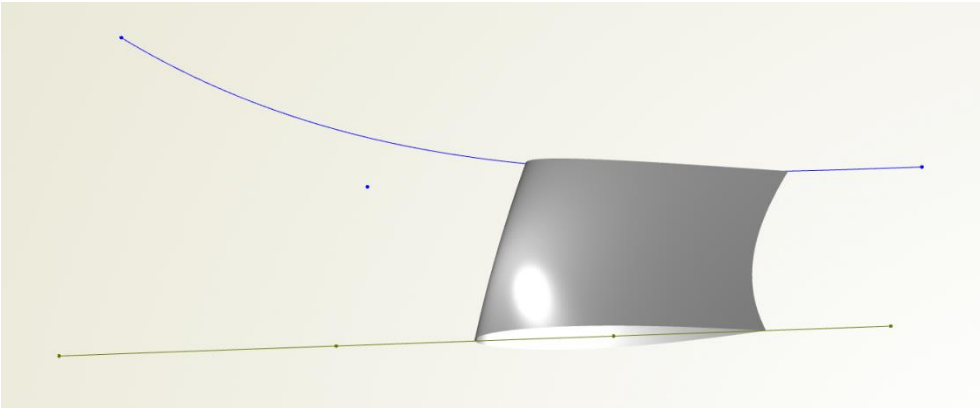
Axial Blade

In this tutorial we will guide you through the entire process of creating a first parametric blade shape. The surface generation is based on *meta surfaces*. The hub and shroud contours are designed, as well as the stacking axis, the 2D profile and the 3D functions for spanwise control.



Compared to other meta surfaces, the 2D-3D transformation is done by an object that is called *stream section*. It takes the 2D profile definition along with hub and shroud information and transforms it into the 3D space.

With the stream section, you are able to design blade shapes that are not necessarily on cylindrical stream surfaces. However, if you have cylindrical surfaces (e.g. propellers and fans), you can use the *cylindrical transformation* entity, which makes the design process a bit more lightweight. There is also a tutorial available for this design situation.

CAESES Project

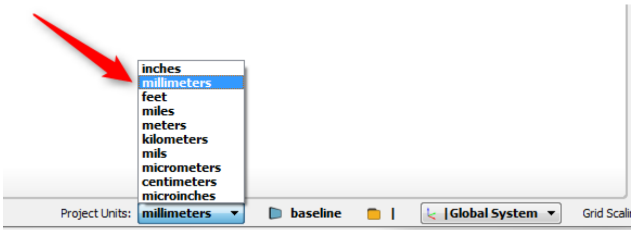
The resulting model can be found in the section *samples* > *tutorials* of the documentation browser.

1

Getting Started

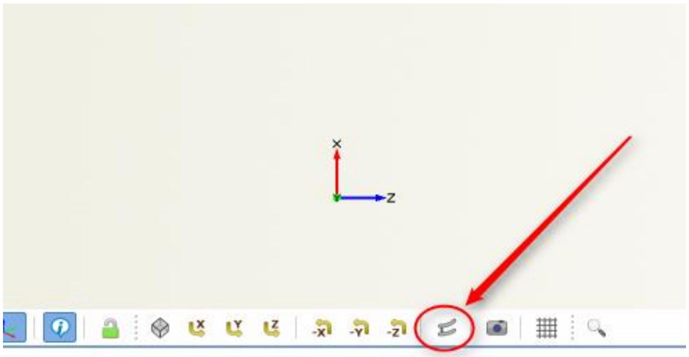
In this preparation step, we make sure that we use the correct project units. In addition, we get in touch with the zx-view which is the main 2D view for designing the blade's hub and shroud contours.

► Switch the project units to millimeters.

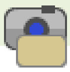


✓ Projects units are relevant when it comes to geometry exports at a later stage.

► Check out the zx-view button at the 3D view which always brings you back to the main hub and contour view in the upcoming steps of this tutorial.



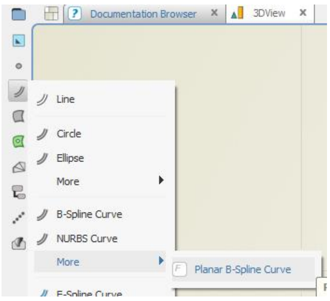
✓ In addition to the zx-view button, you can use the camera positions in the toolbar (upper right corner of the GUI) in order to store and reuse your favorite views.



