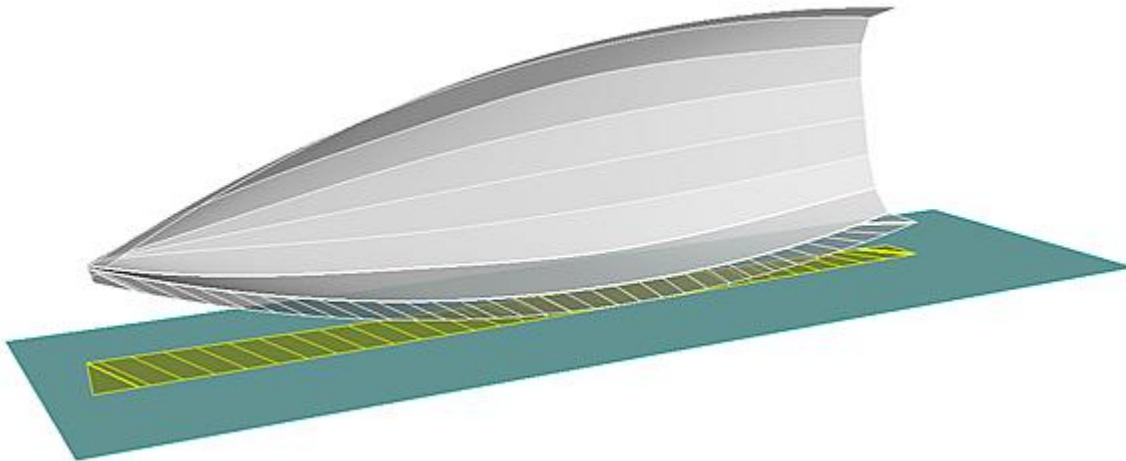


# Developable Surfaces in MultiSurf

## Hull, Deck, Superstructure

by Reinhard Siegel



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## Introduction

Whenever the manufacturing capabilities of the builder and/or economic reasons are taken into account in the construction of a boat the chine hull is selected. Chine form hulls are not commonly looked upon with pleasure and in contrast to round bilged hulls their resistance is increased. However, since the beauty of a boat is mainly defined by her proportions, it should be possible to design chined hulls without neglecting aesthetics. And as far as performance is concerned, especially when using multiple chines, hull forms can be created that are hardly inferior to the round bilge competition. In fact, at high speeds (powerboats) the chined hull is superior to the round bottom version in terms of resistance and sea behavior.

Not every chine hull automatically features developable surfaces. It is a common misconception to believe, that a hull with sections that run straight between sheer, chines and keel is made up of developable surfaces. On the contrary, deck side, chines and profile as curves in space must be shaped to meet very specific conditions, in order to span them with developable fair surfaces.

What might ultimately decide whether to build a hull of the chine form type, there is no reason not to use the advantages of a surface kind, which is employed successfully throughout the technology.

Developable surfaces can be used easily for hull skin, deck and superstructures. They enable even the amateur to save material, cost and time to create a good product.

### Abbreviations used:

cp: control point (support point)

mc: master curve = support curve

cp1, cp2, ...: denotes 1st, 2nd, ... point in the list of supports of a curve. It is not an actual entity name.

mc1, mc2, ...: denotes 1st, 2nd, ... curve in the list of supports of a surface. It is not an actual entity name.

In the following the terms used for point, curve and surface types are those of MultiSurf. This may serve the understanding and traceability.

# 1 What is a developable surface?

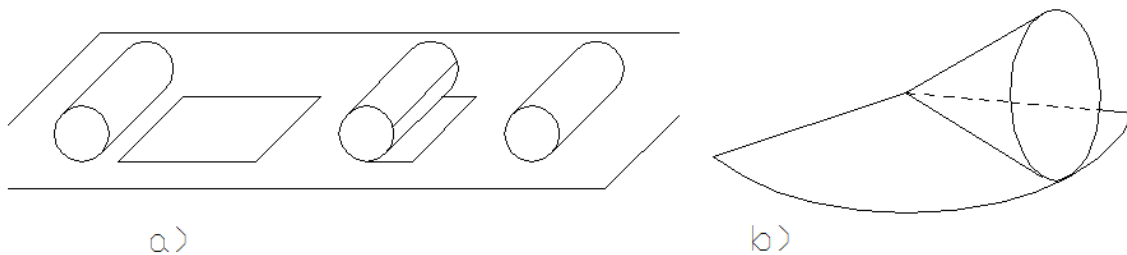
The definition of the developable surface is in words:

*"A curved surface is called developable if it can be rolled out flat onto a plane only by bending, that is without any change of length of the surface fibers."*

Such an expansion is by no means possible for every surface. A portion of the surface of a sphere can only be flattened by force, with extension and cracks occurring at the edges, and wrinkles and compression in the middle. However, a developable surface can be flattened by bending only.

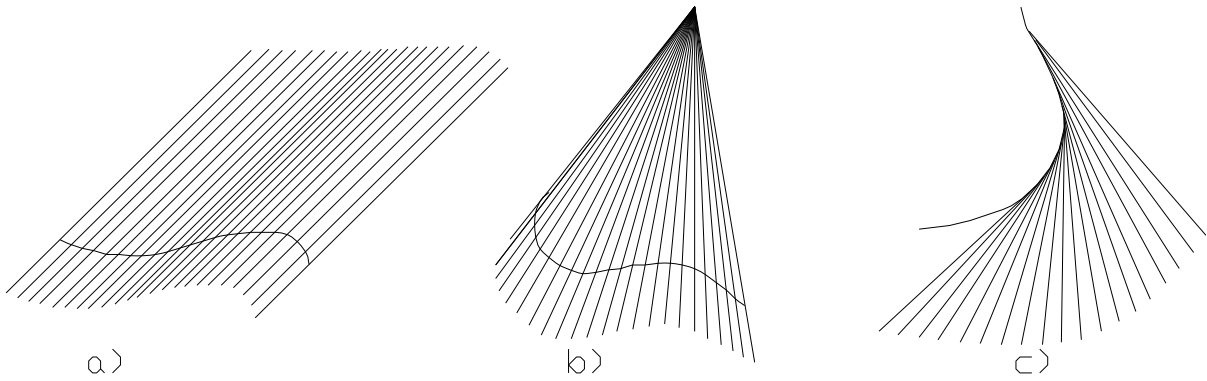
## 1.1 Basic shapes - cylinder, cone, tangent surface

A simple example of a body with a developable surface is a can, geometrically seen a straight circular cylinder (a). If it is cut along the bottom and lid and along the shell, it is easily flattened. It can also be put on a flat surface and completely rolled off. The trace on the support is the development of the can, a rectangle with the height of the can and a side length according to its circumference. Another example is the straight circular cone (b). Rolled onto a flat surface, the expansion of its shell is a segment of a circle.



*Developable surfaces: straight cylinder and straight circular cone*

Slightly more complicated examples of developable surfaces are the general cylindrical and conical surfaces. A cylindrical surface (a) is created when passing through all points of a curve in space (guide) a continuous series of straight lines (generators, rulings) that run parallel to each other. If the generators all intersect at one point, they describe a conical surface (b). That any cylindrical or conical surface can be expanded by bending only can be understood easily, when one imagines to replace it by a polygonal prism or a polygonal pyramid, with all the individual flat surfaces hinged together along the edges. These structures can be unfold onto a plane effortless.

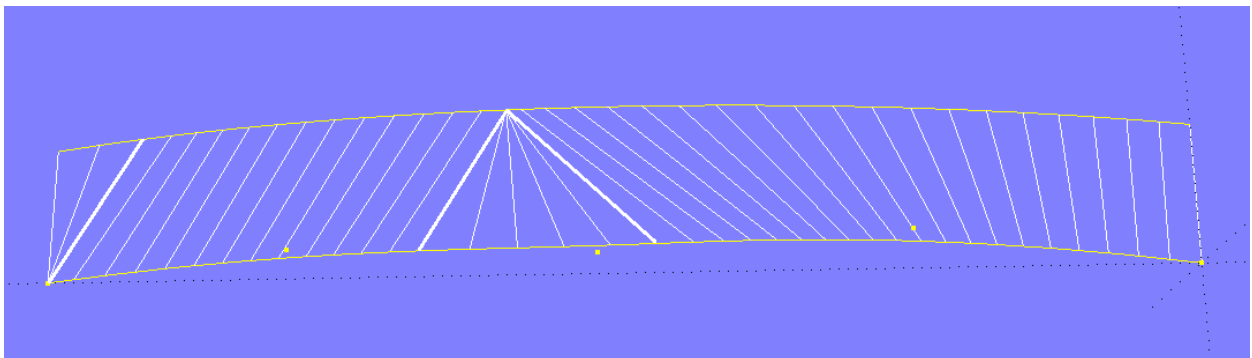


*Basic shapes of developable surfaces: cylindrical surface, conical surface, tangent surface*

Except cylinder and conical surface only the tangent surface (c) can be flattened just by bending. The tangent surface is created by the continuous sequence of tangents to a curve in space.

## 1.2 The general developable surface - combination of cylinder, cone and tangent surface

The general developable surface consists of pieces of cylinders, cones and tangent surfaces attached along common generators (rulings).

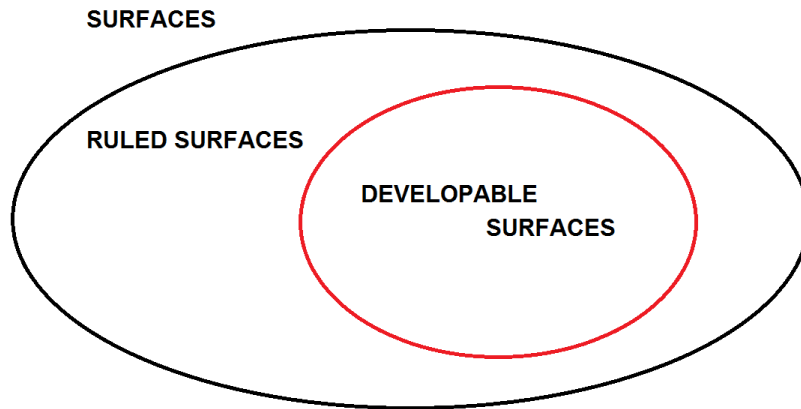


*General developable surface - combination of cylinder, cone and tangent surface*

## 1.3 Ruled surface

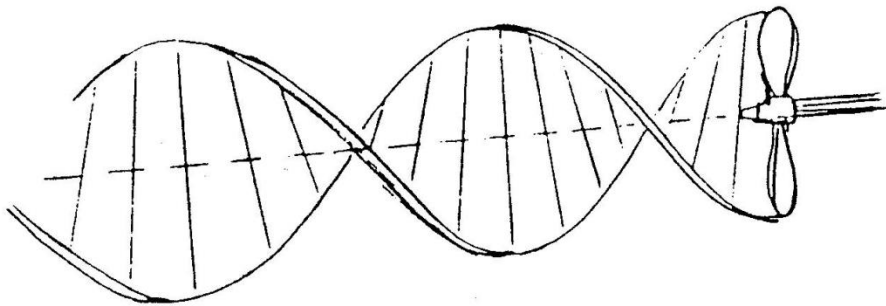
Developable surfaces are often confused with ruled surfaces. The continuous movement of a line in space covers a ruled surface. The individual positions of the line are the generators of the surface.

The distinction between developable surfaces and ruled surfaces is important because all developable surfaces are ruled surfaces. But not all ruled surfaces are developable.



*Developable surfaces are a subset of the ruled surfaces.*

An example of a ruled surface, that can not be expanded by bending alone, is the helical surface, which is swept out by the straight axis of the two blades of a propeller as it turns and moves forward. It is a ruled surface, the successive positions of the blade axis are the generators. But it can not be flattened. A metal strip can not be shaped like this without stretching.



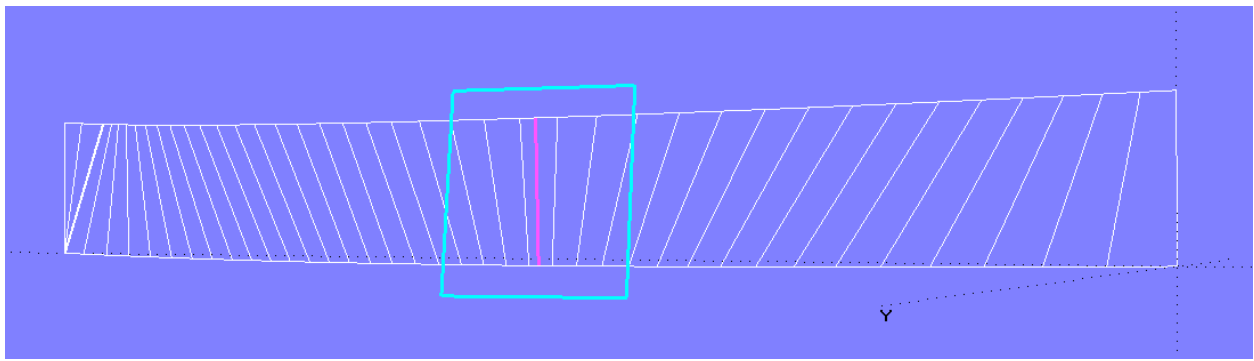
*Helical surface - example of a ruled surface that can not be expanded by bending alone*

Ruled surfaces and developable surfaces is in common that they are created by straight generators. The crucial additional requirement, that a ruled surface is also a developable surface, is this:

*All along a generator, the surface normal must have the same direction.*

Or more clearly expressed:

*A developable surface is touched by a plane always along a generator.*

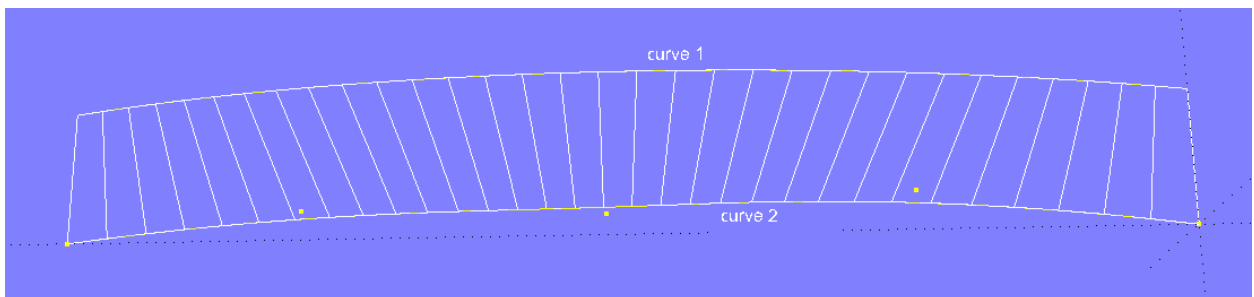


*A plane always touches a developable surface all along a generator (ruling).*

The can rests completely along a shell line on a table, as well as the cone. With the helical surface, the surface normal runs more and more perpendicular to the propeller shaft, the more it is approached to. A sphere touches a plane in a single point. Which makes it clear why a boat with developable outer skin can not be round bilged. If you were to place a round bilged hull on a flat surface, it would touch at one or more single points, but never along a straight line.

### **Ruled surface in MultiSurf**

The *Ruled Surface* entity in MultiSurf is created from two curves (support curves) by connecting points on each parent curve having equal t-parameter values with Lines (rulings). A Ruled Surface interpolates both support curves, leading and trailing edges are straight.



*Ruled Surface*

In special cases, a Ruled Surface is developable. For example, is curve 2 a translational copy of curve 1, then the Ruled Surface is a general cylinder. Is curve 1 or curve 2 a point, then the Ruled Surface is a general cone with this point as apex. Cylinders and cones are always developable.

### **Translational surface with straight generator**

The *Translation Surface* entity in MultiSurf is formed by sliding a generating curve along a guiding curve without twisting, that is, all generators are parallel to each other. If the generating curve is straight, the Translation Surface is a cylindrical surface. Because cylindrical surfaces are always developable, a Translation Surface with a Line entity as generator is a developable surface.

Developable surfaces for deck, cabin side, cabin front etc. can easily be constructed with Translation Surfaces.

## 2 The advantages of developable surfaces

Developable surfaces can be rolled out flat onto a plane only by bending. Or "rolled up" from flat material into a spatial shape. A change in length of the surface fibers, i.e. contraction or expansion, does not occur. If the shell of hull, deck and superstructure of a boat are made from developable surfaces, the following advantages arise:

- Use of plate material. Hull, deck, superstructures can be completely made by flat plates (steel, aluminum, plywood, GRP sandwich). Plate material is available in bigger size, what results in fewer seams.
- No special manufacturing capabilities required. Plates are easier bended than stretched or compressed, so even large metal hulls can be built by hand tools, while otherwise the forming process from flat stock to compound-curved shell plating requires machine tools (roller planishing, die pressing etc.. Therefore very suitable for amateur boat building.
- No fitting work. The expanded outline of the hull plating can be determined accurately. Exact fitting bulkheads, frames, stringers, etc. can be prefabricated.
- The effort for the foundation structure is reduced to a minimum. A few negative frame molds are sufficient to hold the individual plates in the correct position to each other. By stitching the plate edges the hull shape results automatically.
- Short construction time. Compared to an equal sized round bilge hull an average time saving for the shell construction of 50% arises.
- Smooth shell plating. Hull plates can be joined together first, then internal structure like frames, bulkheads, etc. added. Especially with metal hulls this reduces the tendency for bumps to occur.

