, stations can also be transformed one by one if necessary (and surfaces as well, as we will see below).

Hit [Ctrl][z] several times to undo these transformations and revert to the original ship.Double click on 'Sta 18' in the 3D browser to modify this lineand notice that 'Sta 18' is now displayed in red in the Hydrostatic Viewport:



In addition to the NURBS++ line tools, several hydrostatic line transformation shortcuts are also available (see 'Annex 1: Line Modeling Reminder' for details):

-Type [x][+][Enter] for shifting the station longitudinally to the target SAC.
-Type [y][+][Enter] for shifting the station transversally to the target SAC.
-Type [z][+][Enter] for shifting the station vertically to the target SAC.
-Type [y][*][Enter] for scaling the station transversally to the target SAC.
-Type [z][*][Enter] for scaling the station vertically to the target SAC.
-Type [y][z][*][Enter] for scaling the station vertically and transversally to the target SAC.

You can try each of these shortcuts, control its effect on current line in the 3D / hydrostatic viewports and undo the transformation before trying a new shortcut.

Finally, hit the [Esc] key to exit the line modification tools.

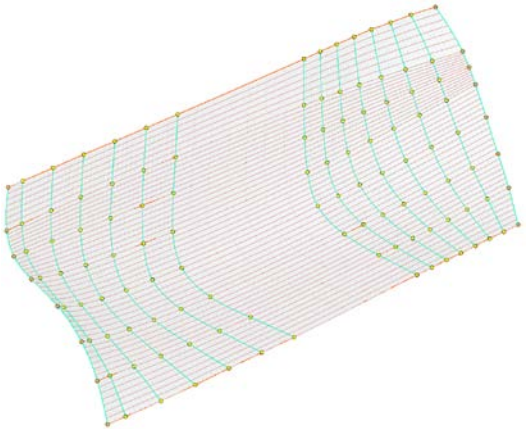
4. NURBS^{++} Surface Modeling:

4.1 Preliminary:

A line can be defined as the geometric object resulting from the continuous transformation of a point and, similarly, a surface can be defined as the geometric object resulting from the continuous transformation of a line.

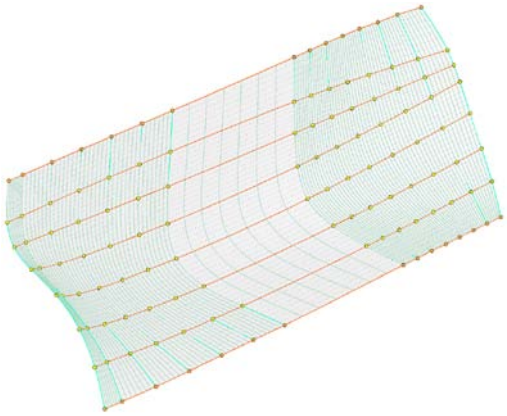
Transforming a NURBS++ line continuously will therefore generate a NURBS++ surface and line's associated knots willsimultaneously generate NURBS++ lines by this transformation.

A NURBS++ surface is therefore the piecewise surface partionedby a network of isoU (red) and andisoV (green) lines, whose intersections are the surface knots:



Like for a NURBS++ line, each iso U or iso V knot is associated toa continuity, so that each surface knot is simultaneously associated with a U and a V continuity.

In MAAT Hydro, clicking on an iso U turns surface's display mode in the iso U mode (see above), where the intermediary iso Us (red) are highlighted and the knot continuities are the U continuities. Conversely, clicking on an iso V will turn surface's display mode in the iso V mode (see below), where the intermediary isoVs(green) are highlighted and the knot continuities are the V continuities.

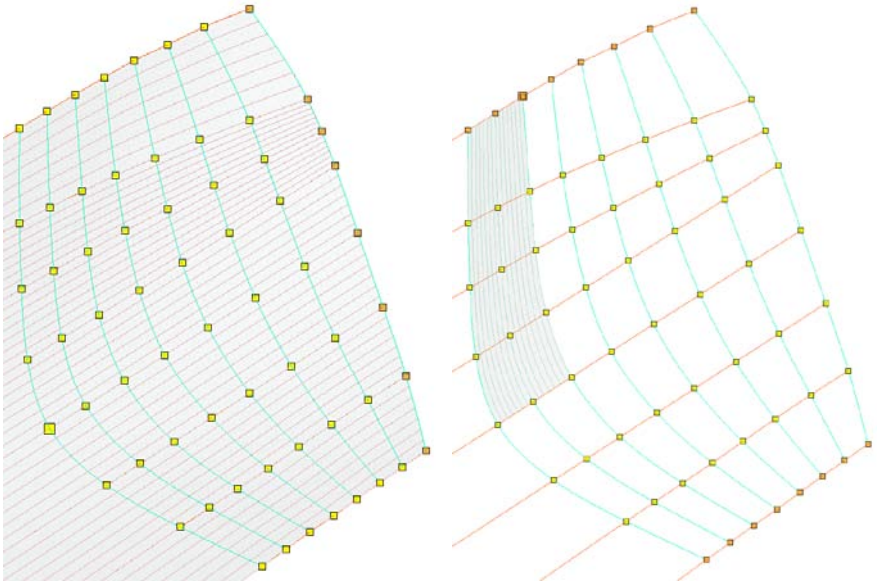


The surface knot continuities are represented with the same colors than the line knot continuities and have the same shortcuts:

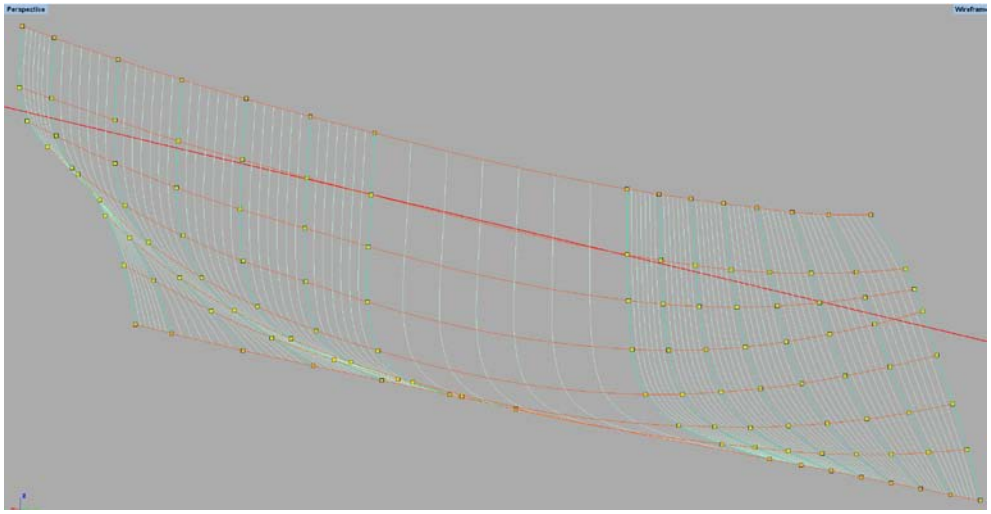
- Positional Continuity
- Tangent Continuity
- Curvature Continuity
- Natural Extremity (zero curvature spline extremity)

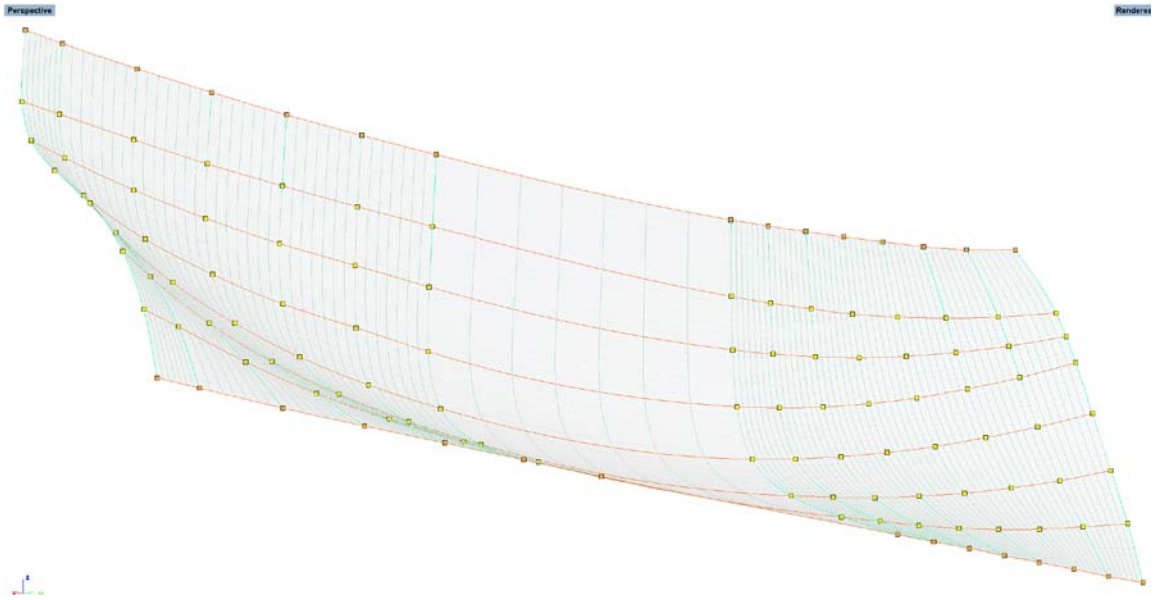
Like for NURBS++ lines, these continuities allow controlling the surface continuity in U and V directions, which will be thoroughly discussed below.

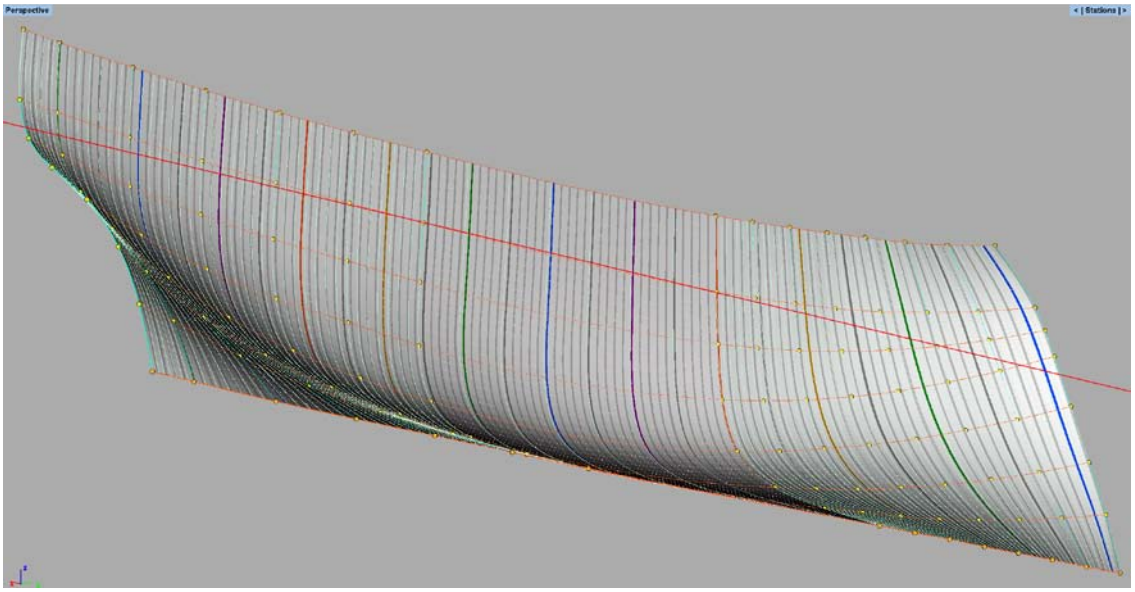
Moreover, like for a NURBS++ line, clicking on a surface knot (or typing its indexes in the i, j format, i.e. [1],[2][Enter] to select knot (1,2) directly) allows selecting it. Once done, selecting a second knot with [Shift] key pressed allows restraining the active part of the surface (Hit [Home] key to revert back to the full surface):

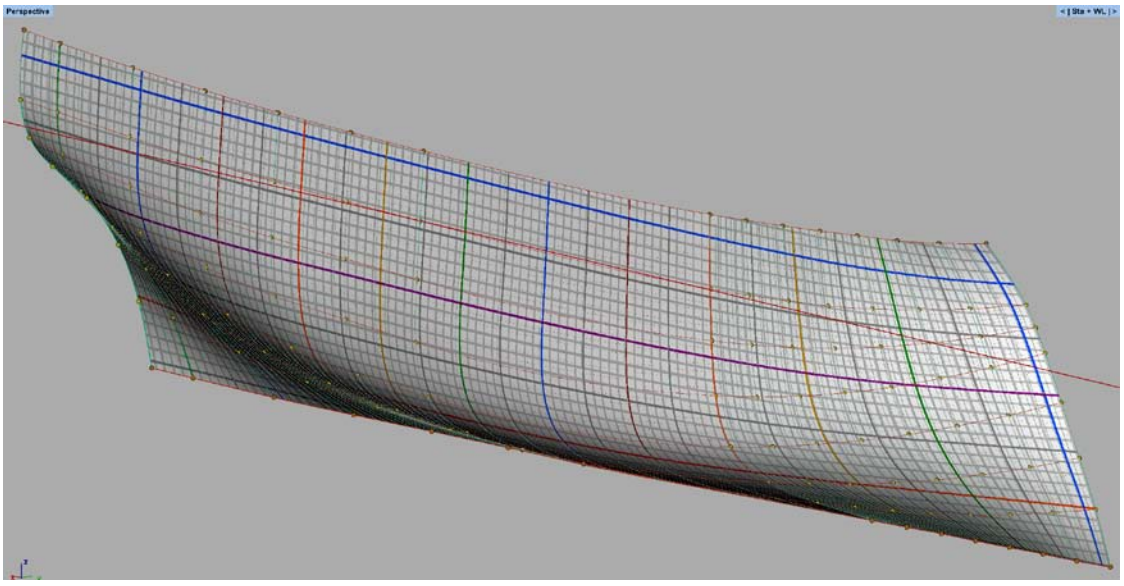


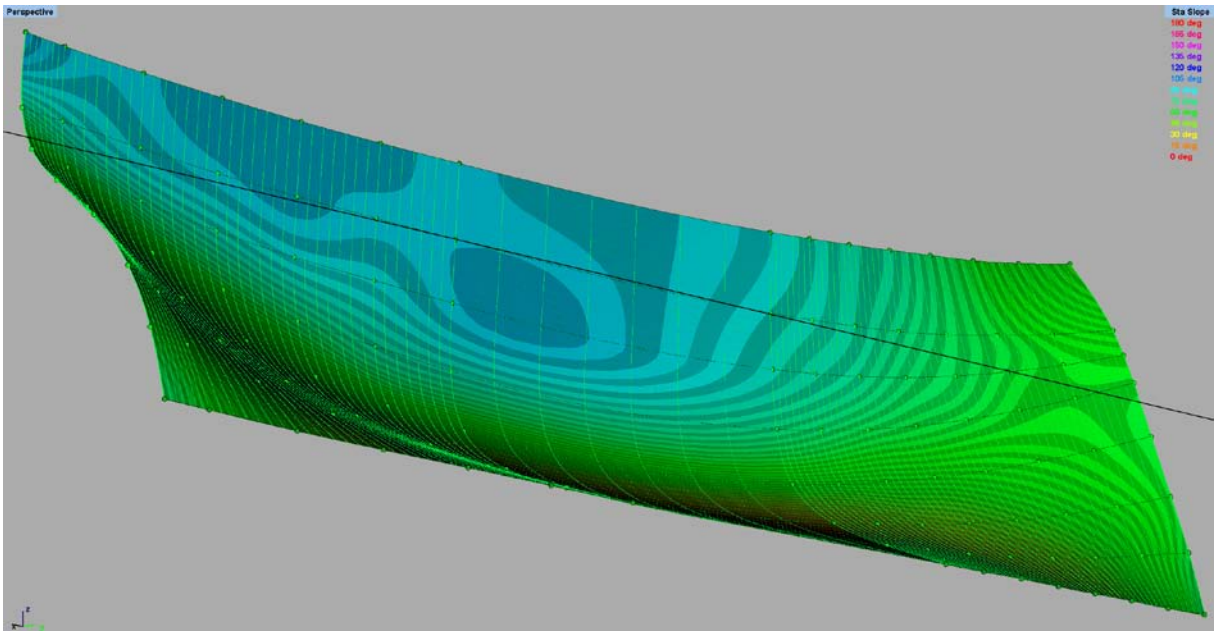
At last, the current surface display mode can be selected by a right click in viewport's upper right title. The following samples will give an idea of the available surface display modes:

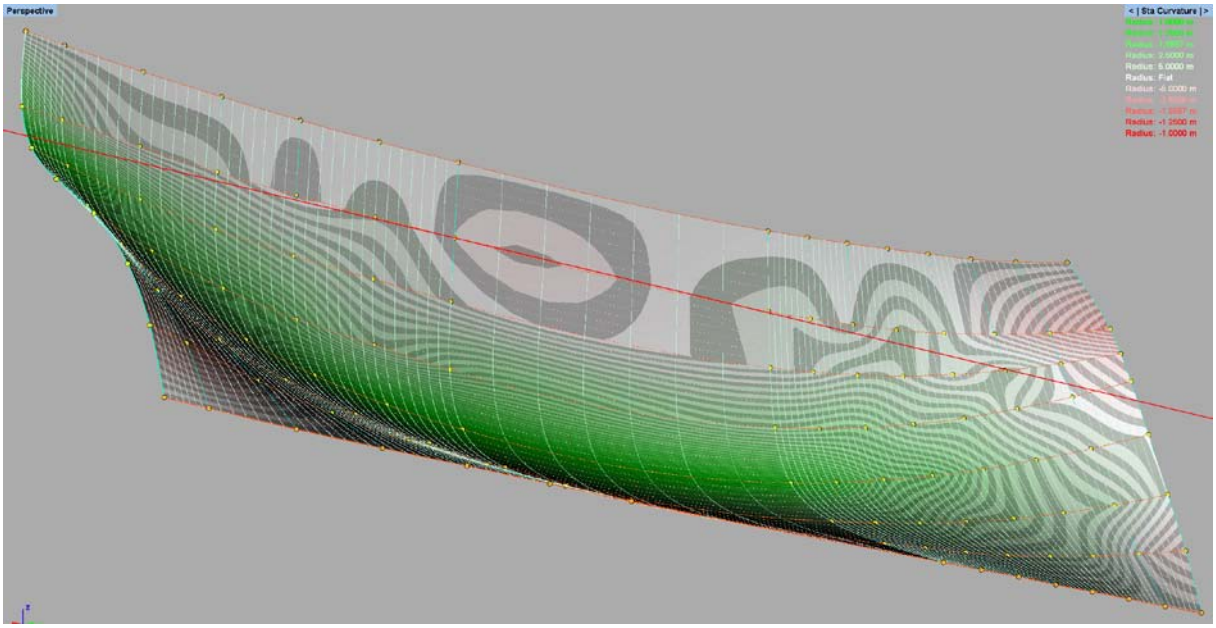



Perspective
Renderer


Perspective
< [Stations] >


Perspective
< [Sta + WL] >





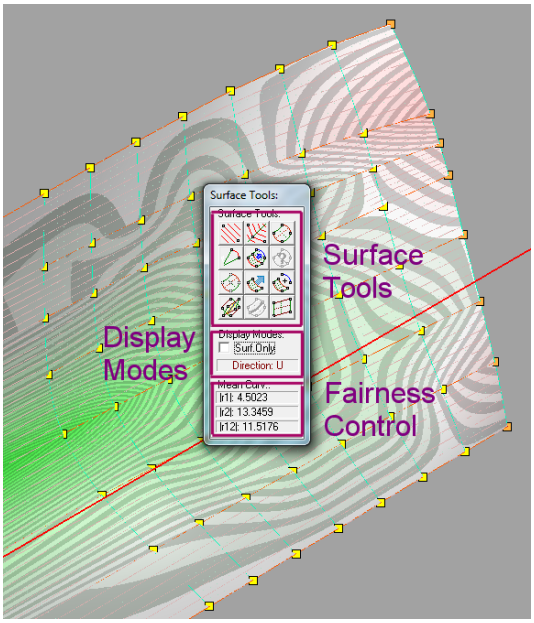
Note 1: The sensitivity of the scanned modes can be adjusted by clicking in the [<] and [>] arrow buttons located on both sides of the upper right title.

Note 2: Different surface scanning modes cannot be used simultaneously.

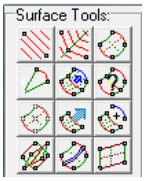
4.2 Presentation of the NURBS^{++}Surface Modes and Tools:

MAAT Hydro provides aNURBS^{++} Surface' toolbox similar to the NURBS^{++} Line' toolbox.

When a surface is being modified (i.e. double clicked in the 3D browser or in any 3D viewport), its knots, iso Us and isoVs are displayedwhile the NURBS^{++}Surface toolbox pops up, providing MAAT Hydro'ssurface tools (button's popup hints will make you familiar with their shortcuts):



The upper frame contains the surface tools:



The available surface tools are the followings (they are sorted according to their analogy with the line tools and have the same shortcuts):

- / ([s][Enter]) This button corresponds to the 'Spline Planking' tool, which allows lofting the current surface area with a continuous network of splines (simulates a traditional frame planking) drawn in the current U direction ( ) or V direction ( ). The current planking direction is displayed at the bottom of the 'Surface Tools' frame and can be selected by clicking on a U or V iso.

- / ([z][Enter]) This button corresponds to the 'Polyhedric Planking' tool, which allows lofting the current surface area with a continuous network of polygons drawn in the current U direction ( )

or V direction (). The current direction is displayed at the bottom of the ‘Surface Tools’ frame and can be selected by clicking on a U or V iso.

- ([/][Enter]) This button corresponds to the ‘Least Energy Planking’ tool, which allows stretching a least energy surface on current surface area’s frame.

- ([c][Enter]) This button corresponds to the ‘Cone’ tool, specially designed for generating stem cone surfaces.

- ([^][Enter]) This button allows setting surface’s extent (i.e. sliding its first / last iso U / iso V inside or outside of the original surface).

-  ([*][Enter]) This button corresponds to the ‘Correlation’ tool, which allows releasing the selected iso in the same way that line knots can be released for fairing.

- ([a][Enter]) This button allows ‘Approximating’ the current surface area, which means removing unnecessary isoUs / isoVs according to a given tolerance. By defaut this approximation tolerance is 1mm, but it can be specified after the ‘a’ shortcut if necessary (i.e. type [a][0][.][0][1][Enter] for re-approximating the surface with a 0.01m tolerance).

-  ([-][Enter]) This button allows extracting the current surface area, which means exporting it as a separate surface in the current folder.

-  ([+][Enter]) This button allows ‘Appending’ an additional line or surface to the current one (additional isoparms must usually be inserted to make both entities compatible).

-  ([x][Enter], ([x][t][Enter], ([x][l][Enter], ([x][h][Enter]) This button allows intersecting current surface by a line or surface. When obtained, the intersection appears as a new isoparm in the current surface.

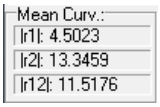
-  ([=][Enter], …) This button allows doubling the selected iso U or iso V.

-  ([x]…[Enter], [y]…[Enter], [z]…[Enter]) This button allows planishingthe current surface area in the plane defined by the entered coordinate (i.e. [x][1][0][Enter] for a x = 10 m plane). When obtained, the intersection appears as a new isoparm in the current surface.

In addition to the surface display modes available in 3D viewport's menu, the 'Display Modes' frame shows the current iso direction and allows displaying the current surface with or without its environment:



At last, the 'Mean Curvature' frame displays significant fairing measures:



Assuming that S is surface's area and k_1, $k_2$its main Gaussian curvatures, r_1 is the radius associated to the mean value of k_1, r_2 is the radius associated to the mean value of k_2 and r_{12} is the radius associated to the mean value of the double curvature product $k_1.k_2$:

$|r_1| = \sqrt{S / \iint k_1(u,v).k_1(u,v).\partial S(u,v)}$
$|r_2| = \sqrt{S / \iint k_2(u,v).k_2(u,v).\partial S(u,v)}$
$|r_{12}| = \sqrt{S / \iint k_1(u,v).k_2(u,v).\partial S(u,v)}$

Practically speaking:

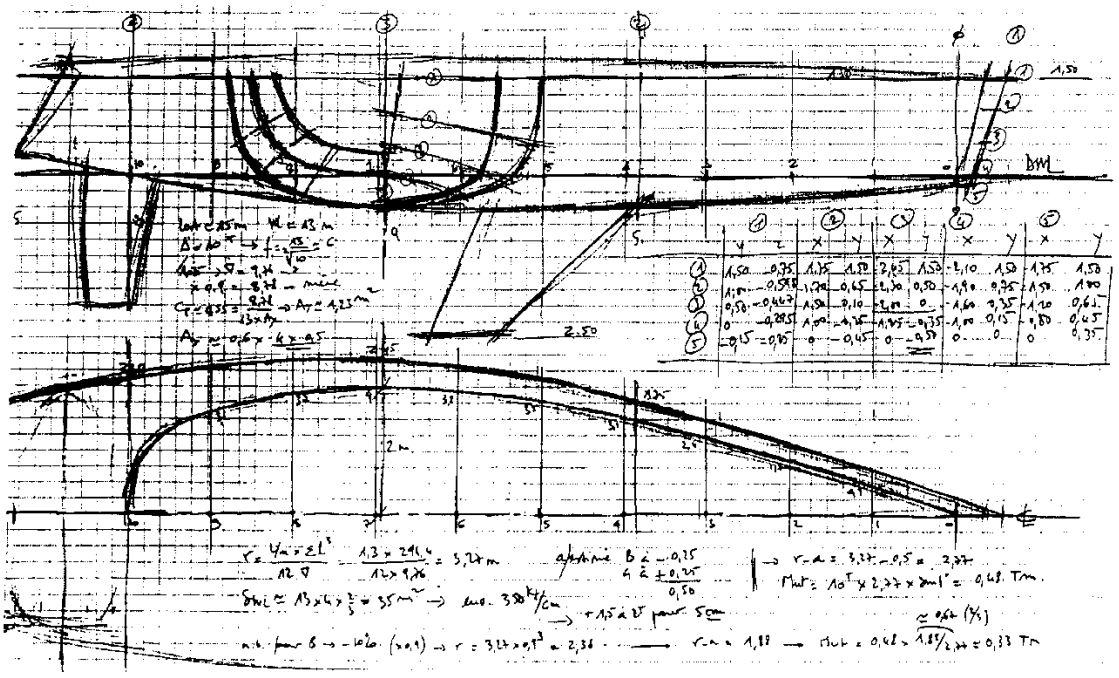
- The greater $|r_{12}|$ is, the most developable the surface is.
- The greater $|r_1|$ and $|r_2|$ are, the less bending energy the surface contains.

4.3 Designing the Hull of a 50” Aluminium Yacht:

4.3.1 Presentation:

This first NURBS++ hull modeling example is a 50’’ aluminium yacht designed by Dominique PRESLESin the 90s with CIRCE-3D / MAAT and published in his famous book ‘ArchitechtureNavale, Connaissance et Pratique’(Dominique PAULET & Dominique PRESLES. Ed. de La Villette / Dunod) to which anyone can refer as the French ship design ‘Bible’.

This is the initial sketch:



Before starting this example, let us notice that, although only few lines are drawn with a free hand precision, designer's ideas concerning surface's organization are relatively clear and allow him to fix the design stations at -1.800 m, 0.000 m, 4.000m, and 8.000m, in addition to the virtual stem line.

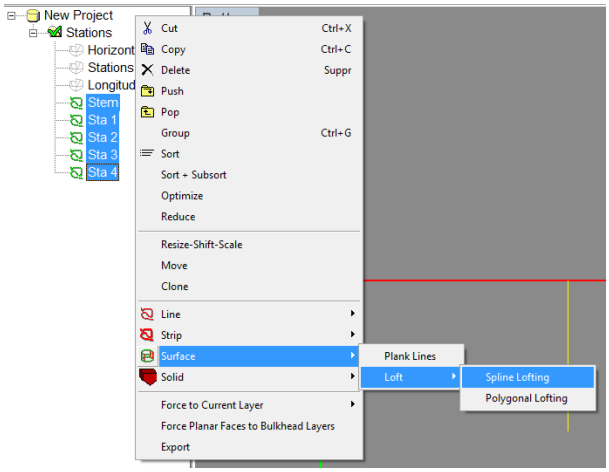
4.3.2 Starting the hull design:

As we have seen in the previous chapters how scanned drawings can be imported and used in a MAAT Hydro project for modeling ship's lines, you can directly open"/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 0.m2a", which contains all the data necessary for starting this example.

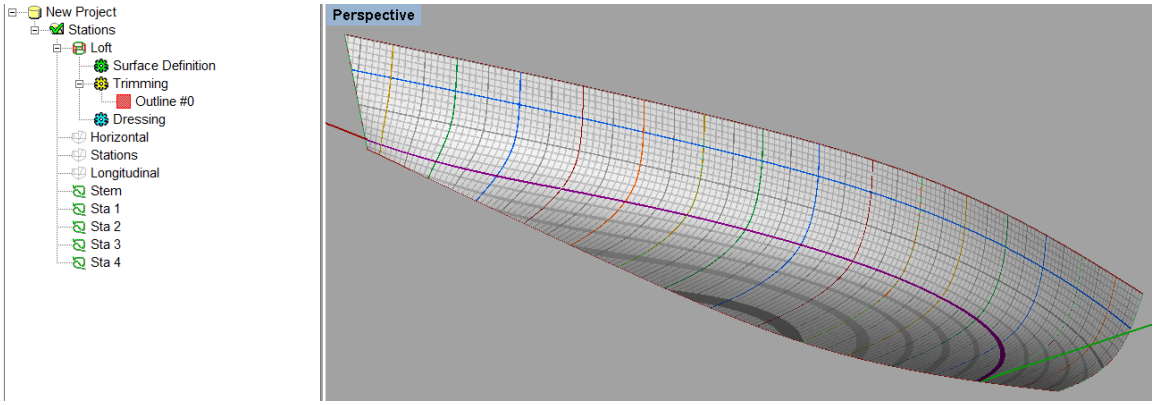
If you prefer starting from scratch, you should:

- Import and scale the body plan bitmap '/Bitmaps/50'' Yacht YZ.bmp'
- Import and scale the profile bitmap '/Bitmaps/50'' Yacht XZ.bmp'
- Import and scale the half breadth bitmap '/Bitmaps/50'' Yacht XY.bmp'
- Copy and Validate Station -1.800 m line on the body plan bitmap
- Copy and Validate Station 0.000 m line on the body plan bitmap
- Copy and Validate Station 4.000 m line on the body plan bitmap
- Copy and Validate Station 8.000 m line on the body plan bitmap
- Copy and Validate the virtual stem line on the profile bitmap

When the lines and bitmaps are created or loaded, select the 5 lines in the 3D browser, right click and select '/Surface/Loft/Spline Lofting' in the popup menu:



A surface named 'Loft' is immediately created in the current folder, which you can render like this by right clicking in viewport's upper right corner and selecting the 'Stations + Waterlines' display modein the popup menu (clicking in the [<] / [>] cells allow incrementing / decrementing the sectioning step):



4.3.3 Macros:

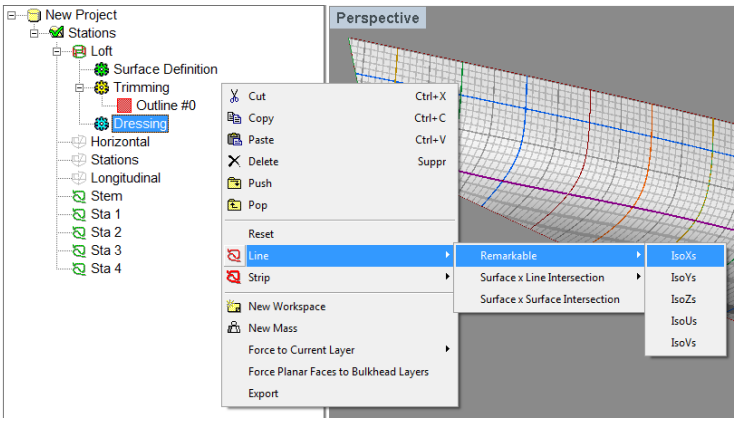
Opening the ‘Loft’ surface we have just created shows that it is parent of 3 child knots, which are its definition macros:

- The Surfacing knot is the macro that defines how the surface has been created, so that any modification of the pointed lines will cause surface’s update.

-The Trimming knotis the macro that defines how the surface has to be trimmed, so that any modification of the pointed lines / surfaces will cause surface trimming’s update.

- The Dressing knot is the macrothat defines how the surface has to be dressed, so that any modification of the pointed lines / surfaces will cause surface dressing’s update.

By example, let us select the Dressing knot in the 3D browser, right click and select ‘Line/Remarkable/isoXs’ in 3D browser’s popup menu:



Once selected, type [0][,][0][.][5][Enter] to include 0.5 m spaced stations starting from x=0 m in the Dressing knot.

At this stage:

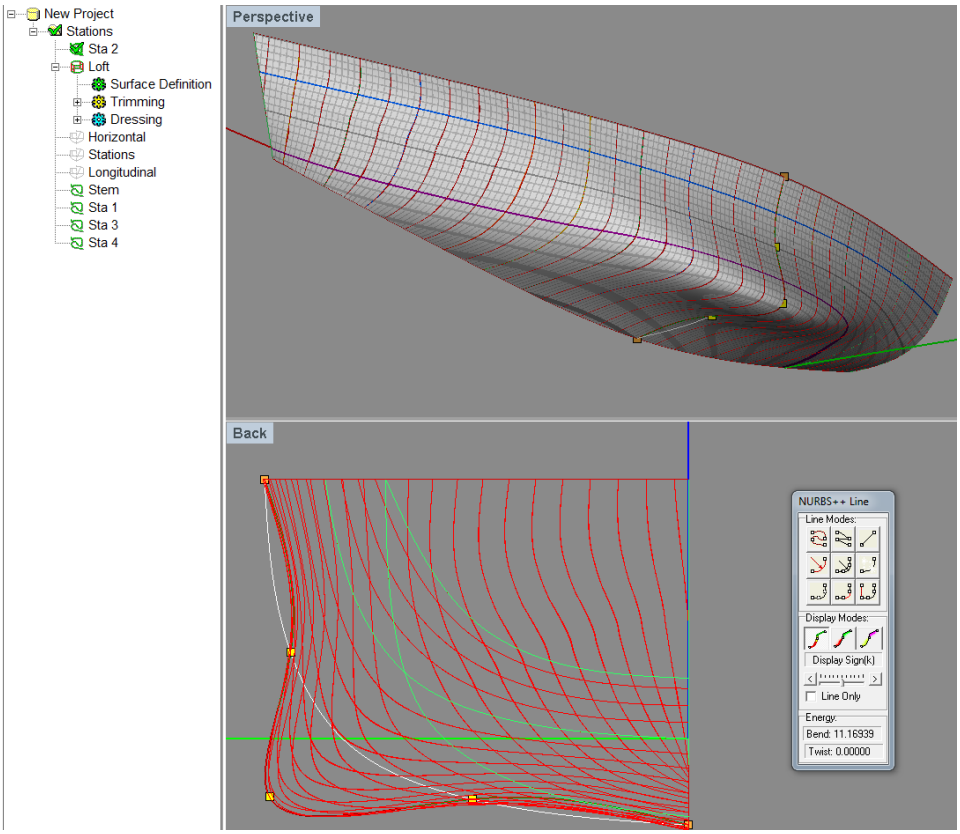
-The Surfacing knot contains the statements defining the surface.
- The Trimming knot contains the statements defining surface’s trimming (currently the default surface outline).
-The Dressing knot contains the statements defining surface’s dressing (currently the 0.5 m spaced stations).

You can destroy these knots if you want, but the parent surface will no longer be able to update itself automatically(in other terms, a surface containing macros becomes a ‘smart’ surface).

Conversely, if you want to transform a ‘raw’ surface into a ‘smart’ surface (by example when it has been imported from another modeling software), select it in the 3D browser, right click and select ‘/Surface/Raw Surface to Smart Surface’ in the popup menu.

The use of these macros will be discussed thoroughly later so, for the moment, let us just double click on ‘Sta 2’ in the 3D browser to modify this line: ‘Sta 2’ becomes active and the Line Toolbox pops up.

Click on the  (Spline) button of the Line Toolbox to switch to the spline mode, drag several spline knots and notice that hull’s spline lofting is updated in real-time, as well as its trimming and its dressing lines (stations):



Before focusing on NURBS++ surface modeling, it is important to understand that all the MAAT Hydro surfaces can contain macros defining how they are generated, trimmed and dressed. When present, these macros transform their parent surface into ‘smart’ surfaces, as they contain all the information necessary for updating their geometry as soon as any source data has changed.

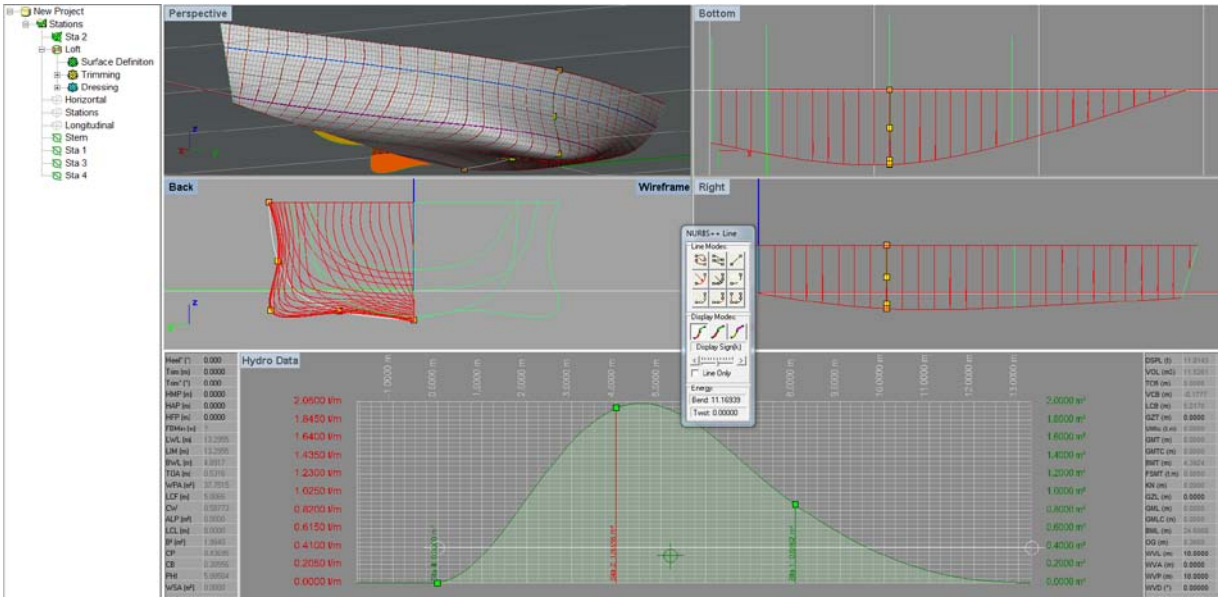
But this mechanism is only possible when the surface geometry depends on external data (i.e. a surface lofted on lines, a cylinder extruded from a line, a swept surface,…).