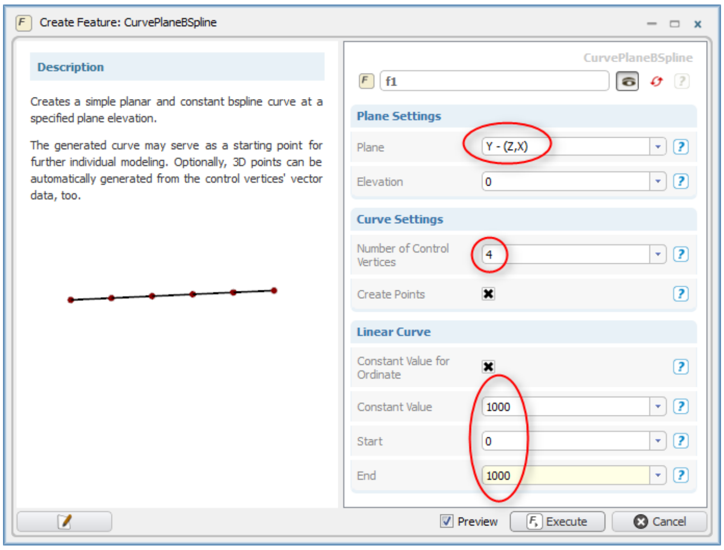
2 Meridional Contour Curves – Hub

We create 2 planar curves in the zx-view, one for the lower and one for the upper stream surface, i.e. hub and shroud.

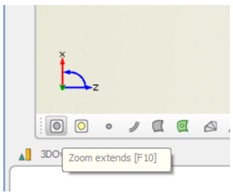
- Choose *Planar B-Spline Curve* from the curve menu, see the screenshot.

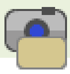


- In the dialog, set the values as shown below. With this, we create a curve in the y-plane, with 4 control vertices and a length and constant height of 1000.
- Press the *Execute* button, which creates the curve in the tree.



- In the 3D window, zoom out to see the curve. Alternatively, press the zoom extends button.

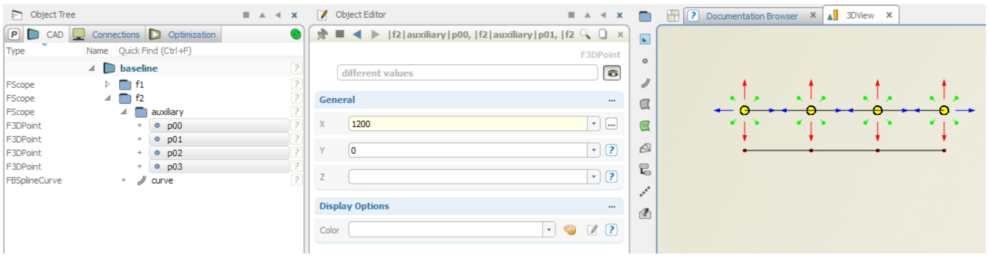


✓ Use the camera positions in the toolbar (upper right corner of the graphical user interface) in order to store and reuse your favorite views, such as the one right now. 

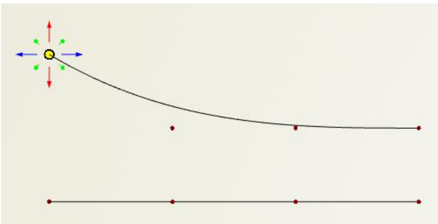
3 Meridional Contour Curves – Shroud

We simply copy & paste the hub curve and move it a bit upwards to have a shroud contour in our model.

- Copy & paste the scope “f1”.
- Select the points of the second curve in “f2” and set the x-value to “1200”.

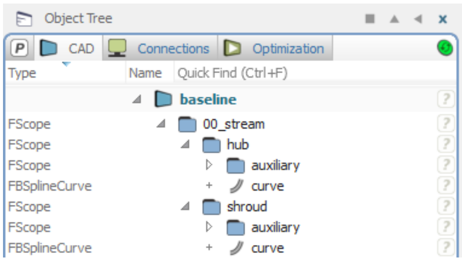


- Set the x-value of “p00” to “1400”.