All advantages summarized: the construction of boats with developable surfaces is simple and at good value.

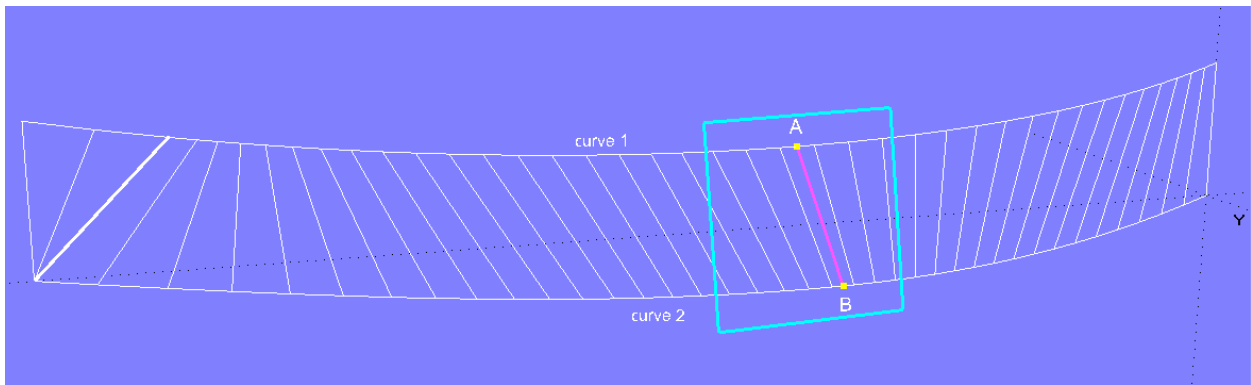
## 3 Developable surfaces with MultiSurf

### 3.1 Developable Surface

The surface entity *Developable Surface* in MultiSurf has two curves in space as parents (support curves). It is created as follows.

#### Determination of generators (rulings)

First, a point A is selected on curve 1. Then a point B on curve 2 is searched for such, that a plane simultaneously touches both curves in these points. The connecting line AB is then a generator or ruling of the Developable Surface. Next another point A is selected on curve 1 and again the corresponding point B on curve 2 is determined. One can visualize this procedure in such a way that a plane is put against both curves and rolled on. The generators are at the same time the bending lines, along which the surface is bent when expanded, or on the contrary, "rolled up", when build from a flat surface.



Contact plane - generation of the rulings of the Developable Surface

The procedure described above is continued until rulings were found between start and end of both support curves. If the end is reached on one of the curves, but not yet on the other one, the remaining rulings run radiating. In the example above this is the case at the left end of curve 2.

If rulings (generators) run parallel to each other, the corresponding surface portion is cylindrical; if fanned out, it is part of a tangent surface; and if rulings share the same end point, it is part of a conical surface.

## Breaklines

If a ruling in a Developable Surface is displayed on the screen in bold fashion, this marks a so-called breakline. A breakline is a curve with  $u = \text{constant}$  or  $v = \text{constant}$  in an area indicating where a discontinuity of slope, parameter speed or curvature occurs. For a Developable Surface a breakline features a spot where rulings have the same endpoint, so radiate.

Breaklines in a Developable Surface are an indication to take a closer look. It can but it does not have to be a problem.

On the one hand, intersections made in the area of radiating rulings may be unfair. In the following more to this topic.

On the other hand, breaklines can cause an error message for children surfaces, which depend on the calculation of geometrical properties of the Developable Surface, for example Rolling Ball Fillet, Sweep Surface or Tangent Boundary Surface. Geometrical quantities like the direction of the tangent at the surface edge, where rulings have the same endpoint, can not be calculated (zero distance between points).

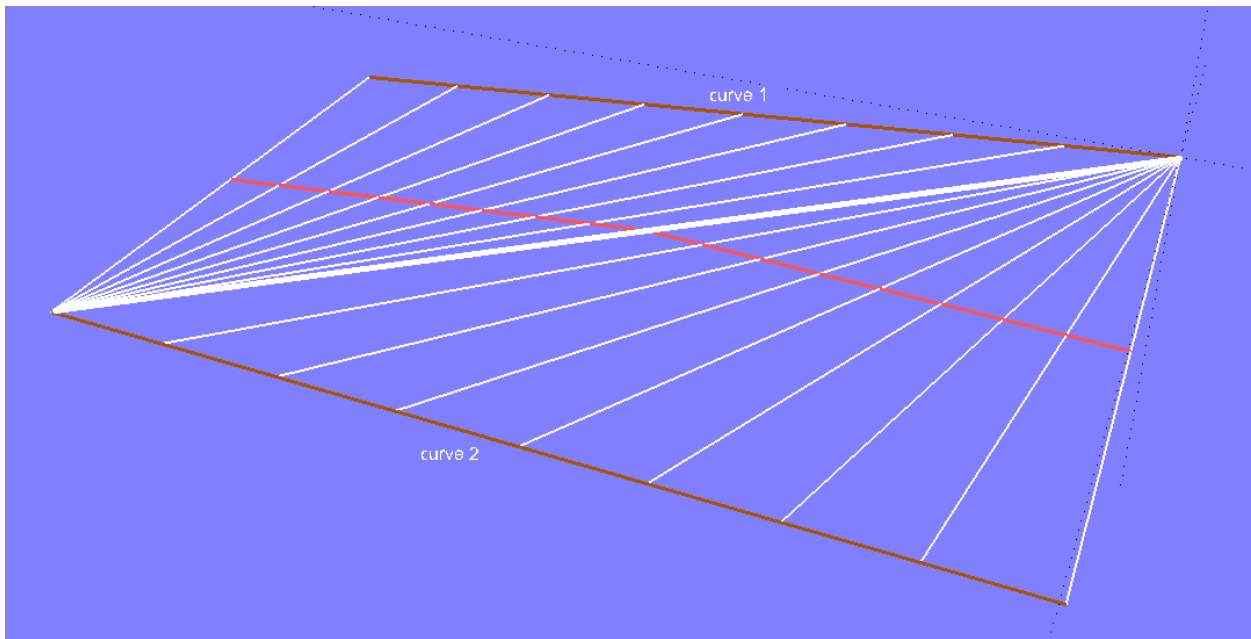
## The arrangement of rulings and its effect on fairness

A Developable Surface is not automatically a smooth surface. Take a sheet of paper and fold it together arbitrarily. It is and remains a developable surface.

Even if both support curves run in a harmonious fashion, irregularities in surface fairness can occur. The arrangement of the rulings gives clear indications in this respect.

Model *2triangles\_a.ms2* holds a Developable Surface spanned between two skewed Lines (curve 1, curve 2). There is a clear break in the longitudinal section. The run of the rulings and the breakline shows that the surface consists of two triangular flat portions.





*Model 2triangles\_a.ms2 – Developable Surface spanned between two skewed Lines*

While point A progresses along curve 1, point B stagnates on curve 2. When point A has reached the curve end, point B moves along curve 2, while point A now in turn stagnates.

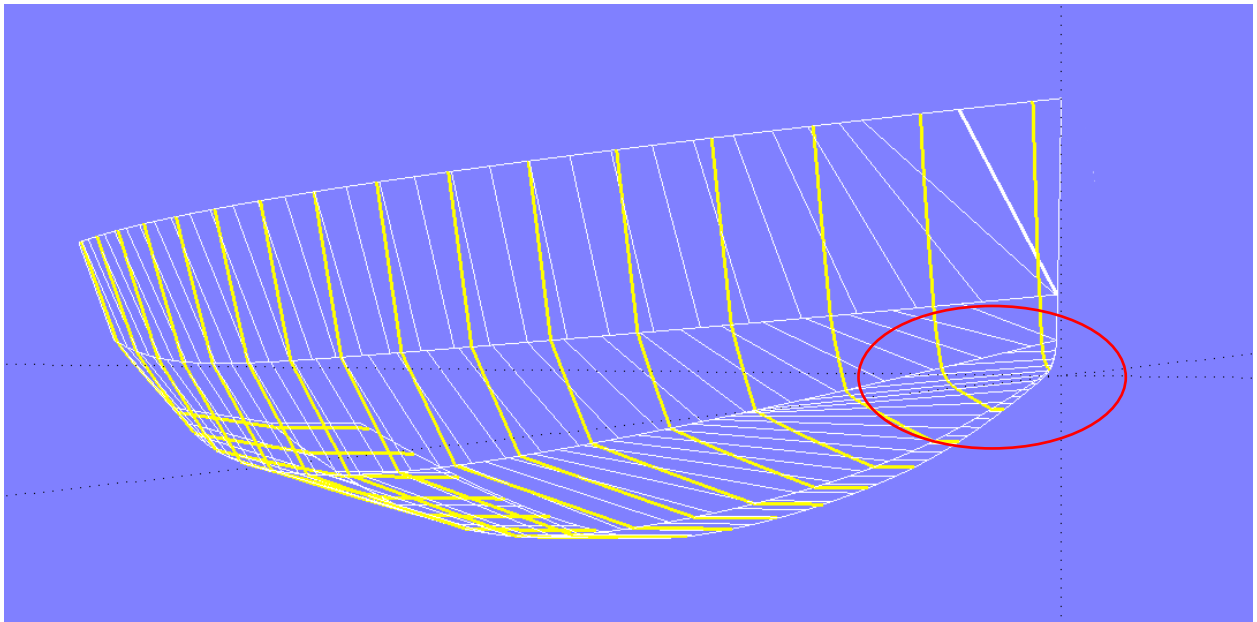
Whenever ruling endpoints do not progress, but stagnate, or change the moving direction, adverse effects on the shape of the surface can arise. If the rulings run regularly, so do waterlines, sections, etc.

The ruling arrangement depends only on the shape of the two supporting curves relative to each other. If the surface is not smooth, the shape of one or both curves must be modified.

For the Developable Surface the type of its parent curves is not important. For example, for the bottom surface of a hull one can use a C-spline Curve for the chine, and a B-spline Curve for the keel profile inclusive the stem forefoot.

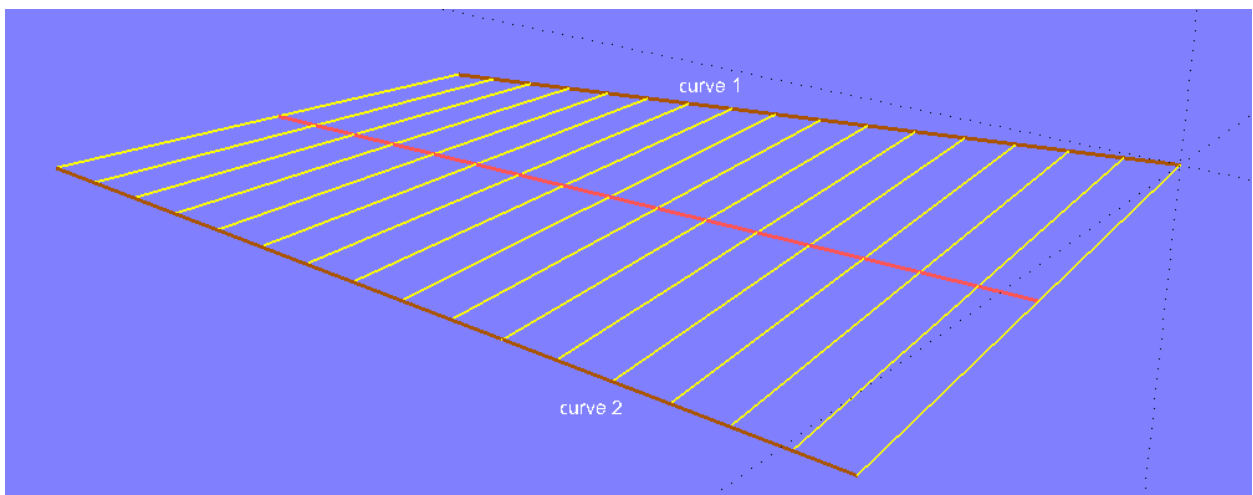
In contrast to surface types such as the Lofted Surfaces, the parameter distribution and the number of control points (cps) of the support curves have no influence on the ruling arrangement. Because of the way, a Developable Surface is created (roll off of a plane), the shape of the supports is crucial.

The curvature of the surface is crosswise to the rulings (bending lines, rolling lines). When rulings run in transverse direction of a hull, sections are straight. When running inclined, sections are convex. The more oblique the rulings, the more convex the sections. The shape of sections, buttocks, waterlines of a Developable Surface can only be modified by the arrangement of the rulings, hence via its support curves and their run relative to each other.



*Severely curved foreship section due to sloping rulings*

If in model *2triangles\_a.ms2* the Developable Surface is replaced by a Ruled Surface, the picture will change completely. See model *2triangles\_b.ms2*. There is no breakline.



*Model 2triangles-b.ms2 - Ruled Surface between two skewed Lines*

Both surface types is in common the straight generators, but the method, how these are determined, is quite different. That is why it is not a good idea, to replace a Developable Surface by a Ruled Surface in order to achieve a regular arrangement of rulings. The developability will be lost.

It should always be kept in mind that developability means a restriction in design. The Developable Surface, set up between its two support curves, has its own laws to which the designer must adapt with his form wishes.

## 3.2 Fairing of Developable Surfaces

It has already been mentioned, that a Developable Surface is not automatically a smooth surface. As well, that the arrangement of the rulings depends only on how its two support curves runs relatively to each other.

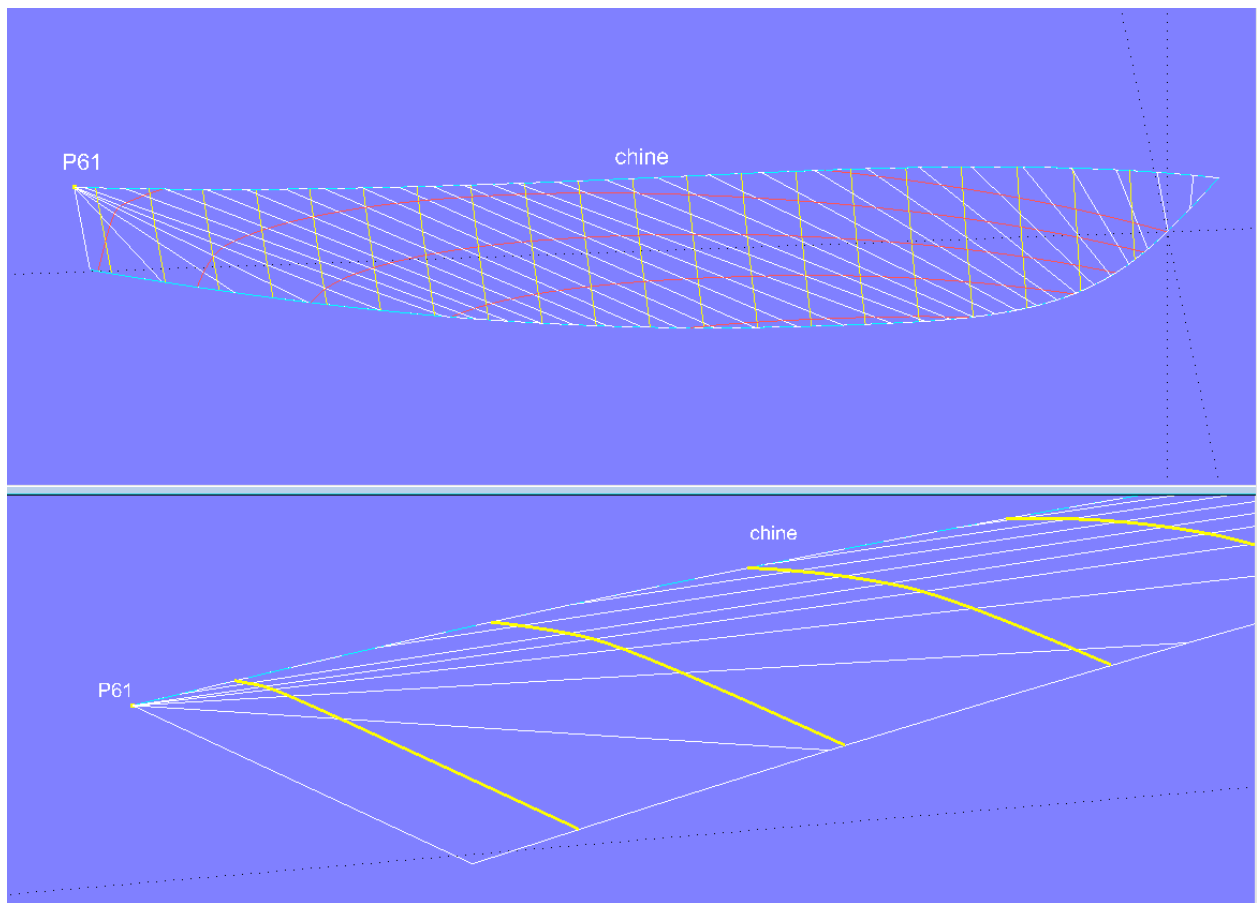
### General information

- One must try to harmonize the run of the rulings. For example, if in the middle of a Developable Surface the rulings are more or less perpendicular, then tilt aft and finally become vertical again towards the end, this will mean for the shape of the sections: no curvature in the middle, then increasing, then decreasing curvature. In a round bilged hull such a sequence of sections would not be accepted. By changing the support curves one should try to get sloping rulings until the aft edge of the surface.
- One must try out on which of the two curves the rulings are most likely to react in the desired way.
- Whenever a sequence of sections starts twisting increasingly, they will show severe curvature, caused by the obliquely running rulings. The only remedy is to reduce the twist of the sections.
- A stem with a strongly curved forefoot poses more problems on harmonious sections than a gradual transition between fairbody profile and stem.
- Hull plates, narrow in transverse direction but with strong curvature must be pre-bent by machine if built from metal. Sheets of plywood or GRP sandwich must be partially cut aligned to the rulings so that they are less rigid.