Conversely, using the NURBS++ surface toolbox as we will do below will directly operate on surface’s internal geometry, which will overwrite and re-initialize its ‘Surfacing’ macro, so that it will no longer be able to update it. Simply speaking, this therefore means that the MAAT Hydro surfaces will remain ‘smart’ as long as they have not been modified internally withthe NURBS++ Surface toolbox but, of course, their ‘Trimming’ and ‘Dressing’ macros will remain active.

4.3.4 Hydrostatic Control (1/2):

Moreover, you can now click onthe [Hydro] button to open the hydrostatic viewport(switch the ‘Integrate Surfaces’ mode on in Hydro viewport’s menu, otherwise no SAC will be calculated for the current surface).

The current surface is automatically mirrored and its hydrostatic data are displayed (current station is marked in red on the SAC.).Modifying the station with the line tools will now not only update the hull surface, but also all the displayed hydrostatic data:



Select ‘/Mass/Dwl Displacement’ in the menu bar and type [0][Enter] to create a displacement mass with VCG = 0: The weight / buoyancy balance can now be calculated, allowing you to use most of the ‘/Tools’ hydrostatic functions.

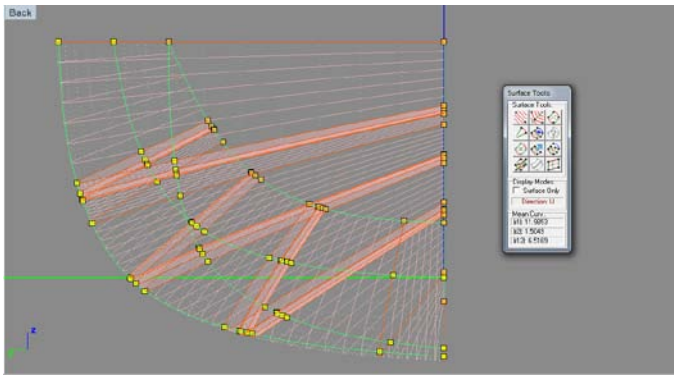
By example, select ‘/Tools/Transverse Stability’ and validate the default data to get current hull’s stability reports.

We will therefore now hit [Esc] to cancel the modification of ‘Sta 2’ and click back on the [Hydro] button to shut down the hydrostatic viewport.

This brief presentation of the macros was necessary for understanding what a MAAT Hydro surface exactly contains, but this topic will be thoroughly discussed later in this manual.

4.3.5 Improving Surface's Parametrization:

In the 3D browser, let us rename 'Hull'the 'Loft' surface we have just created and double click on it in the 3D browser in order to open the NURBS++ Surface toolbox for modifyingit: The 'Hull' surface knots,isoUsandisoVs are now displayed:



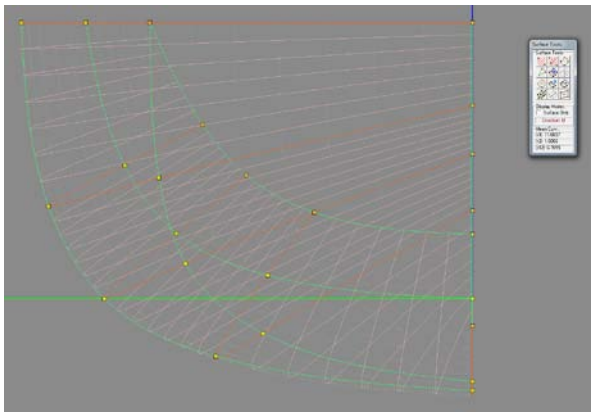
As the Spline Lofting function has to make all the selected lines compatible (i.e. with the same number of knots) before lofting, we can now see that many iso Us are useless, overloading the surface model needlessly (this is the price to pay for an automatic parameterization…).

The NURBS++ surface toolbox therefore allows optimizing model's parametrization manually or automatically:

- For dissolving a useless iso U manually, you just have to click on it and, when selected, hit the [Delete] key. You can repeat this operation as many times as necessary.

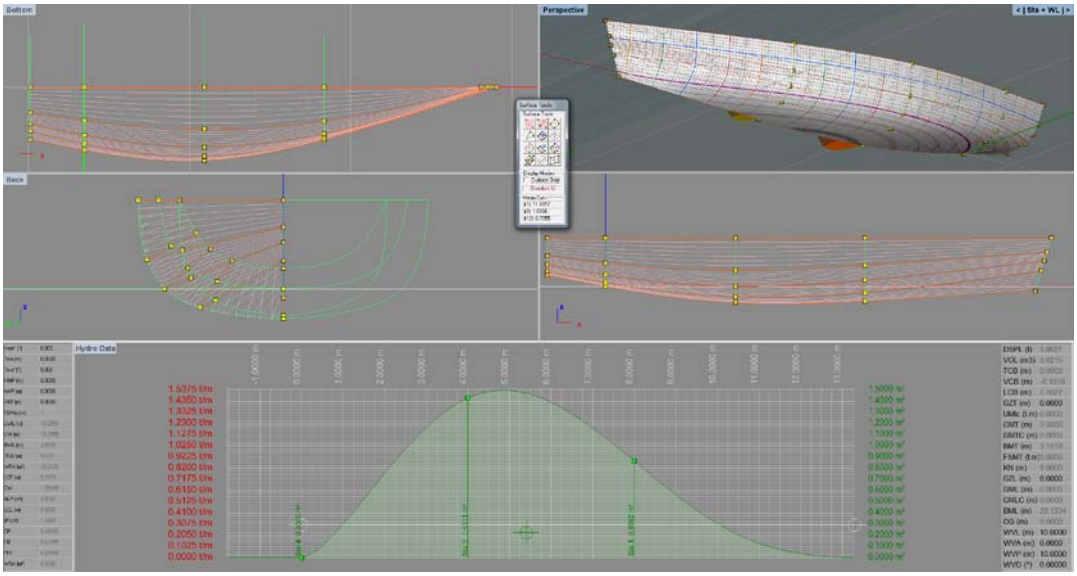
- For dissolving useless isoparms automatically,click on an iso U / iso V to select the isoparm type to dissolve andclick on the 'Approximation' tool, which automatically removes all the useless isoparms according to a 1 mm default tolerance. If you want to specify any other tolerance, you have to use the [a] shortcut followed by the tolerance and [Enter].

In this example, we will click on an iso U and directly select type [a][0][.][0][0][0][1][Enter] for re-approximating the hull surface with a 0.1 mm tolerance.After this 0.1 mm optimization, only 4 isoUs remain out of the 16 initial ones:



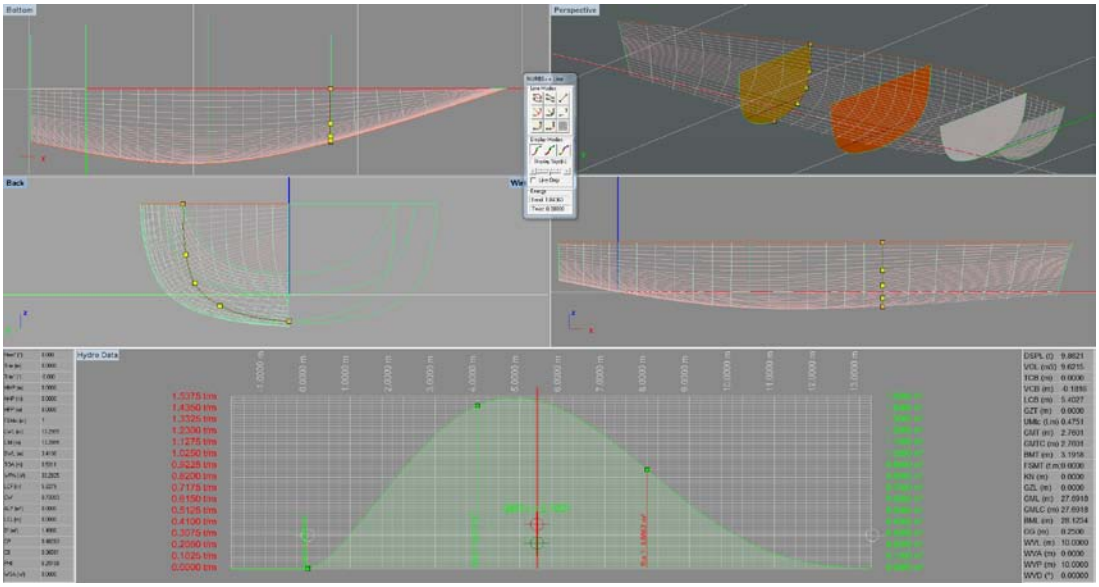
4.3.6 Hydrostatic Control (2/2):

Click on the [Hydro] button to open the hydrostatic viewport, so that the hydrostatic data of the current surface are displayed (if you don't see them, right click on the [Hydro Data] title to display its menu and insure that the 'integrate Surfaces' option is checked):



Most of the hydrostatic viewport functions can now be used for analyzing the current hull surface if necessary.

You can now double click on the Iso V [3] in the 'Back' view to modify it (click on any isoparm to identify it in status bar's right cell): The line knots now replace the surface knots, the line toolbox replaces the surface toolbox and the station is marked in red on the SAC (only when the modified isoparms is a station), which means that the selected line now has the focus instead of the underlying surface:



You can use the line toolbox for modifying any isoparm and notice that the hydrostatic data react in real-time.

Most of the hydrostatic tools are also immediately usable as soon as you have created a realistic mass for allowing the equilibrium calculations, but the line and/or surface tool boxes will automatically shut down once any function is started.

To illustrate this, select‘/Tools/Transverse Stability in the menu bar and validate the default data: The surface toolbox will shutdown and the current surface will be vlidated as soon as the calculation will start.

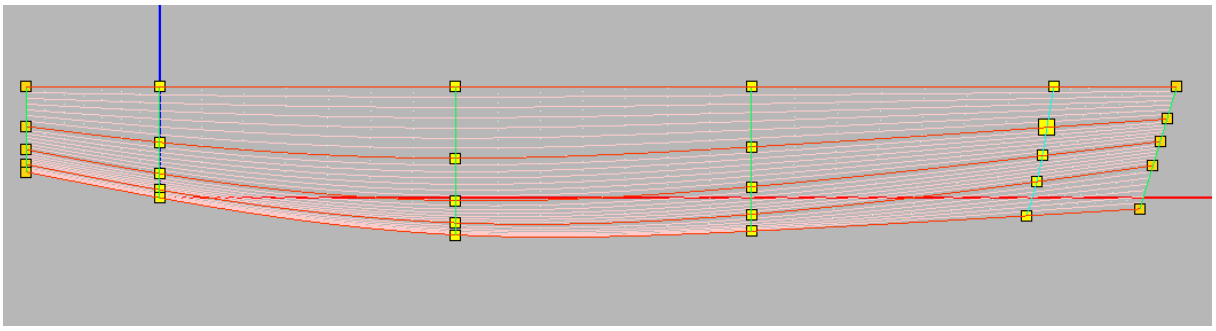
At last, like everywhere in MAAT Hydro, you can hit [Enter] to validate the current surface or [Esc] to cancel it. We will therefore hit [Enter] to validate this modified surface, which can be directly loaded from "/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 1.m2a".

4.3.7 Hull Modification:

Let us now double click on the ‘Hull’ surface knot in the 3D browser to modify it and, assuming that we now want to inflate the fore lines, we must add additional control points in this area.

The easiest way to add control points consists in inserting a new isoparm by clicking on an iso U / iso V where you want to insert it (i.e. click on an iso U to insert an iso V or vice versa)while keeping the [Control] (or [Insert]) key pressed.

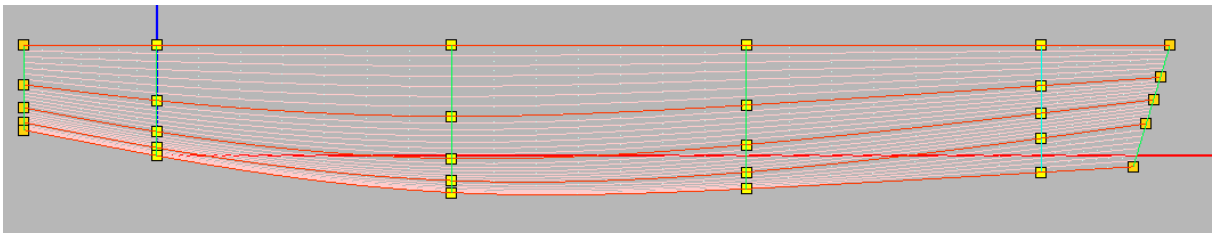
We will therefore click in the right view on (red) iso U 3 by x = 12 m while keeping the [Control] key pressed to get this new (green) iso V crossing iso U 3 by x = 12 m:



We might double click on this new line to modify it but it would be tedious, as this inserted line is not planar. In fact, inserting such isoparms is especially useful for longitudinal lines (i.e. the red iso Us in this case) .

We will therefore click this inserted isoparm to select it and hit the [Delete] key to dissolve it.

In this case, typing [t][1][2][Enter] will directly create a planar **T**ransverse isoparm located at x = 12 m (the [t], [l], [h] shortcuts are accepted for creating **T**ransverse, **H**orizontal and **L**ongitudinal isoparms as long as the specified plane doesn’t cross similar isoparms):



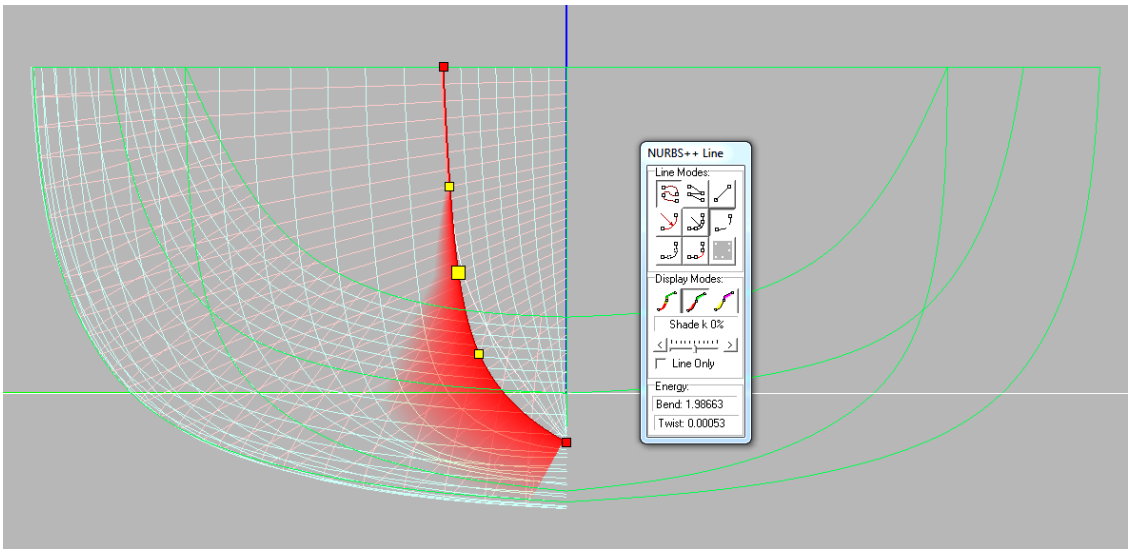
Now that the inserted iso V [4] is planar, we can double click on it and switch to the ‘Back’ view to modify this line.

Once the Line Toolbox is displayed, click on the  (Spline) button to switch to the spline mode. Dragging spline knots (as well as any other line function) now also updates the underlying surface in real-time in addition to the line itself.Please, notice that, by default, only the adjacent surface patches can be updated at this stage, but the Surface Toolbox provides all the tools necessary for redefining the surface more accurately if necessary.

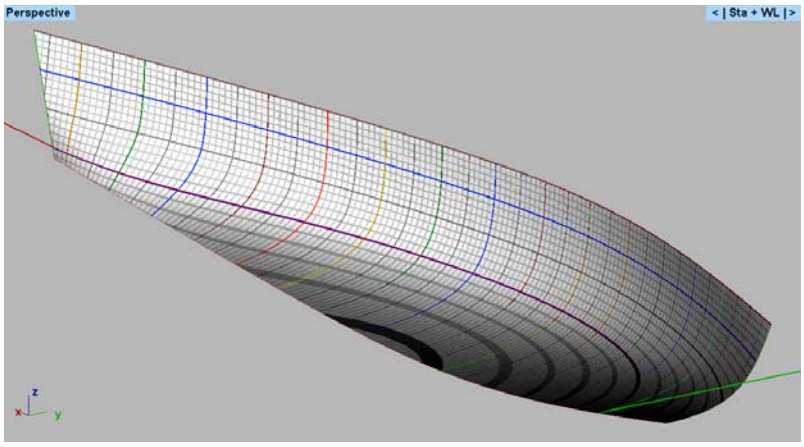
Moreover, like previously, opening the [Hydro] viewport also allows controlling the hydrostatic incidence of line’s modification in real-time if necessary.

In this case, we will select the first knot and type [p] to set a **P**ositional continuity at this extremity instead of the default **N**atural continuity, which produces flat extremities.

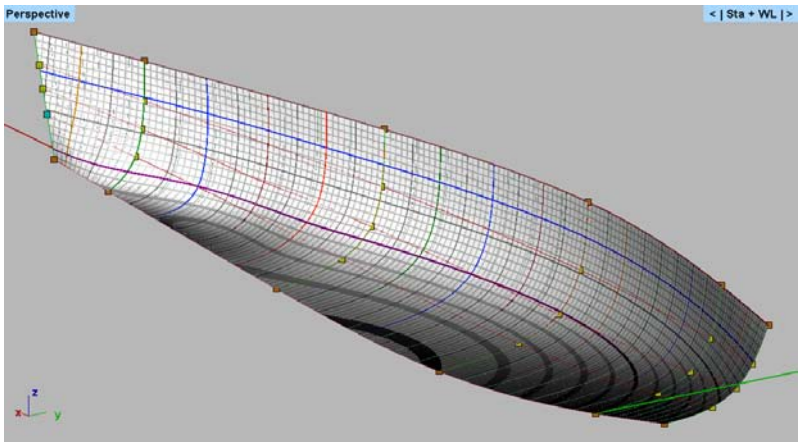
Once done, we will do the same on last knot and adjust theposition of other knots to inflate the station’s foot area:



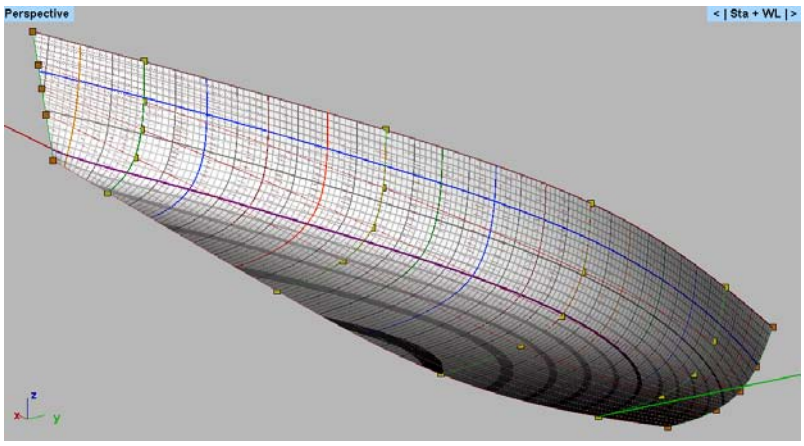
When the station is faired, hit [Enter] to validate it, click on a red isoparm to select this planking direction and click on the button (or type [s][Enter]) for lofting the current surface area with a continuous network of splines. The surface, which was only modified locally aroundiso V [4], is now smoothly planked everywhere:



Initial Hull Surface:



Locally modified Hull Surface after Line modification:



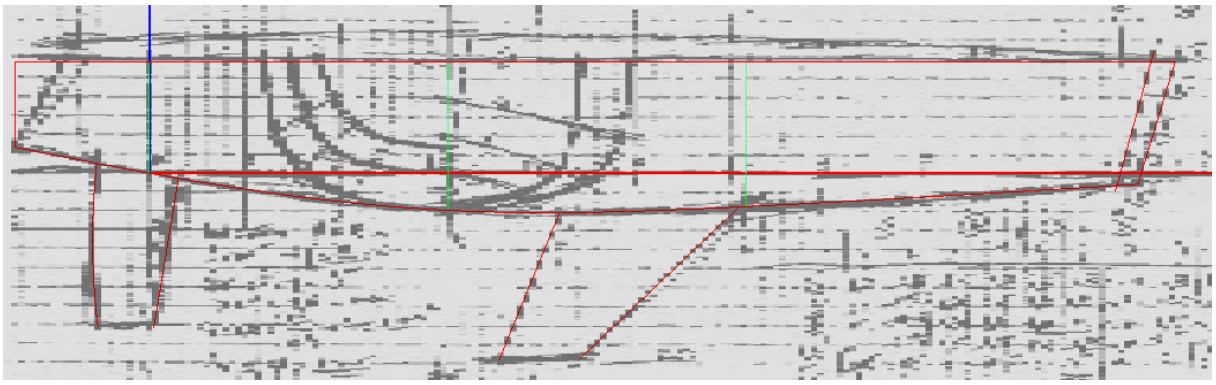
Hull Surface globally faired after Spline Planking:

This hull surface modification procedure can be repeated as many times as needed and as many additional lines as necessary can be inserted in the hull surface, although the most compact models are generally the best ones and the easiest to control.

This hull model can be directly loaded from "/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 2.m2a"):.

4.3.8 Adding Keel and Rudder Solids:

In order to make a more realistic model for hydrostatic analysis, let us now add the complete silhouette bitmap to the project for entering the real stem line, keel and rudder's leading / trailing edges (please, notice that you can keep the [Alt] key pressed for snapping points in the keel line). These data can be directly loaded from "/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 3.m2a"):

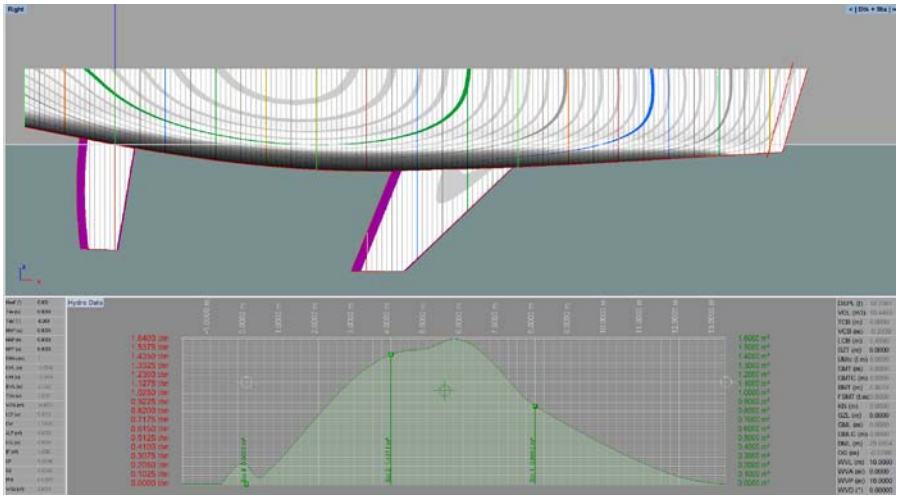


When these lines are created, select '/Solid/Wing' in the menu bar and select '/NACA/NACA 63A/NACA63A010' in the Wing Section Selection' dialog box.

Once done, insure that the positive side is selected in the lower left selector and click on the [OK] button to validate your selection. You can now click on keel's leading edge to create the keel solid.

We will then repeat the same procedure for creating the rudder with a NACA63A 012 wing section.

You can now click on the [Hydro] button to open the [Hydro] viewport and see that the keel and rudder volumes are now added to the hull volume (remember that the [Hydro] viewport menu allows you to enable / disable the hydrostatic engines operating simultaneously in MAAT Hydro). Although these appendages are not exactly intersecting the hull bottom, this model is enough accurate for hydrostatic calculations (this topic will be discussed later):



4.3.9 Defining a Stem Cone:

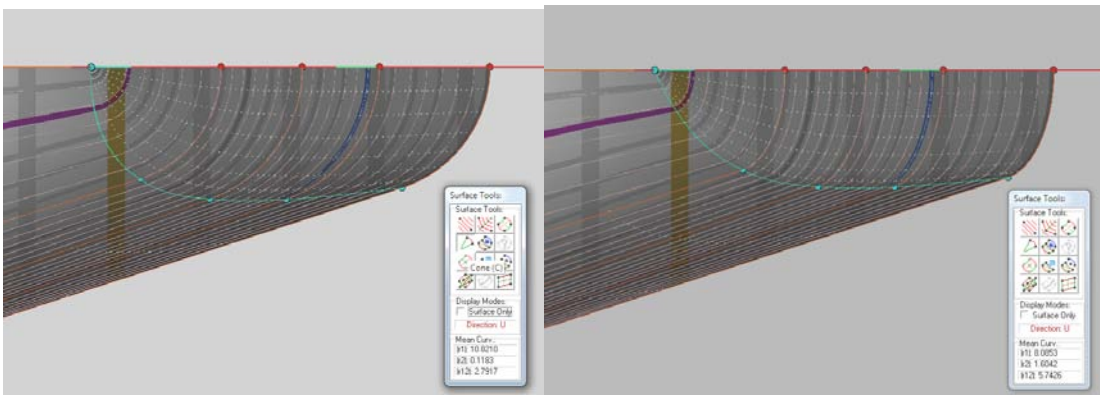
You can now double click on the hull surface in the 3D browser to modify it again and select the 'Cone' tool (or type [c][Enter]). This tool works in 3 different ways, depending on the line you will select:

First of all, we will click on the 'Stem (Real)' line we have copied on the bitmap (in the 3D browser or in a 3D viewport).

A stem 'cone' ending on the selected line is immediately appended to the hull surface and its tangency line is automatically inserted (notice that the associated continuities are automatically set to 'Tangent' and that you can control cone's aspect ratio if necessary by entering it before selecting the line.

In order to demonstrate this, type [Ctrl][z] to undo the operation and select the 'Cone' tool once again. This time, type [r][0][.][5][Enter] before selecting the line and insure that cone's aspect ratio has been updated from 1.0 ro 0.5 (you can also type the ratio directly if necessary: [.][5][Enter]).

Once done, select the real stem line again and compare the new stem cone with the previous one:



Aspect Ratio = 1.0: Aspect Ratio = 0.5

It is important to notice here that when an external line is selected, the 'cone' surface is automatically appended to the surface (i.e. the tangency line is inserted in the surface), so that we can't repeat this function without undoing the operation.

Nevertheless, when a surface isoparm is selected for the 'Cone' tool instead of an external line, no tangency line will be added and it will work differently:

-When the selected iso U or V is the first or the last one, the 'cone' surface will be simply created by blending the existing tangency line with its symmetric line and crossing the selected line (all the lines remain unchanged and cone's aspect ratio is therefore ignored. Blending continuities on the tangency line are taken into account).

-When the selected iso U / V is not the first or last one, it is considered to be the tangency line and the ‘cone’ surface will be generated freely, according to the current aspect ratio, so that first / last isoparm will be modified accordingly.

In order to illustrate these other operating modes, let us now conserve the laststem cone (don’t undo it !) and select the ‘Cone’ tool once again. This time, click on the stem isoparm in the 3D viewport instead of ‘Real Stem’s externalline: Although the stem and tangency lines do not change significantly, the stem cone surface slightly varies, as it is now generated with a network of blending splines instead of the previous ellipses.

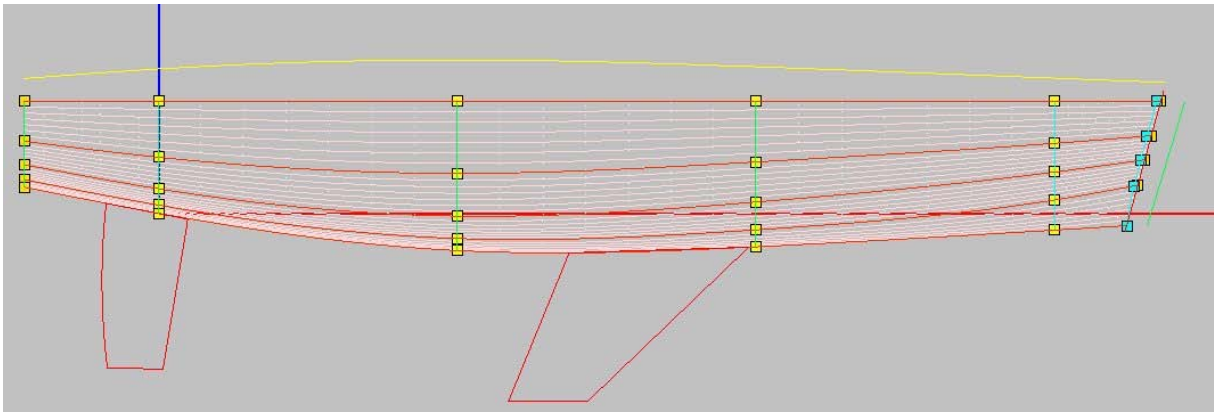
Finally, select the ‘Cone’ tool once again and, this time, click on stem cone’s tangency isoparm in the 3D viewport instead of the stem isoparm: This time, only the tangency line remains unchanged and the stem line as well as the stem cone surface are updated, according to the current aspect ratio as it is generated with a network of ellipses in this case, like for an external line (you can make this change more obvious by modifying the stem line before using the ‘Cone’ function).

Of course, the ‘Cone’ tool can also be used for generating a bulb or stern cone as well as an elliptic deck or a flat bottom, depending on the selected line and aspect ratio.

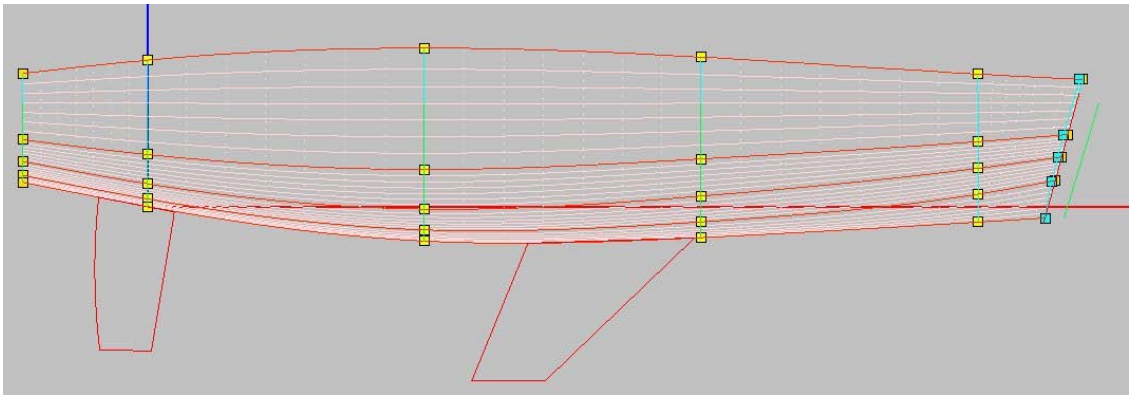
4.3.10 Modifying Surface’s Extent:

At last, we will now prolong this hull surface to make it large enough for calculating any deck intersection.To do so, click on the button (or typing [^][Enter]) tostart setting surface’s extent.

Once done, a yellowisoparm will follow the cursor in the 3D viewports, so that you will just have to click for selecting surface’s newlimit:



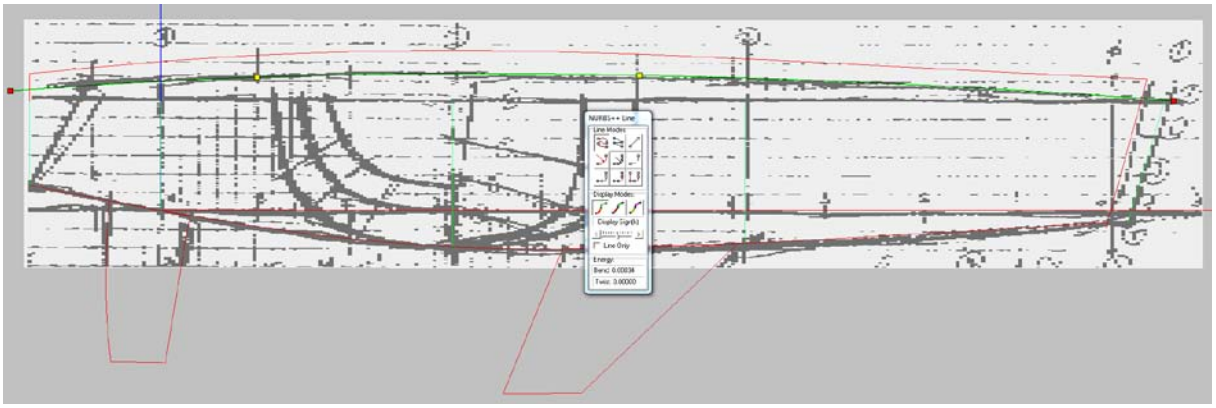
Once you have clicked, surface's upper will be transformed as follows:



You can now press [Enter] to validate this surface (these data can be directly loaded from "/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 4.m2a").

4.3.11 Defining a Deck (First Method):

Let us now double click on the 'Longitudinal' bitmap to turn it on, maximize the ''Right' view and select '/Line/Spline' in the menu bar in order to copy ship's deck line:



Press [Enter] when the deck line is finished, rename it 'Deck Line' in the 3D browser, double click on the 'Longitudinal' bitmap to turn it off, click on the [Data] tab to switch to data page and fix deck line's layer to 'Marking' to 'mark' this line as remarkable (more will be said below about this).

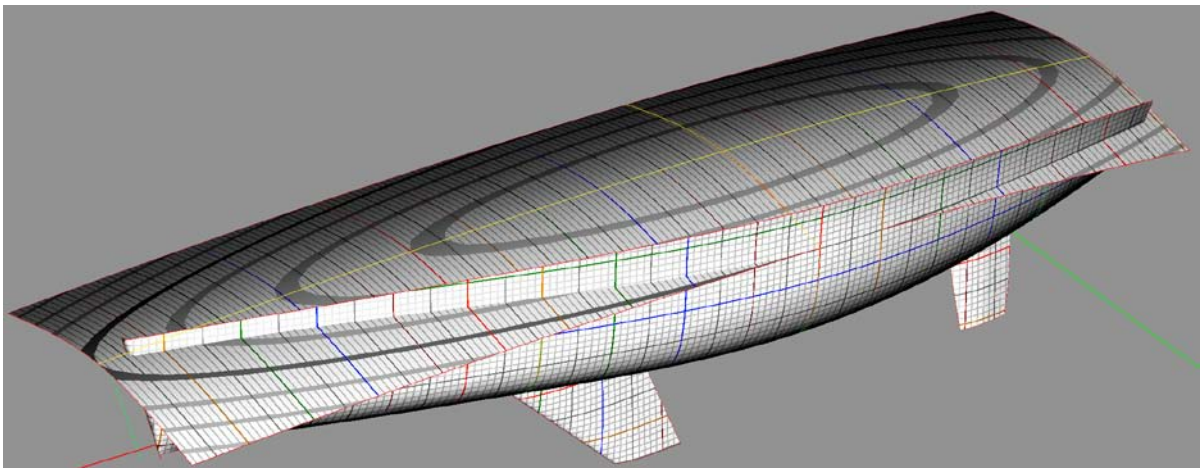
Once done, return to the 3D page, maximize the 'Back' viewport and select '/Line/Arc/Deck Camber' in the menu bar. While keeping the [Shift] key pressed for snapping line's knots, click by 'Sta 2's upper extremity for entering this starting point.

As we want arc's ending point to be symmetric, type [-][y][Enter] to enter it instead of clicking. Moving the cursor now allows setting arc's camber freely. Click when arc's camber looks realistic (it will be fix accurately below).

Double click on this new arc to modify it and, while keeping the [Control] key pressed, click on its top: A knot is now inserted near the middle / top of the arc.

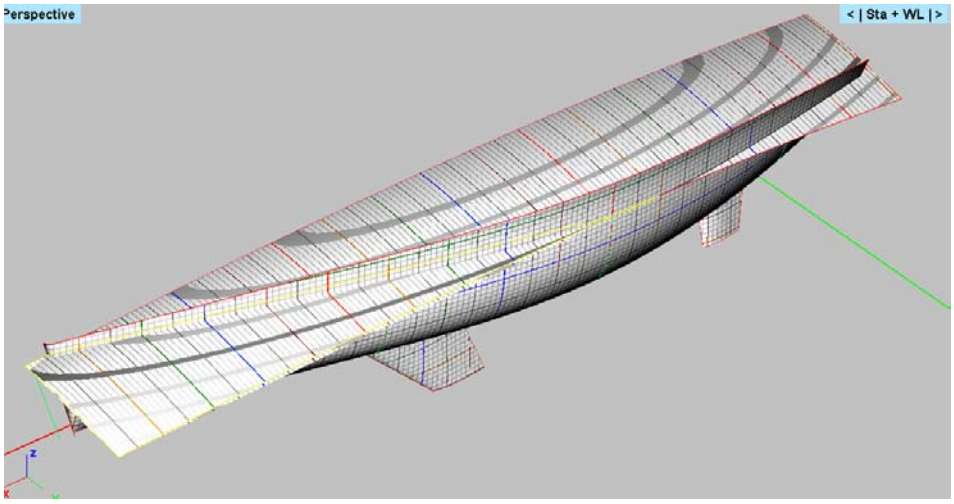
Click on this this knot to select it and type [!][Enter] to snap it on the deck line (This is why we have previously set deck line's layer to 'Marking'.See 'Annex 1: Line Modeling Reminder' for details.): Deck Camber's top is now snapped on the deck line, so that we canhit [Enter] to validate this deck camber.