In the following methods are shown how the shape of Developable Surfaces can be influenced within limits. As an example, the bottom surface of a powerboat is chosen, spanned between the chine curve (chine) and the bottom contour (keel). Because these curves can show little curvature in the aftship, the arrangement of the rulings (generators, rolling lines, bending lines) can be irregular here.

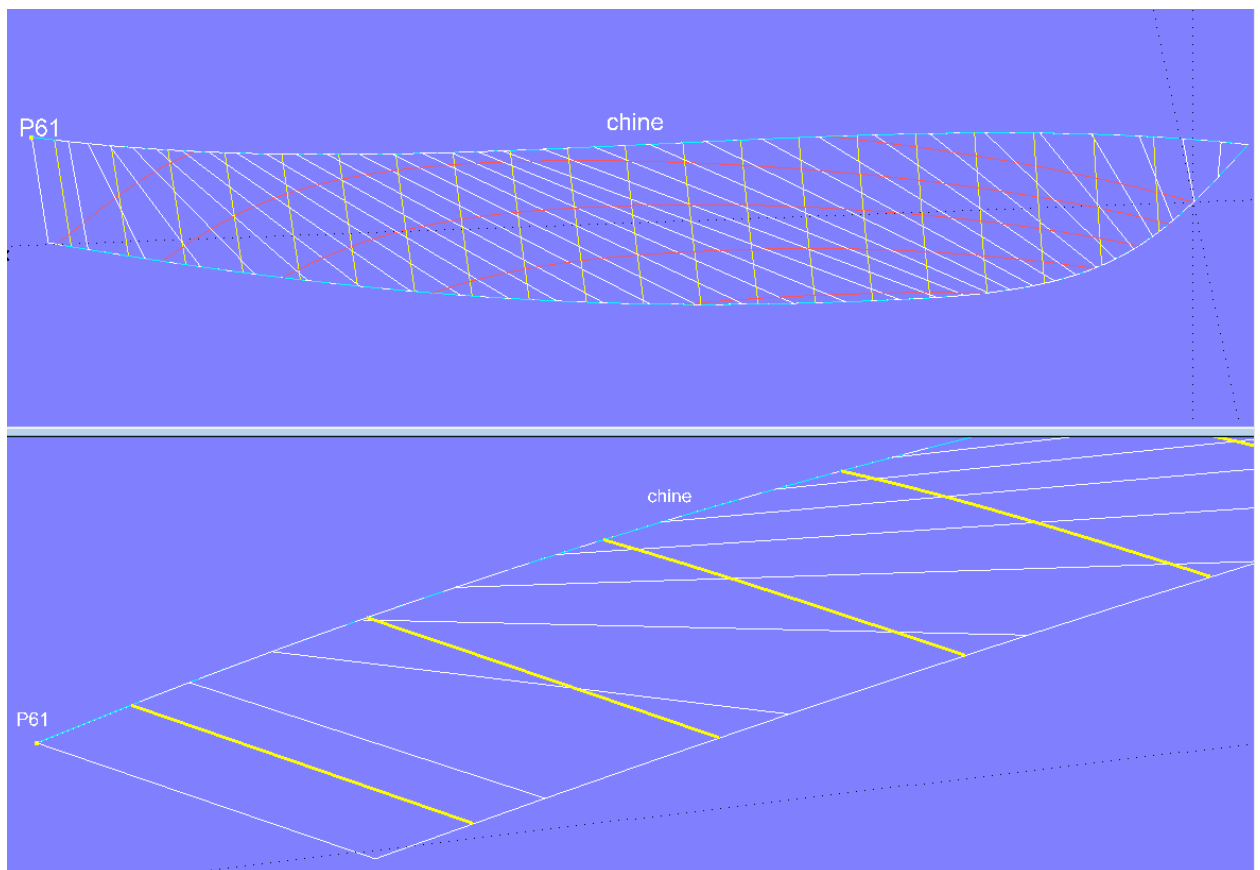
### Radiating rulings

When both supporting curves end at the same X-position, rulings tend to be radial at the end of one curve. In the model *bottom\_panel-1.ms2* it can be seen that those rulings cause an inharmonic curvature of the aft sections.



*Model bottom\_panel-1.ms2 - bottom panel of a powerboat hull. The rulings aft radiate to the end of curve [chine](#).*

If point [P61](#) is raised, the rulings run parallel to the trailing edge and the sections become more evenly.



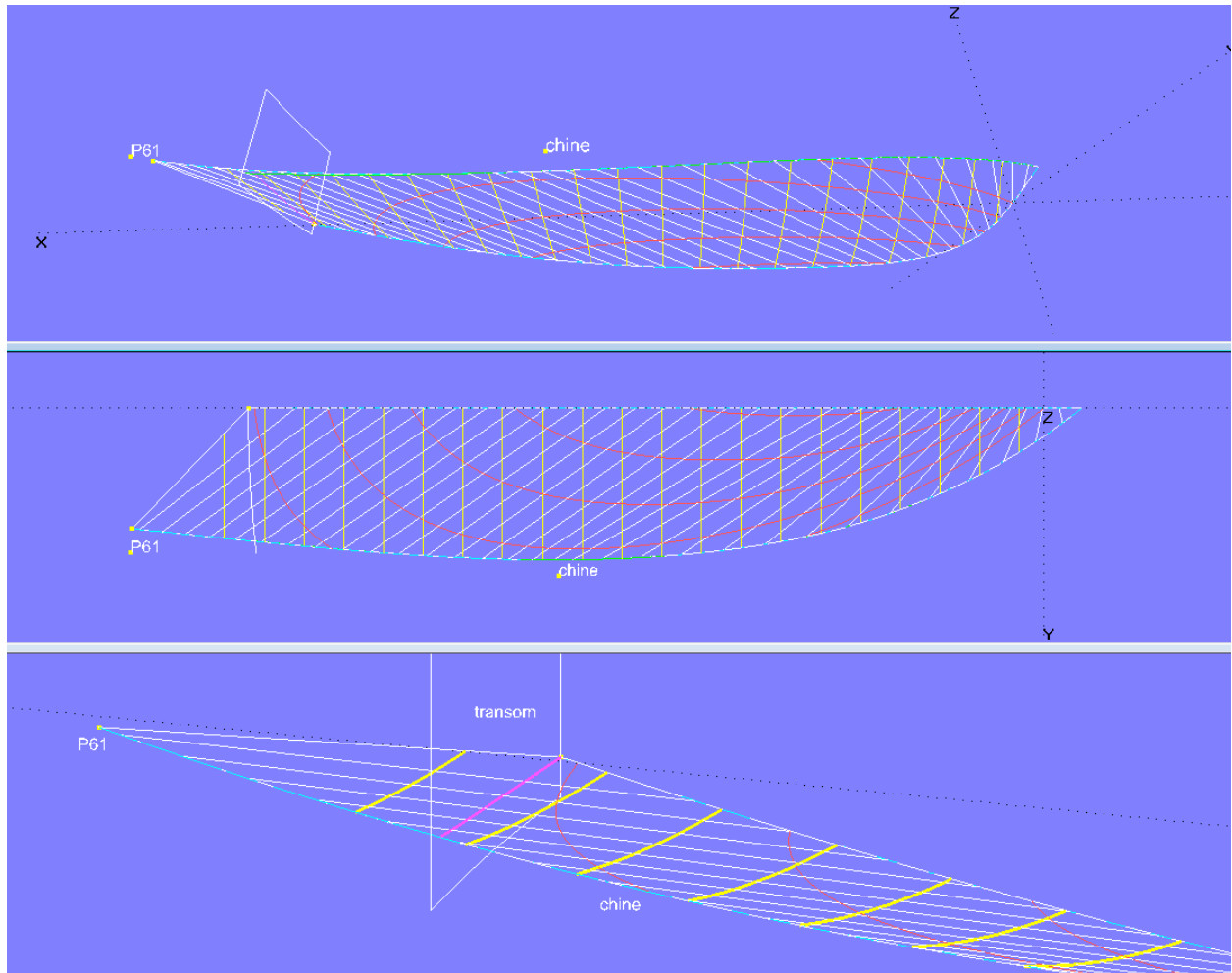
Model *bottom\_panel-2.ms2* - raising point *P61* increases the curvature of *chine*, what has a favorable effect on the run of the rulings and thus on the shape of the sections.

## Curved trailing edge

If in the aftship a convex section shape is strived for, the rulings must be prevented to radiate. There are several methods to achieve this.

### Method 1 - longer support curve

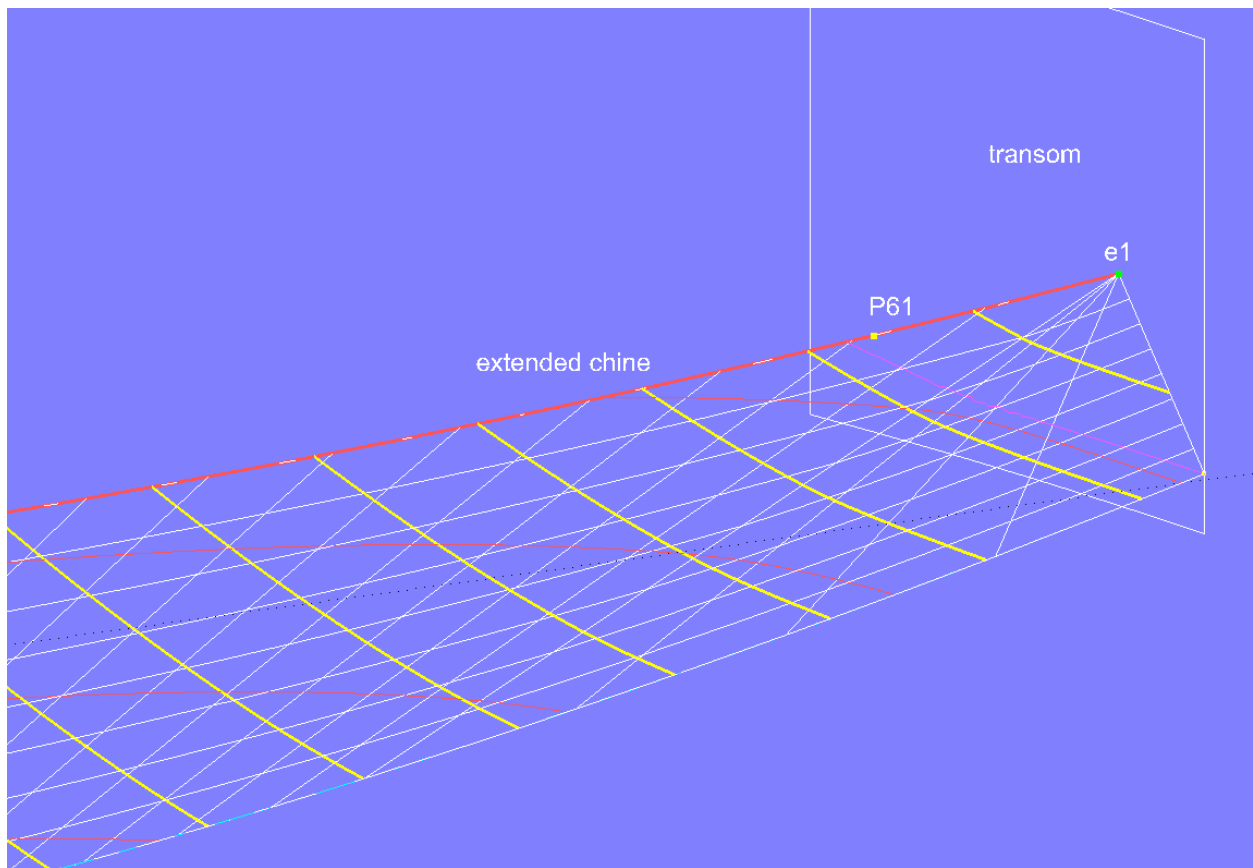
One possibility is shown in model *bottom\_panel-3.ms2*. The curve *chine* does not end at the stern, but extends somewhat beyond.



Model *bottom\_panel-3.ms2* - the curve *chine* ends aft of the transom. As a result, the rulings fan out.

### Method 2 - SubCurve

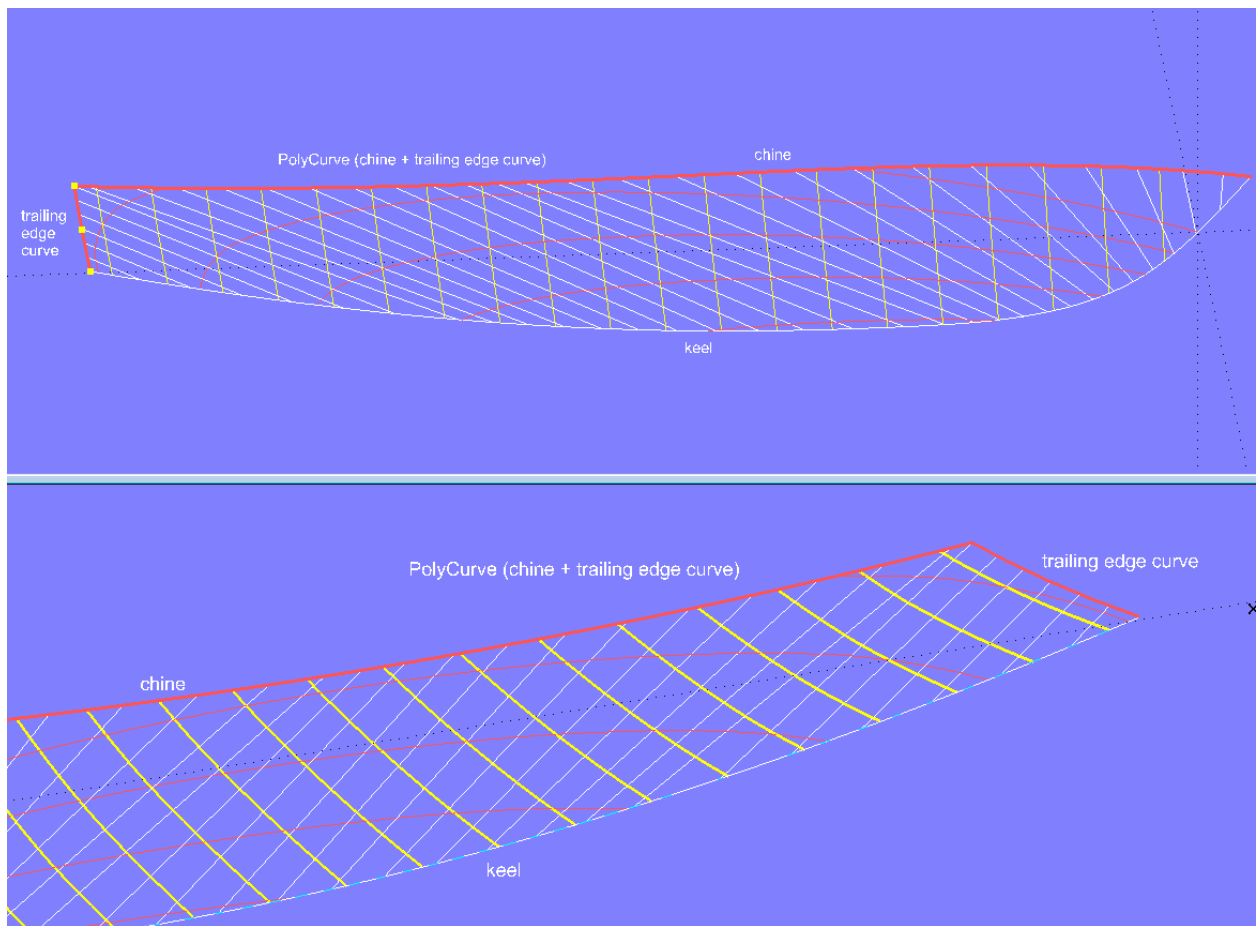
Another possibility is demonstrated in model *bottom\_panel-4.ms2*. Both parent curves end at the stern, but curve *chine* is extended by a SubCurve entity. First, two beads are created, one bead at the start and one bead (*e1*) at the end of *chine*, then a SubCurve (*extended\_chine*). Because in MultiSurf curves are also defined beyond the nominal t-parameter range 0 – 1, an extension of the curve is obtained, if *e1* is shifted beyond the curve end ( $t > 1$ ). This method is often sufficient to give the rulings the desired change.