Click on this 'Deck Camber' line in the 3D browser to select it, right click and select '/Surface/Sweep 1 Rail /Parallel' in its popup menu. Once done, select 'Deck Line' in the 3D browser to create a deck surface and rename it 'Deck':

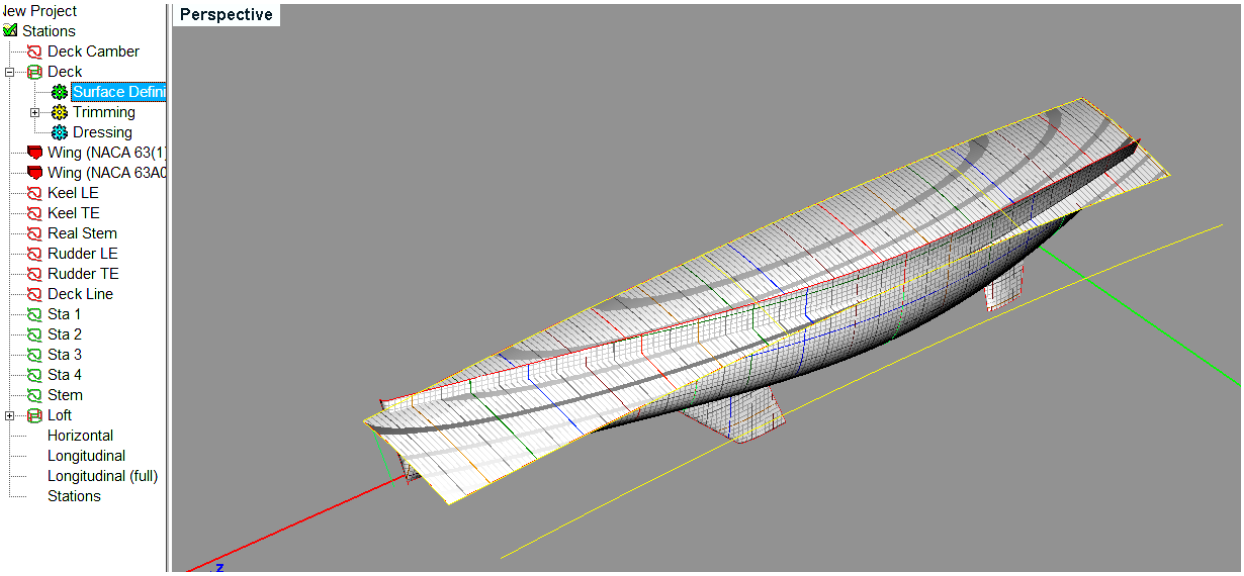


Double click on the deck camber (or the deck line) to modify it and notice that the deck surface follows your modifications in real-time (thanks to its 'Surfacing' macro). Finally select Deck Camber's knot [2] and hit [Delete] to remove it for conserving only the half of the deck camber. Once done, hit the [Enter] key to validate this half deck surface.

Select '/Deck/Trimming' macro in the 3D browser, right click to select 'Cut / Surface' in its popup menu and click on the 'Hull' surface in the 3D browser to use it for trimming the deck surface. Hitting [/] allows selecting Deck's trimmed area (highlighted in yellow) but, in certain cases, the 'Deck' face might not be wide enough for getting the expected outline:

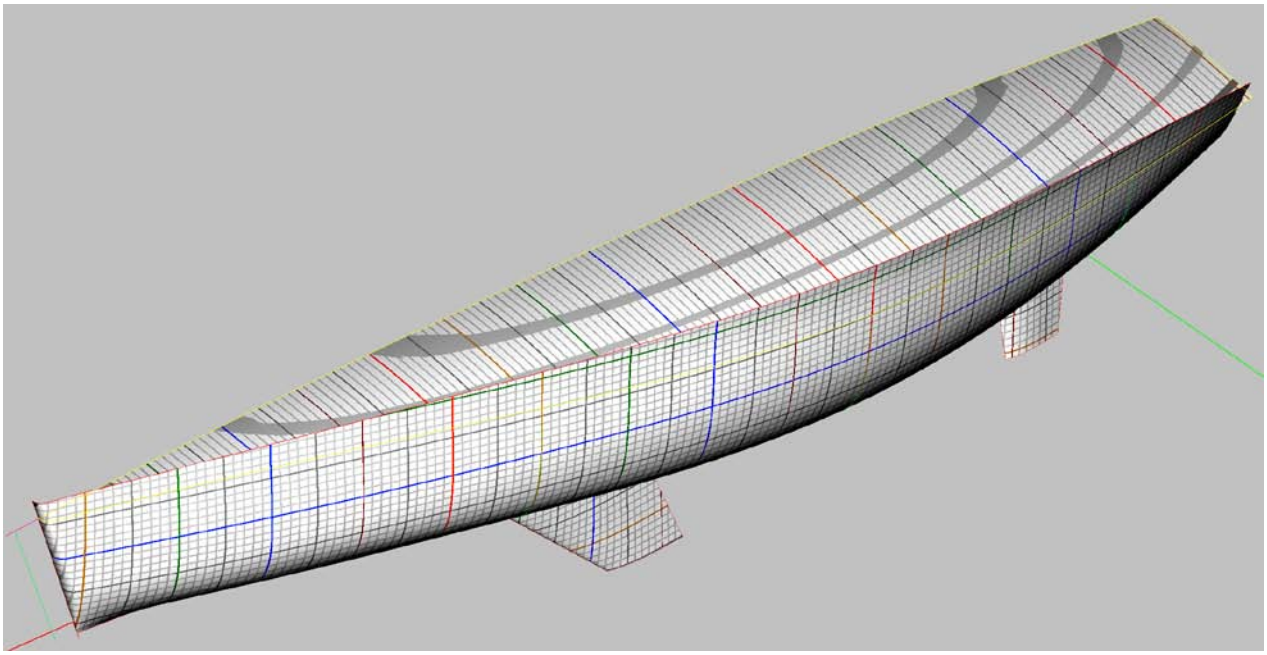


In such a case, you should hit [Escape] instead on [Enter] for cancelling this operation,select the ‘/Deck/Surfacing’ macro in the 3D browser, right click, select ‘Set Extent’ in the popup menu, set deck’s new width like this:

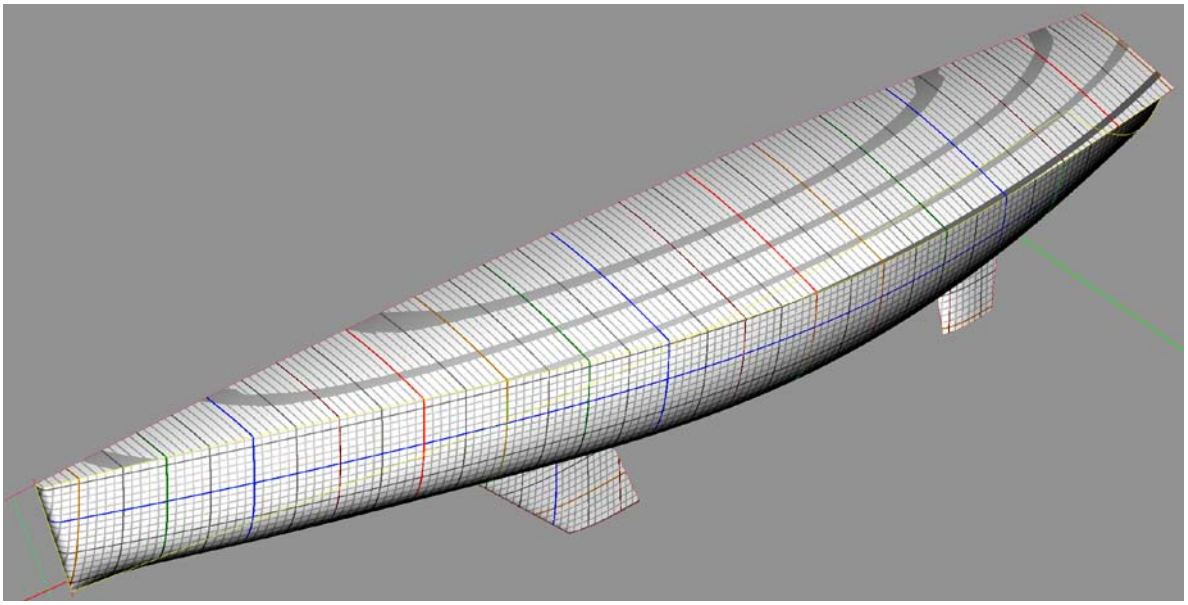


Once deck’s new limit is fixed, click and hit [Enter] directly to validate this prolonged deck surface.

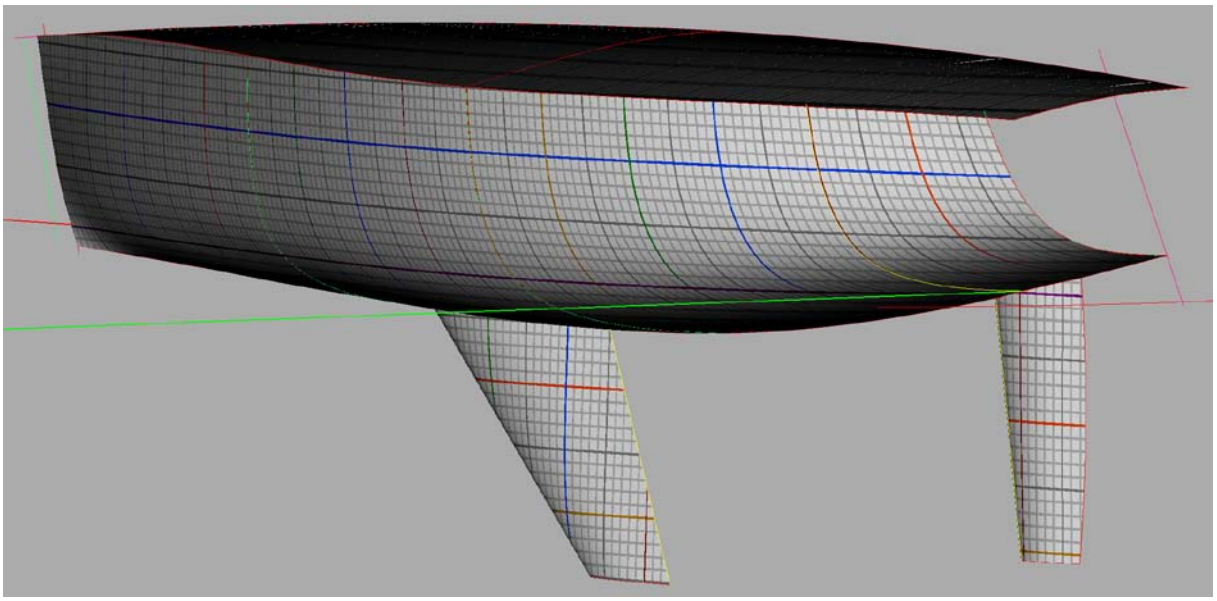
Now that the deck face is wide enough for intersecting the hull surface, re-select ‘/Deck/Trimming’ macro in the 3D browser, right click to select again ‘Cut / Surface’ in its popup menu and click on the ‘Hull’ surface in the 3D browser to use it for trimming the Deck surface: This time, the Deck / Hull intersection is complete and you can hit the [/] key for selecting Deck’s inner trimmed area (highlighted in yellow). Hit [Enter] when the outline is selected for validating the operation:



Once the deck face is trimmed, let us trim the hull surface similarly: We should select the ‘/Hull/Trimming’ macro in the 3D browser, right click to select again ‘Cut / Surface’ in its popup menu and click on the ‘Deck’ surface in the 3D browser to use it for trimming the hull surface: Once done, hit the [/] key for selecting hull’s lower trimmed area (highlighted in yellow).Hit [Enter] when the outline is selected for validating the operation:



Obviously, this Hull xDeck intersection is not visually satisfying, so that we haveto re-define the deck surfaceanother way:

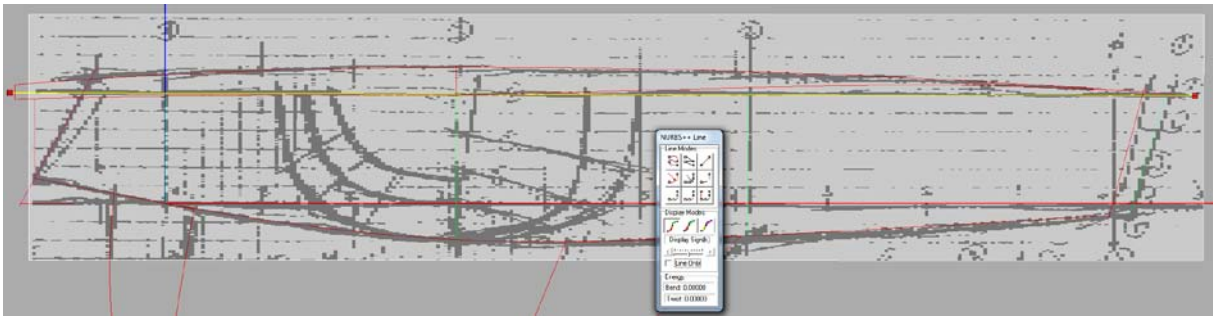


These data can be directly loaded from "/MAAT Hydro/DemoFiles/50’’ Yacht/50’’ Yacht 5.m2a".

4.3.12 Defining a Deck (Second Method):

Let us therefore maximize the Right view and double click on the ‘Longitudinal’ bitmap in the 3D browser to turn it on.

Select ‘/Line/Segment’ in the menu bar for copying sheer line’s right view from the ‘Longitudinal’ bitmap (segment should exceed hull’s extremities to get a clear intersection, as shown below). You can double click on this segment to modify it if necessary and hit [Enter] or [Esc] to validate or cancelyour modification. Finally,rename this line ‘Sheer Trace’ in the 3D browser:



Select the ‘/Hull/Trimming’macro in the 3D browser, right click and select ‘Reset’ in the popup menu to cancel previous deck’s trimming / revert to surface’s default outline.

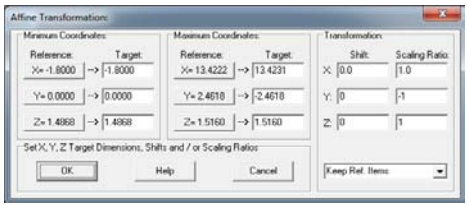
Delete previous deck surface, double click on the ‘Longitudinal’ bitmap to turn it off and on the [Right] title to return to the multi-viewport display.

Select the ‘Hull’ surface in the 3D browser, right click, select ‘/Line/LinexSurface Intersection/Longitudinal View’ in the popup menu and click on the ‘Sheer Trace’ line in the 3D browser to get its longitudinal intersection with the ‘Hull’ surface.

Switch to the [Data] page, set ‘Deck Line’s layer to ‘C_Red’ and set the layer of ‘Sheer Trace x Hull’ to ‘Marking’ to use it as reference instead of the deck line.

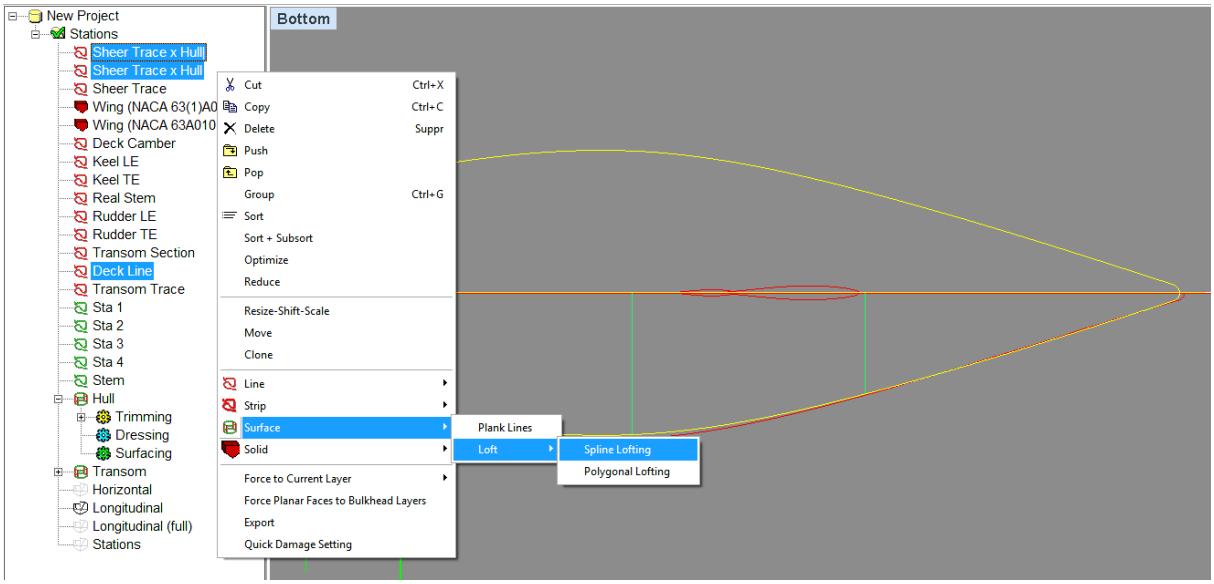
Return to the [3D] page and double click on ‘Deck Line’ to modify it. Once done, click on the  (Spline) button, select knot [0], type [!][Enter] to snap it on sheer line’s foremostextremity instead of its virtual position and hit [Return] to validate this new deck line.

Once done, select the created ‘Sheer Trace x Hull’ intersection in the 3D browser, right click and select ‘Resize-Shift-Scale’ in the popup menu. Set the y scaling factor to -1 and don’t forget to select the ‘Keep Reference Items in the lower right selector for adding the mirrored line to the original one instead of replacing it:



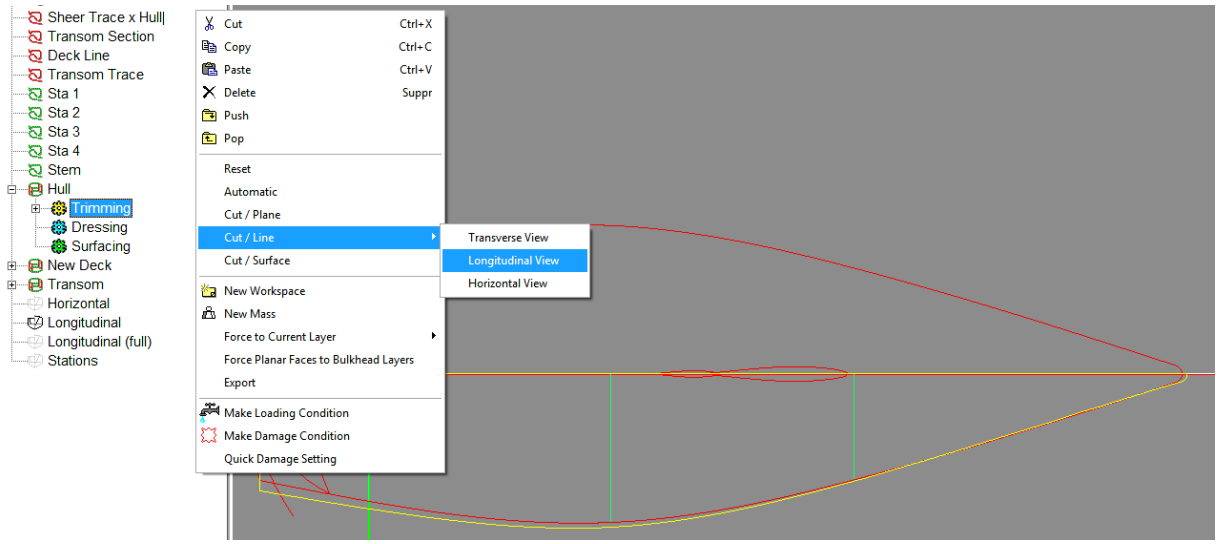
Once these data are validated, the starboard and portside sheer lines are created as 3D lines, so that you can rename them ‘Sheer (SB)’ and ‘Sheer (PS)’.

Select these symmetric sheer lines and the ‘Deck Line’ in the 3D browser, right click and select ‘/Surface/Loft/Spline Lofting’ in the popup menu for creating the new deck surface, which will be renamed ‘New Deck’:

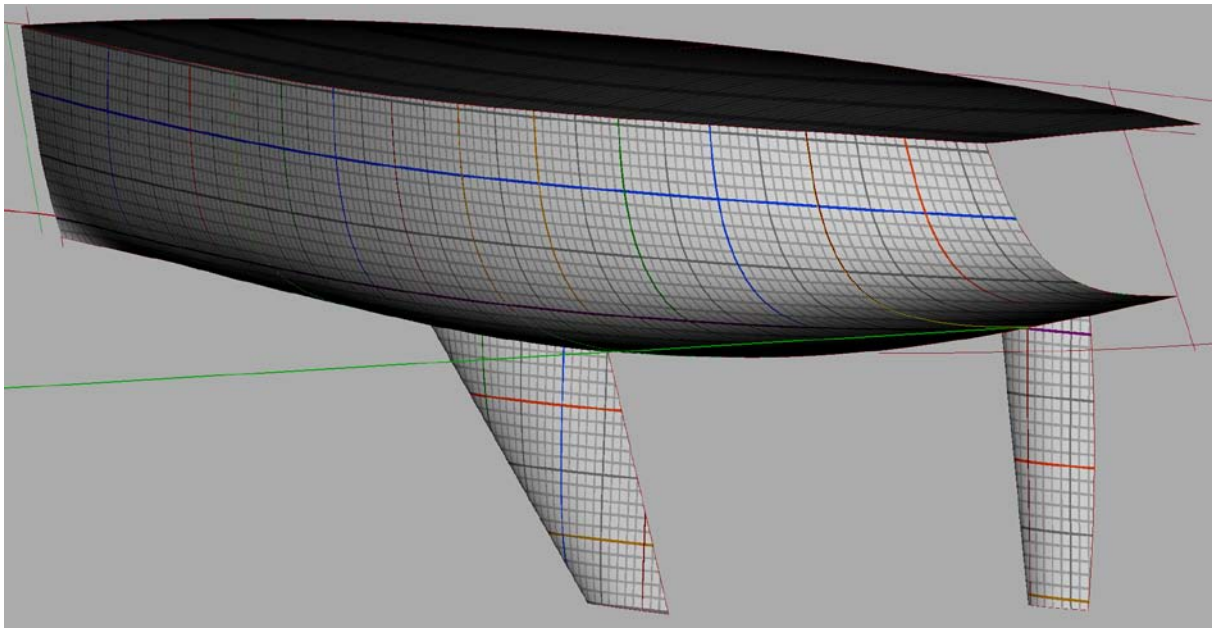


Double click on the ‘New Deck’ surface in the 3D browser to modify it, click on its ‘Iso V [0]’ to select it, hit [Delete] to delete it for conserving only deck’s portside half and hit [Enter] to validate this portside deck.

Select the ‘/Hull/Trimming’ macro in the 3D browser, right click and select ‘/Surface/Cut / Line/Longitudinal View’ in the popup menu to trim the ‘Hull’ surface by the new deck and hit the [/] key to select the lower hull outline:



Once selected, hit [Enter] to validate hull's deck trimming. New sheer line's fairness can then be controlled in the 3D viewports and now seems satisfying:



These data can be directly loaded from "/MAAT Hydro/DemoFiles/50'' Yacht/50'' Yacht 6.m2a".

4.3.13 Defining the Transom:

In order to define the transom in a similar way, double click on the 'Longitudinal' bitmap to turn it on, maximize the 'Right' viewport, select '/Line/Segment' in the menu barand enter transom trace's extremities on the longitudinal bitmap.

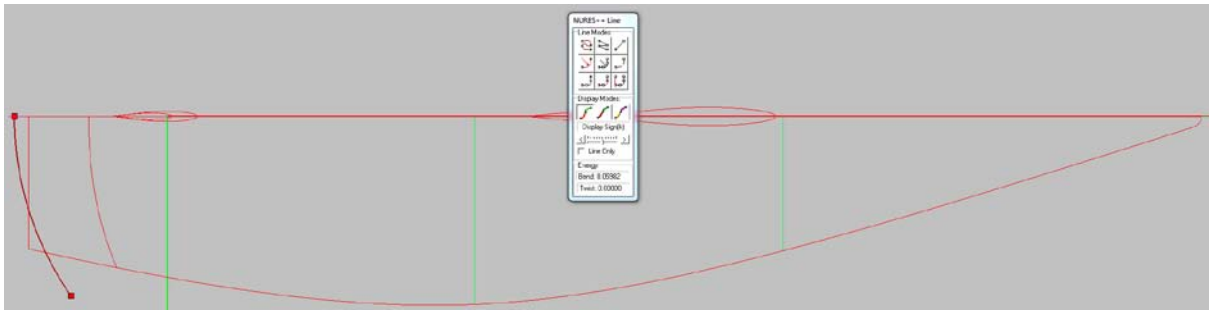
Once transom's straight trace is copied and renamed 'Transom Trace', double click on the bitmap in the 3D browser to turn it off, and on the 'Right' title' to reduce the viewport, so that you can now maximize the 'Bottom' viewport.

Switch to the [Data] page, set Transom Trace's layer to 'Marking' to make it remarkable and switch again to the [3D] page.

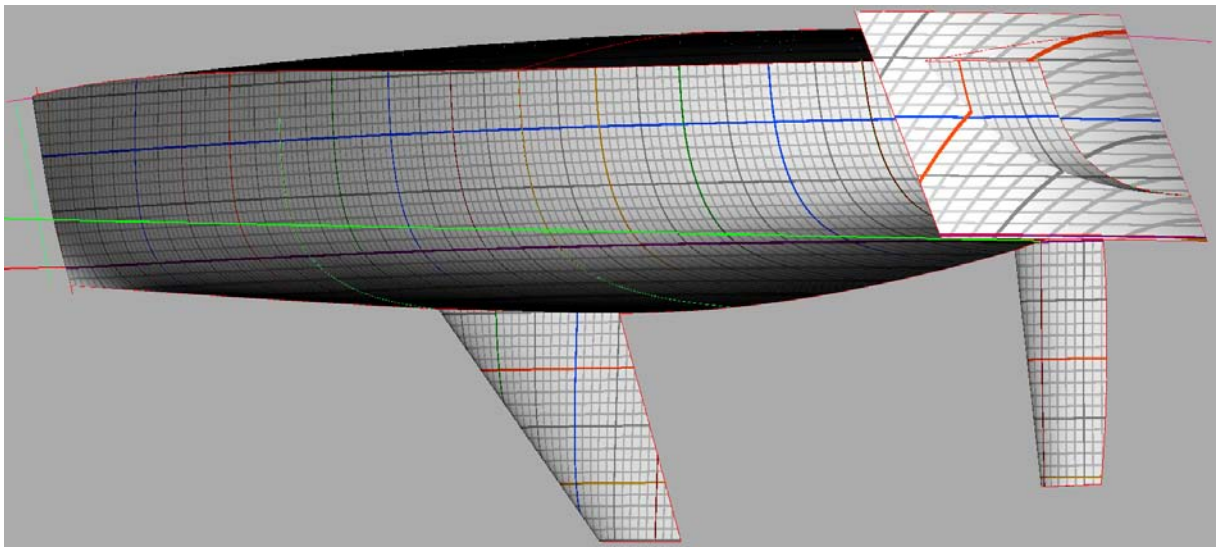
Select '/Line/Arc/Circle' in the menu bar and enter the first extremity of transom's horizontal section sufficiently out of the hull to get a clear intersection with it. Once done, type [-][y][Enter] to mirror this input and set arc's radius approximately.

Double click on this circle arc to modify it and, while keeping the [Control] key pressed, click by its middle: A knot is now inserted near the middle / top of the arc.

Like for deck's camber, click on this knot to select it and type [!][Enter] to snap it on the 'Transom Trace' line (That is why, like previously, we have set its layer to 'Marking'.See 'Annex 1: Line Modeling Reminder' for details.): 'Transom Section's middle is now snapped on the 'Transom Trace' line. Click on the  button (or hit [c][Enter]) to restore arc's circularity. Select knot [2] and hit [Delete] to conserve only the half section and hit [Enter] to validate it:



Rename this arc 'Transom Section' in the 3D browser, select it, right click to select '/Surface/Sweep 1 Rail/Parallel' in the popup menu and select 'Transom Trace' in the 3D browser to create an inclined cylindrical transom face, which you can rename 'Transom' in the 3D browser:

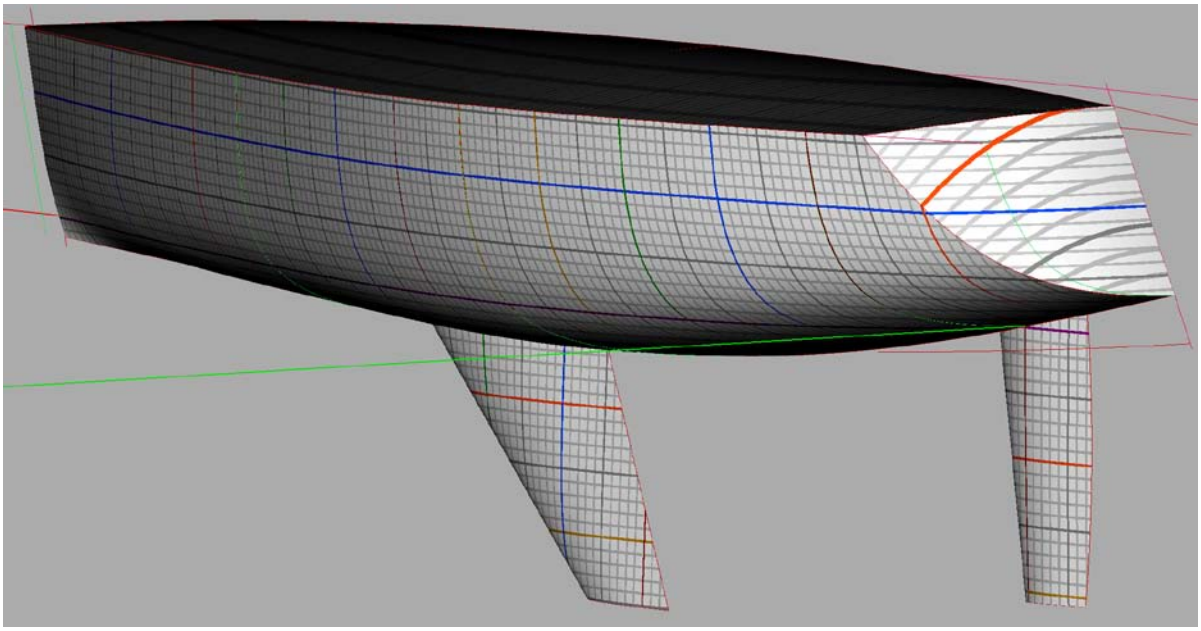


Select ‘/Transom/Trimming’ macro in the 3D browser, right click to select ‘Cut / Surface’ in its popup menu and click on the ‘Hull’ surface in the 3D browser to use it for trimming the Transom face: Hit the [/] key for selecting Transom’s inner area (highlighted in yellow) andhit [Enter] to validate.

Select ‘/Transom/Trimming’ macro in the 3D browser and right click again to select ‘Cut / Surface’ in its popup menu.Click on the ‘New Deck’ surface in the 3D browser to use it for trimming the ‘Transom’ face, hit the [/] key for selecting Transom’s appropriate area (highlighted in yellow) and, when done, hit [Enter] to validate.

Finally, select ‘/Loft/Trimming’ macro in the 3D browser and right click again to select ‘Cut / Surface’ in its popup menu. Click on the ‘Transom’ surface in the 3D browser to use it for trimming the ‘Hull’ face, hit the [/] key for selecting Hull’s appropriate area (highlighted in yellow) and, when done, hit [Enter] to validate.

The Hull model now looks like this:

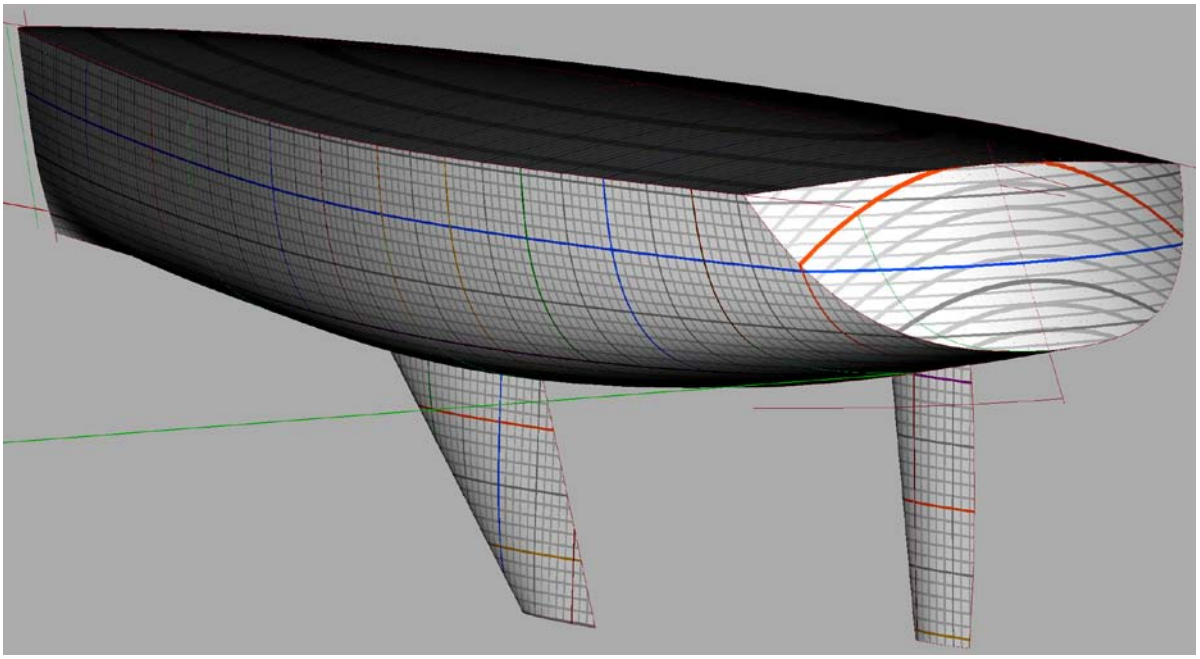


These data can be directly loaded from "/MAAT Hydro/DemoFiles/50’’ Yacht/50’’ Yacht 7.m2a".

4.3.14 Defining the Hull Solid

Select the current workspace in the 3D browser, right click and select ‘Sort’ in the popup menu to sort all the model items.

At last, select the 3 trimmed surfaces we have created in the 3D browser, right click and select ‘/Solid/Mirror Selected Faces to Solid’ in the popup menu to create the final hull solid:



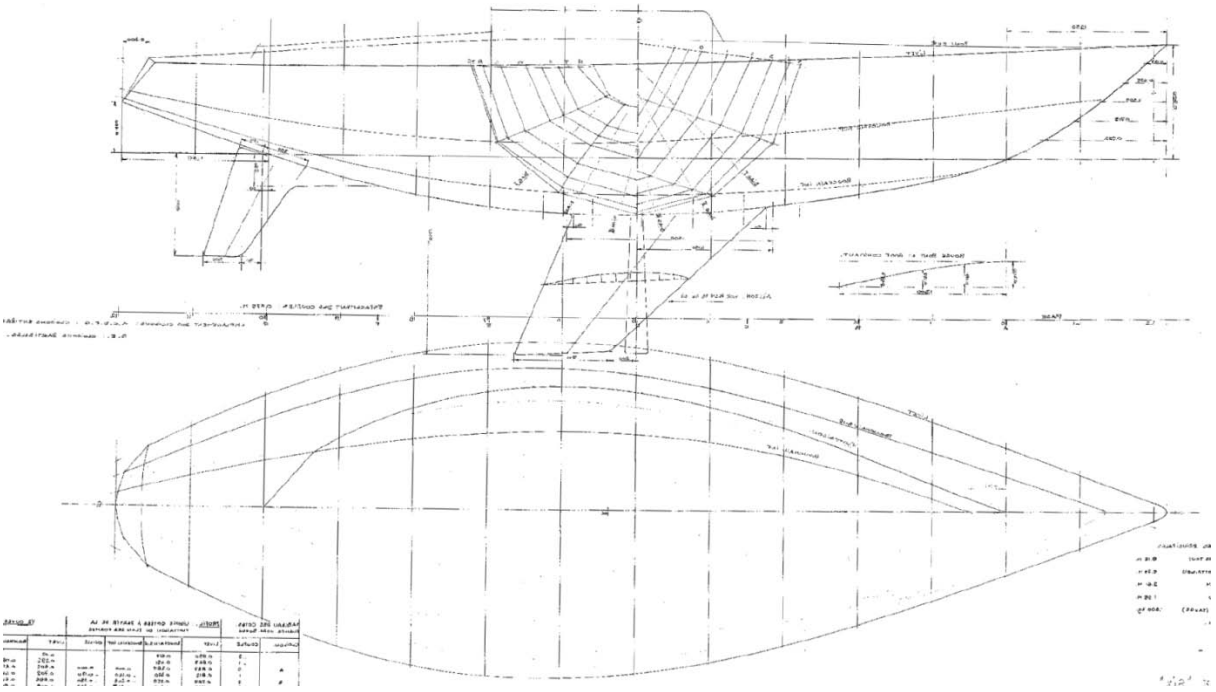
These data can be directly loaded from "/MAAT Hydro/DemoFiles/50” Yacht/50” Yacht 8.m2a".

If necessary, select the 3 solids in the 3D browser, right click and select ‘/Solid/Merge’ in the popup menu to gather all these items into a single solid.

4.4 Designing the Hull of a 30” Hard chine Yacht:

4.4.1 Presentation:

Emeraude is one of the first famous ships designed by Dominique Preslesin the 60s and her simple but beautifulhull is perfect for illustrating various hard chine hull modeling techniques in MAAT Hydro.

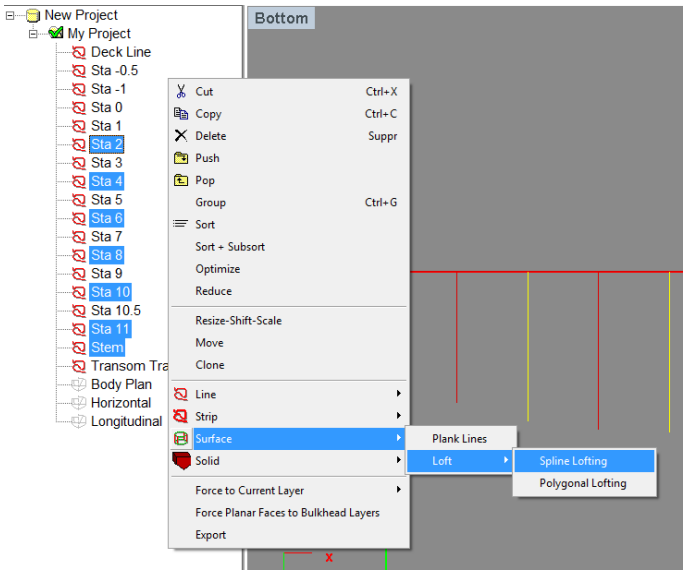


As the bitmap importation and scaling procedure should now have become familiar to you, as well as copying the necessary ship lines, you can directly open"/MAAT_Hydro/DemoFiles/Emeraude/Emeraude_0.m2a", which contains all the data necessary for starting this example.

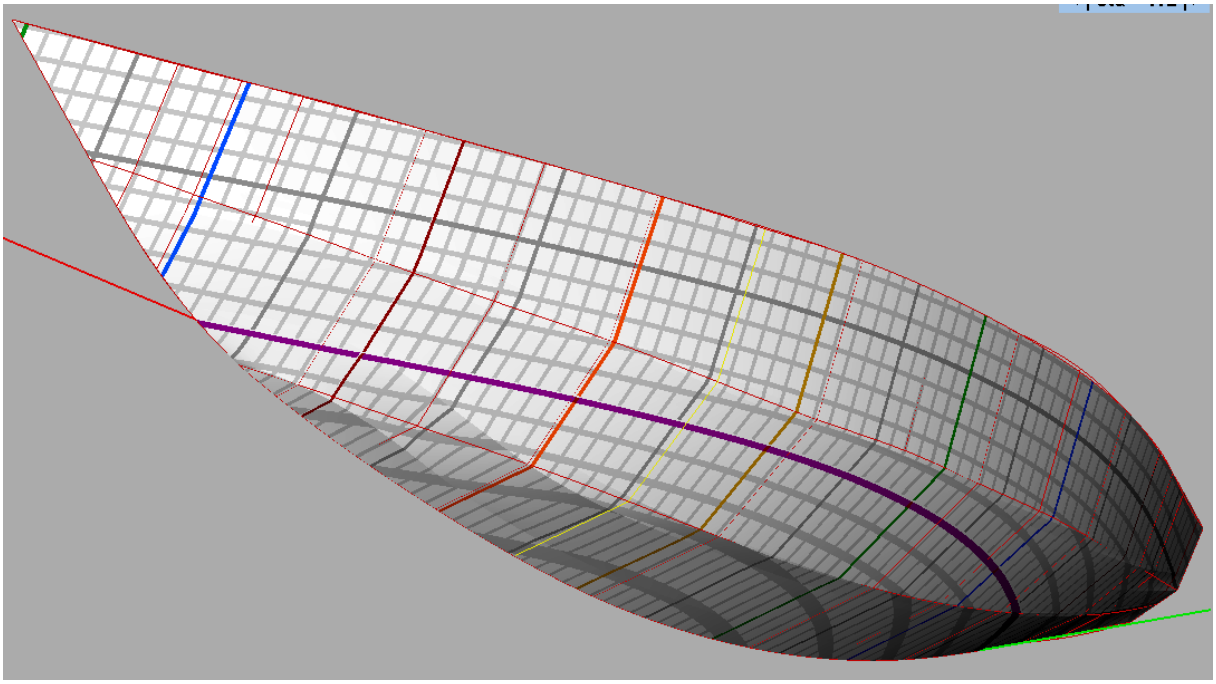
4.4.2 Hull Lofting… and its Limitations:

Let us first try lofting a hull surface on several stations and the stem line, like we did in the previous example:

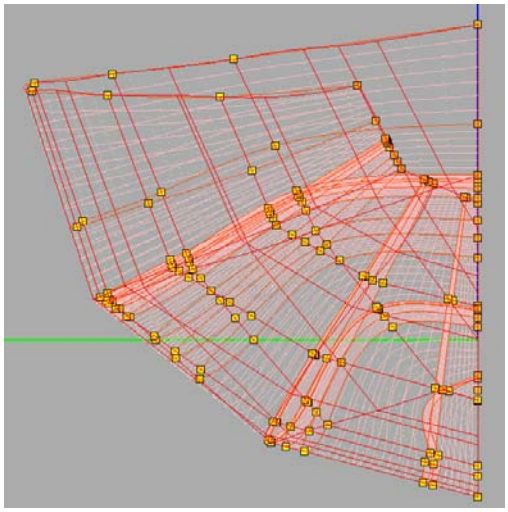
Select Sta 11, Sta 10, Sta 8, Sta 6, Sta 4, Sta 2 and Stem in the 3D browser, right click and select '/Surface/Loft/Spline Lofting' in the popup menu:



A surface is then lofted on the selected lines, but we can immediately see that the hard chines don't look as expected:



Let us double click on the ‘Loft’ surface we have created in the 3D browser to understand why. Once done, we can see obviously that the cause of the problem is that the hard chine isoparms are multiple instead of being single:



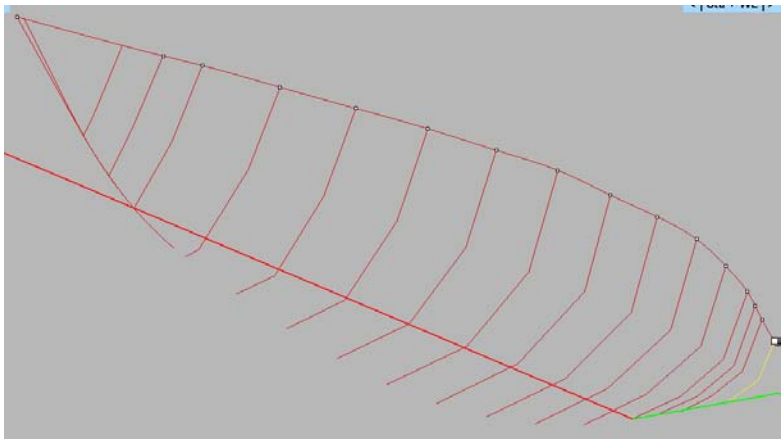
The reason of this situation is that le ‘Lofting’ function doesn’t ‘know’ how the lines match together and, then,only links their knots together according to their relative girth, so that the hard chine knots don’t exactly correspond one to another. We might,of course, remove the redundant isoparms like previously and correct the hard chines knots one by one, but this would be tedious and not satisfactory.

4.4.3 Snapping the Hard Chines on the Stations:

We will therefore delete this surface by selecting it in the 3D browser and hitting the [Delete] key before creating a new hard chine hull more accurately:

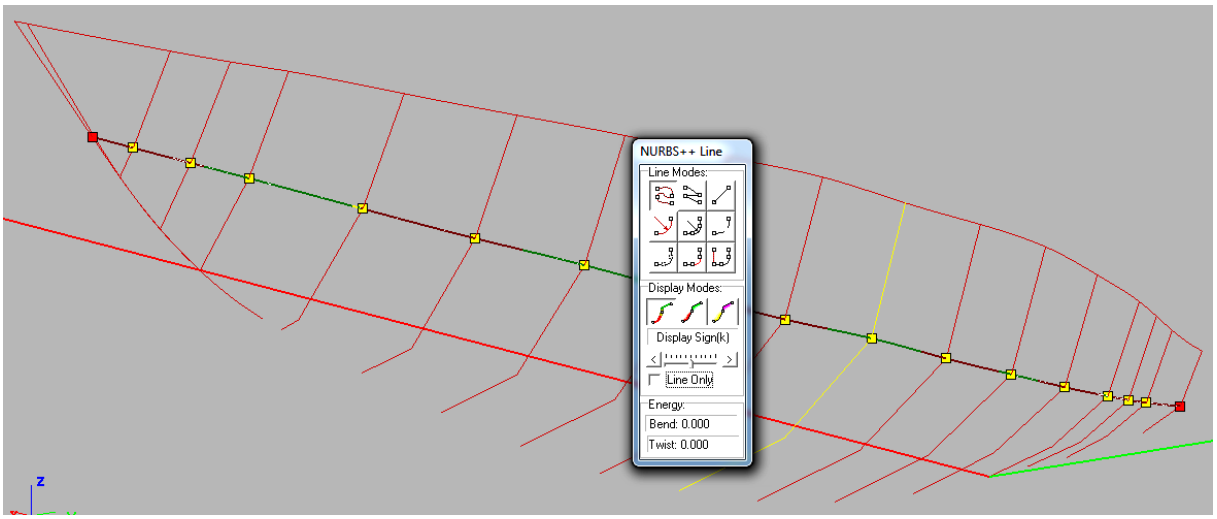
Select ‘/Line/Spline’ in the menu bar, keep the [Shift] key pressed while moving the cursor by the top of the stem line and click for entering the spline knot as soon as stem’s upper knot is snapped (i.e. becomes highlighted).

While keeping the [Shift] key pressed, snap the other sheer line knots on the stations until you have reached the last one on ‘Sta -0.5’ (notice that the cursor only snaps to line’s closest point when the [Alt] key is pressed instead of the [Shift] key).



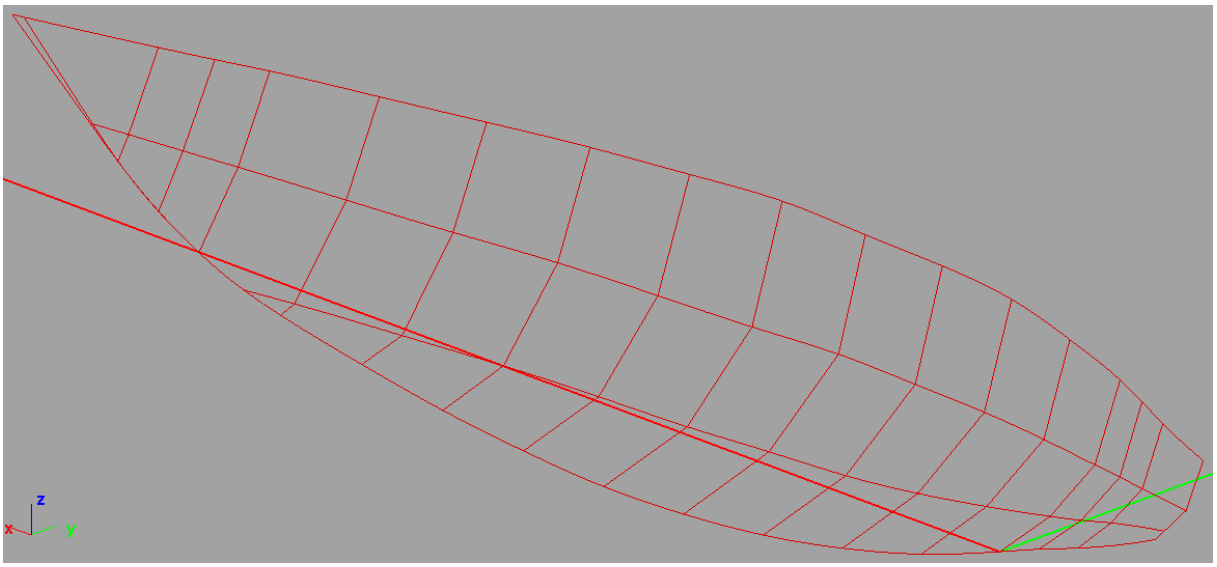
When all the sheer knots are entered, right click to end the spline and open the Line Toolbox: Although it is useless (the real fairing will be achieved when the surface will be created), all the line tools are available here for fairing the sheer line before hitting [Enter] to Validate it.

Let us repeat this procedure for snapping the upper hard chine:While keeping the [Shift] key pressed, we will here start snapping chine's knot on 'Sta -0.5', so that we will be able to press the [Alt] key instead of the [Shift] key for snapping the last 'Stem' knot accurately (this hard chine knot islocated between 'Stem' knots).



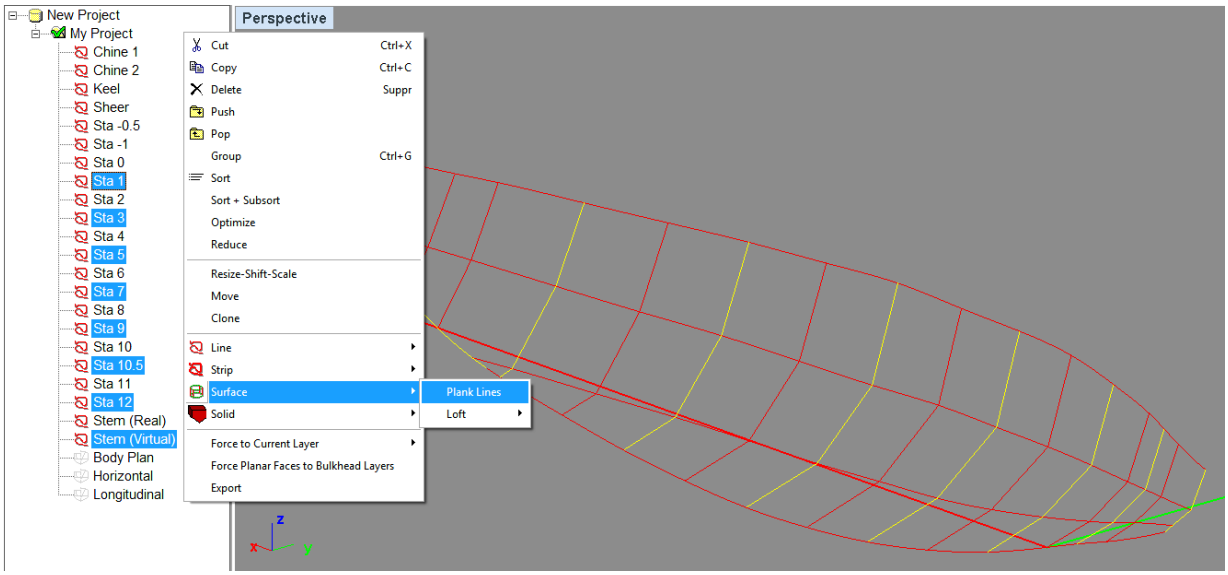
Once done, let us repeat this procedure for snapping the second hard chine on the stations and stem lines, as well as the keel line.

Finally, let's rename these lines 'Sheer', 'Chine 1', 'Chine 2'and 'Keel' before saving the current model(which can be directly loadedfrom "/MAAT Hydro/DemoFiles/Emeraude/Emeraude1.m2a") if necessary):

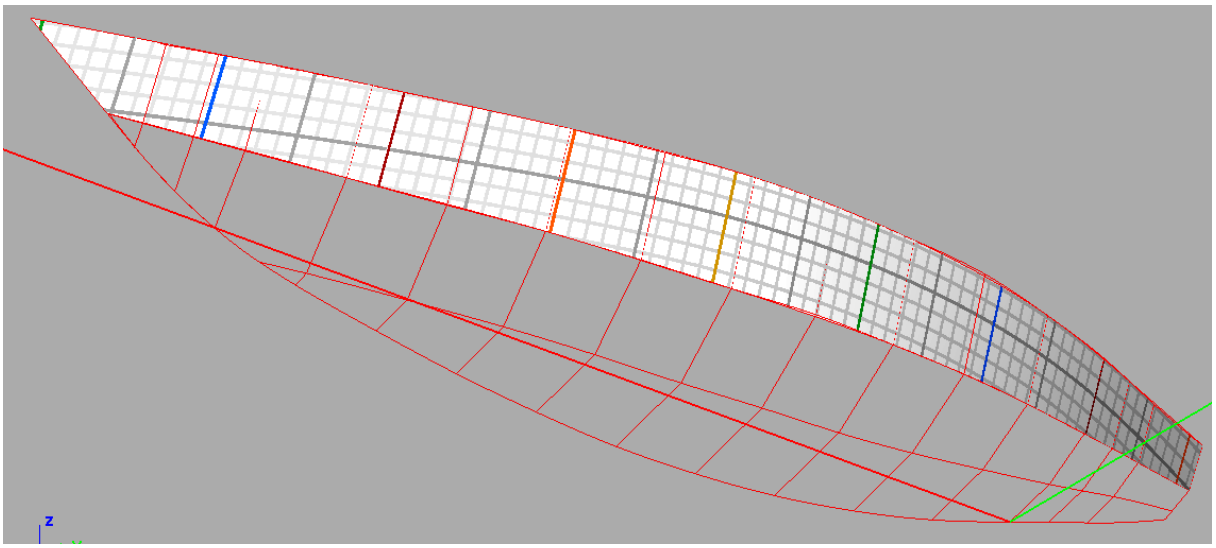


4.4.4: Modeling the Hull more accurately:

Now that we have created an accurate ‘hull skeleton’, let us select the templates necessary in the 3D browser for simulating hull’s planking, right click and select ‘/Surface/Plank Lines’ in the popup menu:

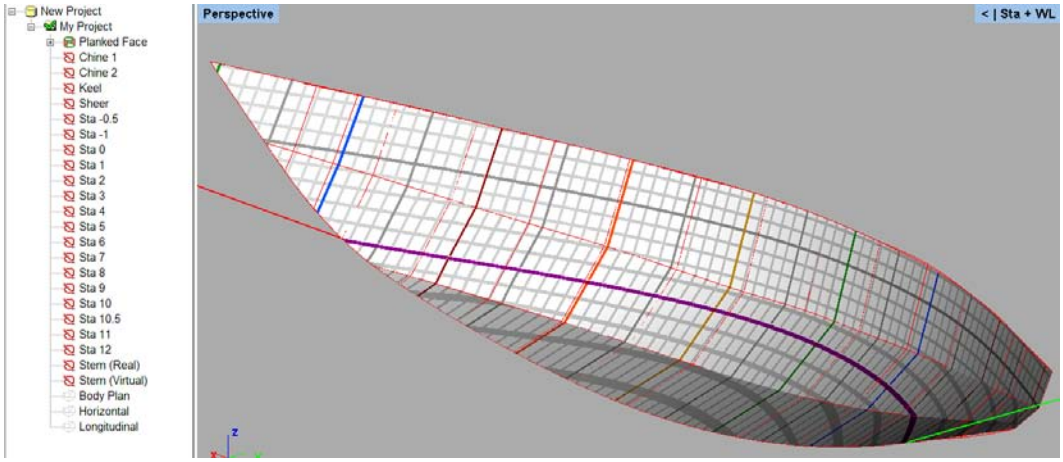


Once done, right click in the upper right corner and turn viewport’s display mode to ‘Stations + Waterlines’, select ‘Sheer’ line in the 3D browser and select ‘Chine 1’:The upper strake is then ‘planked’ on the selected stations, which can be seen in the rendered viewports:

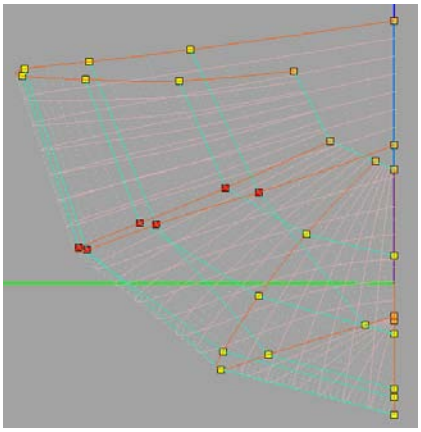


Let us continue and select‘Chine 2’ and ‘Keel’ in the 3D browser for planking the complete hull and<u>don’t forget to hit the [Enter] key for validating it</u> (or hit the [Escape] key to cancel it).

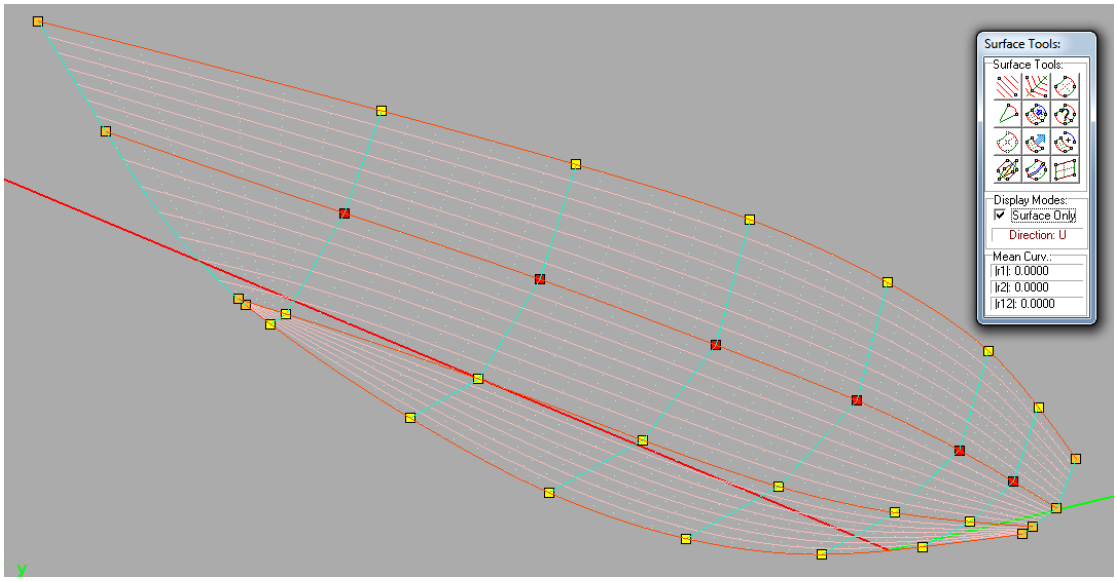
Once done, a ‘Planked Face’ surface is created in the 3D browser:



Double click on this new surface knot in the 3D browser and notice that the hard chine isoparms are now fully matching with our expectations:



All the surface tools are now available for fairing this hull if necessary. Nevertheless, assuming that this hull surface is satisfactory, hit [Enter] to validate this hull surface (or [Escape] to cancel) and rename it ‘Hull’ in the 3D browser.

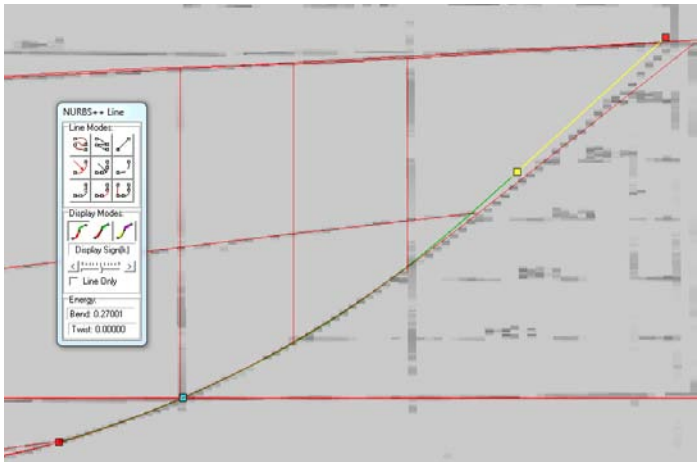


4.4.5:Defining the Stem Cone:

Before starting the stem cone definition, double click on the 'Longitudinal' bitmap in the 3D browser to turn it on and double click on the upper left 'Right' view' title to maximize the viewport, so that we can copy the real stem line:

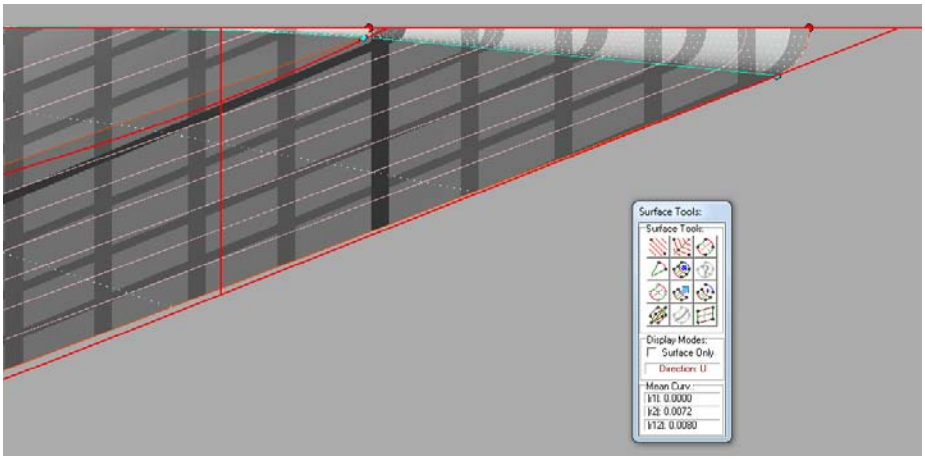
Real stem's lower knots are snapped into the existing virtual stem line by keeping the [Alt] key pressed while approaching the cursor from is bottom, so that both real and virtual knuckles will coincide.

Conversely, the upper knots will be entered freely (keep in mind that the real stem line must necessarily be behind / on the left of the virtual stem line for creating a stem cone with positive radii):



Once the real stem line is defined, hit [Enter] to validate it, rename it 'Stem (Real)' and double click on the 'Longitudinal' bitmap to turn it off.

Double click on it in the 3D browser to modify it. Once the Surface Toolbox is displayed, click on the 'Cone' tool and on the 'Stem (Real)' line in the 3D browser to create the hull's cone with its default aspect ratio (1):

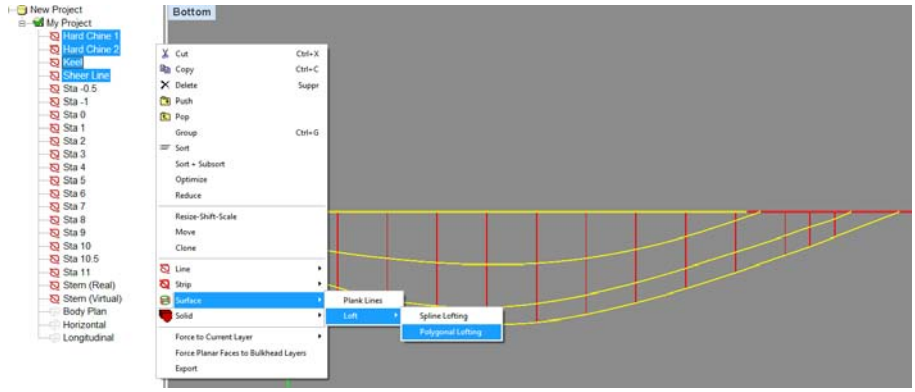


Hit [Enter] to validate this surface, which you can directly load from"/MAAT Hydro/DemoFiles/Emeraude/Emeraude2.m2a").

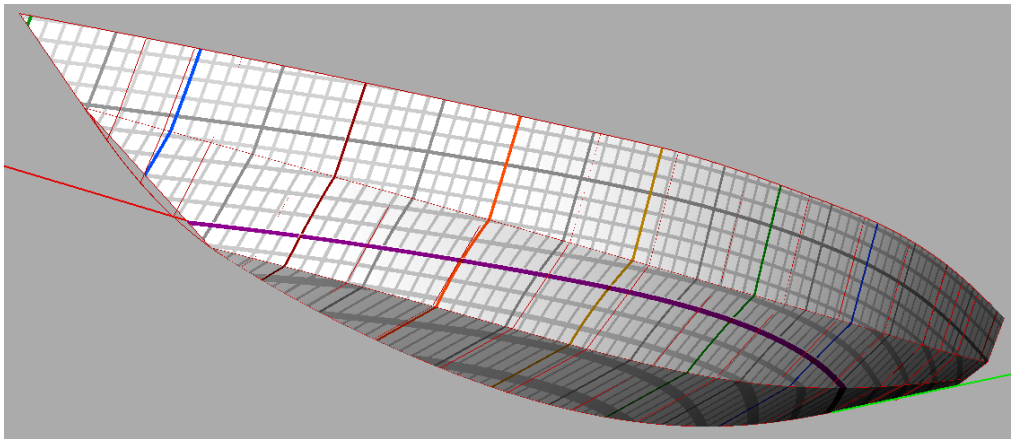
4.4.6: Lofting the Hull from its Hard Chines:

A very direct alternative method is also possible as soon as the sheer, chine and keel lines are drawn, without needing any station nor stem line.

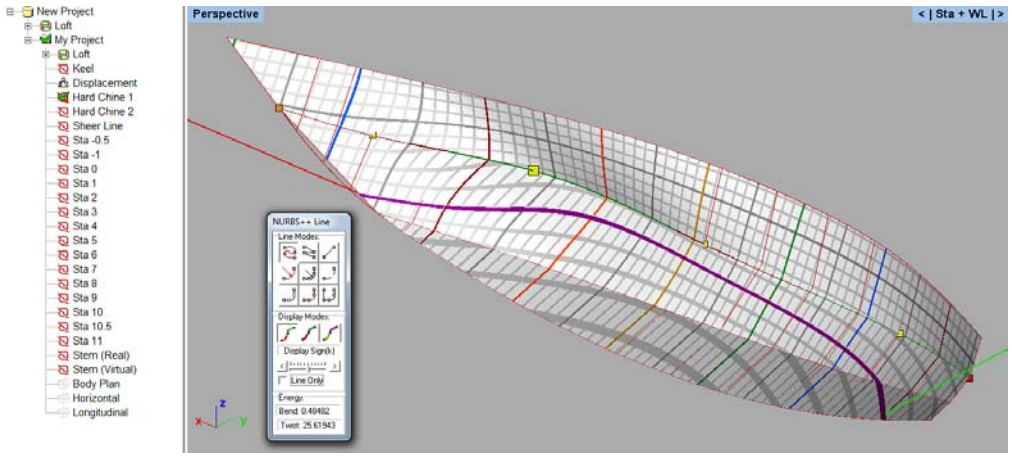
Delete the previous surface, select these 4 lines in the 3D browser, right click and select '/surface/Loft/Polyhedral Lofting' in the popup menu:



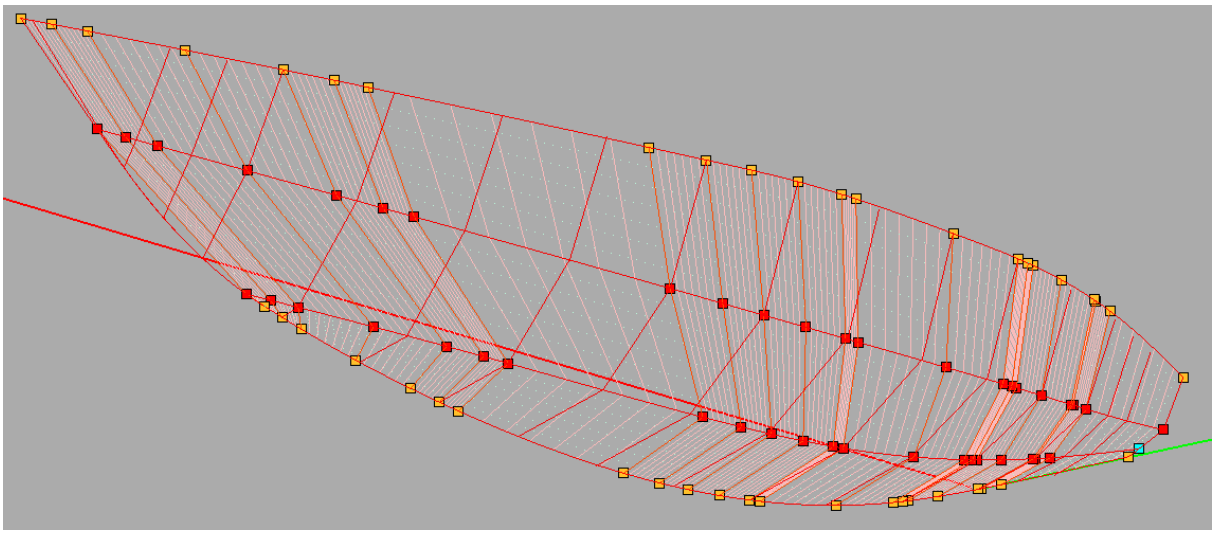
Once selected, a polyhedral surface is drawn on the 4 selected lines:



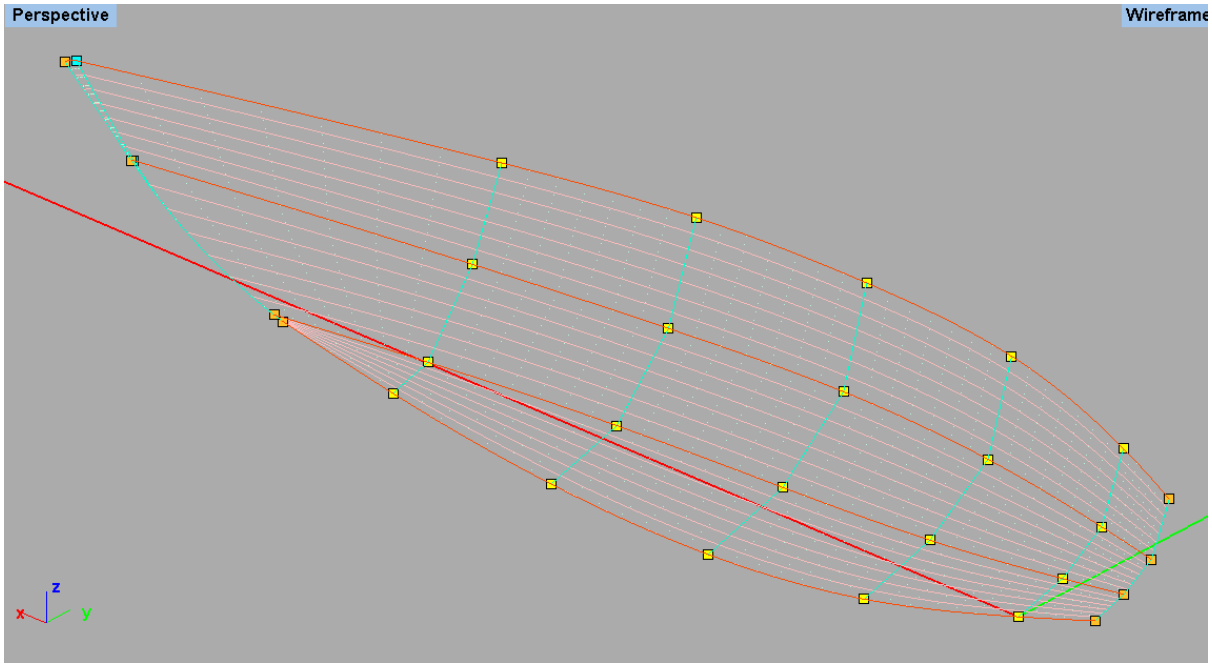
Moreover, like for the 'Spline Lofting' function, you can double click on any of these 4 lines in the 3D browser and notice that, thanks to the 'Surfacing' macro, the polyhedral surface will follow the line modifications in real-time:



Nevertheless, hit [Escape] to cancel the line modification and double click on the new surface in the 3D browser:Like for the ‘Spline Lofting’, you will see that surface’s underlying isoparms are not optimized at all, so that this quick and flexible lofting technique is just suitable for a rough sketching, like previous ‘Spline Planking’:



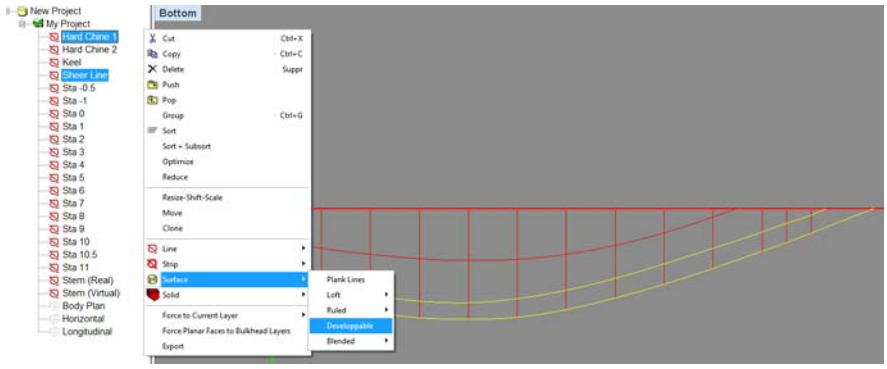
To make this clear, this result must be compared with the previous one:



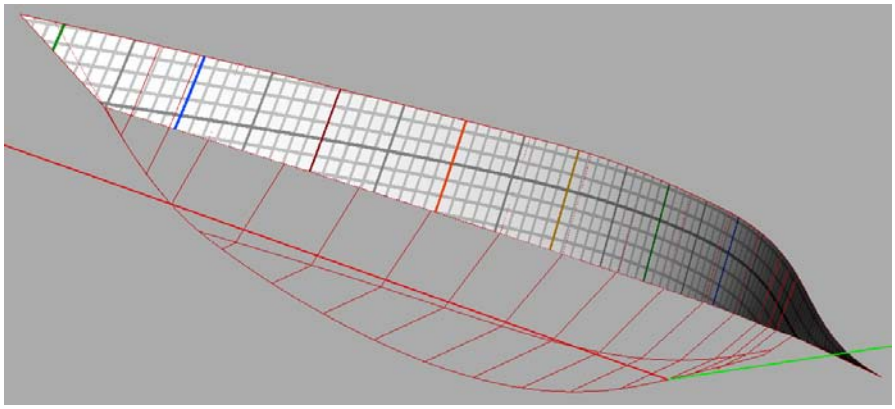
Hit [Enter] to validate this surface, which you can directly load from"/MAAT Hydro/DemoFiles/Emeraude/Emeraude3.m2a").