*Model bottom\_panel-4.ms2 - extension of the chine curve by a SubCurve entity*

### **Method 3 - composite support curve**

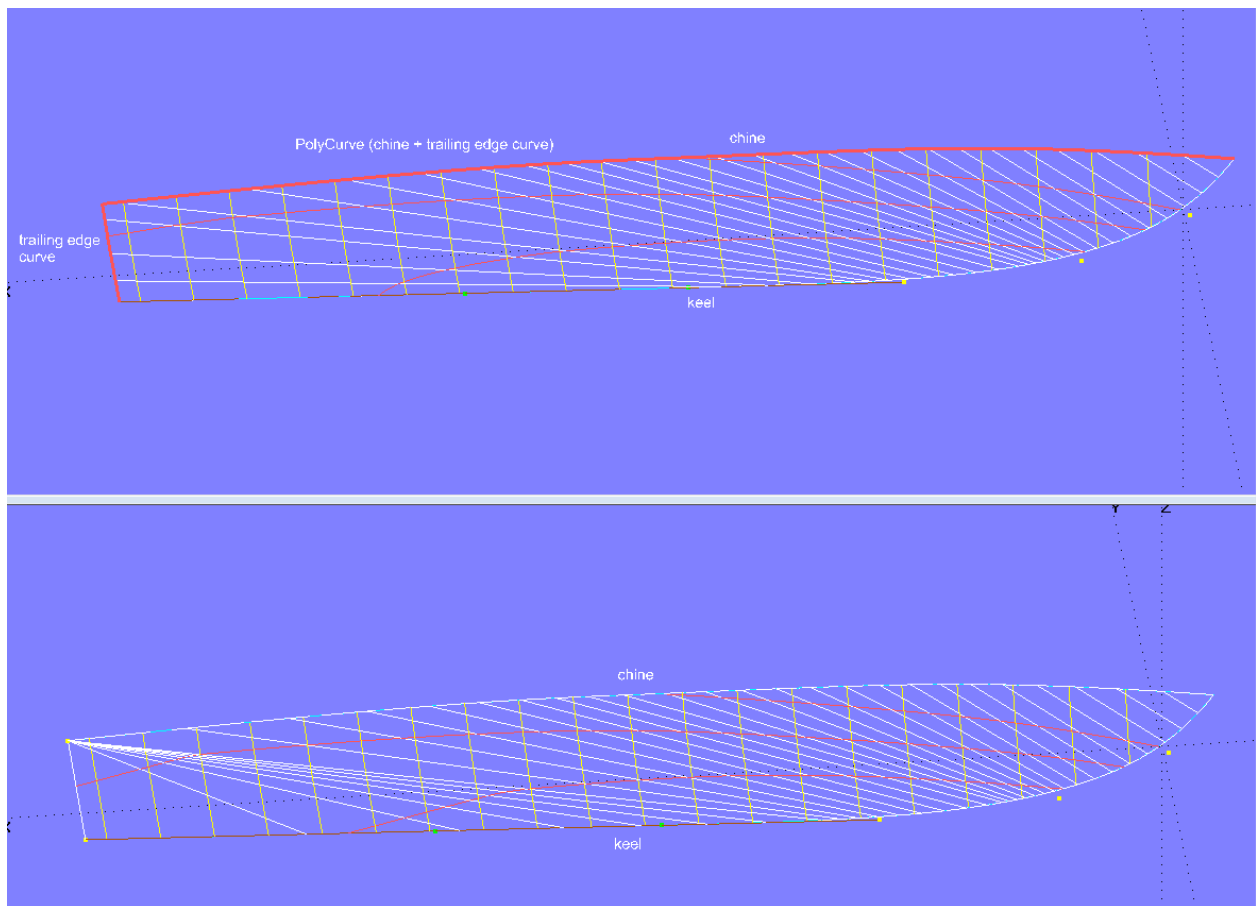
It is not required that the support curves of a developable hull surface run in longitudinal direction only. As shown in model *bottom\_panel\_5.ms2*, they can be combined piecewise in order to include the trailing edge of the surface. In this way, the curvature of sections can be controlled in this area.



Model *bottom\_panel-5.ms2* - support curve as PolyCurve (composed of *chine* and trailing edge curve)

### Partly straight run of a support curve

In case a support curve of the Developable Surface becomes straight, the unrolling plane will touch completely along the straight curve portion, and not just in a single point. This causes radially arranged rulings, resulting in unfairness. Model *bottom\_panel-6.ms2* shows an example. The bottom contour is a B-spline Curve, degree-3; its cps 4, 5, 6 and 7 are aligned, from cp5 on the bottom profile (*keel*) runs straight.



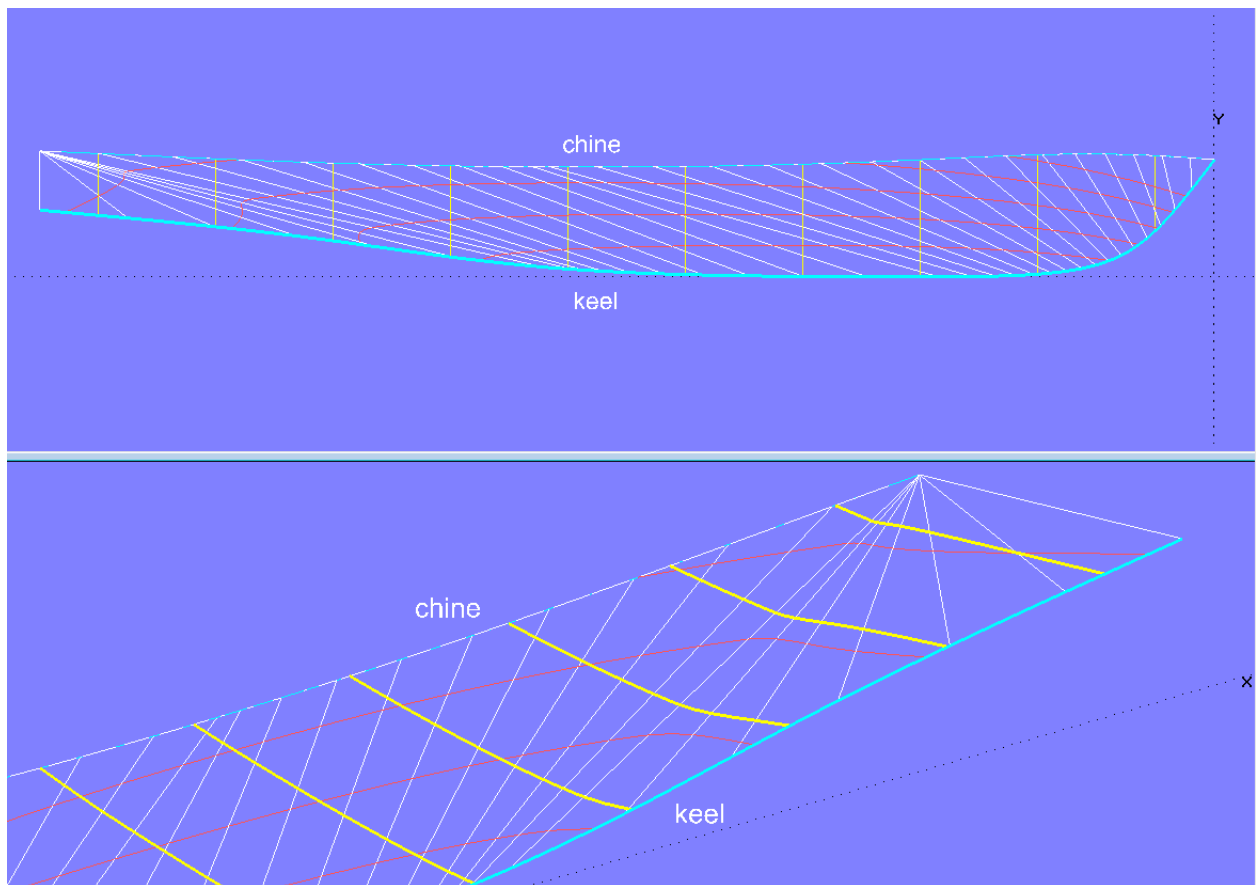
*Model bottom\_panel-6.ms2 - the bottom profile (*keel*) is straight aft. Combining chine and trailing edge makes the ruling arrangement more regular.*

Combining chine and trailing edge makes the ruling arrangement more regular. And thus surface intersections (sections, waterlines, etc.) are more fair.

### Support curve with inflection point

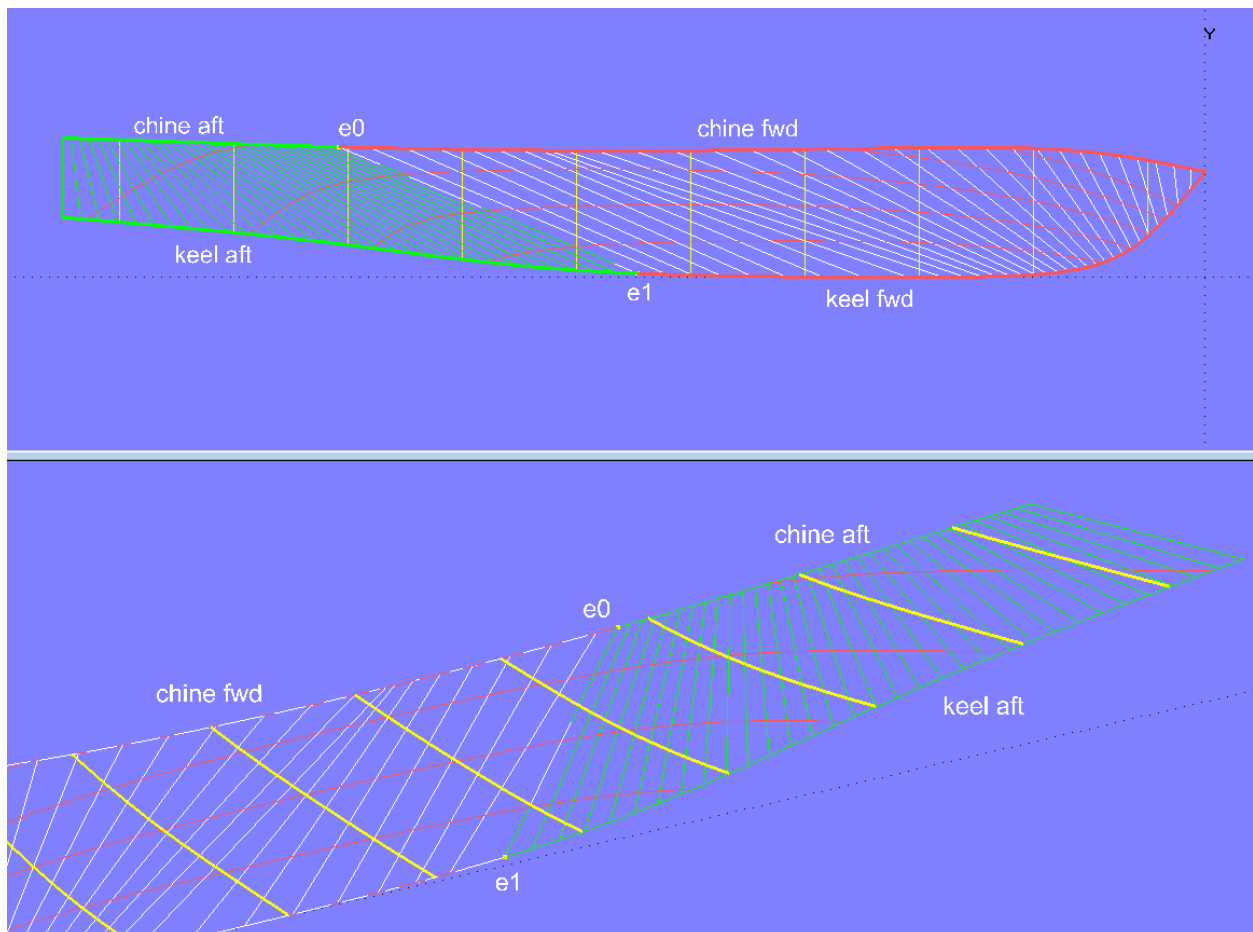
Should a support curve of a Developable Surface shows for design reasons an inflection point, for example the bottom profile of a powerboat, irregularities in the run of the rulings will arise – and as a result unfair waterlines, sections, buttocks. The model *bottom\_panel-7a.ms2* is an example for this.





*Model bottom\_panel-7a.ms2 – the inflection point of curve **keel** causes a non-uniform run of the rulings – sections become unfair.*

In such a case the only remedy is to split the bottom surface into two patches. The front surface in model *bottom\_panel-7b.ms2* is developable (Developable Surface), the rear surface is a Ruled Surface. Often it must be only slightly forced into place during construction.



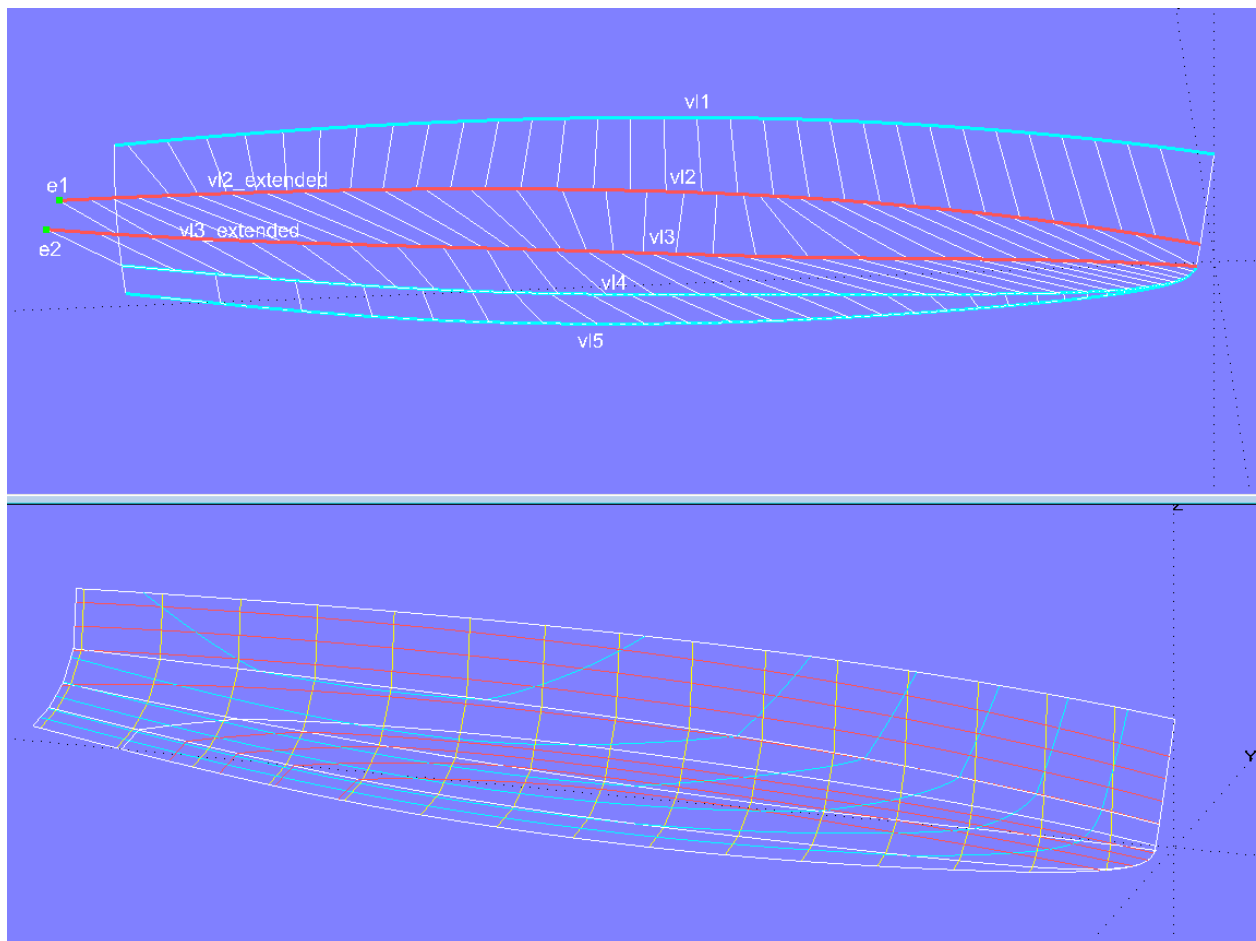
Model *bottom\_panel\_7b.ms2* – bottom divided into two parts. Foreship is developable (Developable Surface), aftship is a Ruled Surface (requires some plastic deformation).

## 4 Hull design with developable surfaces

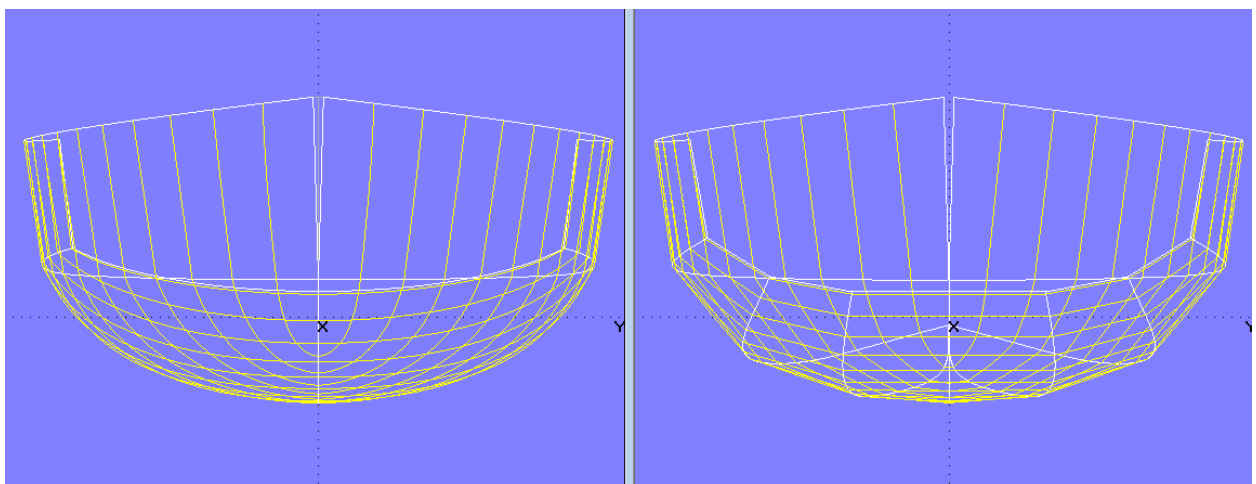
A boat with developable hull surfaces can only show a hull with one or more full length chines. Flat bottom boats, skiffs, scharpies are examples of chine hulls for sailing yachts, the V-shape is widespread with motorboats. It will be shown in the following, how typical hull shapes can be designed with developable surfaces.

### 4.1 Modern multichine hull

Model *sy15\_double\_chine.ms2* is the chine hull version of the model *sy15\_full\_chine.ms2* described in the tutorial "Round bilge hull with full length chine". The hull area below the topside surface consists of 3 Developable Surfaces. The lower support curve of the bilge surface *chine\_strake\_2* is a B-spline Curve with 8 cps; it includes the rounding of the forefoot. In the bow area, the sections cutting this surface, are severely curved, due to the sloping rulings. The surface is bent across the rulings, and since these run obliquely to the direction of the sections, these are necessarily convex.



Model sy15\_double\_chine.ms2 - modern multichine hull. The upper support curves of the two bilge surfaces are each extended aft by SubCurves to achieve a uniform arrangement of rulings.

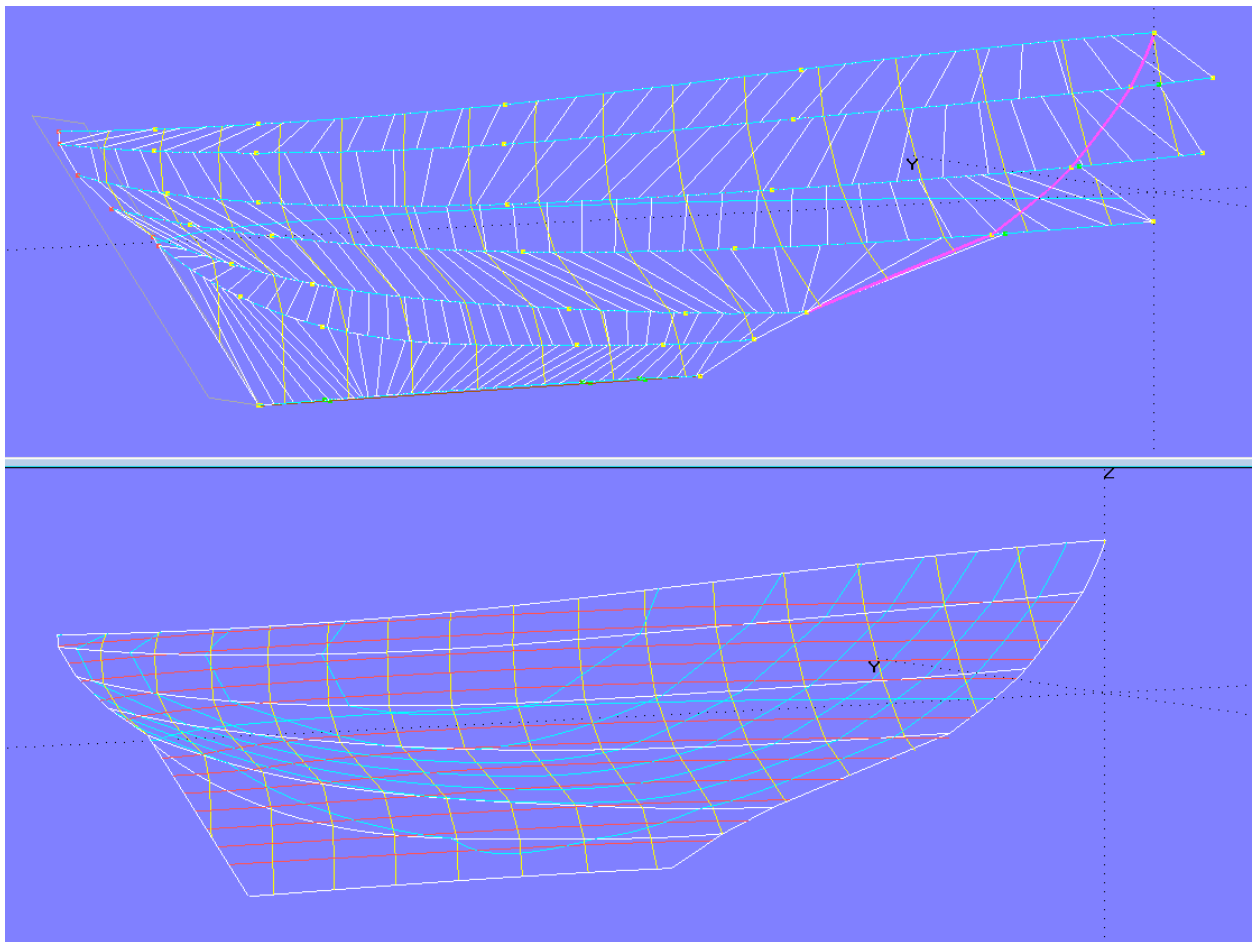


Body plan comparison - basic model sy15\_full\_chine.ms2 versus multichine version sy15\_double\_chine.ms2

## 4.2 Classic multichine hull

Model *multi\_chine\_classic.ms2* shows a longkeel chine hull. At the stem the upper 4 panels extend beyond the midship plane to get a curved stem profile. The stem shape is therefore determined indirectly.

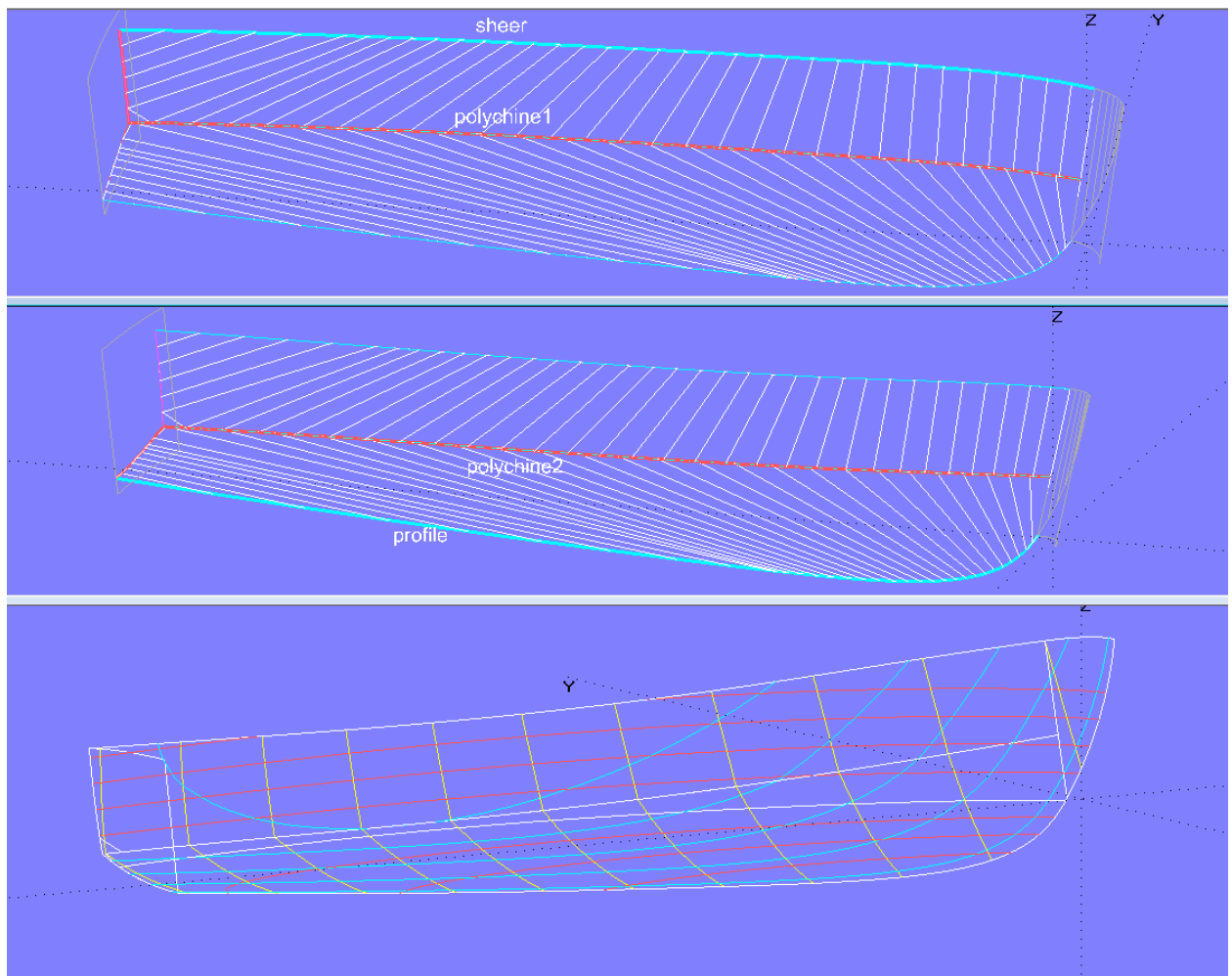
The end control points of the support curves are magnets on the transom surface.



Model *multi\_chine\_classic.ms2* - longkeel multichine hull

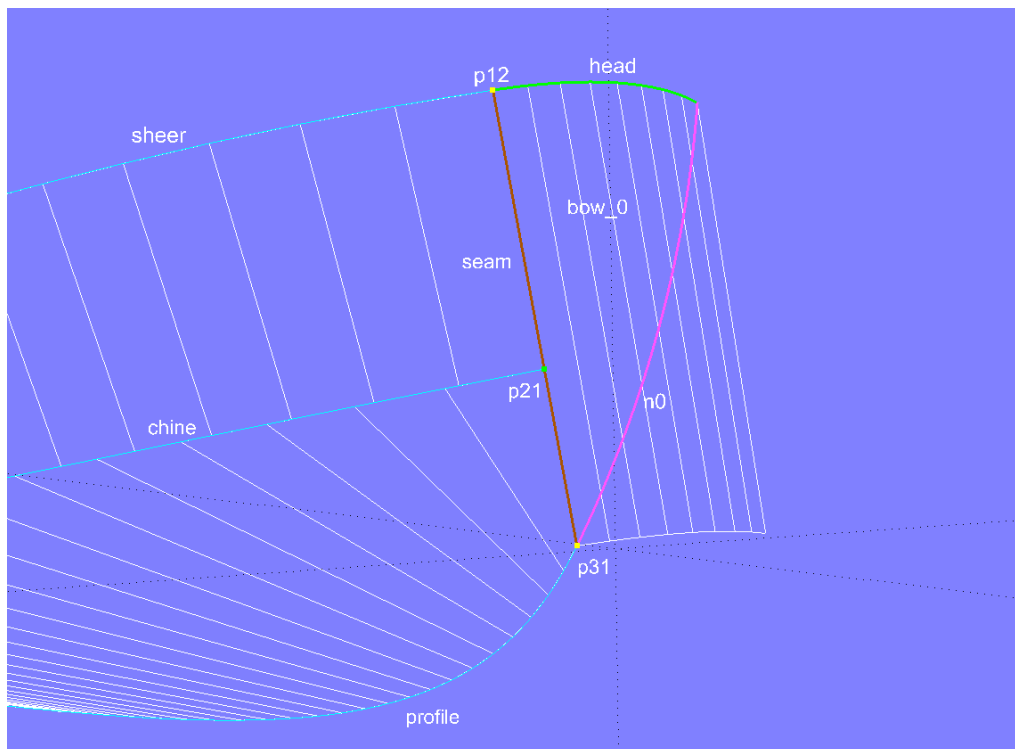
### 4.3 Powerboat

Model *cruiser.ms2* features the hull of a powerboat (derived from a MultiSurf model from AeroHydro Inc.). Topside, bottom, bowround and transom are developable surfaces. For the lower support curve of the hull side (**topside**), the chine curve (**chine**) and the trailing edge (**n1**) are combined by the PolyCurve **pol-ychine1**. The same applies to the bottom surface; here **chine** and trailing edge **n2** are the components of PolyCurve **polychine2**.



*Model cruiser.ms2 - support curves for topside and bottom*

The trailing edges of side and bottom are B-spline Snakes ([n1](#), [n2](#)) on the transom base surface ([transom\\_0](#)), so there is no need to trim off any parts.



Model cruiser.ms2 - construction of the bowround

The base surface of the bowround is the Translation Surface **bow\_0**, created by Line **seam** and the B-spline Curve **head**, the rounding of the upper edge of the hull (C-spline Curve **sheer**). Line **seam** connects the first cp (**p11**) of the hull upper edge and the first cp (**p31**) of the bottom profile (B-spline Curve **profile**). The first cp of the chine curve (**chine**) is a bead (**p21**) on Line **seam**, thus topside and bottom start along this line as well as tangential to the Translation Surface **bow\_0**.

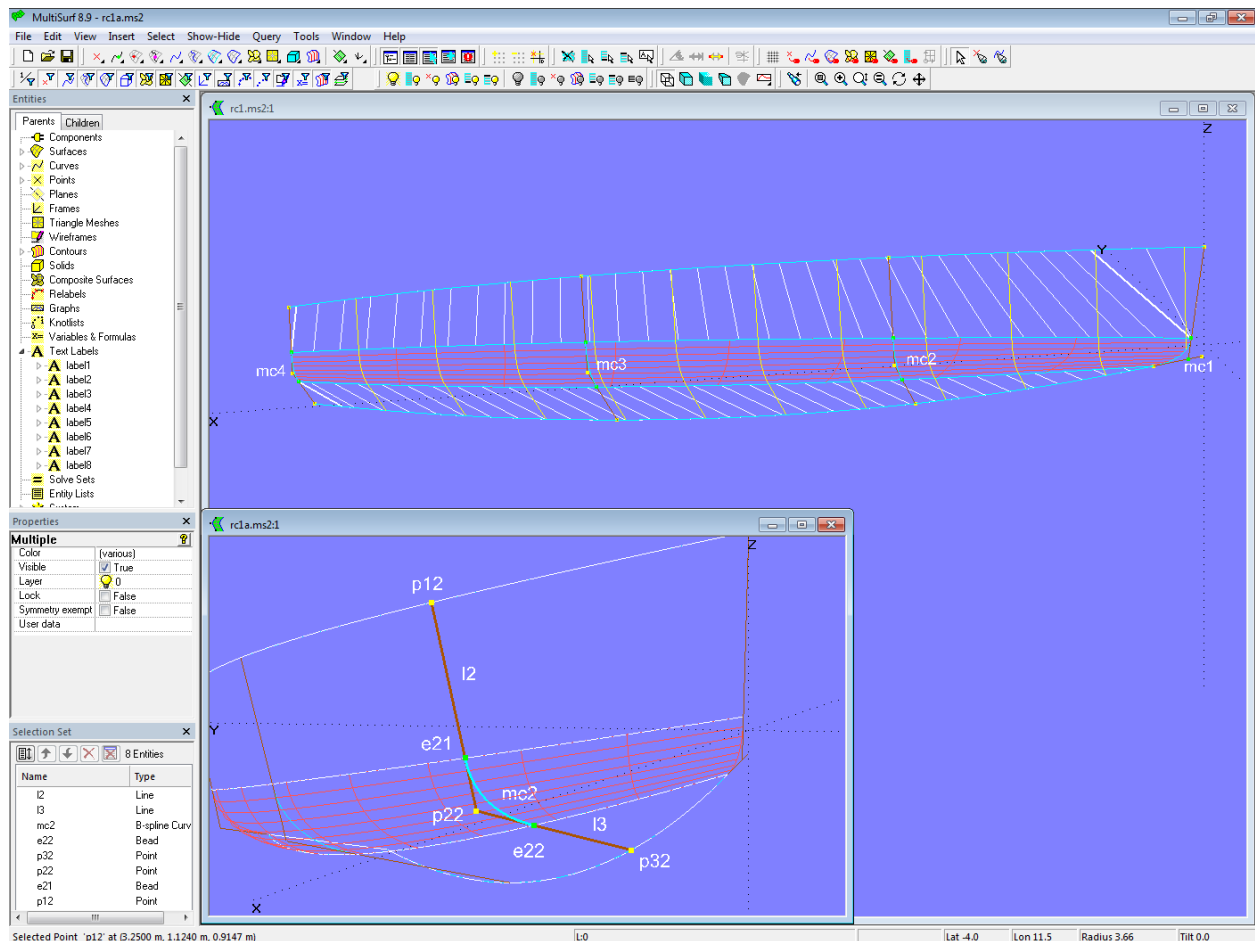
## 5 Special hull shapes

### 5.1 "Radius chine" hull

If one wishes to exploit the manufacturing advantages of developable surfaces but wants to avoid disadvantages by increased resistance, the "radius chine" hull form offers its service. First a single chine hull with developable surfaces for topside and bottom is designed. Then the bilge area is rounded off.