4.4.7: Setting Developable Strakes on the Hard Chines:

At last, other modeling tools are also available for creating developable strakes:After deleting the previous hull surface, select ‘Sheer and ‘Chine 1’ in the 3D browser, right click and select ‘/Surface/Developable’ in the popup menu:



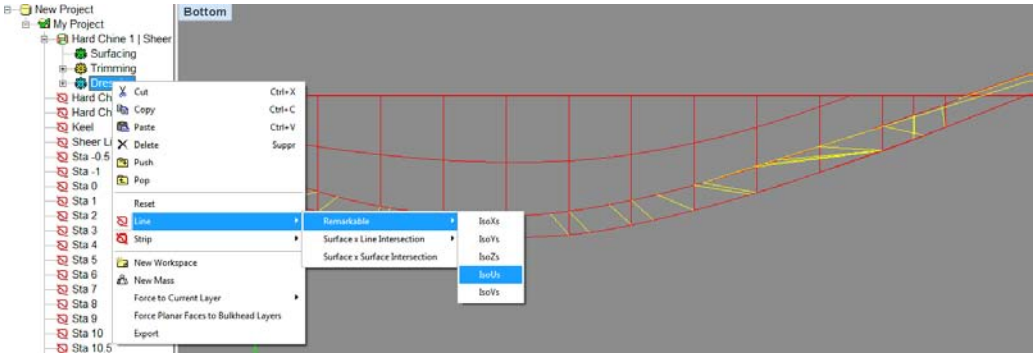
Once done, a developable strake is created between the selected lines:



Notice that, depending on ruler’s slant, <u>the strake is prolonged out of its supports</u>.

It is therefore helpful to display strake’s rulers for a good understanding of strake’s geometric structure and how its developability might be improved.

Clicking on strake’s ‘Surfacing’ macro automatically displays its isoparms / rulers, but you can also include them permanently by selecting its ‘Dressing’ macro and, then,selecting ‘/Line/Remarkable/IsoUs’ in the popup menu:



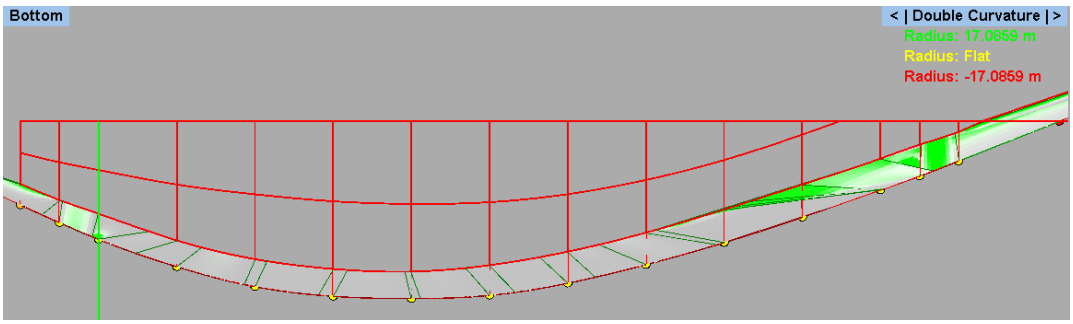
Depending on lines fairing, this may reveal a problem, like here in strake's foremost area, where the rulers are crossing together.

As we see,strake's developability is sometimes impossible to reach (especially when hollows or present on the lines, or at least where the curvature vanishes), so that MAAT Hydro automatically creates the 'most developable' surface (in terms of twisting energy) in these areas.

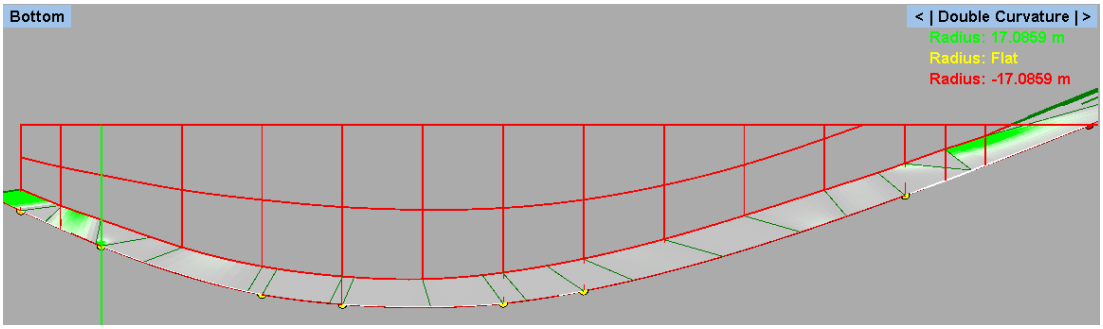
The best way to reach / optimize strake's developability is therefore to adjust carefully the line(s) between which it is drawn and try avoiding inflexion points. In addition to displaying the rulers, it is therefore also good habit to right click in the upper right corner for switching to the 'Double Curvature' scanning mode and setting a realistic scanning sensitivity.

It is recalled here that the double curvature is the product of the 2 Gaussian curvatures associated to any surface point and that one of these curvatures vanishes when the surface is locally developable, so that the curvature product is nullified. In order to be as explicit as possible, the double curvatures are scaled as radii in m, (i.e. the radii of the equivalent sphere). A developable curvature should therefore have a zero double curvature (infinite radius) everywhere but practically, wesometimes have to minimize the double curvature to an acceptable value according to a critical radius depending on material's plasticity and thickness.

Now that we have turned the double curvature scanning on and included the rulers in strake's 'Dressing' macro, we can double click on the 'Sheer' line in the 3D browser to modify it:



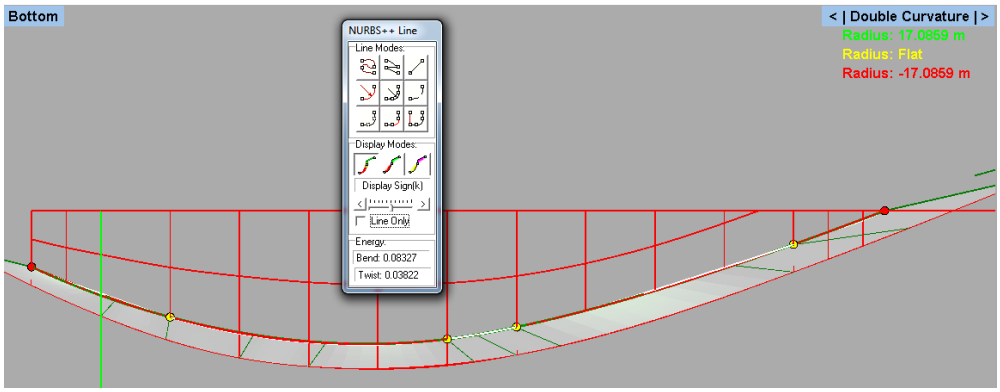
Just type [a][0][.][0][0][0][0][1][Enter] to remove the useless knots according to a 0.01 mm tolerance and then click on the  (Spline) button or type [s][Enter] to draw a spline with the remaining knots. The developable strake reacts in real time:



Finish sheer line's fairing manually, select knot [6] and type [p][Enter] to set its continuity to 'Positional', for removing any flat area on this extremity (using [N]atural spline extremities often causes developabilty problems).

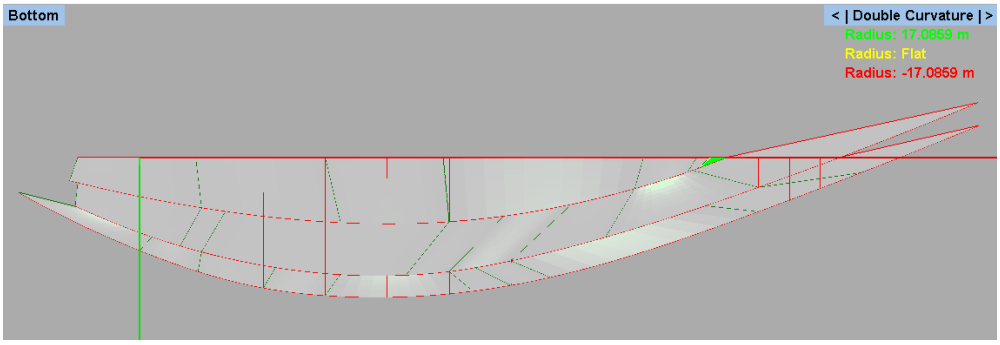
After controlling this faired sheer line on all the views, hit [Enter] to validate it and double click on 'Chine 1' in the 3D browser to modify it.

Similarly, type [a][0][.][0][0][0][0][1][Enter] to remove the useless knots according to a 0.01 mm tolerance and type [s][p][p][Enter] to draw directly a spline with 'Positional' extremities on the remaining knots. After fairing 'Chine 1' similarly, the developable strake is now almost developable:

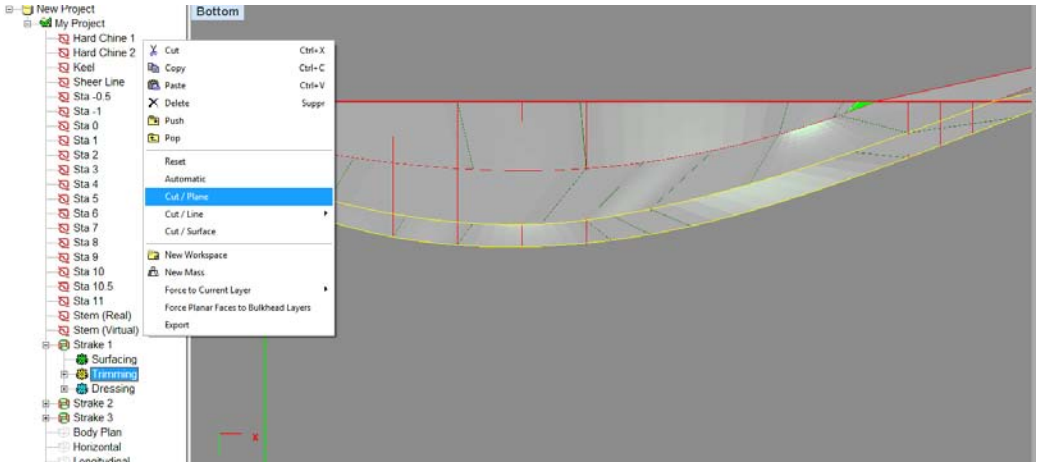


If necessary, you might dissolve several knots and/or release their weight for smoothing the lines furthermore, but this should probably have no practical incidence on strake's construction cost.

Hit [Enter] to validate this faired line and let us repeat the same operations for generating the 2 other developable strakes:

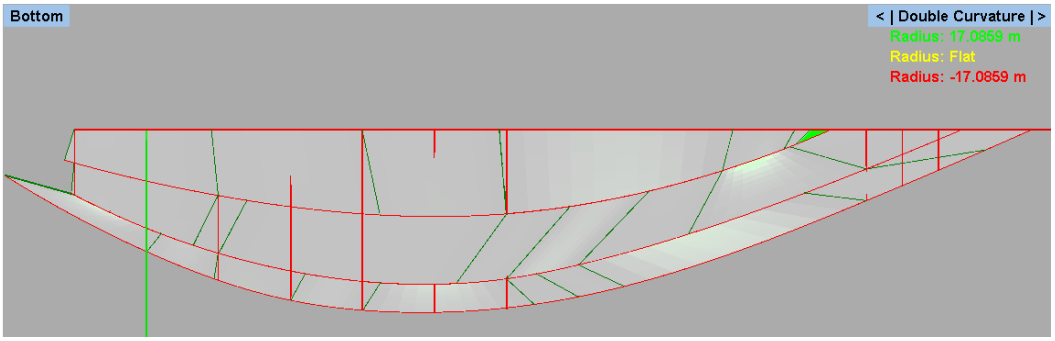


Once the developable strakes are defined and renamed ‘Strake 1’, ‘Strake 2’ and ‘Strake 3’, their negative extension must finally be trimmed, which will be done by right clicking on ‘/Strake1’ in the 3D browser and selecting ‘Cut / Plane’ in the popup menu:



Type [l][0][Enter] or [y][0][Enter] for splitting the strake by a longitudinal plane located at y = 0, hit the [/] key for selecting strake’s final outline and, finally, hit [Enter] to validate the current selection, or [Escape] to cancel it.

Once done, you can repeat this trimming operation on ‘Strake 2’:



Please, notice that, as this trimming is now registered in surface’s trimming macro, it will be automatically executed every time the strake surface is modified, in particular when the hard chine lines will be modified.

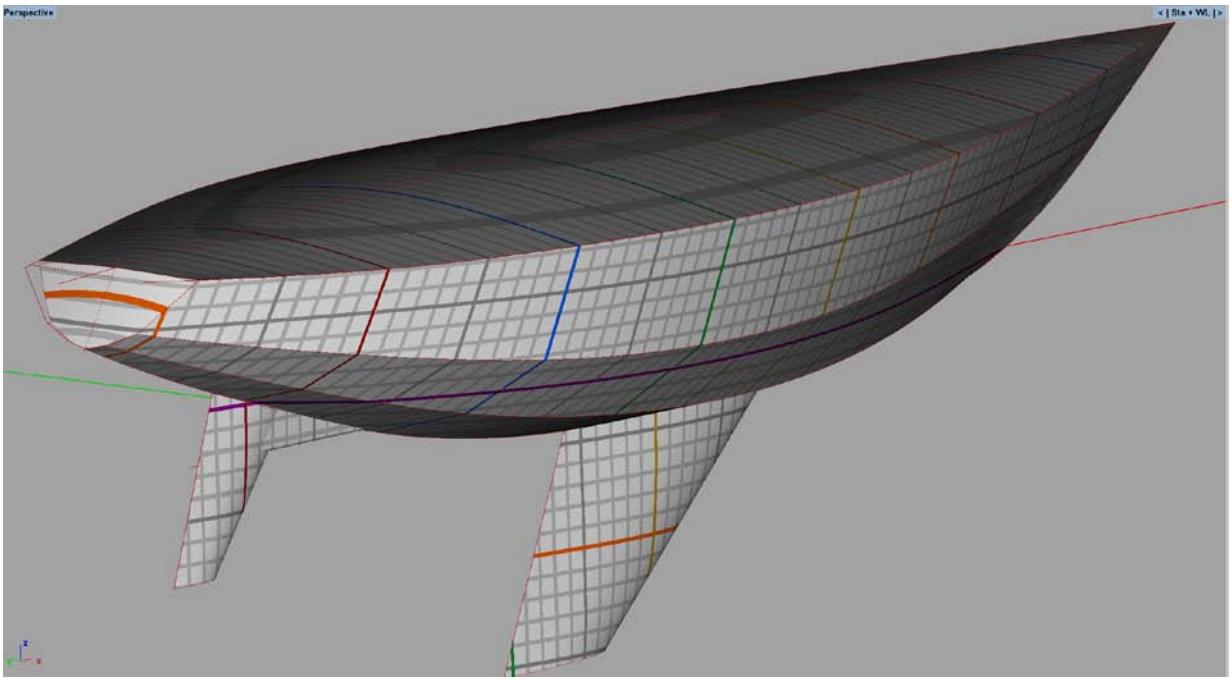
Nevertheless, if you double click on ‘Strake 1’, ‘Strake 2’ or‘Strake 3’ to modify it and validate any modification, its ‘Surfacing’ macro will be re-initialized so that strake’s geometry will no longer be updated when its lines will be modified.

Finally, in this case, comparing these developable strakes with the transversally ruled ones will reveal that the offset between them is smaller than 1 mm.

This model can be directly load from"/MAAT Hydro/DemoFiles/Emeraude/Emeraude4.m2a").

4.4.8: Finishing the hull model:

At last, deck, transom, keel and rudder can be added like for previous examples, which therefore won't be re-explained here:



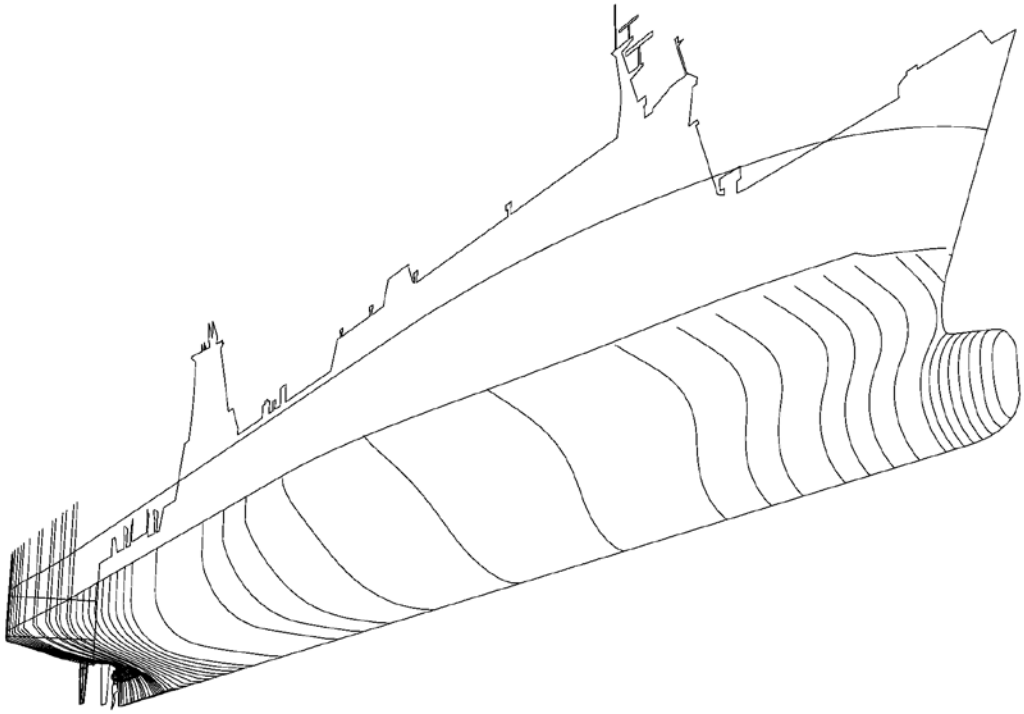
This final model can be directly load from"/MAAT Hydro/DemoFiles/Emeraude/Emeraude5.m2a").

4.5 Copying the Hull of a 200m Ro-Pax:

4.5.1Presentation:

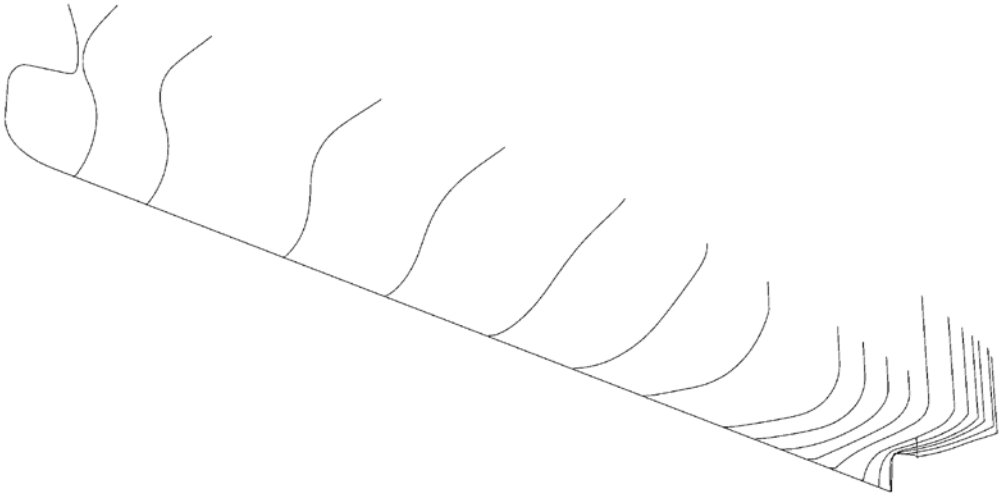
This hull will allow presenting more thoroughly the possibilities of MAAT Hydro's built-in NURBS++ modeler.

Unlike the previous examples, we will here start from a set of 3D lines describing the hull, imported from Rhino 3D instead of bitmaps:



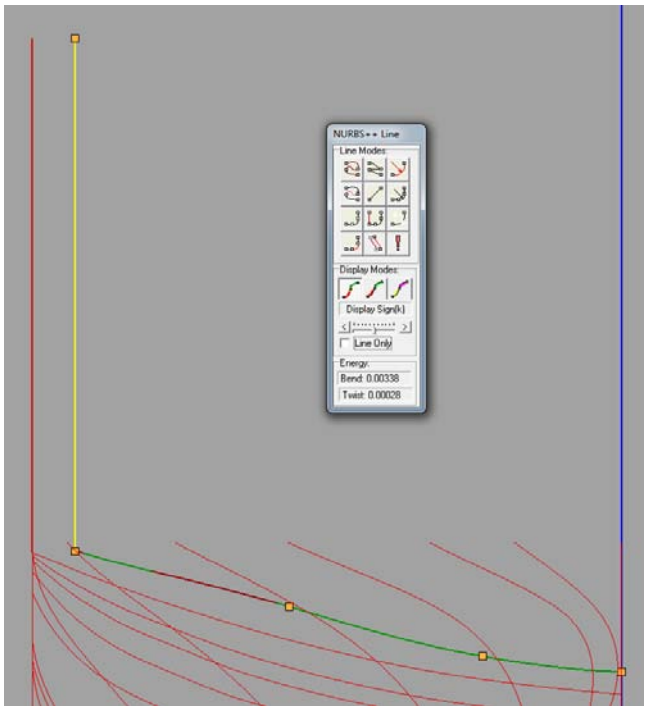
4.5.2 Preparing the stations:

The first step will consist in removing the unnecessary lines, so that only the useful ones will remain:



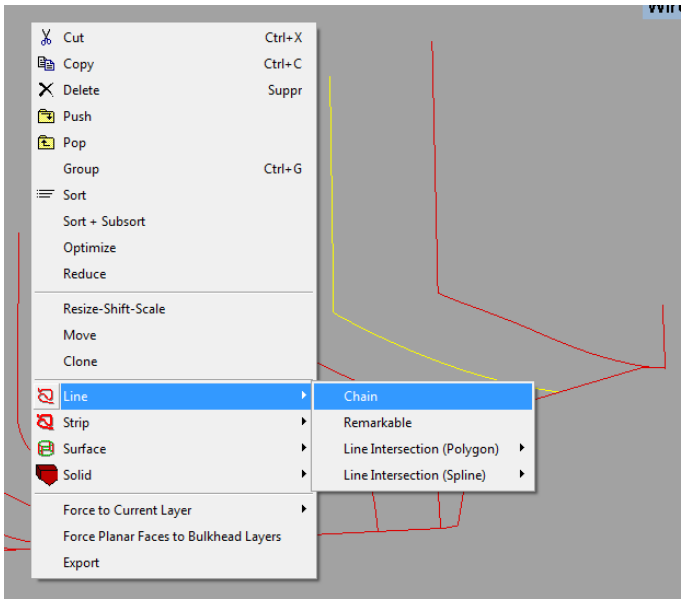
The second step will consist in inspecting and ‘cleaning’ each station so that it can be used for supporting a planked surface and prolonged arbitrarily to z = 20 m.

Starting by the aftermost station, we will double click on it to modify it with the NURBS++ Line toolbox. Once station’s knots are displayed, click on the upper one to select it and type [2][z][20] to ‘slide’ it to z=20 m: As the station now looks satisfactory, hit [Enter] to validate it:

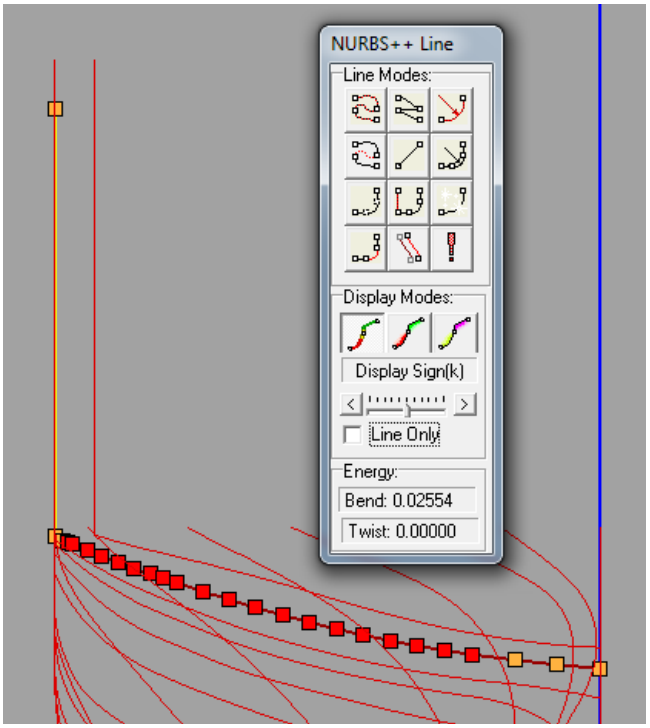


When selecting the next station, we will notice that it is made of 2 distinct arcs, so we will click on the first one and, while keeping the [Ctrl] key pressed, on the

second one, so that both of them will be selected. Right click when done and select '/Line/Chain' in the popup menu:

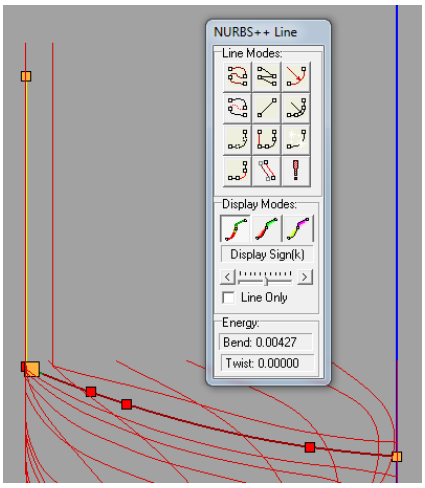


When both arcs are chained into a single one, we can double click on it by repeating the previous procedure:



Once done, we will also notice that too many knots are used for describing station's bottom, so we will select this arc by clicking on the bottom knot and, with [Shift] key pressed, on hard chine's knot. Once the bottom arc is selected, click on the [Approximate] button to reduce the number of knots automatically (default approximation tolerance is 0.1mm but, for example, you can type [a][0][.][0][0][1][Enter] to set it to 1 mm).

We will therefore notice that hard chine's closest knots can also be removed by selecting each of them and hitting the [Delete] key:

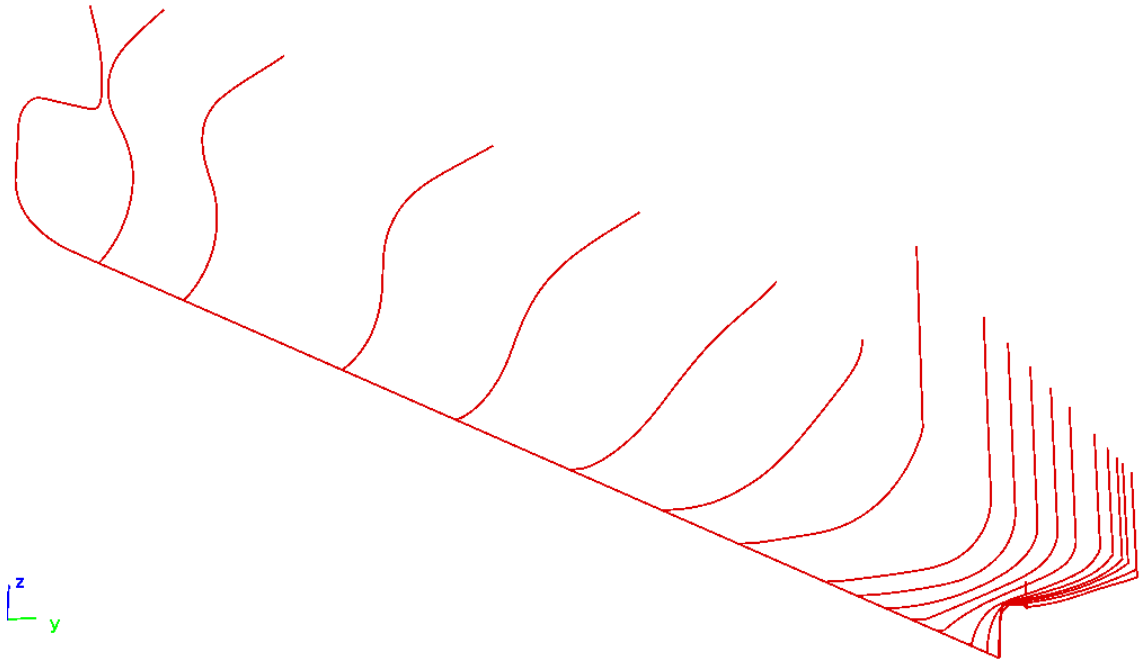


After dissolving these 2 knots, the second station now looks satisfactory and we can hit [Enter] to validate it.

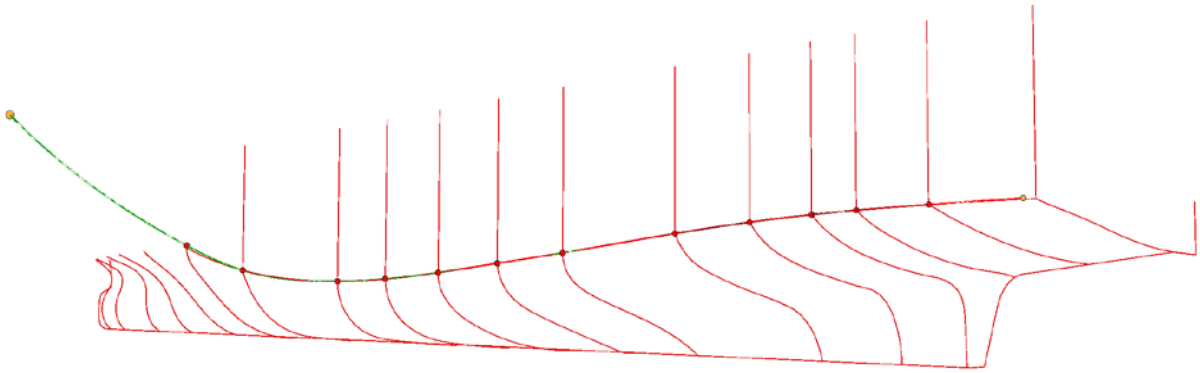
We can therefore repeat this procedure for the third station, except that, instead of clicking the [Approximate] button, we will have to type [a][0][.][0][0][1][Enter]for removing a greater number of useless knots (removal tolerance is set to 1 mm instead of the default 0.1 mm).

At last, we can also repeat this procedure for the 5th, 6th and 7th after stations, without paying special attention to their fairness, which will be improved later.

Although next station's upper knot is located far under z=20 m, we can repeat the same procedure on it, as well as for the next ones, until the 12 after stations are adapted:



Defining vertical side's limit is now necessary for completing the other stations and we will therefore select '/Line/Spline' in the menu bar to snap this line on the stations we have prepared, after having set an appropriate framing in the perspective viewport. Once done, while keeping the [Shift] key pressed, move the cursor on after station's knuckle to snap it and left click to start the line: You can now continue snapping the spline knots on the 11 following stations, and even with the next one:



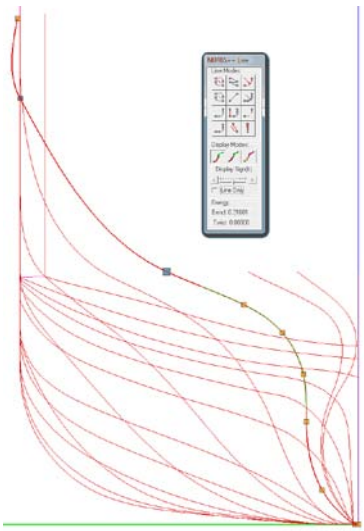
Finally, when all the knots have been snapped, type the x, y, z coordinates of the final knot and right click to finish hull's side line:

[9][6][.][2][,][1][3][.][2][,][3][0][.][7][Enter]

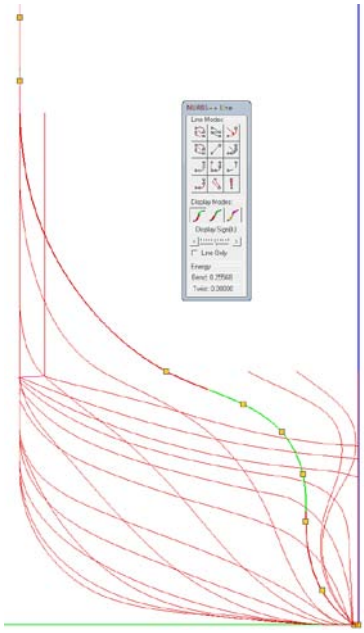
You can then hit the [Enter] key to validate this line directly.
In order to make the side line remarkable so that we can use it for completing the stations, we must switch to the [Data] page and turn its layer to 'Marking'.

When done, we can double click on the next station to modify it and type [a][Enter] for removing the useless knots with the default 0.1mm tolerance.

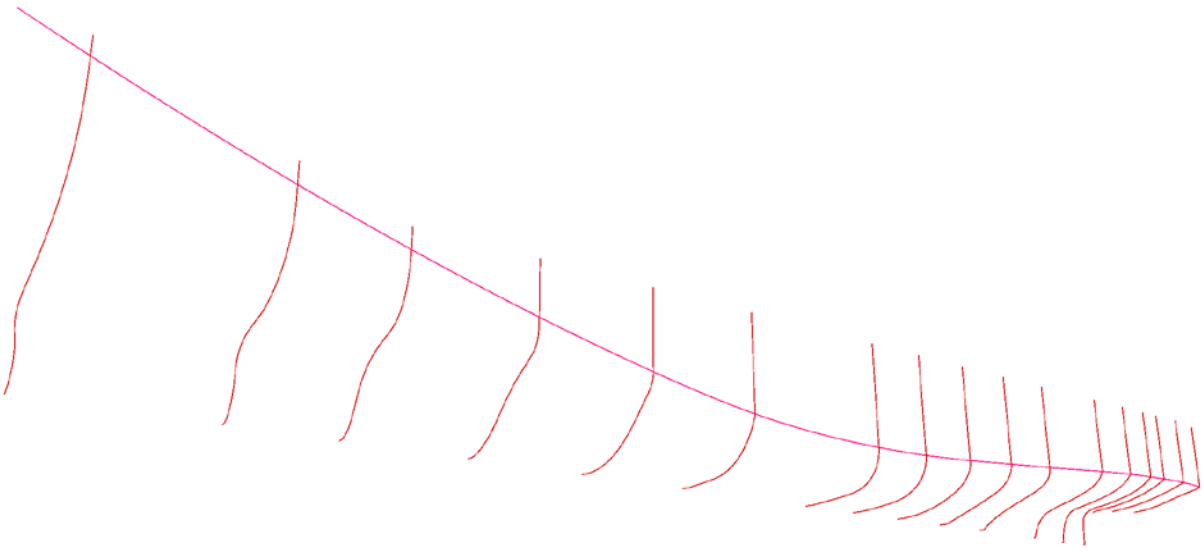
Once done, click on station's upper knot to select it,click on the [Append] button, click 2 times by the side line to add 2 knots and right click to finish.



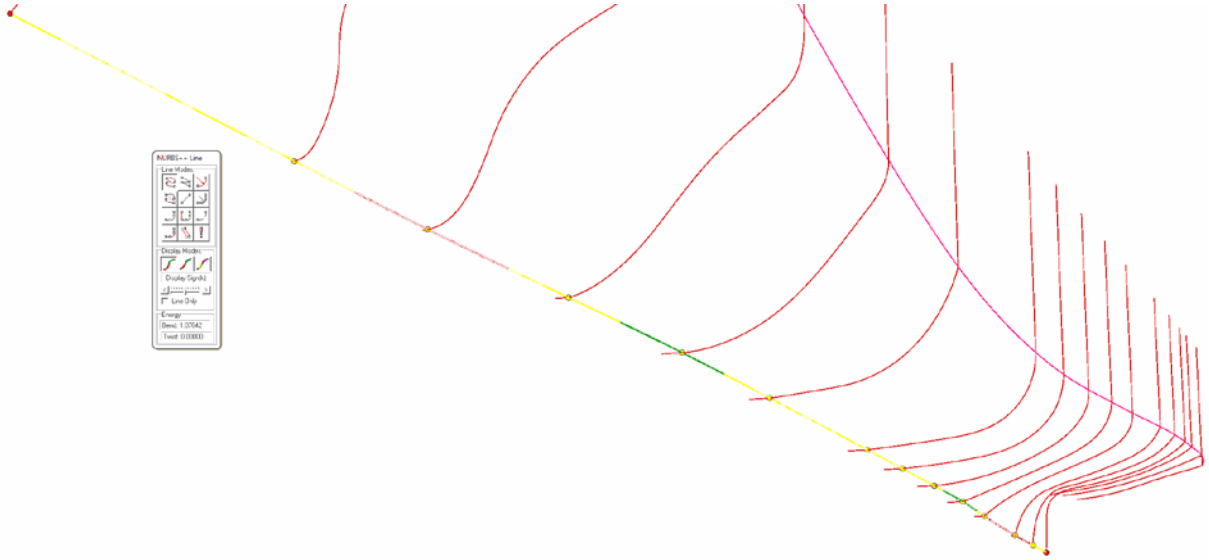
You can now select knot [8] and type [.][Enter] to snap it on the marked side line. After this, select the upper arc by clicking on the upper knot and on the previous one with [Shift] key pressed. Once the upper arc is selected, type [y][1][3][.][2][Enter] to make it vertical and hit the [Backspace] key to reset the active arc.Select arc [6, 8](Notice that we don’t pay attention to first knot’s height, as the first arc is only used for getting a tangency constraint). Click on knot 8 to select it, type [k][Enter] to set its continuity to curvature and repeat the same operation on knot [6] before clicking on the [Spline] button (or typing [s][Enter]): The vertical side is now blended with the bottom arc and you canhit the [Backspace] key again to display the complete line.Hit [Enter] to validate it:



After repeating the same procedure for the other stations, we finally get this model:



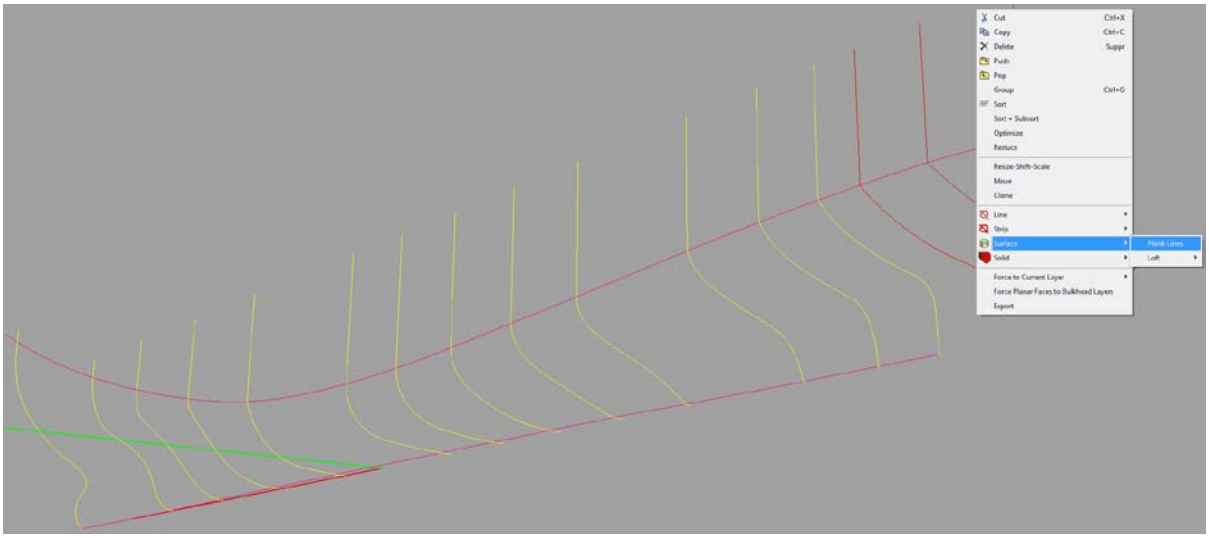
We will now snap a keel line on station's lower knuckles by selecting '/Line/Spline'again in the menu bar and carefully clicking the knuckle points (knots are highlighted when snapped), one by one while keeping the [Shift] key pressed (if necessary, you can pan and zoom with mouse's right button and wheel). Right click when all the keel knots are snapped and, as this line will be faired later, we will directly hit [Enter] to validate it:



Rename this spline 'Keel' and, like for the upper side line, set its layer to 'Marking' to make it usable as a reference line.