#### Method 1

In model *radius\_chine-1.ms2* the bilge rounding is a C-spline Lofted Surface with 4 B-spline mcs. Because a B-spline Curve begins tangentially to the line between its 1st and 2nd cp and ends tangentially to the line between its last but one and final cp, the smooth joint to side and bottom is built in firmly, if for cp1 and cp3 a bead on the line between sheer and chine respectively between chine and bottom is used. Example: the cps for **mc2** are Bead **e21**, Point **p22** and Bead **e22**. Bead **e21** is on Line **l2** between **p21** and **p22**, so **mc2** starts tangent to this one. Bead **e22** is on Line **l3** between **p22** and **p32**, so **mc2** ends tangent to **l3**.

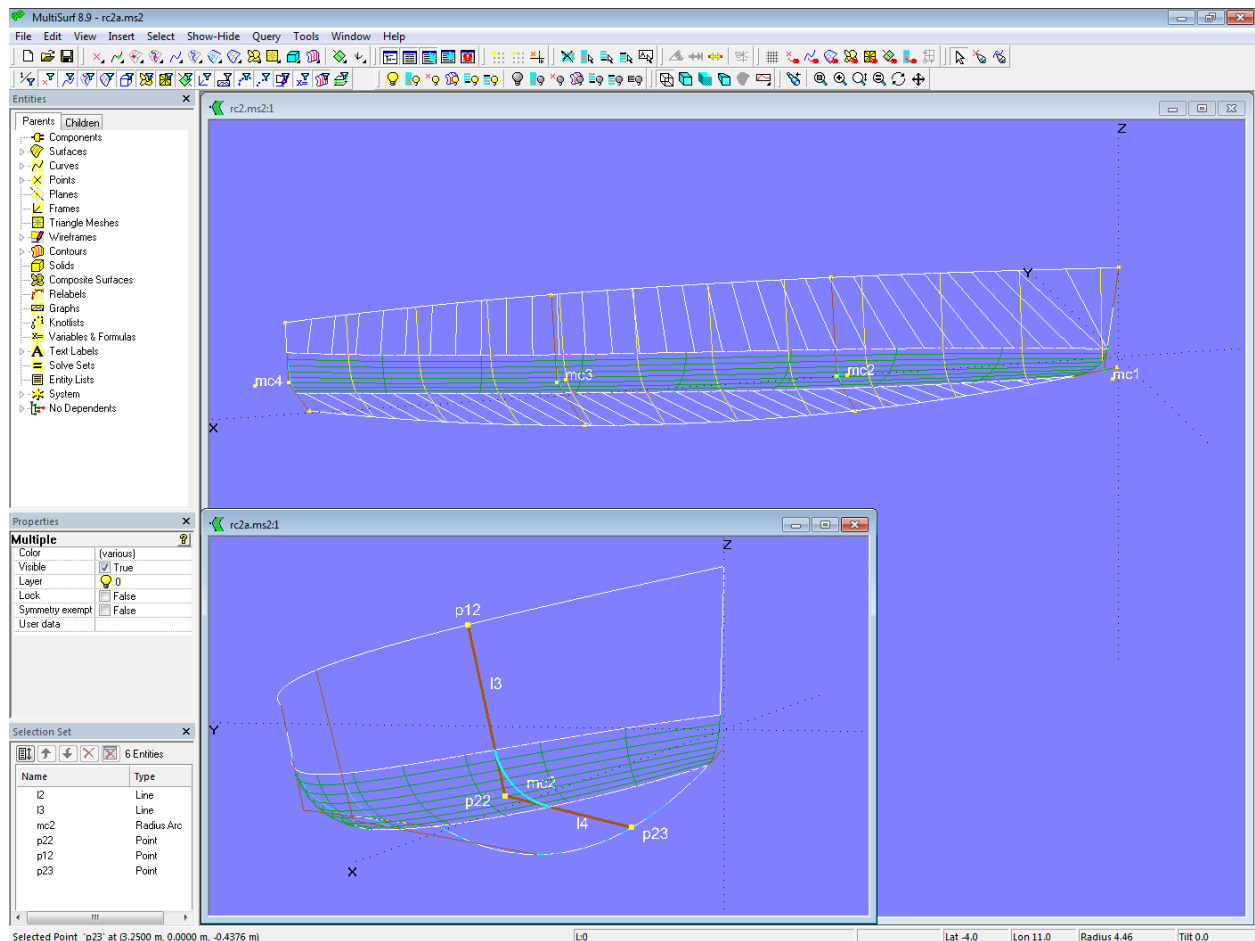


Model *radius\_chine-1.ms2* - rounding between the developable surfaces of topside and bottom by a C-spline Lofted Surface. The tangential joint of the mcs is hard-wired, e.g. at *mc2* by Bead *e21* on Line *l2* and Bead *e22* on Line *l3*.

## Method 2

Model *radius\_chine-2.ms2* has a similar structure to model *radius\_chine-1.ms2*, but for *mc2*, *mc3* and *mc4* the curve type Radius Arc is used. Example *mc2*: the arc starts tangentially to Line *l2* between the Points *p12* and *p22* and ends tangentially to Line *l3* between Points *p22* and *p32*.

In this way the size of the round off radii can directly be specified by numbers.



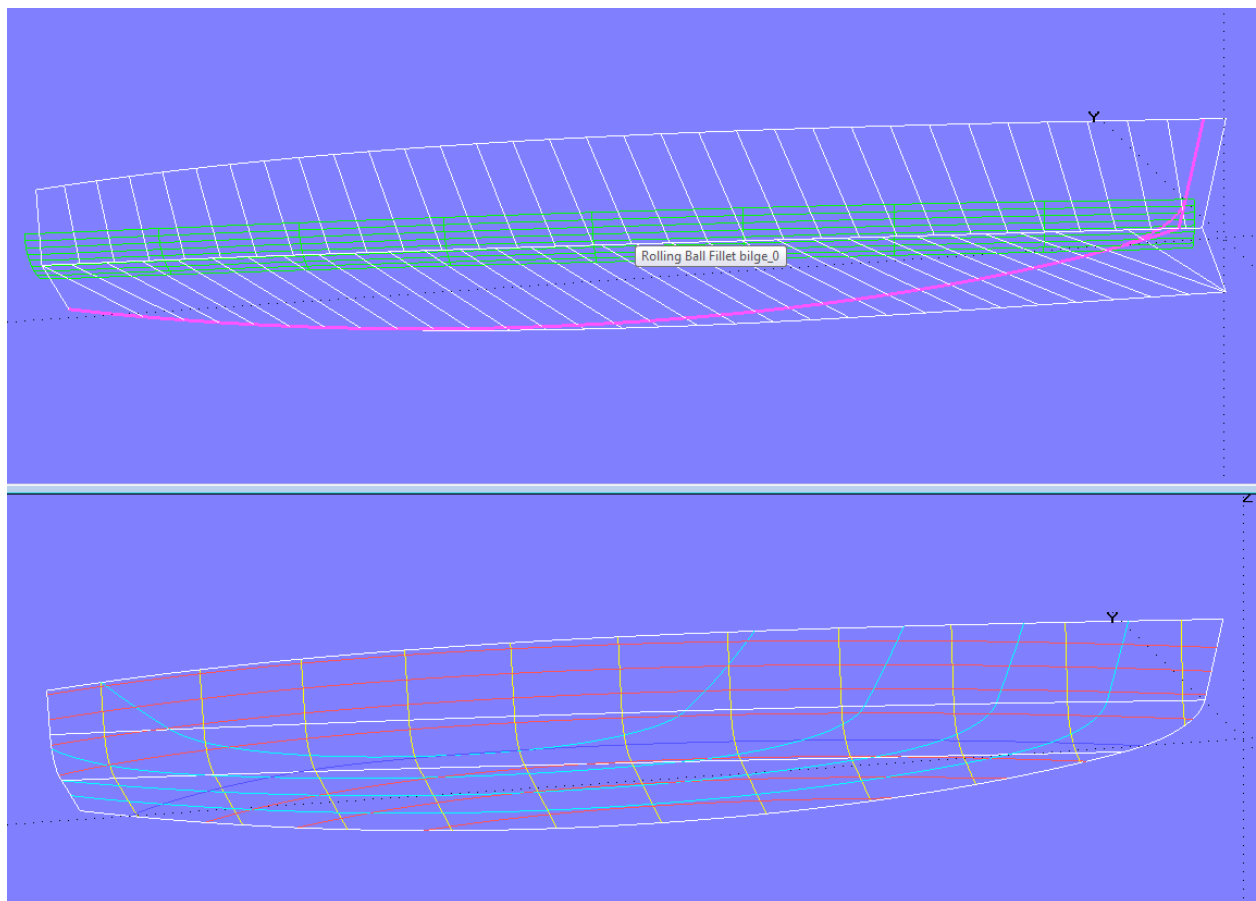
Model radius\_chine-2.ms2 - master curves of type Radius Arc allow to specify the size of the round off radii directly by numbers.

### Method 3

In the model *radius\_chine-3a.ms2* the bilge rounding is formed by a Rolling Ball Fillet. As the name implies, this type of surface can be thought of by a sphere that rolls between both surfaces and thereby surpasses a rounding, which extends between the path of all points of contact on the one surface and the path of all points of contact on the other surface.

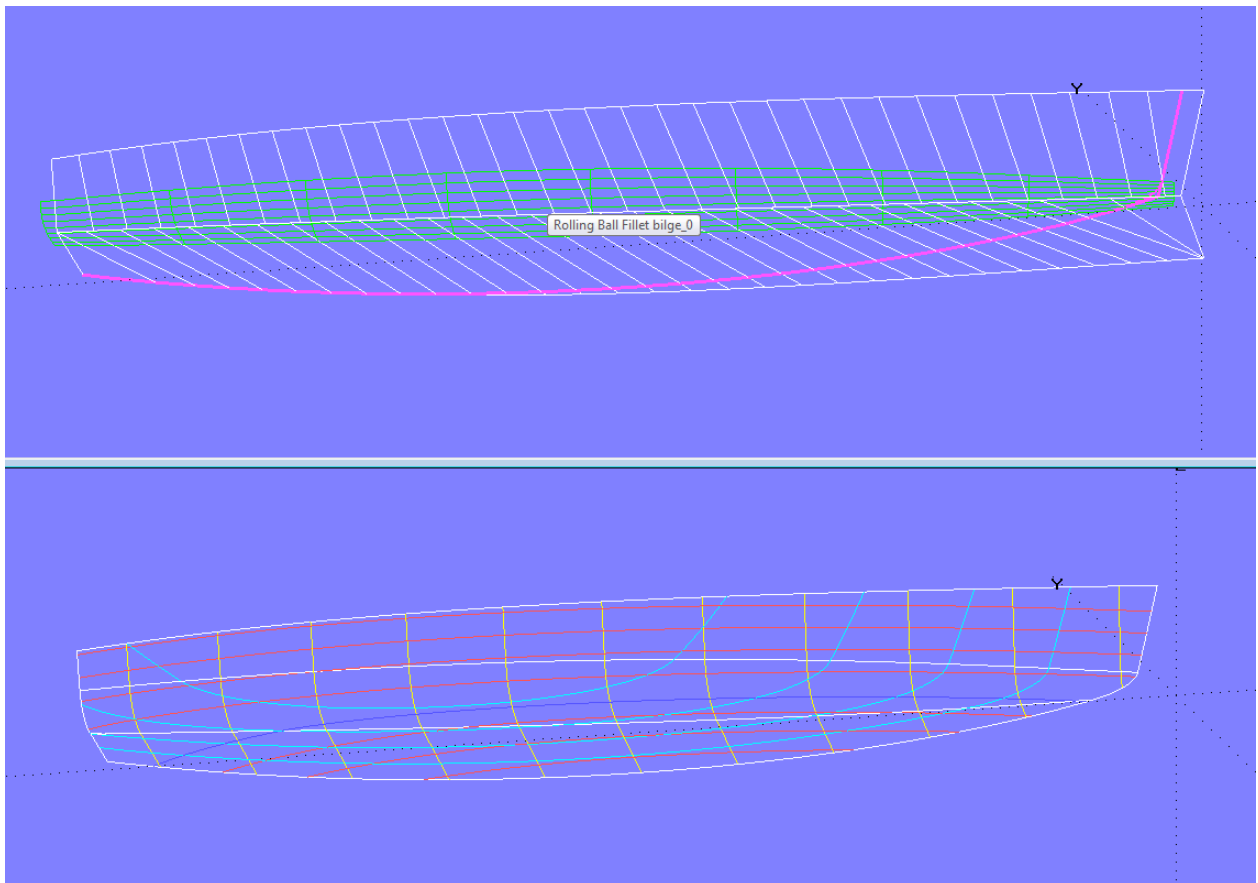
In order to make the sphere touch, the bottom surface must extend beyond the centerplane; therefore its lower control curve runs on the negative side of the centerplane. In the bow also the topside must extend beyond the centerplane. Stem and bottom profile are thus the intersection of these basis surfaces with the centerplane (\*Y = 0).





*Model radius\_chine-3a.ms2 - rounding between side and bottom by Rolling Ball Fillet (constant radius)*

The radius of the Rolling Ball Fillet can be changed by a Graph entity. This is shown in model *radius\_chine-3b.ms2*. Using the Graph [h0](#) the radius of the Rolling Ball Fillet [bilge\\_0](#) is at the bow half the radius at midships and at the stern twice the radius at midships.



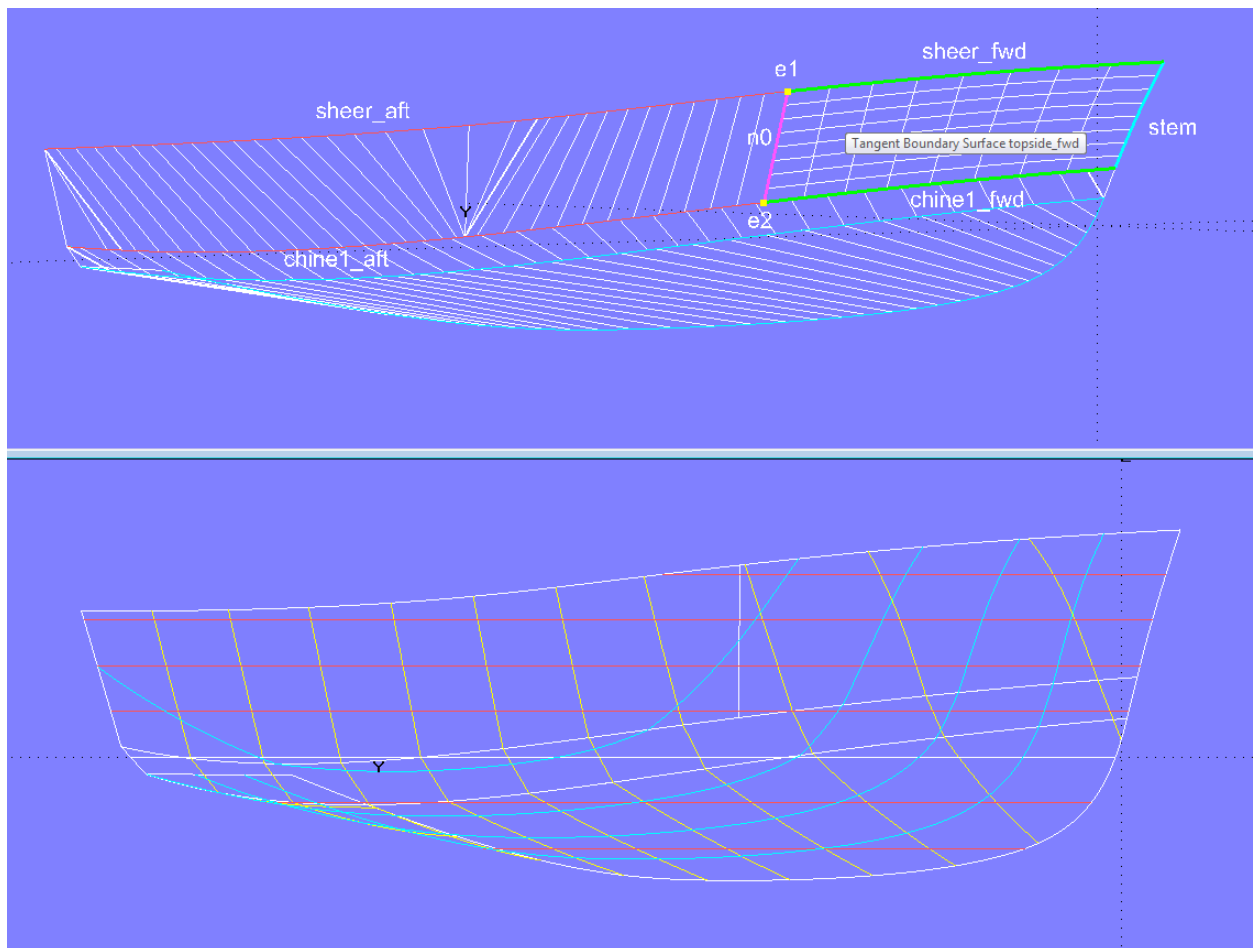
Model radius\_chine-3b.ms2 - rounding between side and bottom by Rolling Ball Fillet (variable radius)

Which method to use for the bilge rounding on a radius chine hull depends on bounding conditions. In method 1, the rounding can be shaped freely, for example, as parabolas. With method 2 the rounding is always a circular arc. Values for varying radii must be chosen carefully to maintain fairness. In method 3, the rounding is a circular arc of constant or variable radius, but stem and bottom profile are indirectly defined; just one single entity is required for the bilge rounding.