4.5.3 Setting and fairing the hull body:

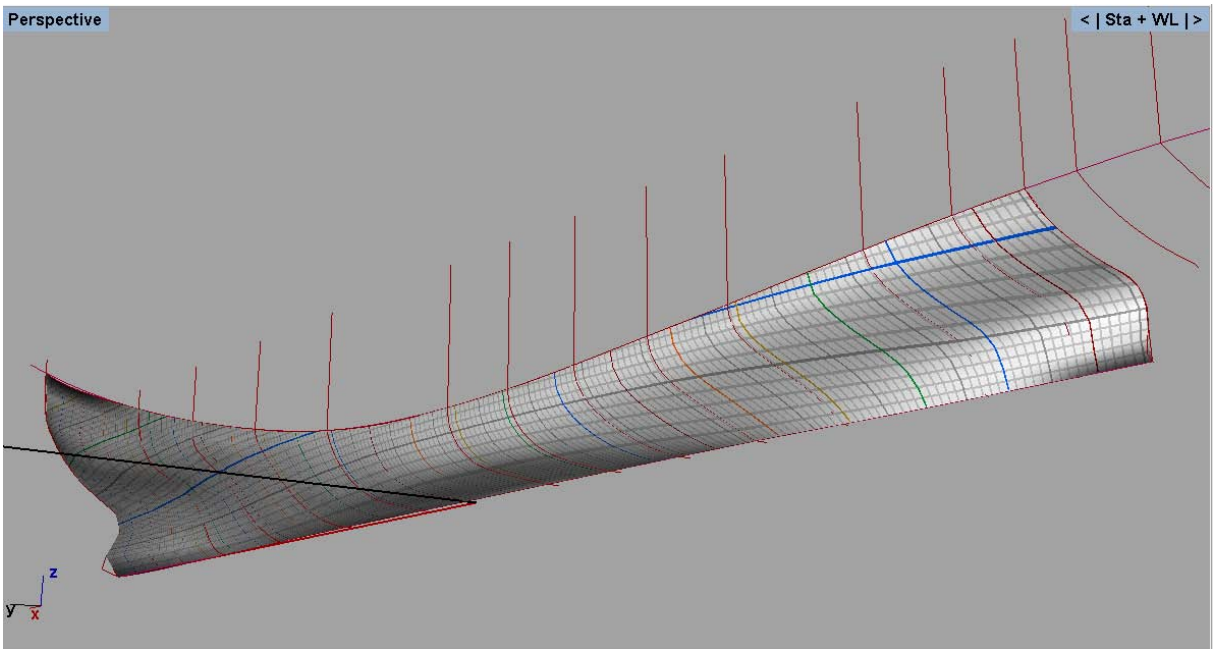
As we are now intending to set a first hull body surface ontothe stations, let us first right click in the upper right corner and select the 'Stations + Waterlines' display mode (nothing changes, as no surface is yet present). When done, select the body stations (i.e. excluding the 3 after ones), right click and select '/Surface/Plank Lines' in the popup menu:



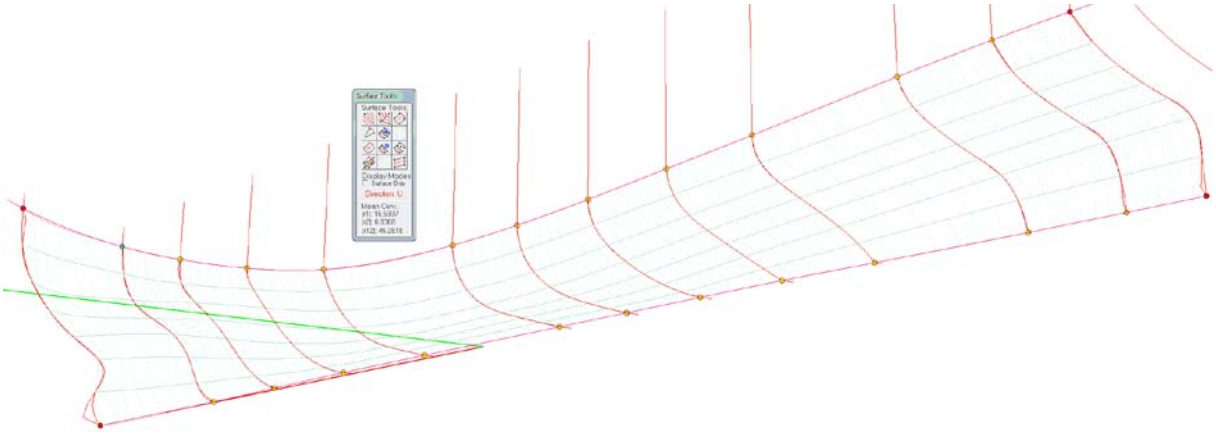
Once done, click on the upper side line. As no surface will be created as long as you haven't selected at least one other line, now click on the keel line.

Although we might select as many lines as necessary (see below), we won't use any other line for the moment and will directly hit the [Enter] key for validating the created surface (don't forget to do it otherwise the current surface won't be created. Conversely, you can hit the [Escape] key if you want to cancel).

A first hull surface is now created, whose transverse isoparms correspond to the stations and whose longitudinal isoparms correspond to the selected longitudinal lines (click several timed on the upper right '|>' cell to increase grid's step and clarify the display):



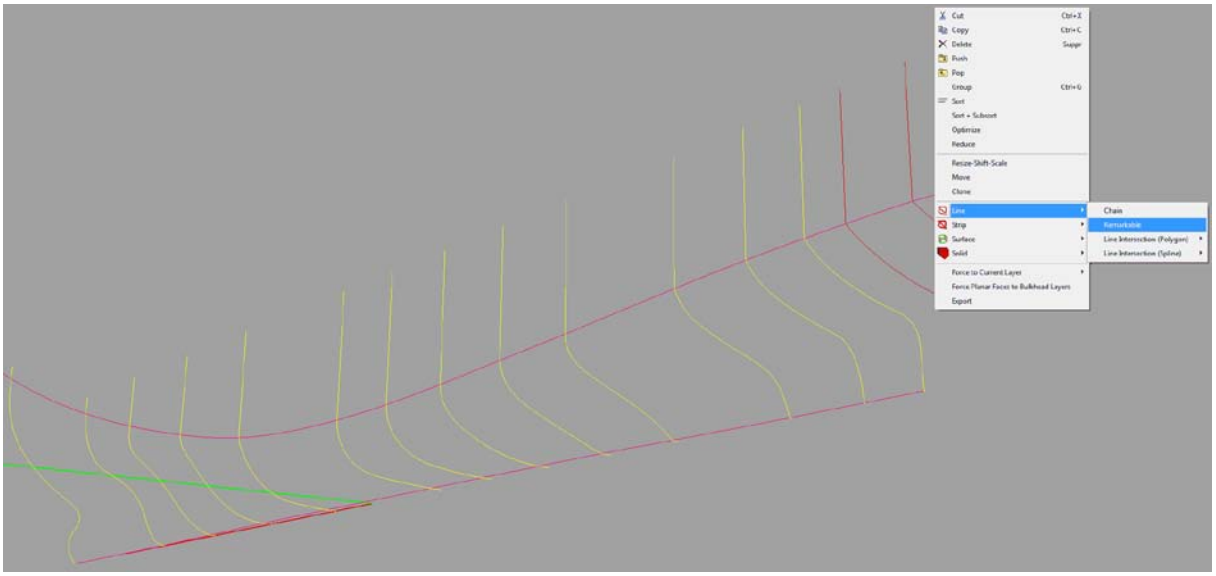
Double click on the created surface in the 3D browser to open the NURBS ++ Surface toolbox, which reveals surface's internal paramerization:



Surface's stations correspond to the best 8th order approximation of the original station arcs, which is obviously not close enough from the first and last stations.

We will therefore hit [Escape] to exit the NURBS++ Surface toolbox and delete this surface in the 3D browser before creating a better one.

We will therefore maximize the perspective viewport by double clicking on the upper left title and select the body stations once again, right click and select '/Line/Remarkable' in the popup menu:

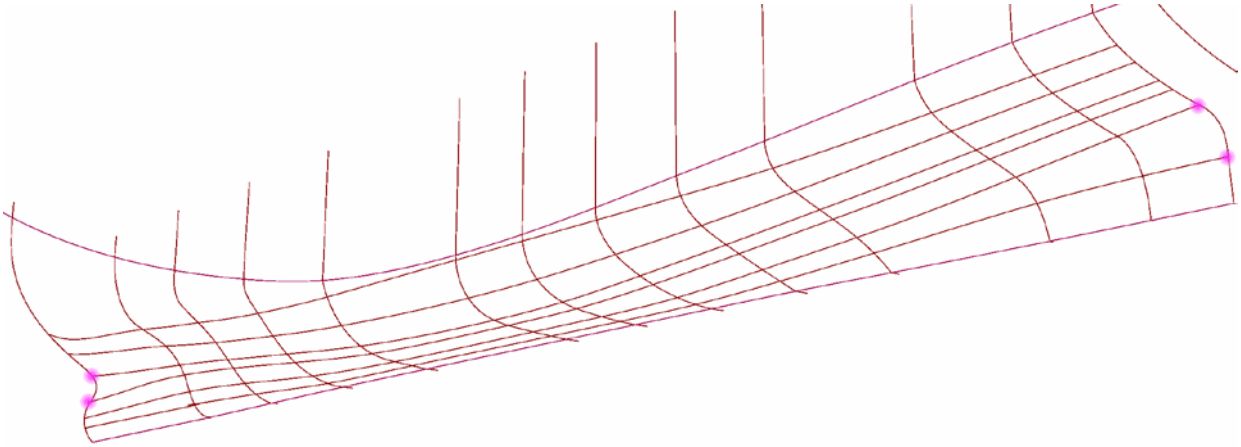


This function automatically lofts a smooth auxiliary (i.e. hidden) surface onto the selected lines, which will be used for setting remarkable lines (i.e. isoparms, iso-coordinates, iso-slopes, geodesics, curvature lines,…). Although this auxiliary surface is just lofted, therefore heavy and unfaired, it is good enough for what we have to do.

Once selected, move the cursor between the stations and notice that an ox geodesic (the default line type, which is the most usual) follows it. The upper prompt recalls all the possible line types and you can try severalof these modes to see the resulting lines by typing:

- [t][Enter] for [t]ransverse lines (stations)
- [l][Enter] for [l]ongitudinal lines (buttocks)
- [h][Enter] for [h]orizontal lines (waterlines)
- [k][n][Enter] for minimum Gaussian curvature lines
- [k][x][Enter] for maximum Gaussian curvature lines
- [g][y][Enter] for o[y][g]eodesics
- [g][z][Enter] for o[z][g]eodesics
- …
- And, finally, [g][x][Enter] for returning to the default ox geodesics mode.

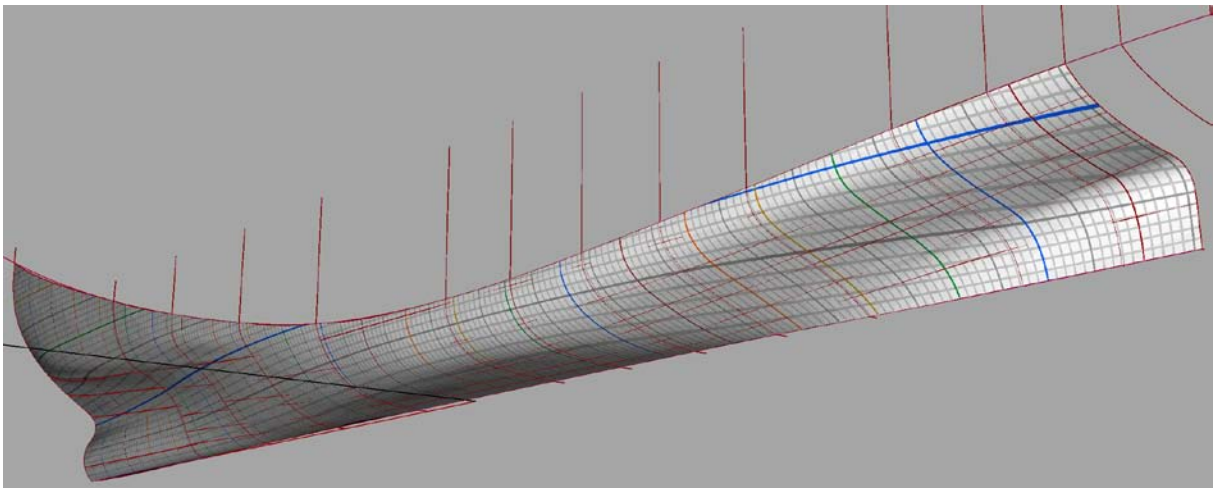
In order to provide a more accurate control of the hull body surface, we will set 6 additional geodesics on the selected stations, provided that corresponding surface knots must frame bulb and skeg's blending arcs (highlighted below) and that we need at least 3 more knots for controlling the upper area. For obvious reasons, these lines must not cross together and, finally, don't forget to hit the [Enter] key when the 6 geodesics will be entered (or [Escape] to cancel), otherwise the lines will be lost.



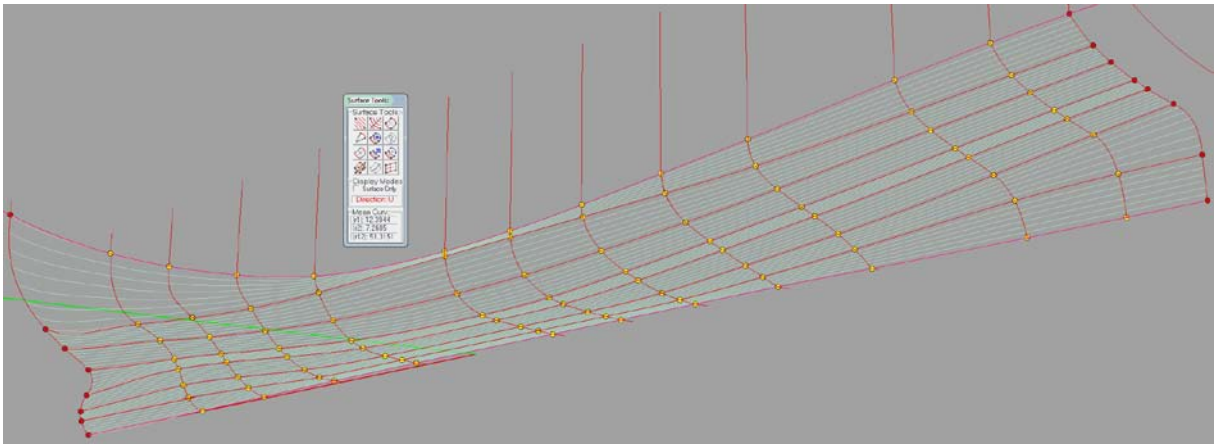
As the underlying auxiliary surface is just roughly lofted, the resulting geodesics are not fair everywhere but, although it might be possible to double click and smooth them one by one with the NURBS++ Line toolbox, we will use them as they are, as the fairing work will bedirectly done onto the surface itself, which is more synthetic.

Once these 6 geodesics are created, we will have 8 lines for re-planking the stations, which should be enough. We can therefore re-select the hull body stations, right click and re-select '/Surface/Planking' in the popup menu as previously.

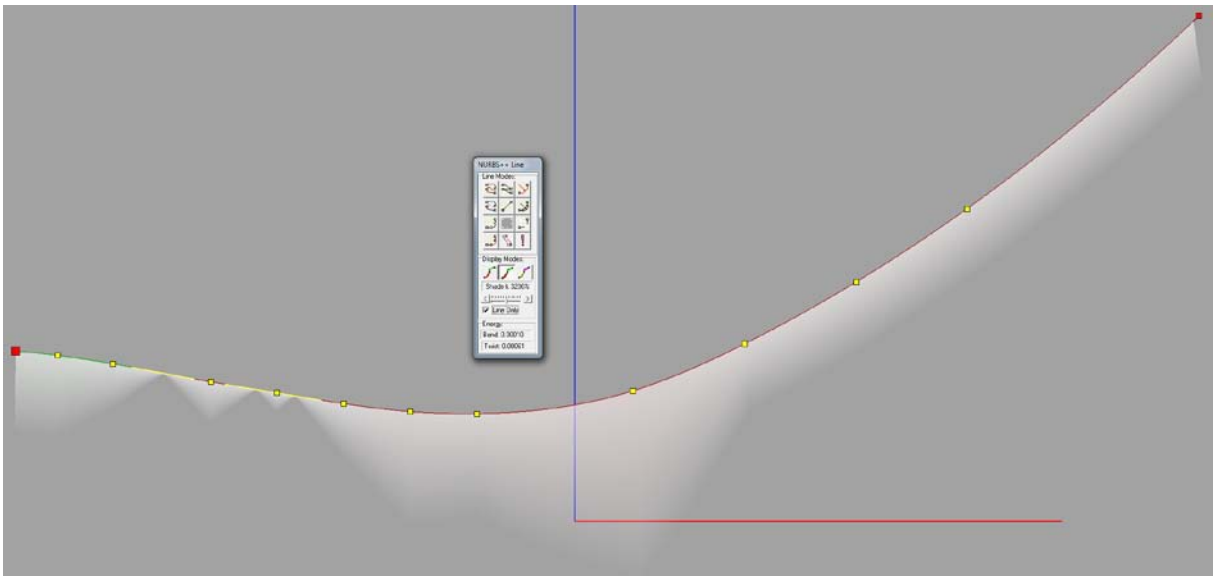
This time, one by one, we will select 8 longitudinal lines instead of 2, from top to down (or down to top, provided that the lines are selected consecutively). If a shaded display mode is selected, the resulting surface will be displayed after each selection. When the last longitudinal line is selected, don't forget to hit [Enter] for validating the current surface (or [Escape] to cancel):



This surface is now good enough for starting the hull body fairing work and we can therefore double click on it in the 3D browser for opening the NURBS++ Surface toolbox:

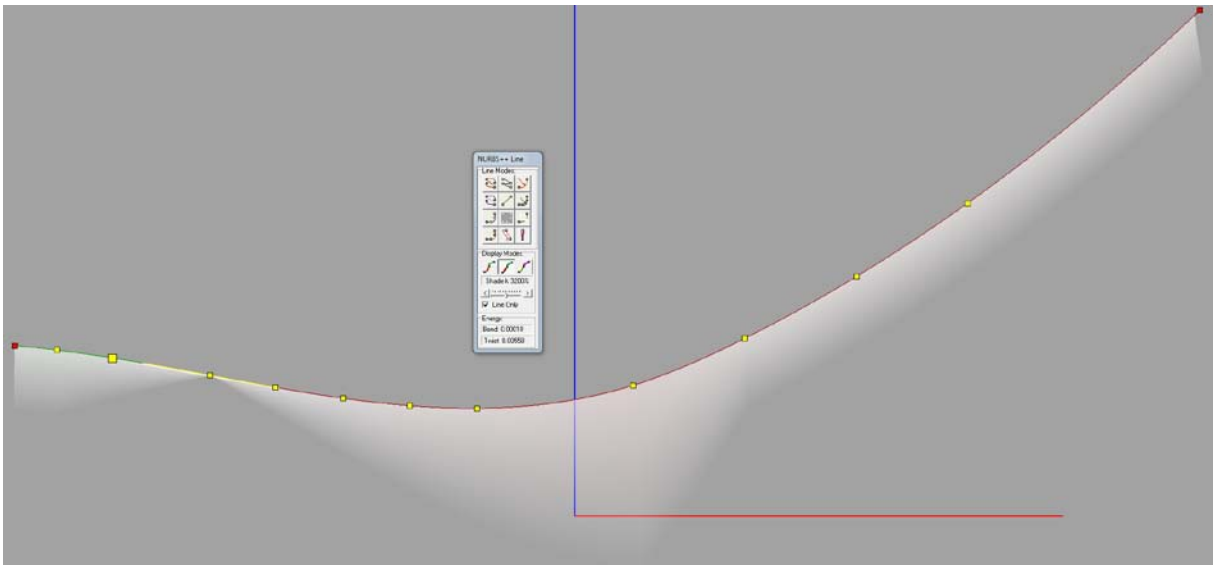


First of all, let us double click on the upper side line so that we can adjust it accurately. Once done, the side isoparm becomes active and the NURBS++ Line toolbox pops up. Let us maximize the right view, check the ‘Line Only’ tick in the tool box, turn the curvature scanning on and set its sensitivity to make its the longitudinal unfairness visible. Moreover, you can also move the cursor vertically with right mouse button and [Alt] key pressed to shorten the view and enhance line’s unfairnesses:



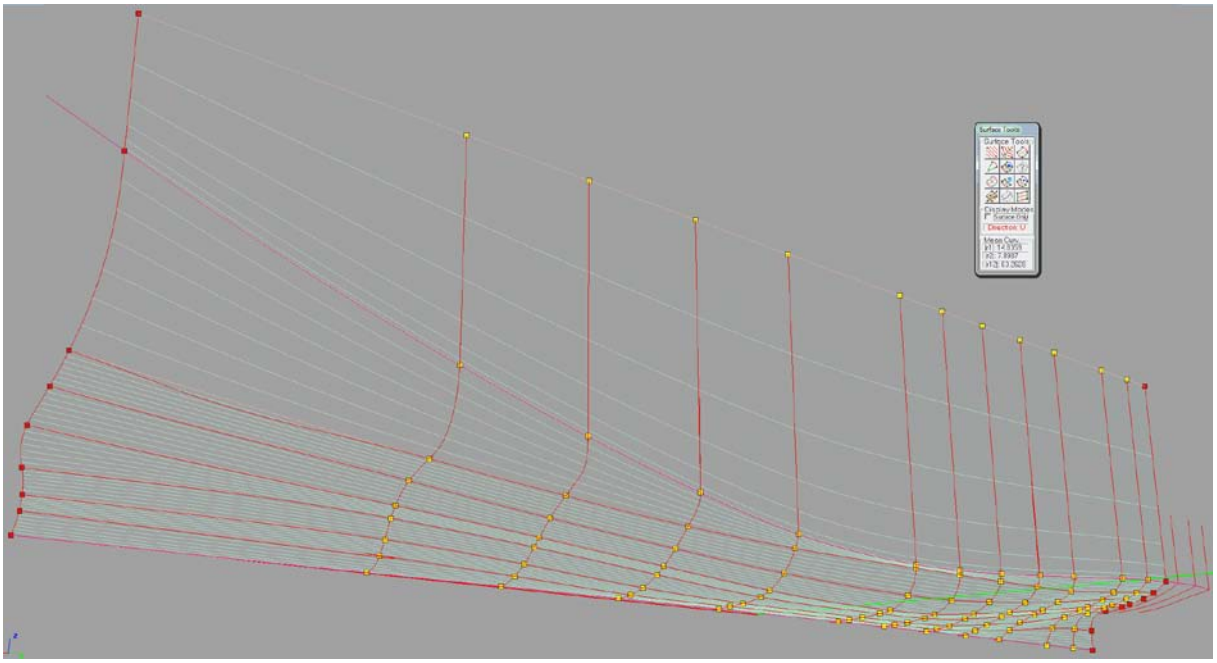
As knots [8] and [9] obviously need a slight correction, let us click on the [Spline] button, click on knot [8] to select it and then hit the [Page Down] key 10 times to release it completely (keeping the [Shift] key pressed provides greater increments, resp. smaller with [Control] key pressed).

When done, we can repeat the same procedure on knots [8], [6] and [10], so that line's fairness now looks satisfactory:

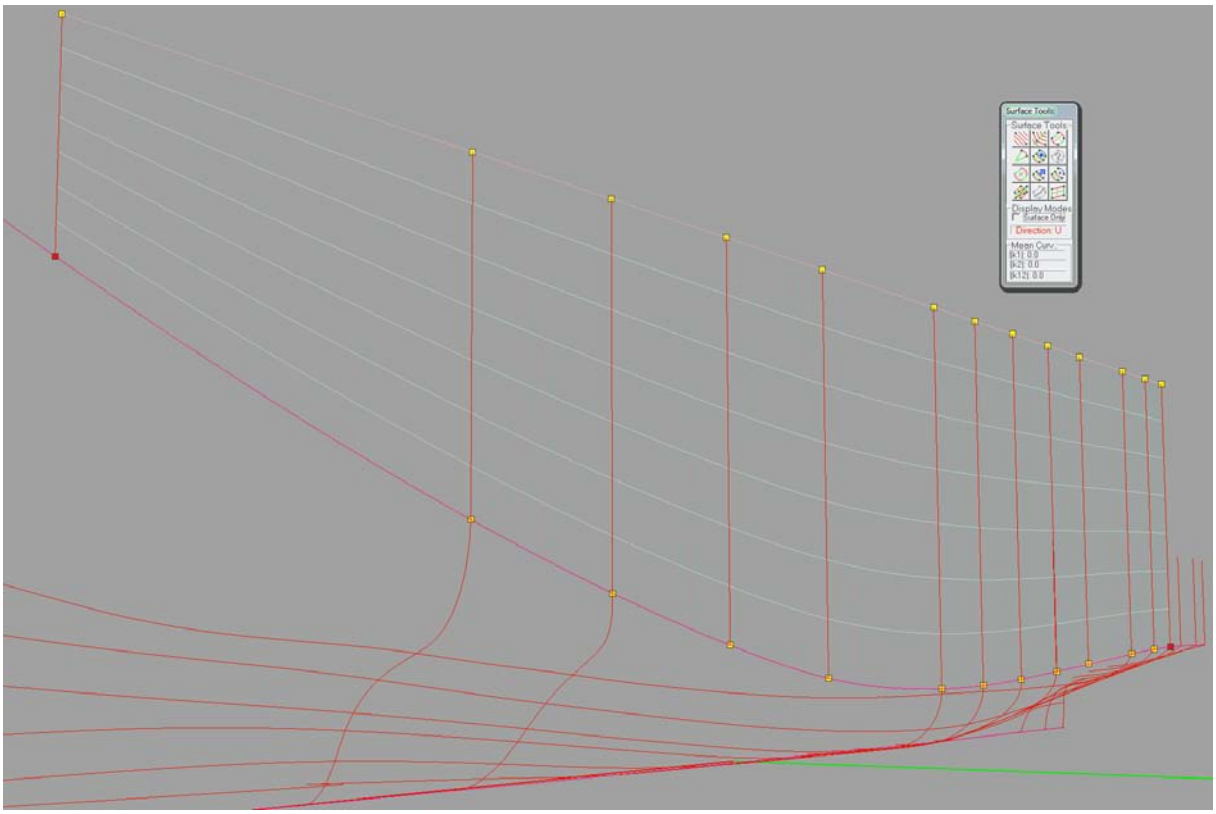


Hit the [Enter] key to validate this faired side line (as this line is planar, we don't have to check the other views) and click on it to make it selected when the NURBS++ Surface toolbox popsup. As soon as the line is selected, the [Double Iso] button becomes active, so that you can click on it for doubling the selected isoparm.

Click on the doubled side isoparm, so that IsoU [0] is selected (see status bar) and hit [Enter] to modify it (an alternative to double clicking, when lines are duplicated). When the NURBS++ Lines toolbox pops up, type [z][4][0][Enter] to planish the line in a z = 40 m horizontal plane and hit [Enter] to validate this line: Hull's vertical side is now created:

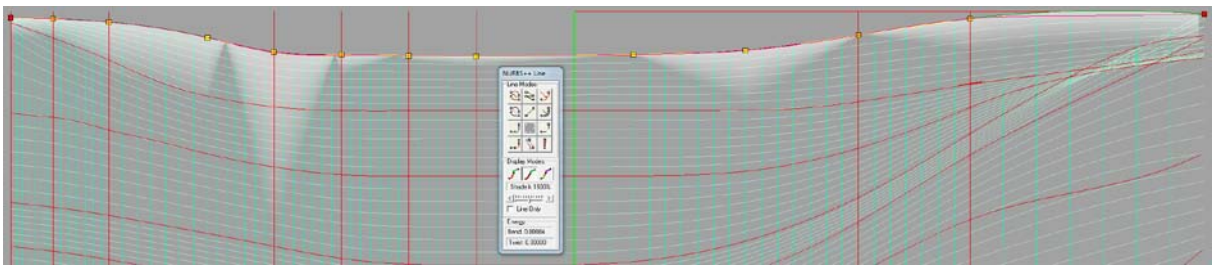


Let us now click on surface's knot [0][0] and, with [Shift] key pressed, on knot [1][12]: Hull's side has now become the active area, so that we can click on a station for selecting the transverse plating direction and on the [Polyhedric Planking] button to draw a transversely ruled surface between the side lines:



Once hull's side plating is accurately defined, hit the [Backspace] key to make the full surface active, double click on the keel isoparm to make it active (the NURBS++ Line toolbox pops up) and maximize the bottom viewport.

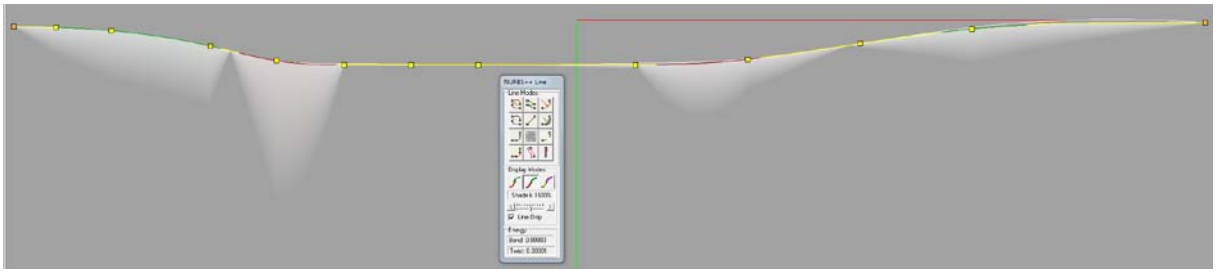
Like for the hull side line, you can turn the curvature scanning on, set its sensitivity accordingly and move the cursor vertically with right mouse button and [Alt] key pressed, to shorten the view and magnify its unfairnesses



Click on knot [4] to select it and, with [Shift] key pressed, click on knot [7] to restrain the active area to arc [4, 7]. Once done, type [y][1][.][3][5][Enter] to flatten this arc to y = 1.35 m and hit [Backspace] to reset line's active area.

Select arc [7, 12] similarly, click on the [Spline] button (or type [s][Enter]), click on knot [12] to select it and type [n][Enter] to select a natural (flat) spline extremity.

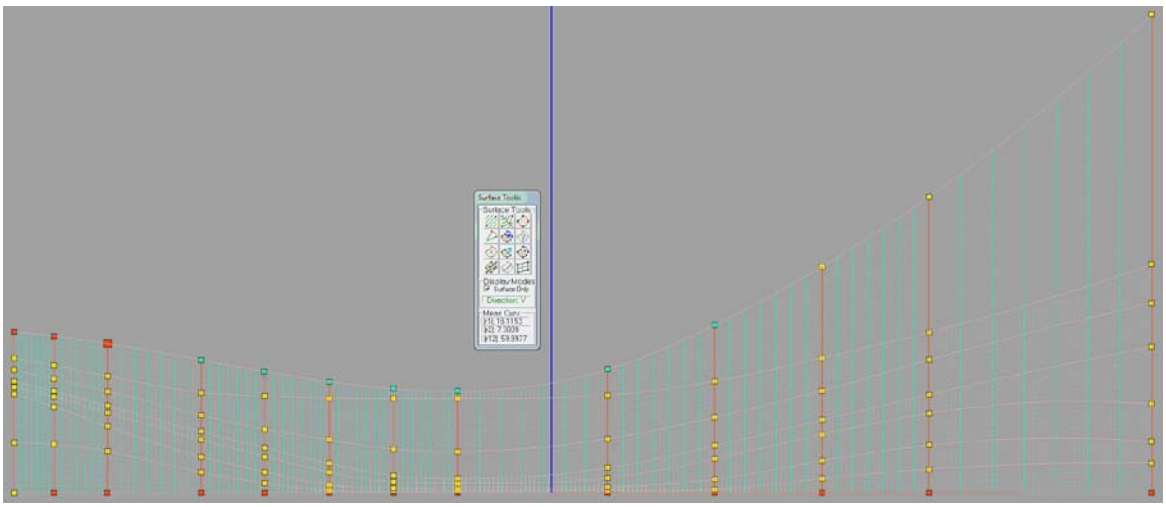
When done, hit [Backspace] to reset the active area and select arc [0, 4] similarly. Click on the [Spline] button (or type [s][Enter]), click on knot [0] to select it and type [n][Enter] to select a second natural (flat) spline extremity. Moreover, as arc [0,1] becomes negative, select knot [1] and hit [Page Down] as many times as necessary for getting positive half breadths in this area (you can also repeat this operation on knot [3]).Once done, hit [Backspace] to reset the active area:



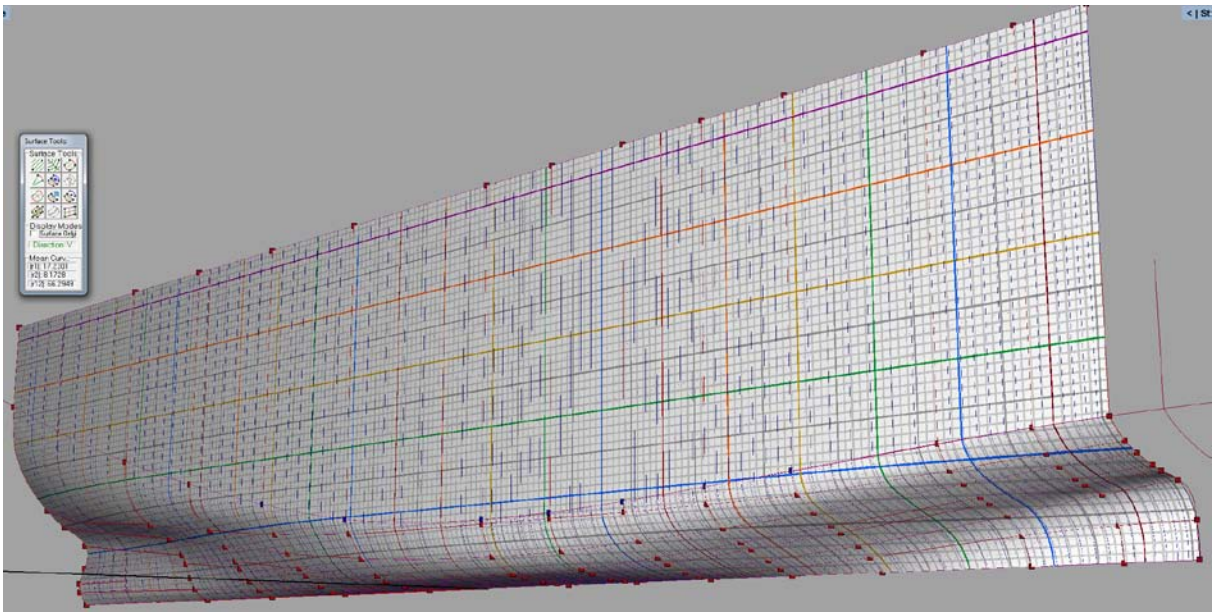
At last, you can type [z][0][Enter] to ensure that the keel line is exactly horizontal, afterwards you can press the [Enter] key for validating the keel isoparm.

When the NURBS++ Surface toolbox has popped up, click on hull's knot [1][0] and, with [Shift] key pressed, on knot [8][12] to exclude side plating from the active area. As we now want to blend the side plating transversally with the lower lines in order to create a fair hull surface, we must accurately set the transverse blending continuities as they vary longitudinally (this ability to process variable continuity blending is one of the powerful features of NURBS++ surfaces).

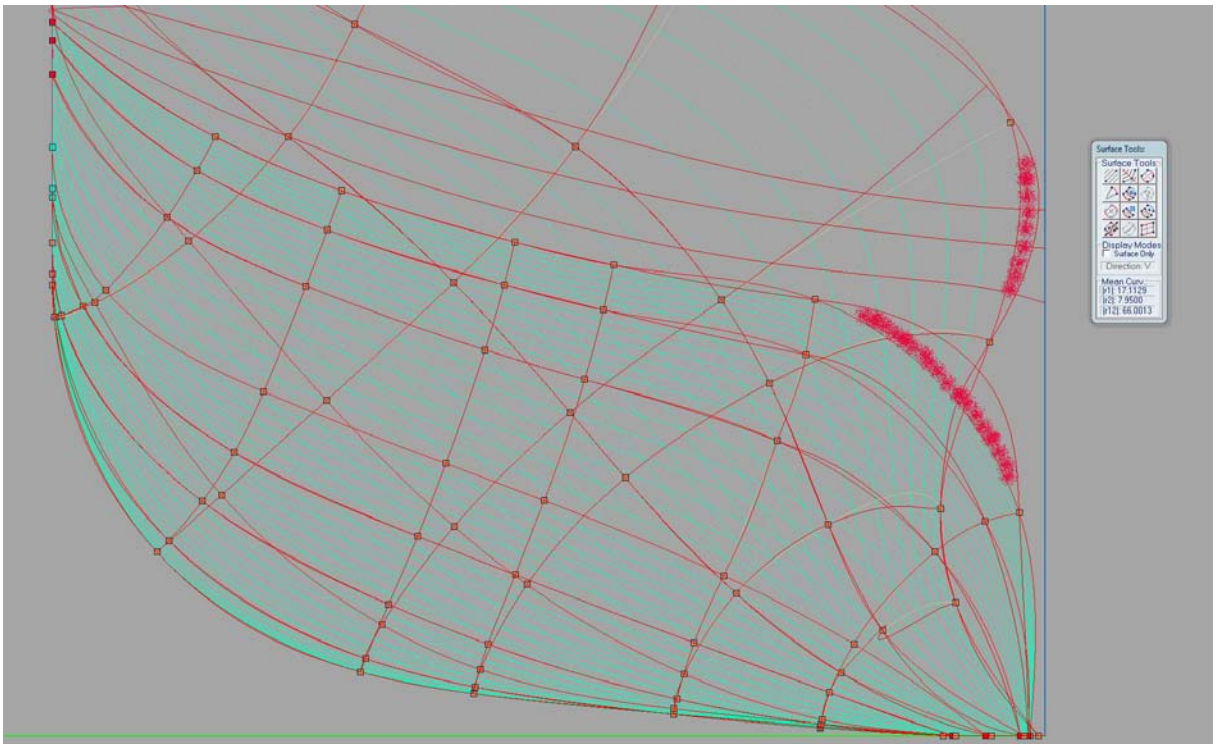
First click on the side isoparm to select it and, as most of the transverse continuities along this line are tangent continuities, just type [t][Enter] to pre-set all the transverse continuities along this line to 'tangent'. Once done, select knot [0] and type [k][Enter] to set a transverse curvature continuity on it and repeat this operation on knots[2] and [3]. Finally, select knot [10] and type [p][Enter] to set a positional continuity on this knot (the after hard chine starts between stations 9 and 10) and repeat this operation on knots [11] and [12]. When done, select the keel isoparm and type [p][Enter] to pre-set a positional transverse continuity along it, select knot 12 and type [n][Enter] to set a natural transverse continuity. Finally the transverse continuities along the side and keel isoparms are the followings (red = positional, blue = tangent, yellow = curvature):



When the transverse continuities are correctly set, insure that the transverse plating direction is selected by clicking on a transverse isoparm and click on the [Planking] button (or type [s][Enter]). Finally, hit the [Backspace] key to reset the active surface area:

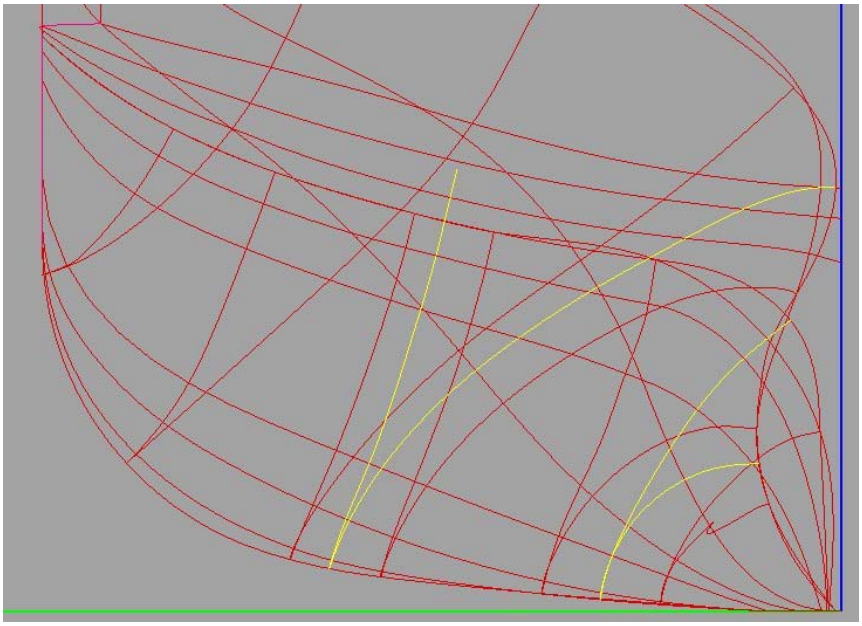


Checking this first hull body reveals that the bulb and skeg blendingsare too loose compared with the original ones:



In order to illustrate how important the longitudinal isoparms setting is according to hull's geometry, we will add2 additional geodesics in these areas for holding the hull surface closer to the initial stations.

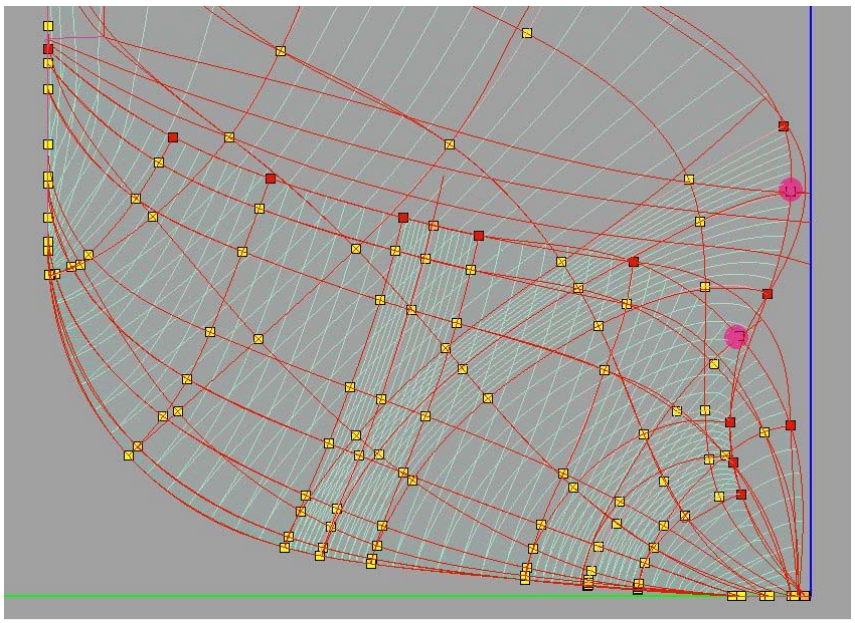
We will therefore press [Enter] to validate this surface, select stations 3 to 12 in the 3D browser and, like previously, right click to select ‘/Line/Remarkable’ in the popup menu for adding these extra geodesics:



Don’t forget to hit [Enter] to validate the lines !

Let us now double click each of these linesto remove the useless knots so that only the stations knots remain. When done, set the extremity continuities to [p]ositional, type [s][Enter] to draw a spline on these knots and hit [Enter] to validate.

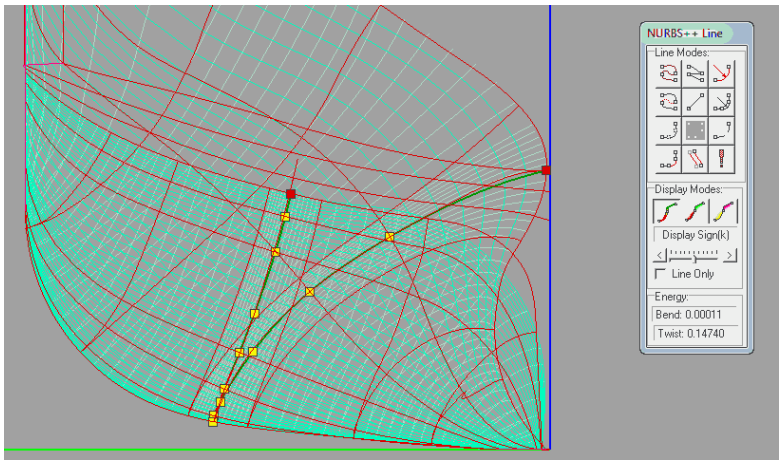
When both lines have been ‘cleaned’ with the NURBS++ Line toolbox and validated, rename them anddouble click on the hull surface for including directly these additional lines in it. Once the NURBS++ Surface toolbox is displayed, maximize the back view and, while keeping [Control] key pressed, left click on the intersection of Iso V 0 and the new geodesic to insert an additional Iso U on this point:



Once inserted, double click on this new Iso U to modify it and select arc [0, 2] by clicking on knot [0] and on knot [2] with [Shift] key pressed.,

When done, click on the [Clone] button in the NURBS++ Line toolbox and click on the corresponding geodesic (although we will clone thex,y,z coordinates, any subset can be selected if necessary by typing its shortcut before selecting the line, i.e. [y][z][Enter] for cloning the y,z coordinates and, therefore, conserving x).

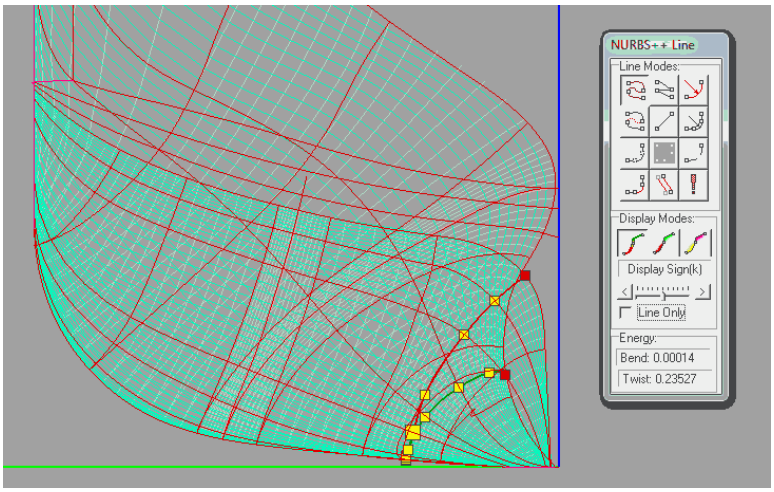
The corresponding arc of newly created geodesic has now been cloned on Iso U's arc [0, 2];let us just hit [Backspace] to reset the active arc and click on the [Spline] button to smoothen it before hitting [Enter] to validate the modified isoparm:



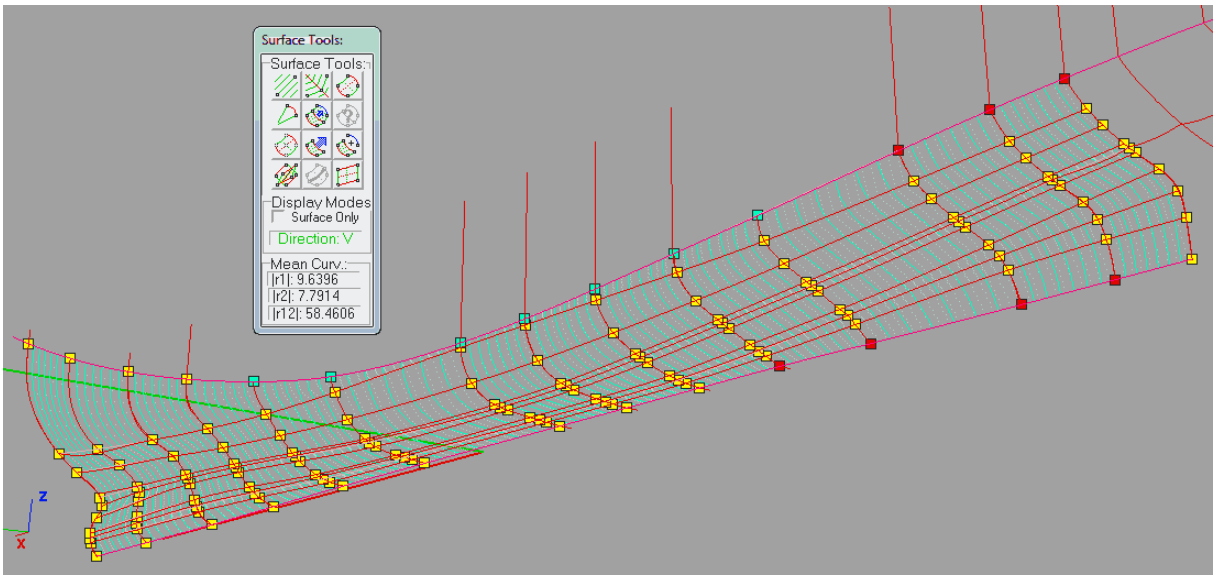
Let us now double click on the other Iso U to modify it similarly and select arc [11, 13] by clicking on knot [11] and on knot [13] with [Shift] key pressed.,

When done, click on the [Clone] button in the NURBS++ Line toolbox and click on the corresponding geodesic.

The corresponding arc of the second geodesic has now been cloned on Iso U's arc [11, 13]; hit [Backspace] to reset the active arc, select arc [9, 13] and click on the [Spline] button to blend the cloned area before hitting [Enter] to validate the modified isoparm:

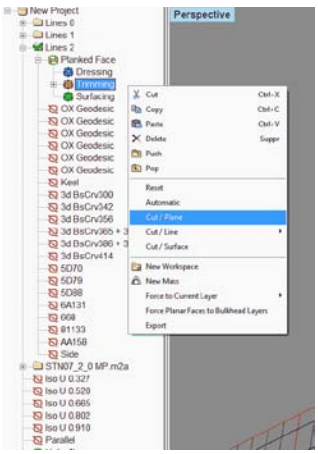


Once the NURBS++ Surface toolbox is displayed, we must now click on hull's knot [1][0] and, with [Shift] key pressed, on knot [10][13] to exclude side plating from the active area. As we now want to blend again the side plating transversally with the completed lower lines, we must check the transverse blending continuities before clicking on an Iso V for selecting a transverse planking direction and clicking on the [Spline Planking] button.



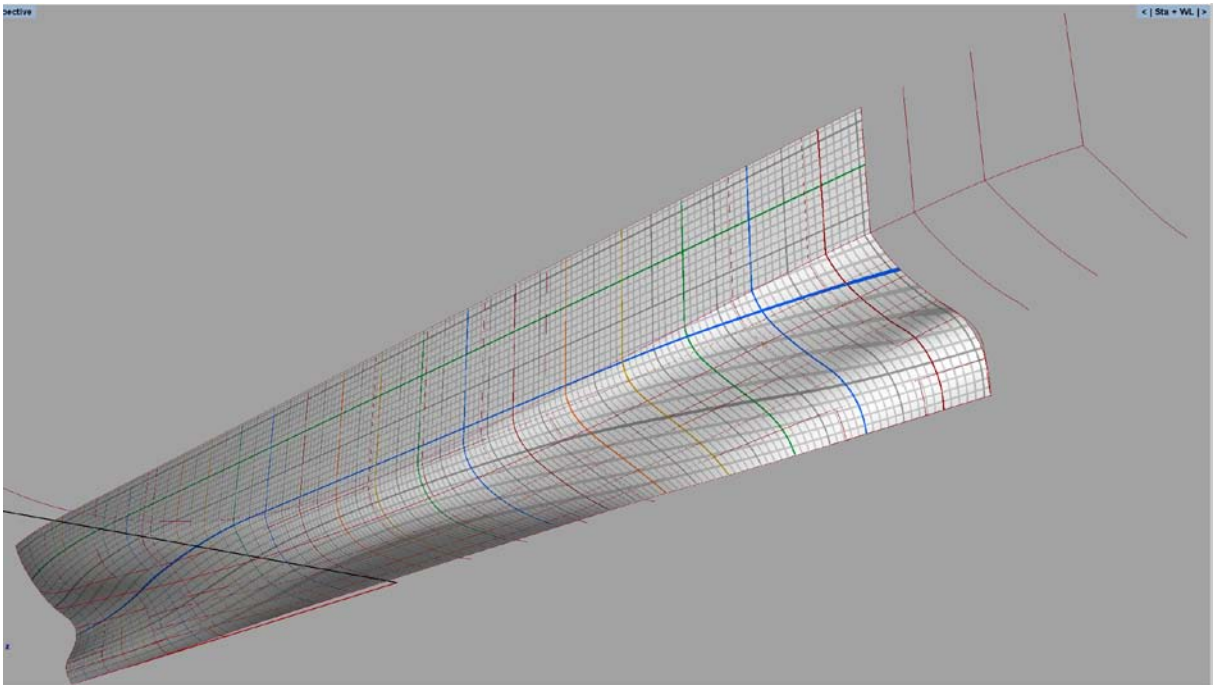
Notice that, as seen previously, you can hit the [Hydro] button at any time if you want to check hull's hydrostatic and, even more, provided that a realistic mass in included in the active folder, you can use most of the hydrostatic tools as long as no tank nor compartment is needed.

Finally, hit [Enter] to validate the hull body surface and select its 'Trimming' macro in the 3D browser, right click, select '/Trimming/Cut / Plane' in the popup menu and type [h][2][0][Enter] to trim surface's outline by a z = 20 m horizontal plane.

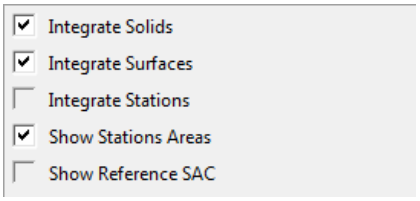


Hit the [/] key to select the lower hull outline instead of the default upper one and [Enter] to validate your selection.

The hull body is now done:



As everywhere, you can click on the [Hydro] button and / or select most of the hydrostatic tools, provided that hydrostatic viewport's integration options are correctly switched:

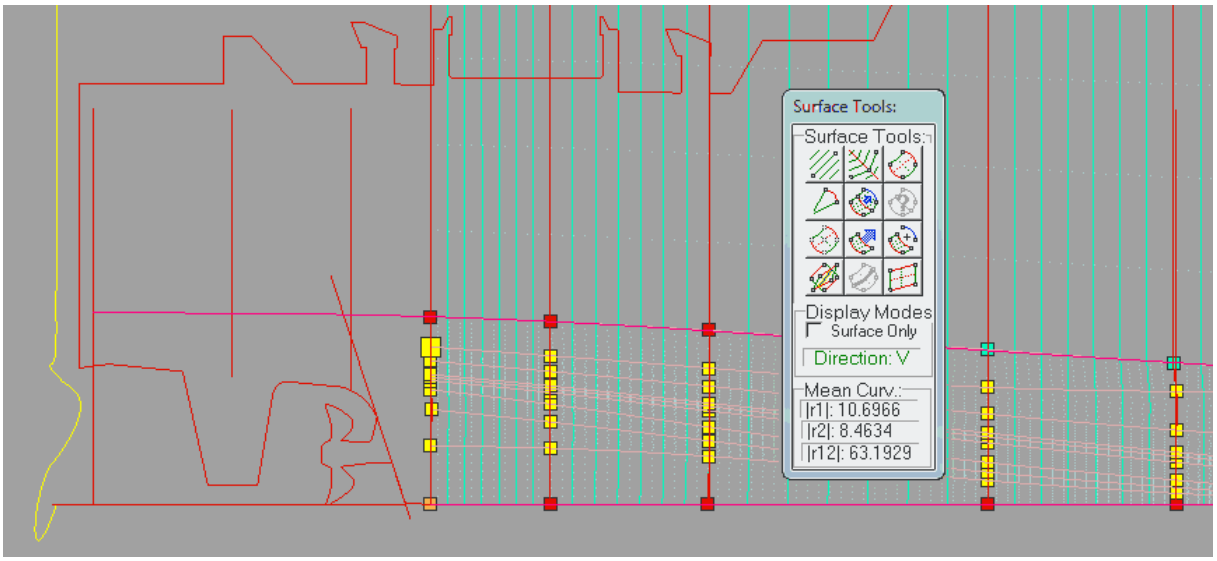


This hull body surface can be found in 'Ro-Pax' file's 'Hull Body' folder.

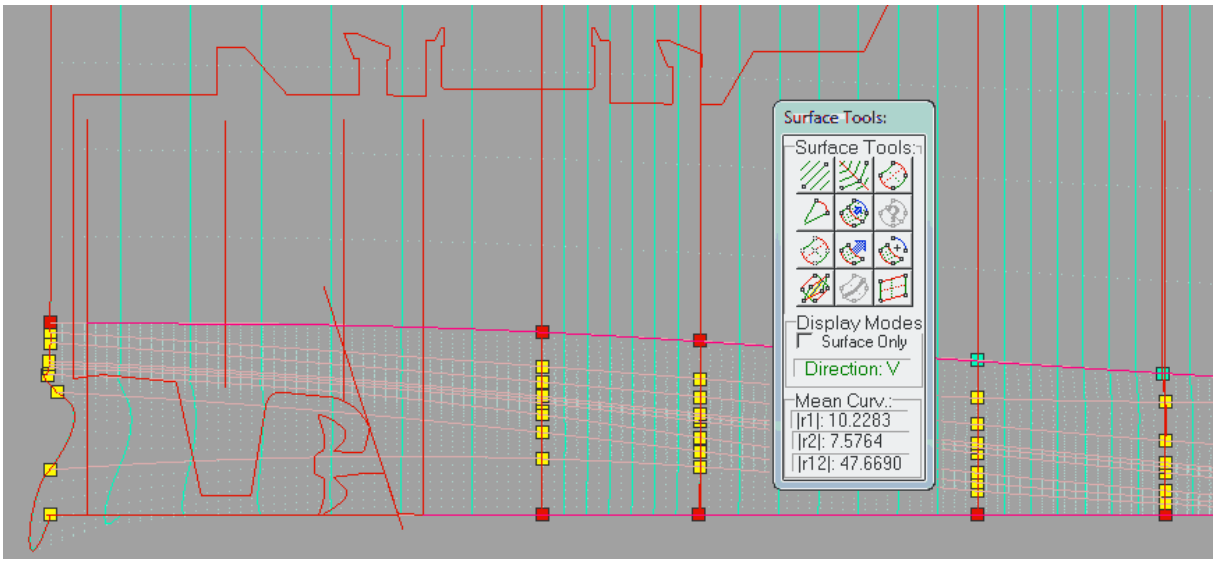
4.5.4 Adding the stern and skeg to the hull body:

Let us now double click on the hull body surface in the 3D browser to re-open the NURBS++ Surface toolbox. In order to append hull's stern and skeg, we will first click on the 'Set Extent' button (or hit [^][Enter]), so that moving the cursor by surface's boundary displays the associated new boundary (warning: the farther you move, the most 'noised' the boundary is).

In this case, we will move the cursor behind the transom on the right view:

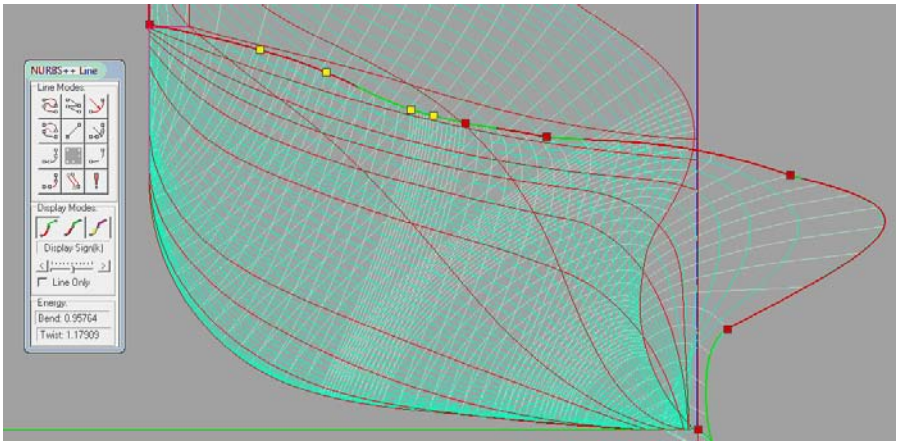


Once we have clicked for validating this surface extension, surface is prolonged so that is after boundary reaches the current line we have set:



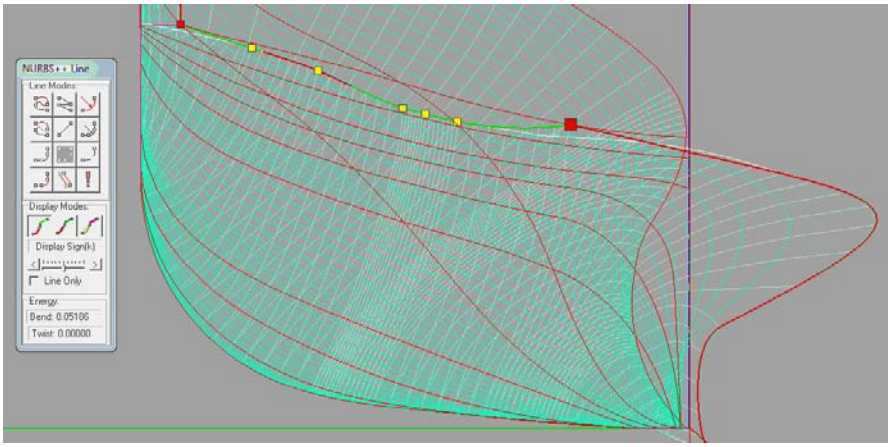
In order to control thoroughly the fairness of this hull surface extension, let us type [t][-][9][7][.][2][9][Enter] to insert a station at x = -97.29 m, where Sta 0 is located. When done, let us click on the last isoparm to select itand hit [Delete] to remove it: We don't need it anymore as it is not planar.

We can now double click on this new station to compare it with the original one:

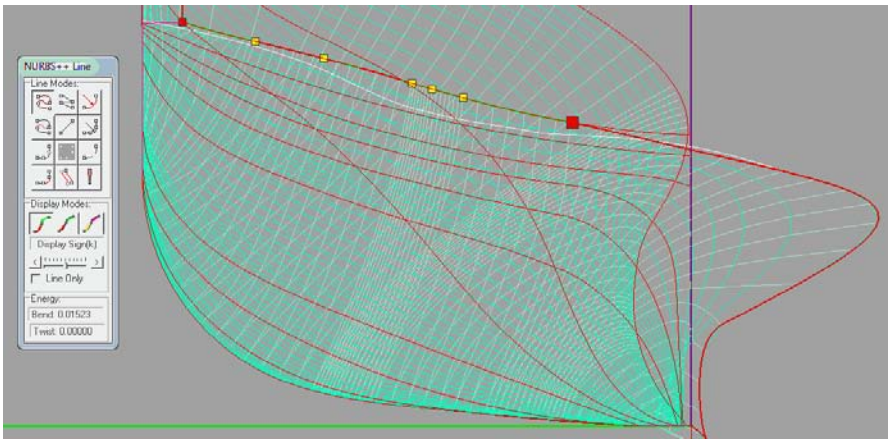


We will now select arc [1, 7] by clicking on knot [1] and on knot [7] while keeping [Shift] key pressed.Once done, click on the [Spline] button for drawing a spline on this arc. While keeping [Shift] key pressed, drag knot [1] by station 0's hard chine and release the mouse button when snapped (snapped knot appears in white).

Similarly, let us drag knot [7] by Station 0 with [Alt] key pressed, so that it can be snapped anywhere in itand release the mouse button when done.

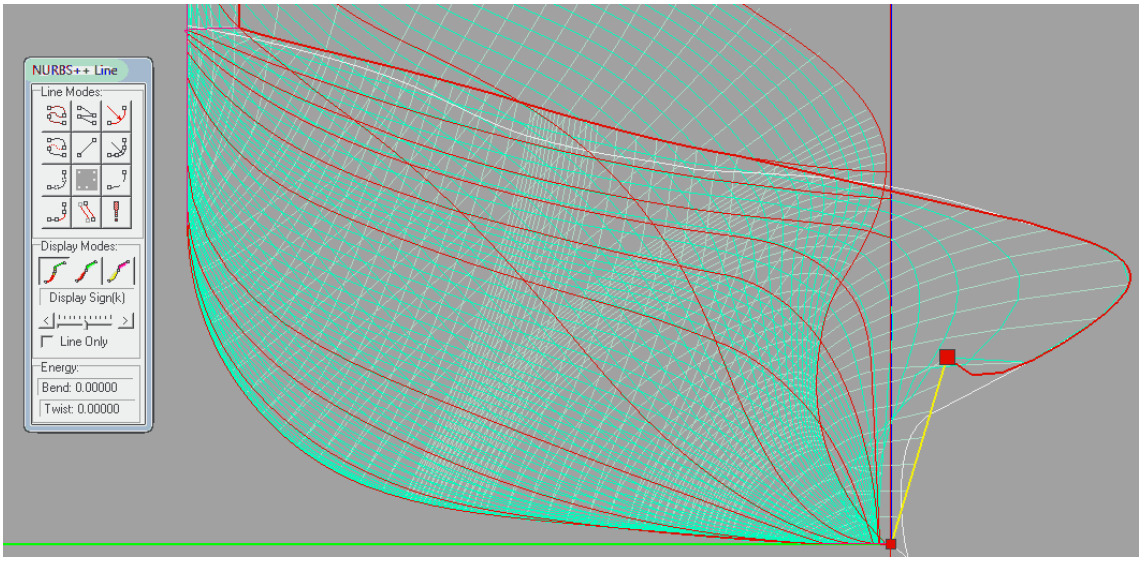


Finally, click on the [Clone] button and, then, on station 0, which will be duplicated in current arc:

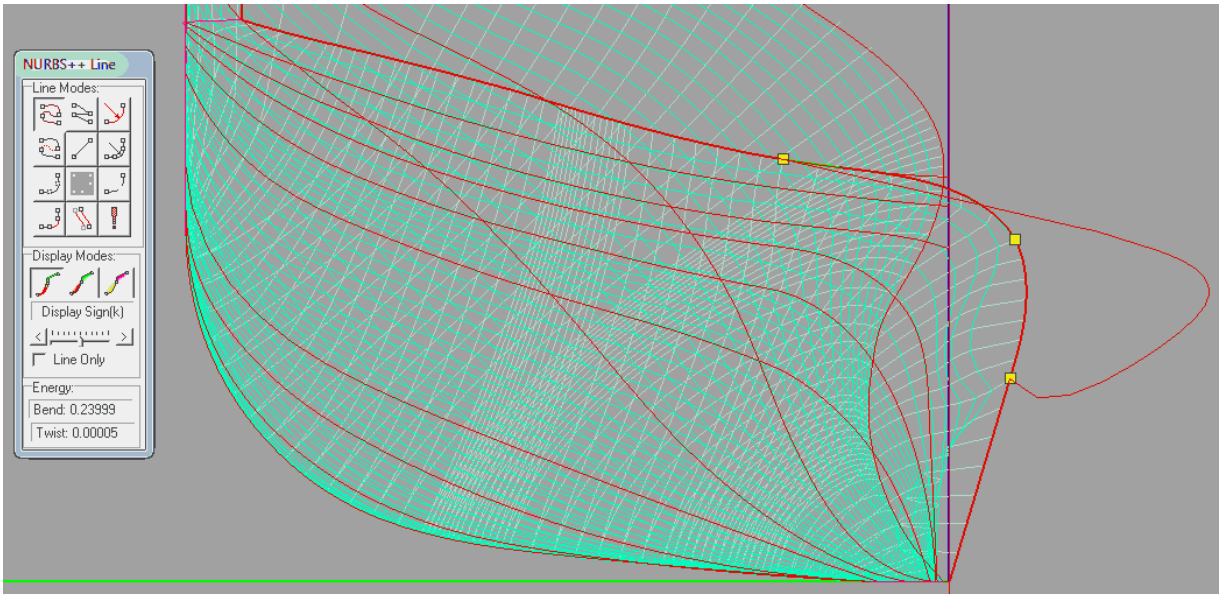


Hit [Backspace] to reset current arc, click on knot [1] to notice its y coordinate in the status bar (y = 12.2335 m) arc click on knot [0] with [Shift] key pressed to select station's side arc. Once done, type [y][1][2][.][2][3][3][5][Enter] to make this arc vertical and hit [Backspace] again to reset the current arc.

Click on knot [9] and on knot [10] with [Shift] key pressed for selecting station's last arc.Click on the [Segment] button (or type [/][Enter]) to make it straight and drag knot [9] in the extension of Iso U [9]:

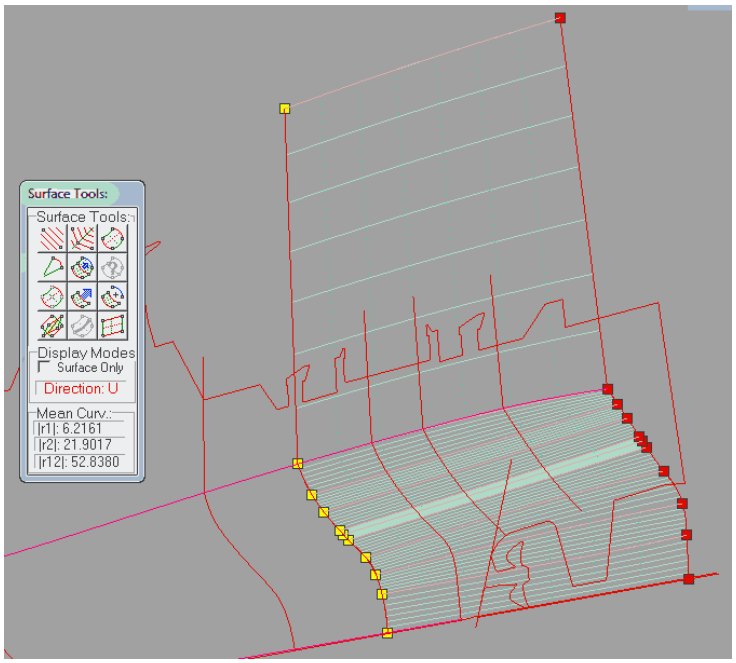


When done, hit [Backspace] to reset current arc and select arc [7, 9] by clicking on knot [7] and knot [9] with [Shift] key pressed. Click on knot [7] to select it, type [k][Enter] to set its continuity to curvature and repeat this operation on knot [9] before clicking on the [Spline] button. When done, you can drag knot [8] for setting skeg's blending fairness:

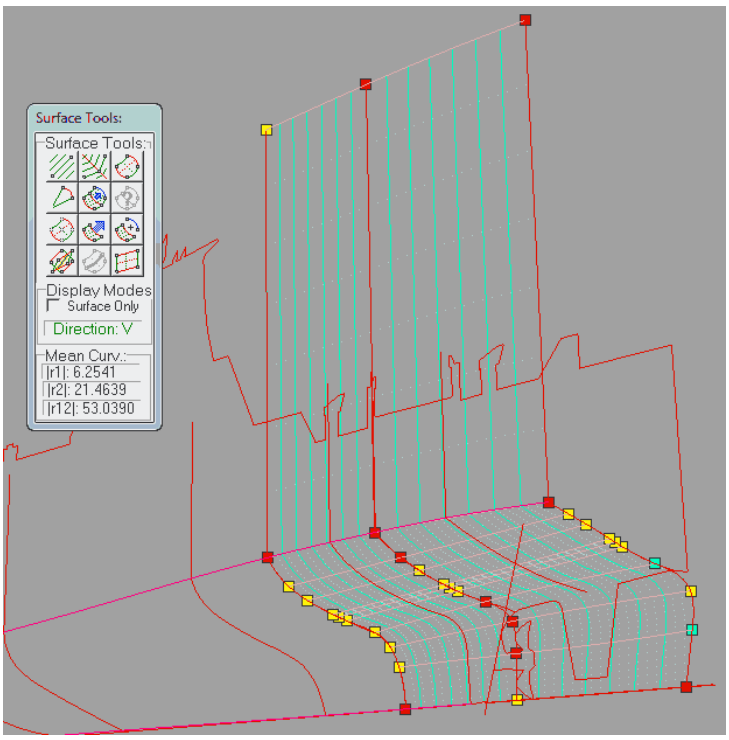


When finished, hit [Backspace] to reset line's arc and [Enter] to validate it.