## 5.2 Hull with non-developable surface patch

Developability means restrictions in design. The inner shape of the surface can only be influenced within narrow limits (via the run of the rulings). For example, with a Developable Surface it is not possible to create flared out foreship sections. If one does not want to renounce that, then the respective hull area must be modeled by a different surface type. The principle approach is demonstrated in model *hard-chine\_powerboat.ms2*.

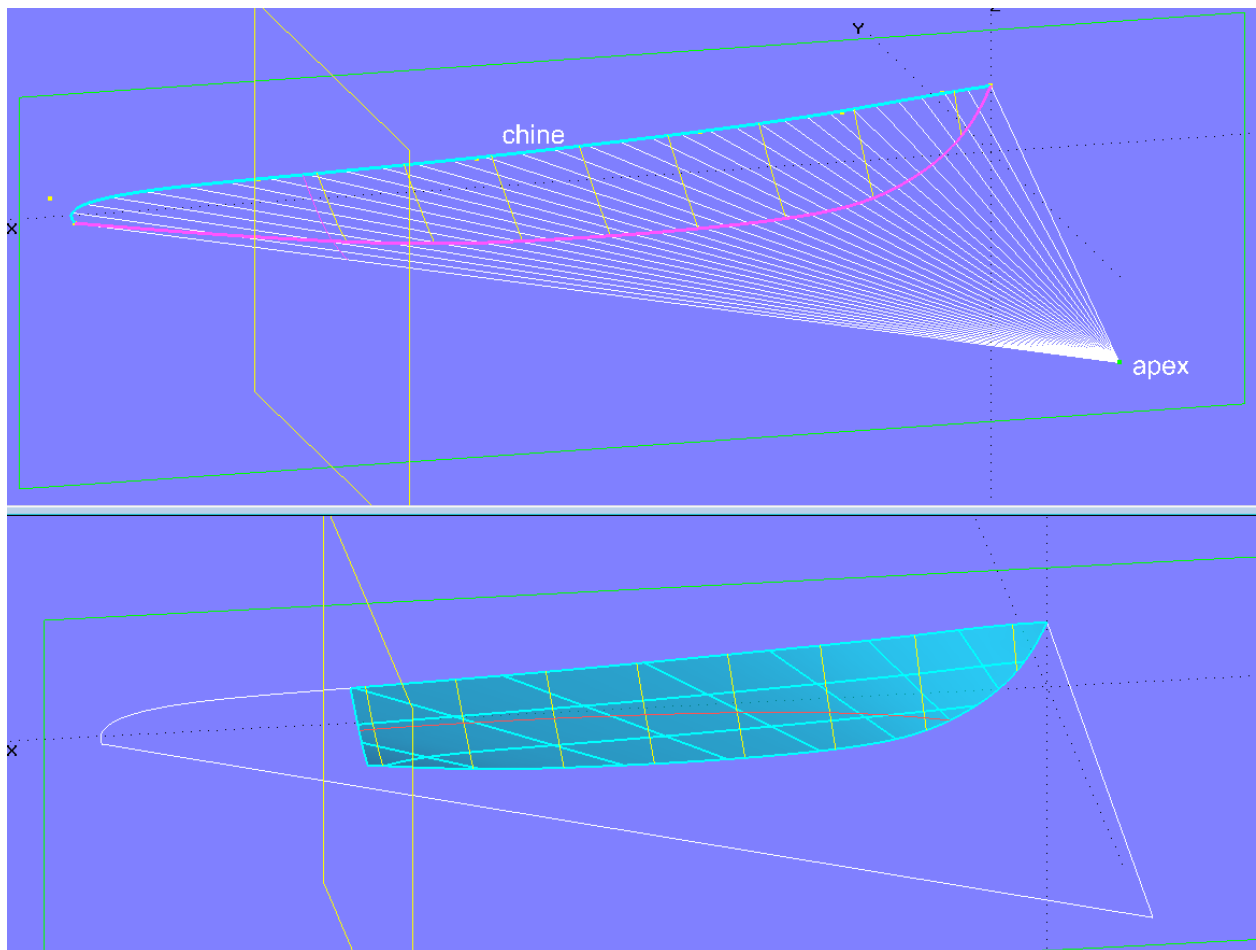
First, the support curves involved (here *sheer* and *chine1*) are subdivided into two SubCurves. With the SubCurves *sheer\_aft* and *chine1\_aft* the Developable Surface *topside\_aft* is defined. At its front edge the EdgeSnake *n0* is then created. With the SubCurves *sheer\_fwd*, *chine1\_fwd*, the snake *n0* and the bow curve *stem* the Tangent Boundary Surface *topside\_fwd* is created (with tangency continuity along *n0*). If necessary its shape may be modified by internal control points.



Model *hardchine\_powerboat.ms2* - the patch of the topside at the bow is not developable.

### 5.3 Hull with conical surface

Sometimes a chine hull should be formed by conical surfaces only. Model *conic\_bottom.ms2* shows this on the example of a bottom surface. Chine curve and the cone apex can be specified. However, the keel contour is not arbitrary, it can not be chosen freely, but results as the intersection of the conical surface with the centerplane. Thus the hull shape is subject to restrictions.



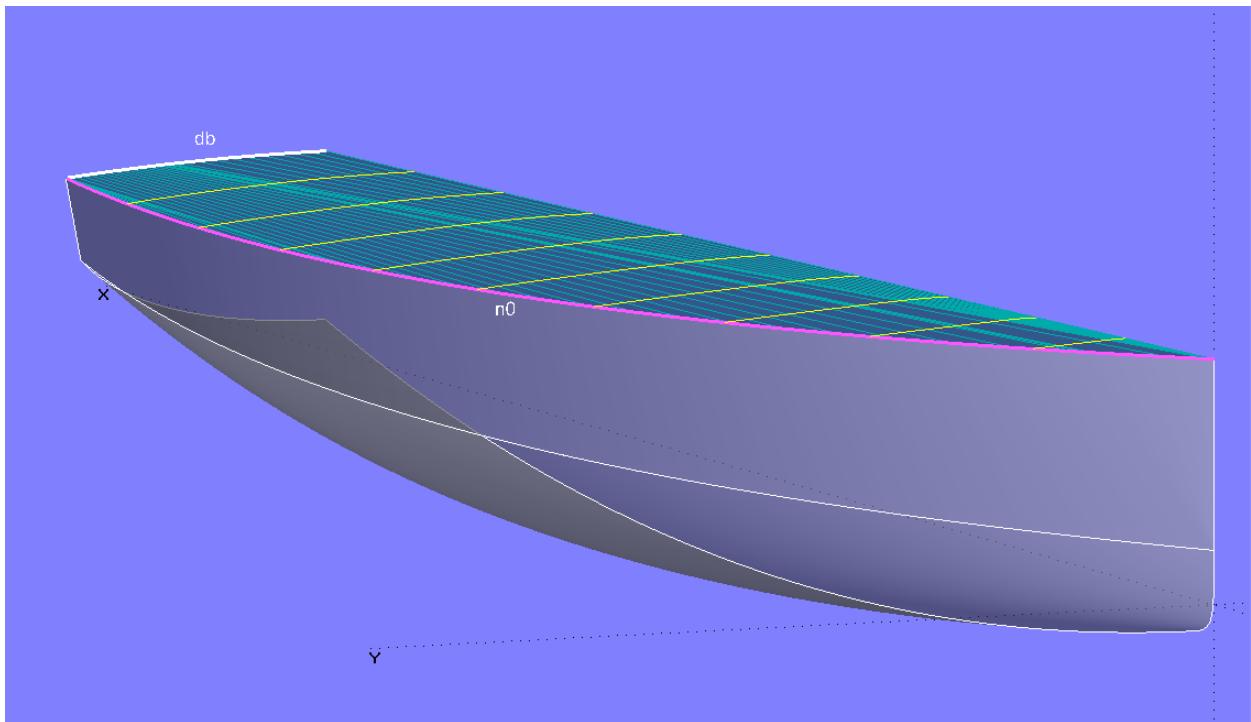
*Model conic\_bottom.ms2 - example of a hull bottom surface as part of a cone. The bottom profile results indirectly as centerplane intersection.*

## 6 Deck with developable surface

Standard deck definitions generally result in surfaces that can not be rolled out flat (by bending only). Although superstructure and cockpit cut out large portions of the deck, what reduces the problem of necessary pre-forming, decks can also be designed using developable surfaces.

One way to create a developable deck is shown in model *deck\_devsurf.ms2*. The Developable Surface [deck\\_0](#) is spanned between the upper edge of the hull (EdgeSnake [n0](#)) and a deck beam at the stern (Arc [db](#)).

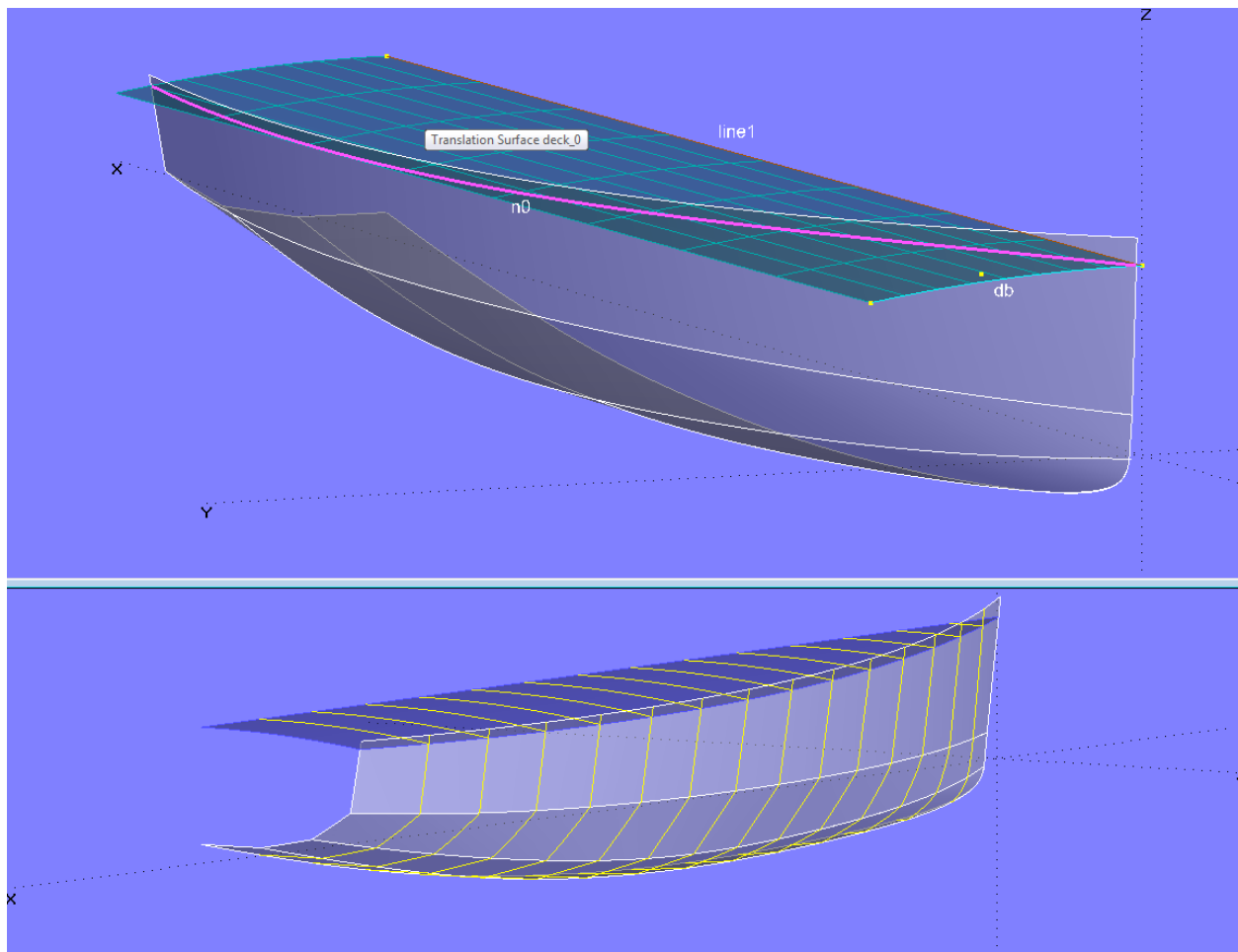
The price for the easier construction of a developable surface (only bending) is the restriction in form. The deck curve on centerplane straight, sections partly run straight too.



*Model deck\_devsurf-1.ms2 – Developable Surface spanned between top edge of hull **n0** and deck beam **db** aft*

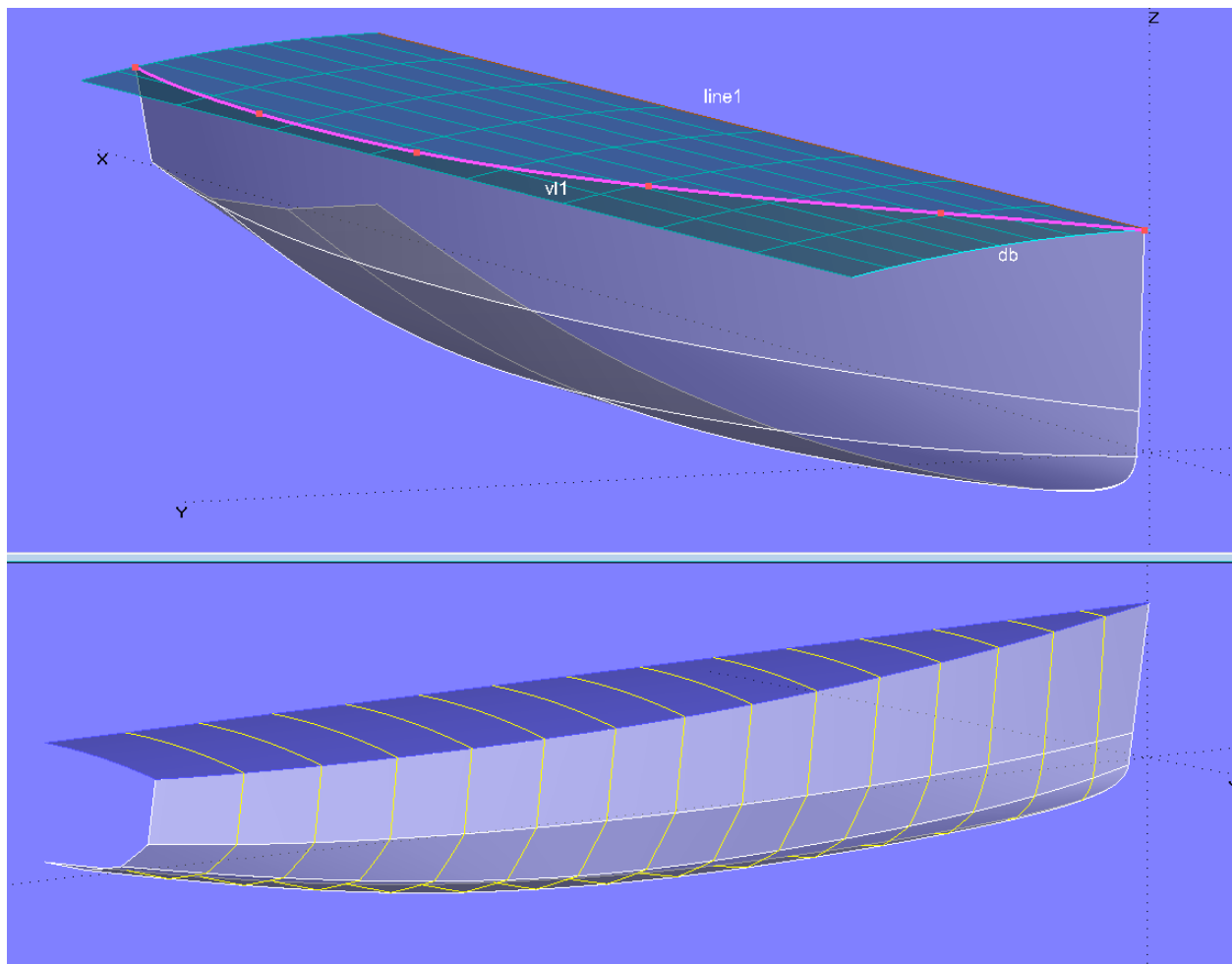
Another possibility is to use a circular cylinder for the deck surface. If the sheer edge of the hull claims priority, the deck needs to be lowered a bit, leaving a low bulwark or toerail. This is shown in model *deck\_devsurf-2.ms2*.