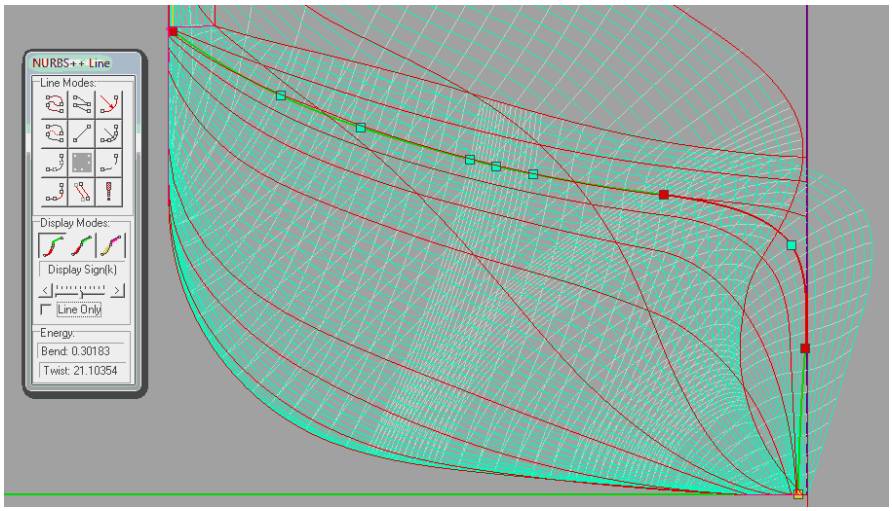
We can now click on surface's knot [0][13] and on knot [10][12] for selecting the new after area (where ship side's half-breadth decreases) and click on Iso U 0 to select a longitudinal planking direction. Insure that the longitudinal blending continuities are set to curvature alongIso V 12 (otherwise, select it and type [k][Enter]) and to positional alongIso V 13 (otherwise, select it and type [p][Enter]). When done, click on the [Spline Planking] button to reconstruct this surfaceaccording to the current continuities:



Hit [Backspace] for returning the full surface and type [t][-][8][4][.][2][9] for inserting a station located at x = -84.29 m:

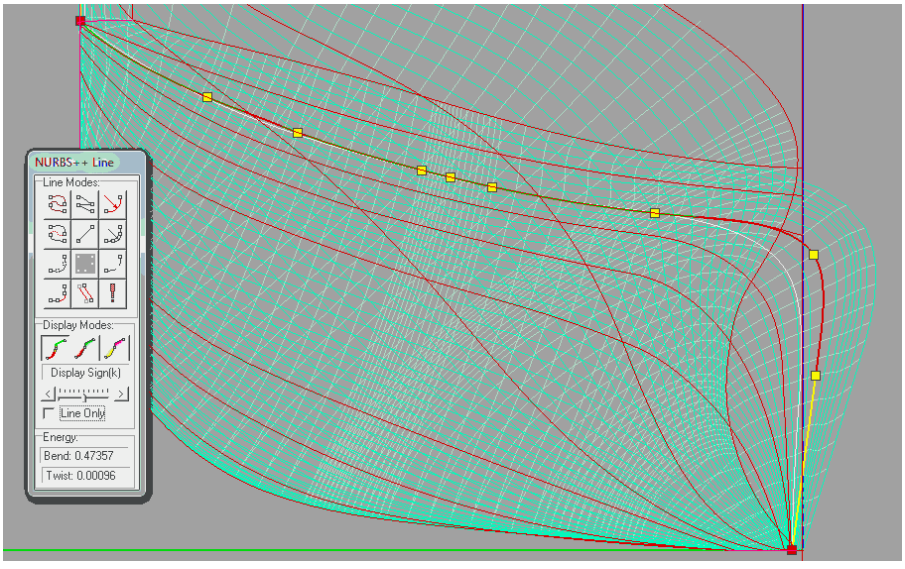


Double click on this new isoparm, so that we can compare and fit it with Station 2:



Let us repeat the same procedure than previously for copying Station 2 on this isoparm:

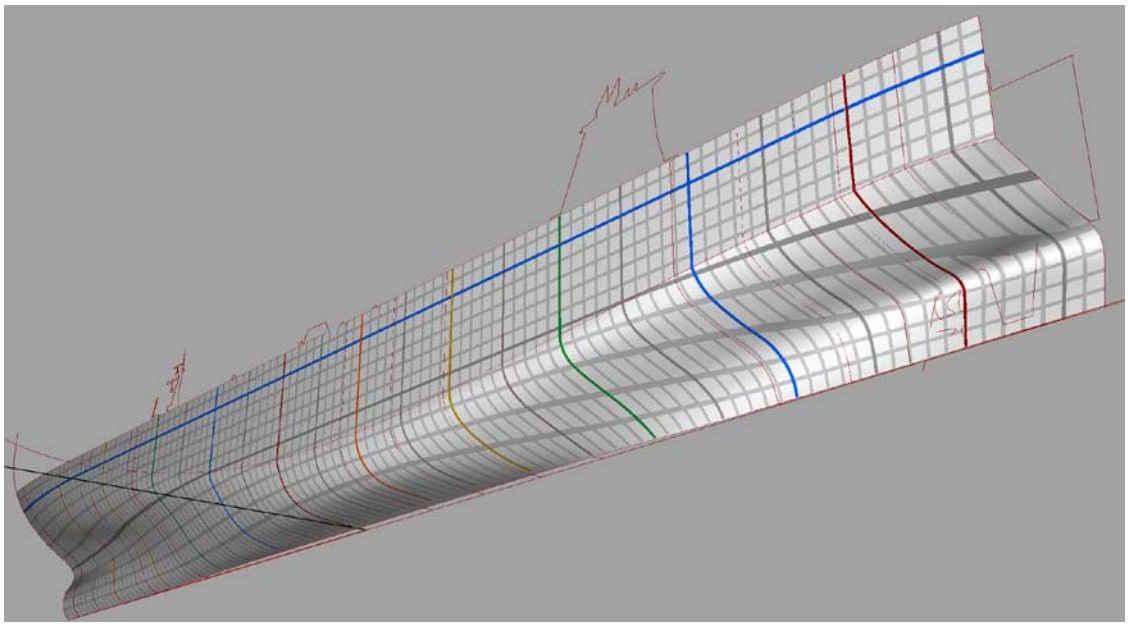
- Select arc [1, 7].
- Draw a spline arc.
- Drag and snap knot [1] on station 2's hard chine.
- Drag and snap knot [7] in station 2 to improve associated iso U's fairness.
- Clone Station 2's geometry into current arc [1, 7].
- Draw a spline arc once again.
- Select arc [9, 10] and draw a straight segment on it.
- Drag knot [9] to optimize blending and associated iso U's fairness.
- Select arc [7, 9] and set its continuities to curvature.
- Draw a [Spline] blending and set knot [8] to optimize it.
- Hit [Backspace] to reset line's active area:



Hit [Enter] to validate Station 2 when copied and faired.

Click on surface's knots [0, 14] and [10, 12] with [Shift] key pressed for selecting the after area, click on any iso U to select the longitudinal planking direction, ensure that the longitudinal blending continuities are satisfactory and click on the [Spline Planking] button to 'plank' this surface longitudinally.

At last, hit [Backspace] key to reset the active area and [Enter] to validate this new hull surface:



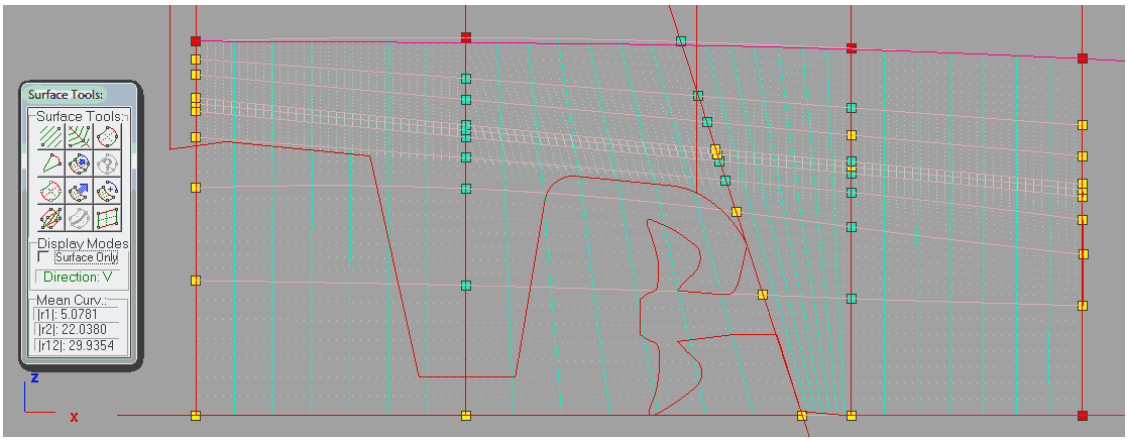
Maximize the right view, zoom the skeg area, select '/Line/Segment' in the menu bar, copy skeg's trailing edge and double click on it to adjust its control points:



Hit [Enter] to validate the segment and double click on the surface knot in the 3D browser to re-open the NURBS++ Surface toolbox.

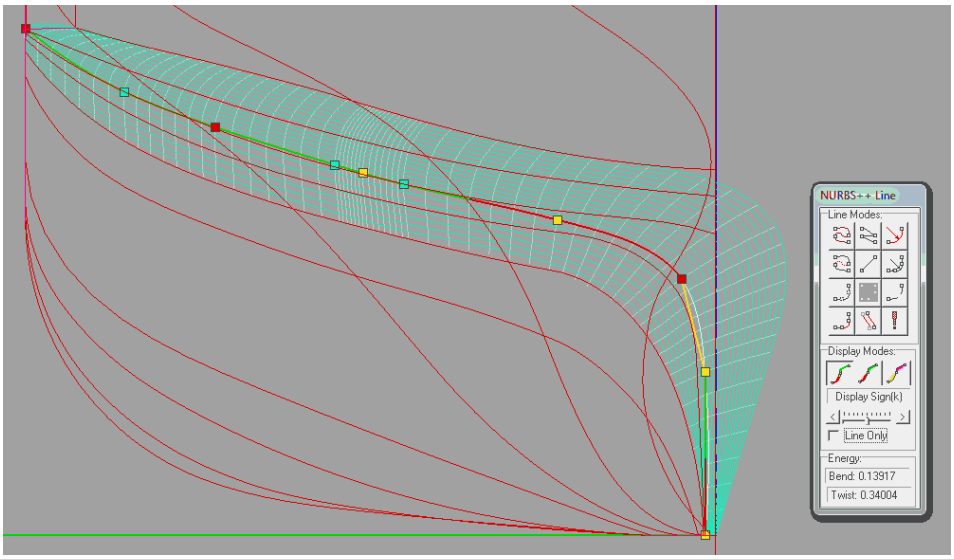
Type [t][-][7][4][.][2][9] for inserting a new station at Station 3's location and [t][-][9][0][.][2][9] for inserting a new station at Station 1's location. Once done, click on Iso V 14 to select it and hit [Delete] to dissolve it, as it is now useless.

Click on surface's knots [10, 12] and [1, 15] with [Shift] key pressed for selecting the lower aft area and type [x][l][Enter] for intersecting a line with current area on the [l]ongitudinal view (you also might have clicked on the [Intersection] button and typed [l][Enter] for selecting the same operation). When done, click on skeg's trailing edge segment to intersect it with the hull surface in the longitudinal view: We have just created this isoparm for constraining skeg trailing edge's half breadth to 0.2 m:



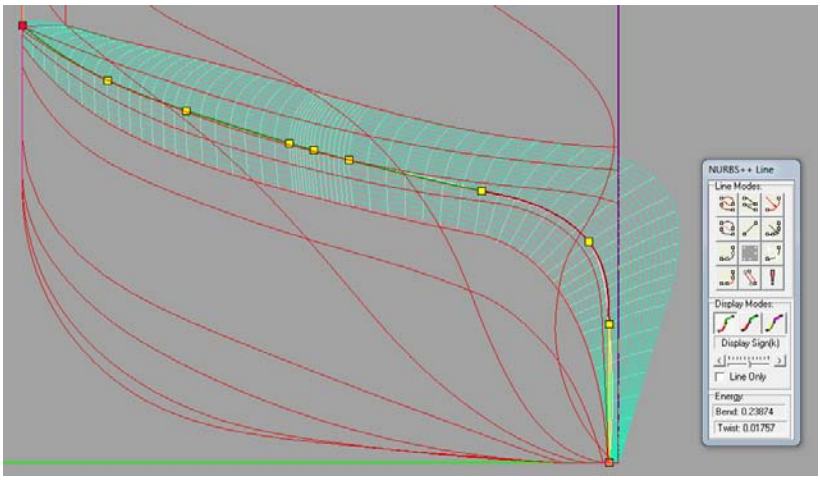
Click on Iso V 13 to select it and hit [Delete] to dissolve it as it has become useless now that skeg's oblique isoparm has been inserted.

Double click on the skeg's oblique isoparm to modify it, switch to the back view, click on knot [9] and on knot [10] with [Shift] key pressed to select the lowest arc. When done, type [y][0][.][2][Enter] to planish this arc into the y = 0.2 m plane and hit [Backspace] to reset the active arc:



Click on knot [1]and on knot [7] with [Shift] key pressed to select the upper arc, select knot [7] again and type [p][Enter] to set a [p]ositional continuity and click on the [Spline] button to draw a spline arc.

Hit [Backspace] to reset the active arc, click on knot [7]and on knot [9] with [Shift] key pressed to select the blending arc, click on knot [7], type [k][Enter] to set its continuity to curvature, repeat this operation on knot [9] and click on the [Spline] button (or type [s][Enter]) to draw a spline blending (don't compare this oblique isoparm with neighbouring stations):

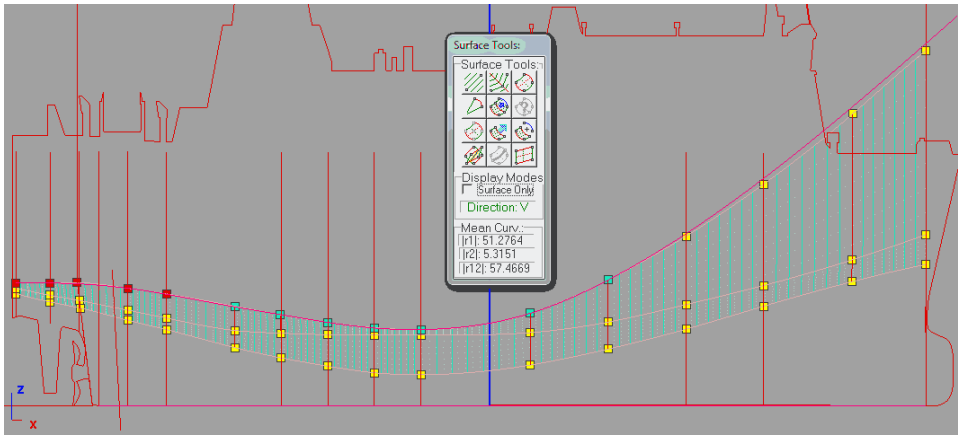


When done, hit [Enter] to validate the line and [Backspace] to reset surface's active area. If necessary, you can control any iso V by double clicking on it and repeating the same copying procedure than for previous stations (see above).

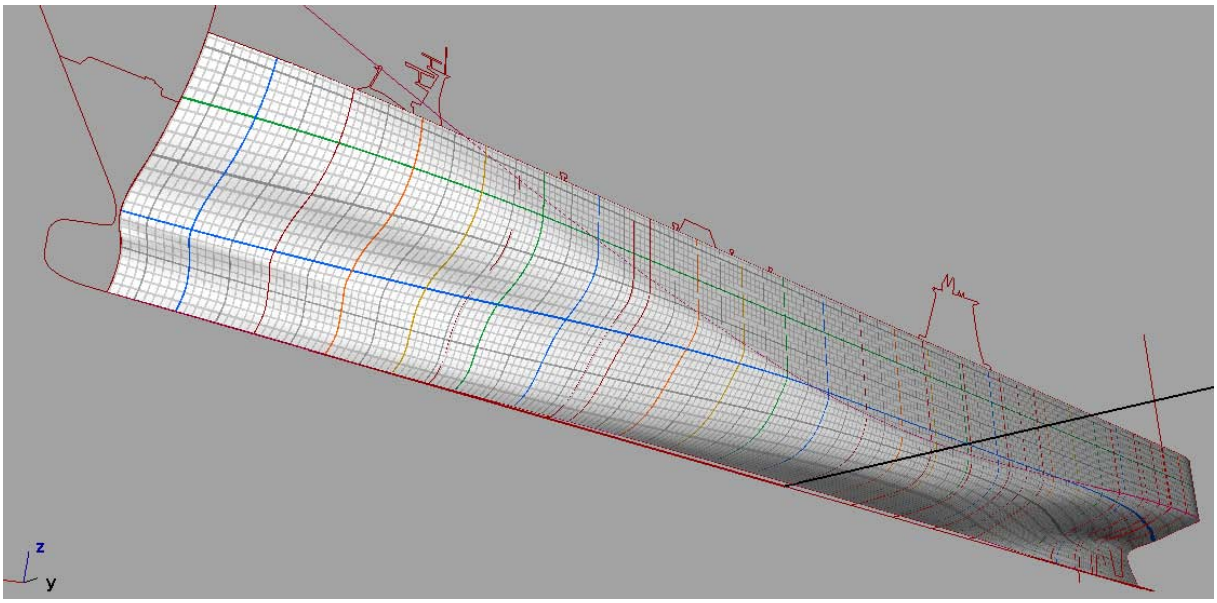
When all the after stations look fine, click on knot [10, 8] and on knot [3, 15] with [Shift] key pressed to select this after part of the bottom, click on an iso U to select the longitudinal planking direction and click on the [Spline Planking] button to plank this area.

Hit [Backspace] to reset surface's active area, click on knot [3, 15] and on knot [1, 0] with [Shift] key pressed to select this complementary part of hulls bottom.

Click on an iso V for selecting the transverse planking direction and control thecorresponding blending continuities, which should be like this:

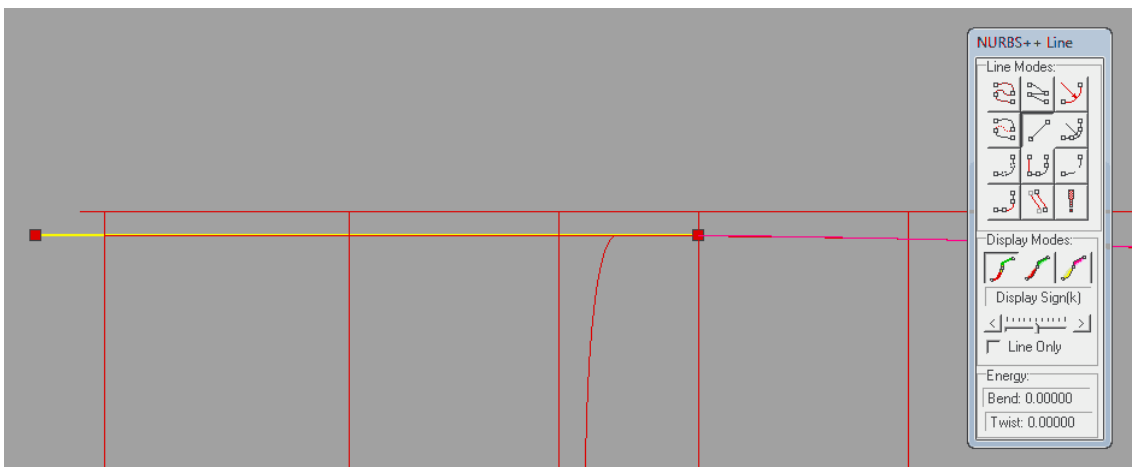


Once done, click on the [Spline Planking] button to blend the previously planked area with the upper hull side according to the current transverse continuities. Hit [Backspace] to reset surface's active area and [Return] to validate this final surface:

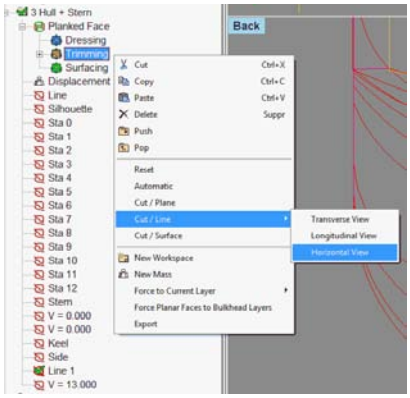


Click on the hull surface in the 3D browser to select it, right click and select '/Line/Remarkable' in the popup menu. When done, type [v][Enter] to select surface's iso V and move the cursor in the skeg area while watching the current display in the status bar and notice that skeg's trailing edge isoparm is Iso V 13 (trailing edge's lowest knot will be needed below for removing hull's virtual part).

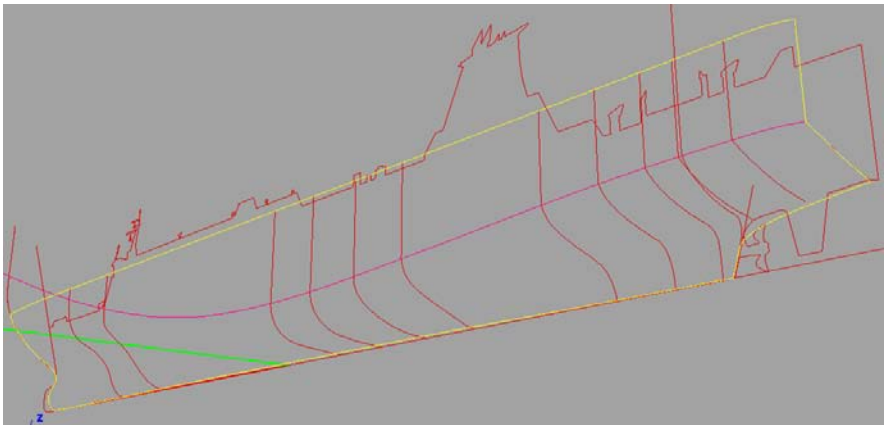
Just type [v][1][3][Enter] to include exactly this isoparm in the current workspace and [Enter] again to finish this operation. We can now maximize the bottom view and zoom the after area for defining after hull's cutting line. Select '/Line/Segment' in the menu bar and move by trailing edge's lowest knot with [Shift] key pressed, in order to snap it (x = -81.546, y = 0.2, z = 0). Left click to enter this point and once again after having moved the cursor behind the hull transom. Once the segment is created, double click on it to finish its definition and type [y][0][.][2][0][0][1][Enter] to planish the segment in the y = 0.2001 m plane (0.1 mm from skeg's trailing edge for avoiding anyintersection 'side effect' on face's limit).



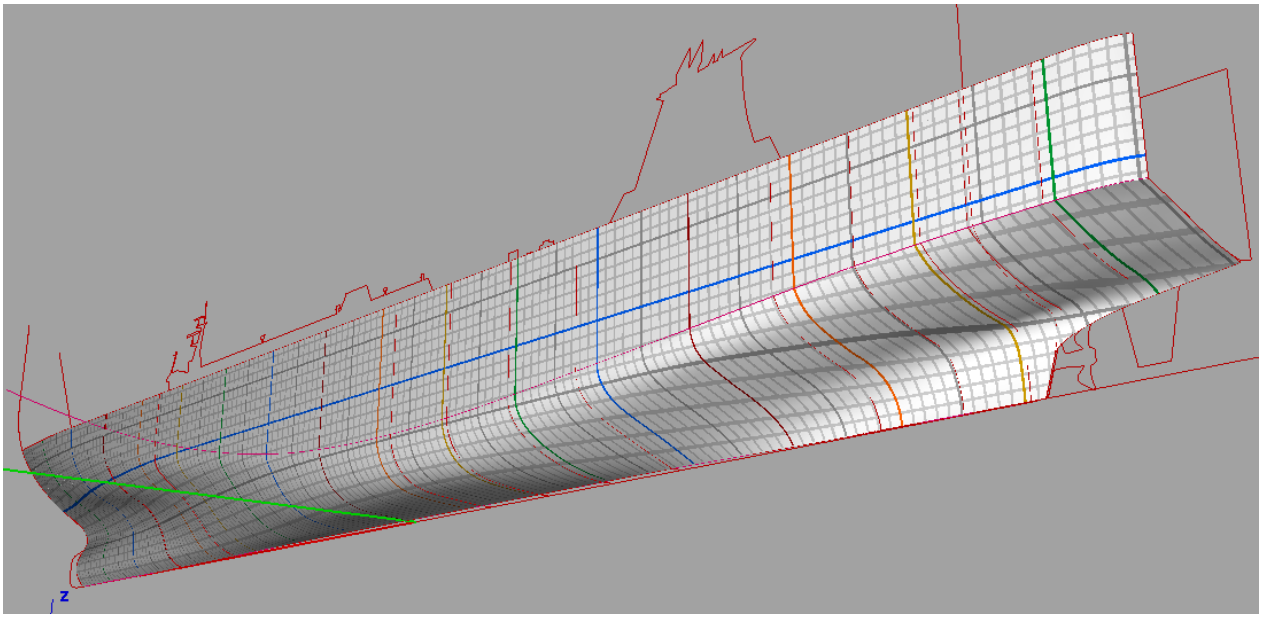
When the segment is finished, hit [Enter] to validate it, select hull surface's 'Trimming' macro in the 3D browser, right click, select '/Cut / Line/Horizontal View' in the popup menu:



Once selected, click on the segment we have just created for splitting hull's outline: Hitting the [/] key isnot necessary here, as the default selection is the right one:



We can therefore hit [Enter] for validating this trimming.

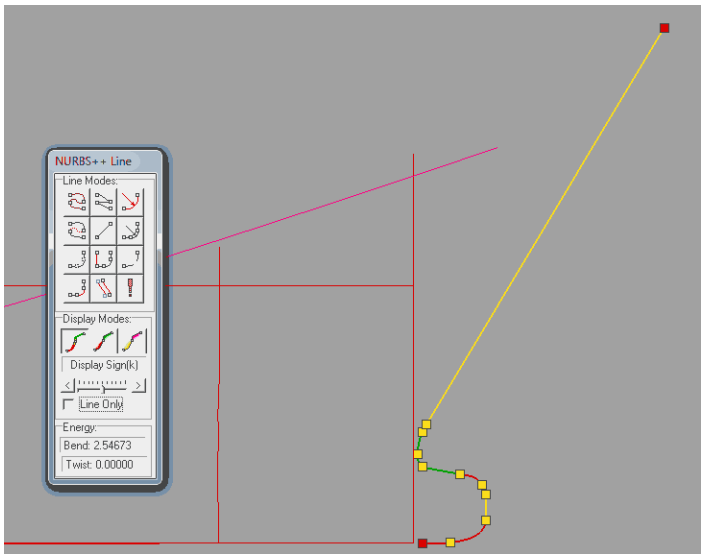


4.5.3 Adding the stem cone and bulb to the hull body:

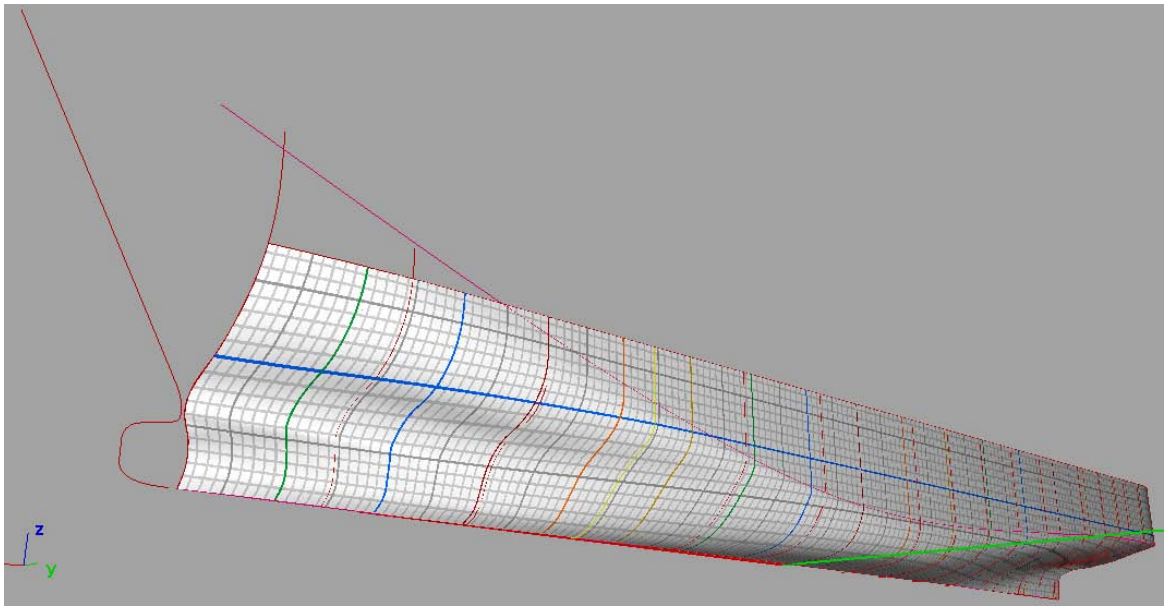
Let us now define hull's bulb and stem cone, which starts by extracting the stem + bulb line from ship's silhouette.

Just double click on the silhouette line to make it active, click on knot [223] and on knot [251] with [Shift] key pressed to make this arc active and click on the [Approximate] button to reduce its number of knots.Once done, click onon the [Trim] button for trimming this arc.

Finally, click on knot [0] to select it and type [2][z][4][5][Enter] for sliding it up to z = 45 m:

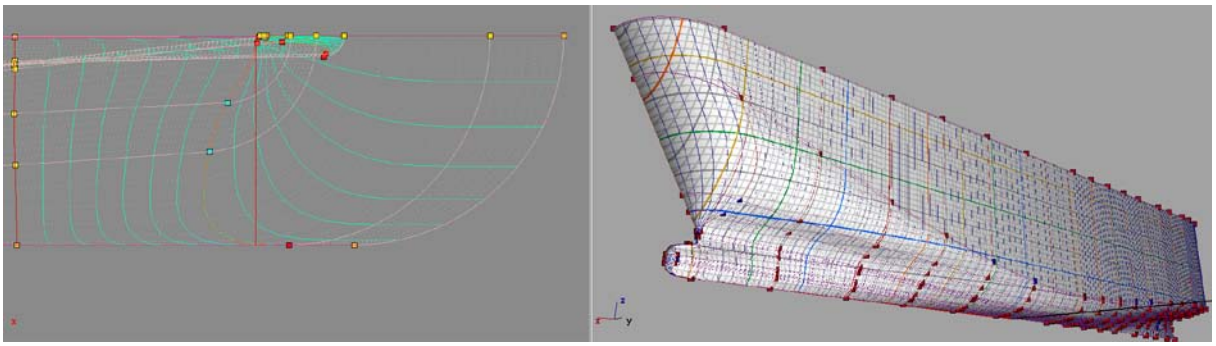


Hit [Enter] to validate this prolonged stem + bulb line and notice that silhouette's trimmed arcs are now separated (Silhouette, Silhouette[+] and Silhouette [-]). As they are now useless, these arcs can be deleted, so that only the stem + bulb arc remains:

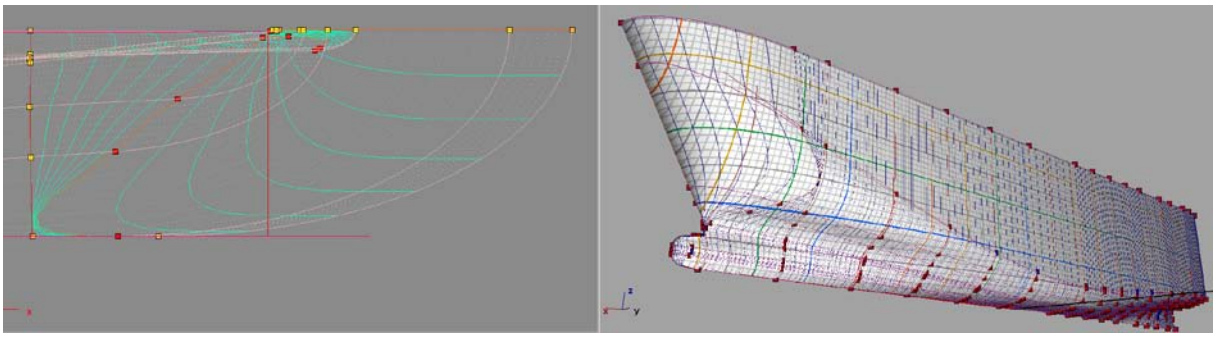


You can now double click on the hull surface knot in the 3D browser to open the NURBS++ Surface toolbox and click on the [Cone] button.

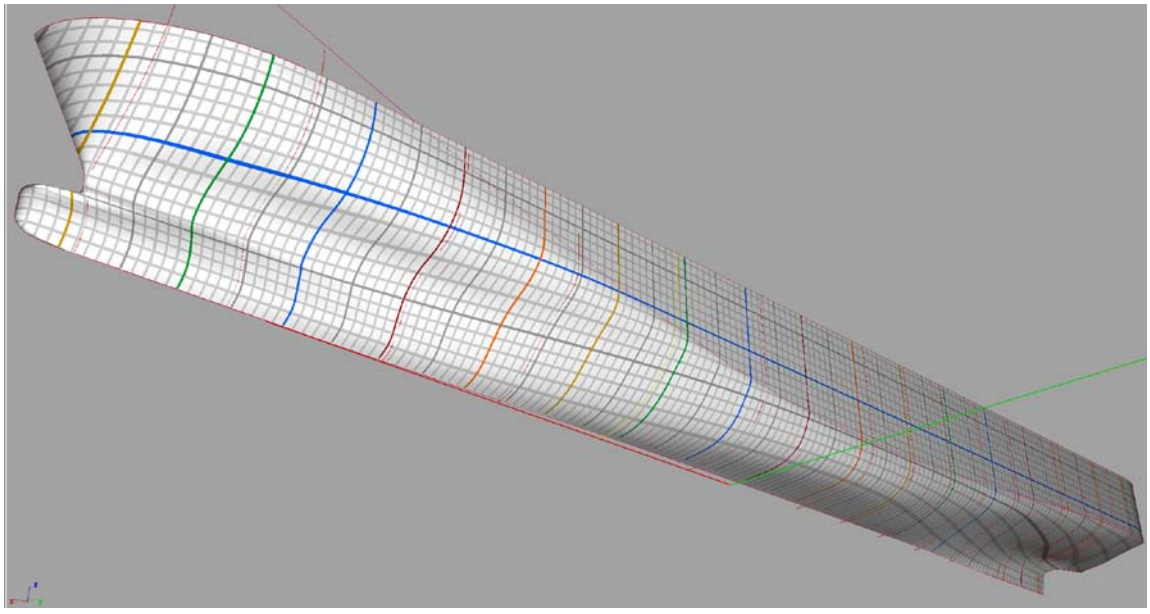
Clicking directly on the stem + bulb line would generate the stem cone surface with the default aspect ratio (1 i.e. circle):



As we look for a smoother cone blending, we hit [Ctrl][z] to undo this operation, re-start it as previously and type [2][Enter] before clicking on the stem + bulb line, so that cone's aspect ratio will now be 2 (2 is obviously almost the maximum ratio, as corresponding tangency line is almost crossing the next isoparm):



At last, as this new stem cone seems satisfactory, hit [Enter] for validating this final hull surface:



ANNEXES:

Annex 1: Line Modeling Reminder:

Knot Selection:

- Selected knot is highlighted / coordinates are displayed in status bar.
- Click on the knot or directly enter its number to select it.
- Hit [↑]/[↓] keys to increment / decrement it.
- Hit [←]/[→] keys to slide the knot in the line (keep [Shift]/[Ctrl] key pressed for larger / smaller increments).

Knot Insertion / Deletion:

- Keep [Control] key pressed and click on the line to insert a knot.
- Once selected, press the [Delete] key to delete the knot.

Arc Selection:

- Select first arc limit and select the second limit with [Shift] key pressed.
- Enter arc's knot numbers n_0 and n_1 in the n_0[,]n_1[Enter] format.
- Hit the [Backspace] key to reset the arc.

Direct Knot / Arc transformations:

-The X coordinate of this table can be replaced by Y or Z if necessary.
-'*value*' represents any valid decimal string.
- Any knot coordinates can be entered directly*** in the x, y, z [Enter format]
- Please, remember that **a negative shift must be entered in the format 'x+-*value'***(typing 'x-*value'* would force X to the negative –*value* position).

Shortcut		**Effect:**	**Example:**
X*value*	*	Forces the X coordinate to *value*	[x][0][Enter]
-X	*	Reverses the X coordinate (mirror)	[-][x][Enter]
X+		Shifts station's X to equal its immersed area with ref. SAC's area ****	[x][+][Enter]
X*		Scales station's X to equal its immersed area with ref. SAC's area ****	[x][*][Enter]
X+*value*	*	Adds *value* to the X coordinate of selected knot	[x][+][1][Enter]
X+-*value*	*	Subtracts value to the X coordinate of selected knot	[x][+][-][1][Enter]
X**value*	*	Scales the X coordinate of selected knot by *value*	[x][*][2][Enter]
X/*value*	*	Divides the X coordinate of selected knot by *value*	[x][/][2][Enter]
X.		Snaps the X coordinate of selected knot on nearest Marking Line**	[x][!][Enter]
.		Snaps all the coordinate of selected knot on nearest Marking Line**	[!][Enter]
X=		Snaps the X coordinate of selected knot on the nearest initial knot	[x][=][Enter]
=		Snaps all the coordinate of selected knot on the nearest initial knot	[=][Enter]
X!		Snaps the X coordinate of selected knot in the initial line	[x][.][Enter]
!		Snaps all the coordinate of selected knot in the initial line	[.][Enter]
X?		Releases the X coordinate of selected knot (least energy)	[x][?][Enter]
?		Releases all the coordinate of selected knot (least energy)	[?][Enter]
2X*value*		Slides selected knot in the line to reach x = value	[2][x][5][Enter]

* These shortcuts operate on the knot when selected, otherwise on the current arc.
** Any line set in the 'Marking' layer can be used as a marking line.
*** Only possible when a geometric function (i.e. [Spline], [Polygon], …) is selected.
**** Only possible when the line is a station and when a reference SAC is defined.

Annex 2: Surface Modeling Reminder:

Knot Selection:

- Selected knot is highlighted / coordinates are displayed in status bar.
- Click on the i, j knot to select it or directly enter its Gaussian coordinates in the i[,]j[Enter] format (by example [0][,][0][Enter] for selecting knot 0,0).
- Hit [↑]/[↓][←]/[→] keys to increment / decrement it.

Line Insertion / Deletion / Modification:

- While keeping [Control] key pressed,click on the isoparmwhere you want to insert a cross isoparm.
- Once isoparm to dissolve is selected, press the [Delete]key to dissolve it.
- Once isoparm to modify is selected, press the [Enter]key to modify it.

Patch Selection:

- Select first patch limit as explained above and select its second limit with [Shift] key pressed.
- Hit the [Backspace] key to revert to the full surface.

Direct operations:

-The X coordinate of this table can be replaced by Y or Z if necessary.
-'*value*' represents any valid decimal string.
- Any knot coordinates can be entered directly*** in the x, y, z [Enter format]
- Please, remember that **a negative shift must be entered in the format 'x+-*value'***(typing 'x-*value'* would force X to the negative –*value* position).

Shortcut	Effect:	Example:
Xvalue	Forces Area's X coordinate to value	[x][0][Enter]
-X	Reverses Area's X coordinate (mirror)	[-][x][Enter]
X+value	Adds value to Area's X coordinate	[x][+][1][Enter]
X+-value	Subtracts value to Area's X coordinate	[x][+][-][1][Enter]
X*value	Scales Area's X coordinate by value	[x][*][2][Enter]
X/value	Divides Area's X coordinate by value	[x][/][2][Enter]
Tvalue	Inserts a transverse isoparm located at x = value when possible	[t][0][Enter]
Lvalue	Inserts a longitudinal isoparm located at y = value when possible	[l][0][Enter]
Hvalue	Inserts a horizontal isoparm located at z = value when possible	[h][0][Enter]
Uvalue	Inserts an iso U located at u = value	[u][0][.][5][Enter]
Vvalue	Inserts an iso V located at v = value	[v][0][.][5][Enter]