The deck surface is a Translation Surface with Line **line1** as generator and Arc **db** as guiding curve. Since the generator is straight, this translation surface is developable. It intersects the hull surface in the Intersection Snake **n0**.



Model *deck\_devsurf-2.ms2* - Translation Surface generated by *line1* and deckbeam *db* as developable surface

If hull and deck edge should coincide, the upper support curve of the topside must lie on the deck surface. Because of this constraint the sheer curve is somewhat limited in shape. Model *deck\_devsurf-3.ms2* shows an example. If the sheer has considerable curvature in the foreship it can show an inflection point when the hull is viewed from aside.

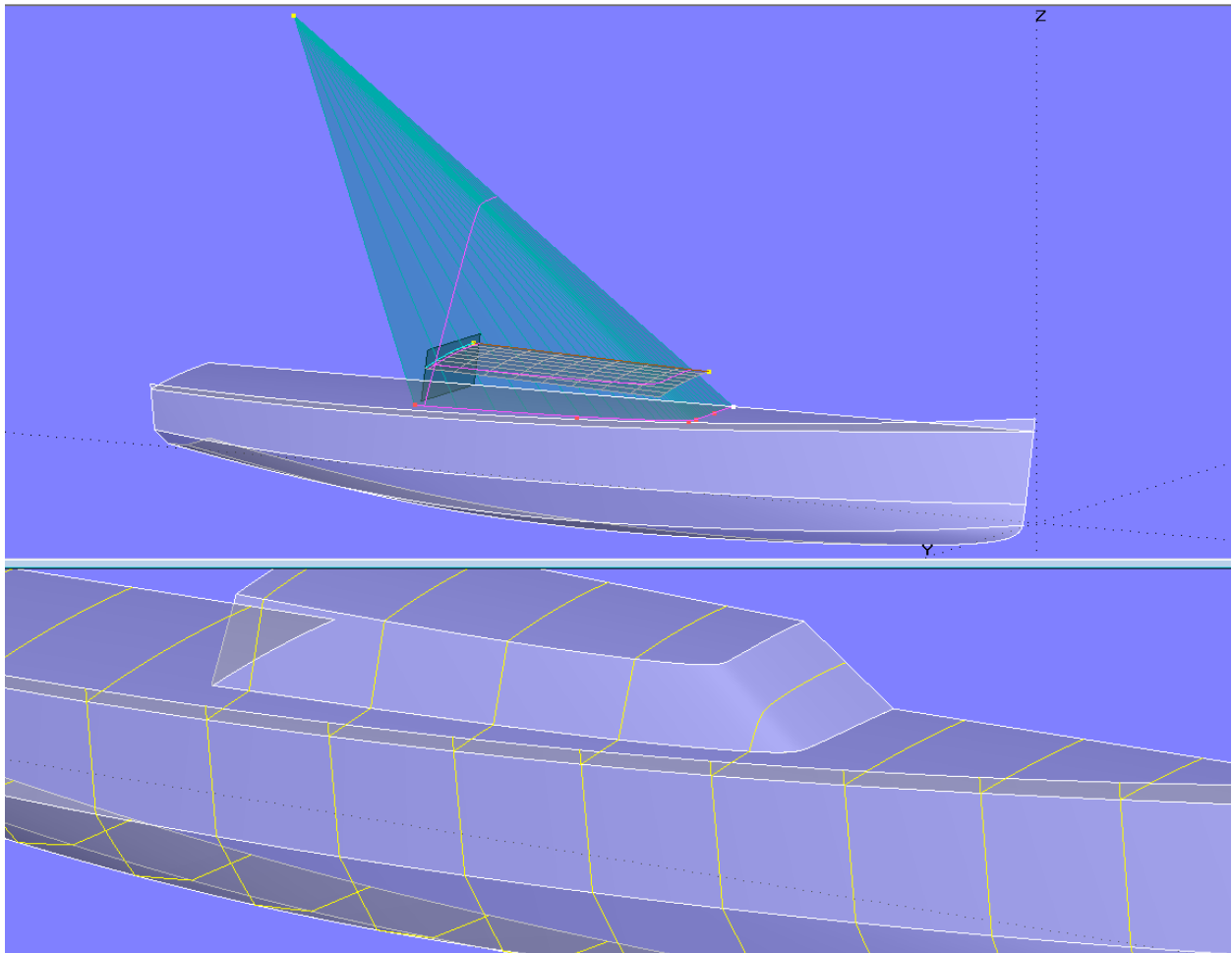


Model *deck\_devsurf-3.ms2* - the upper support curve of the topside is a C-spline Snake on the developable deck surface.

## 7 Superstructure with developable surfaces

In the tutorial “*Decks and Superstructures*” there are several examples of how to model box-shaped superstructures. If their surfaces are of the type Translation Surface, where the generating curve is straight, they are developable. See the models *trunk\_cabin-1.ms2*, *trunk\_cabin-2.ms2*, *trunk\_cabin-3.ms2*. Because in these models the guiding curve for the cabin roof is not straight, it must be replaced by a Line entity to make the roof developable. Although its profile on centerplane will no longer run curved, which may suffer aesthetics, but this is the price to pay for simple construction work.

Model *conic\_cabin.ms2* is another example. Cabin side and cabin front should be made from one single surface. For this a general conical surface is chosen. Its guide is the bottom edge of cabin side/front (B-spline Snake on the deck surface). The apex of the cone is positioned according to the desired slopes of cabin side and front. The cabin top is a circular cylinder. Trimmed Surfaces make the final surfaces of the superstructure.

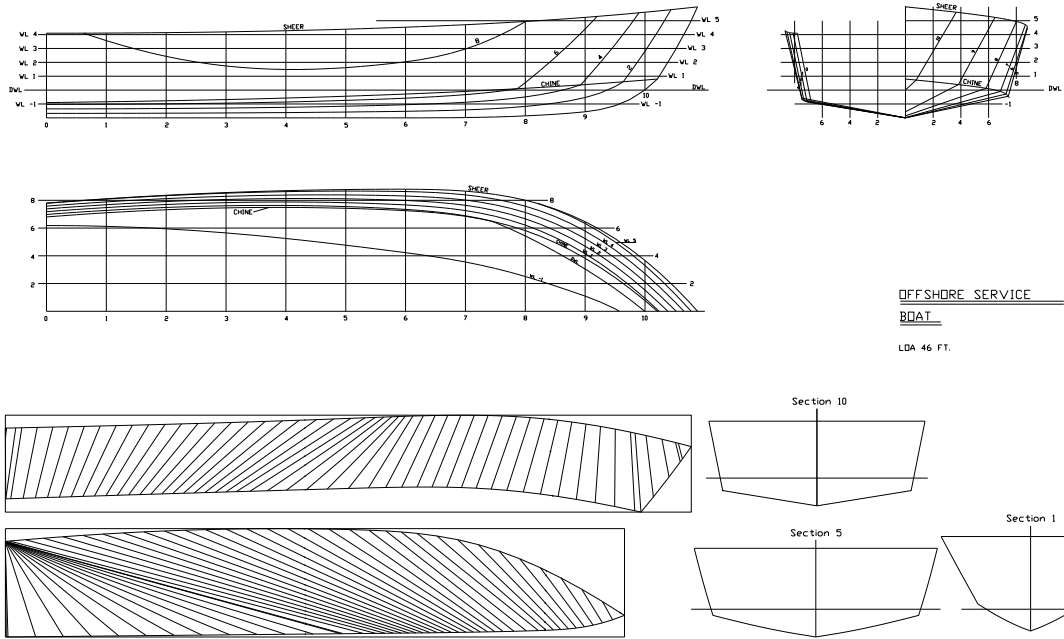


*Model conic\_cabin.ms2 – cabin side and front as part of a conical surface*

## 8 Surface expansion

All developable surfaces can be expanded and exported as CAD files with the AeroHydro *MSDev* program or the MultiSurf add-on module *Flattener*. On the flattened surfaces there can be markings for bending lines, sections, waterlines, etc.

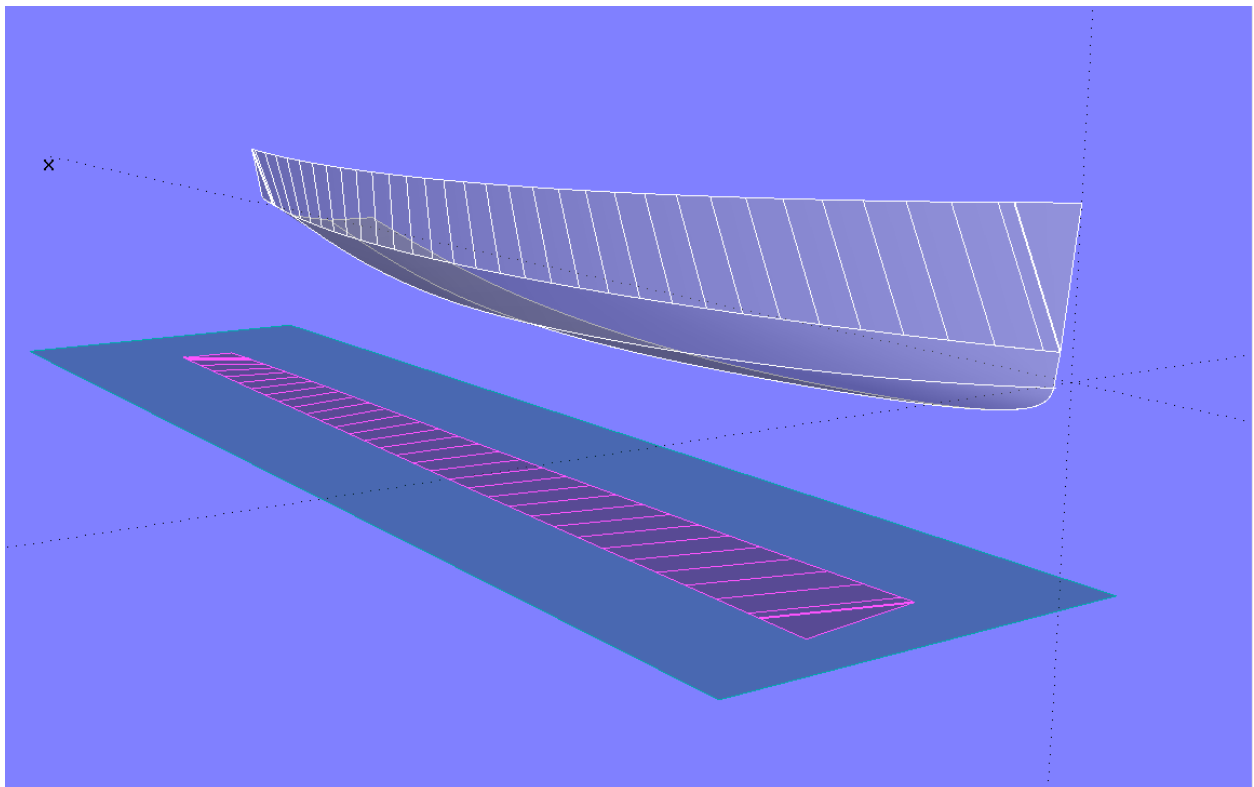




Expanded hull plates of a powerboat

## Expanded Surface

If MultiSurf is authorized including the *Flattener* module, the surface type *Expanded Surface* is enabled. This allows surfaces to be expanded directly in MultiSurf.



Model *expanded\_surface.ms2* - surface flattening directly in MultiSurf with the surface type *Expanded Surface*

## Transom Development

For ease of construction many boats feature a transom which is a portion of a circular cylinder. The model *cyl\_transom\_expansion.ms2* explains how to construct the expanded shape of the transom within Multi-Surf.

The Translation Surface **transom\_0** is the basis surface of the cylindrical transom. Its guiding curve is the Arc **c1**, generator is Line **l1**. The control points of both curves are defined in the 3-point Frame **F1**, so that one can rake and shift the transom without changing its shape.

Hull and deck are intersected by the surface **transom\_0** in the Intersection Snakes **n1** and **n3**, which in turn are projected onto **transom\_0** as Projected Snakes **n2** and **n4**.

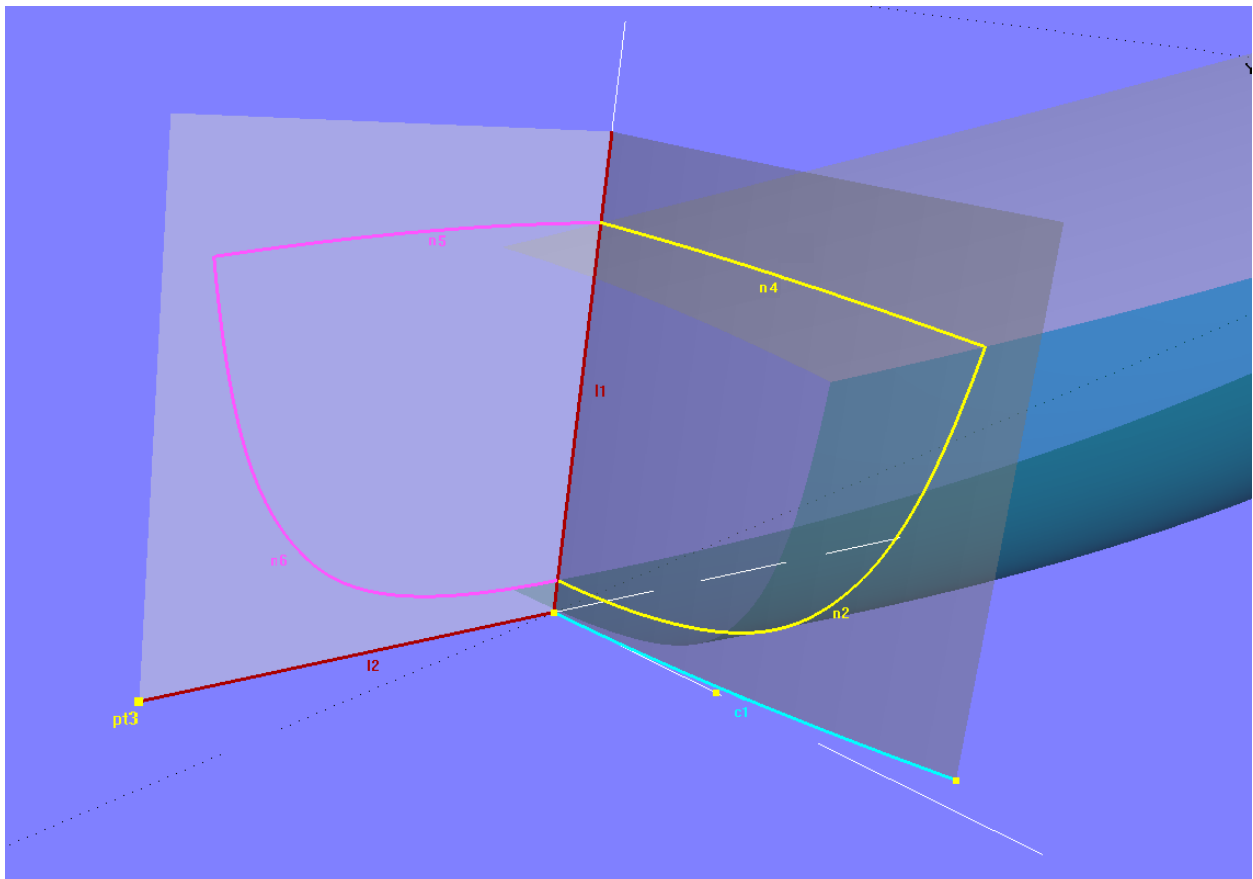
The expansion of the transom basis surface is the Translation Surface **s0**, whose guiding curve is the Line **l2** (end point is Point **pt3**), the generator is again Line **l1**. The length of Line **l2** must be equal to the length of the Arc **c1**. Since **s0** is in the XZ plane of the Frame **F1**, the Z-coordinate of Point **pt3** (end point of Line **l2**) simply corresponds to the length of **c1**. This length is displayed in Tools/ Mass Properties.

When the arc is changed, for example, to increase the camber of the transom, the position of **pt3** must be adjusted manually.

To avoid this, the simple Formula **f1**:

$$f1 = \text{ARCLEN}(c1, 0, 1)$$

which calculates the length of Arc **c1**, is used for the Z-coordinate of **pt3**. In this way it is guaranteed, that **s0** always is just as long as Arc **c1**.



Model *cyl\_transom\_expansion.ms2*

In order to get the developed shape of the transom on **s0**, the two Projected Snakes **n2** and **n4** are copied onto **s0** as Copy Snake entities. Since **s0** is in the centerplane, the profile view of the model (Y-view) shows this outline in real size. Alternatively, View/ Modify/ Set View/ Normal to ... also provides the vertical screen view (select **s0** beforehand). The view can be exported then via File / Export 2D / DXF.

In this way the true outline of the circular cylinder transom is constructed without a specialized program.

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