In addition, rename and organize your project:

- Rename scope “f1” to “hub” and “f2” to “shroud”.
- Select both scopes and create a new one that you call “00_stream”.

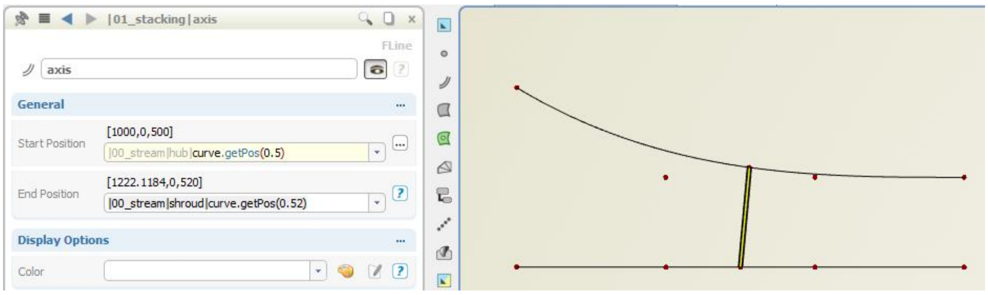


- Don’t forget to save your project!

4

Stacking Axis

For this simple model, we want to use a *line* as stacking axis that connects a position on the hub curve with a position on the shroud curve. Note that the stacking axis does not necessarily have to be designed in the zx-plane, it can also be a more complex 3D shape.



- Create a line via *CAD > curves > line*.
- Set the name to “axis”.
- For the start position, set “|00_stream|hub|curve.getPos(0.5)”.
- For the end position, set “|00_stream|shroud|curve.getPos(0.52)”.

✓ Remember: You can drag & drop the curves into the editor field, and use auto-completion (CTRL-SPACE) for the position command. Or, use the ALT-key to paste the names!

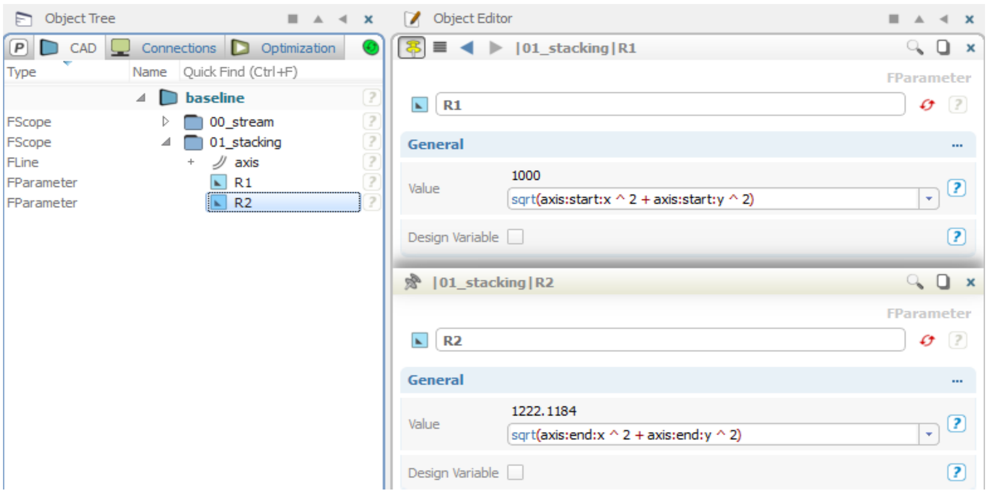
More information can be found in the first tutorials, in particular, see the GUI introduction tutorial and the tutorial videos (website/youtube).

- Create a new scope “01_stacking” and put the curve into it.

5 Stacking Axis – Hub and Shroud Radii

In addition, we store the hub and shroud radii of the stacking axis, which we will need in a later step. This is also helpful general information.

- Create a parameter via *CAD > parameters > parameter*.
- Set the name to “R1” and the value to
  `sqrt( 01_stacking|axis:start:x ^ 2 + 01_stacking|axis:start:y ^ 2 )`
- Copy and paste this parameter, set the name to “R2”, and set the value to
  `sqrt( 01_stacking|axis:end:x ^ 2 + 01_stacking|axis:end:y ^ 2 )`
- Move the two parameters into the scope “01_stacking”.



✓ Note again that we rotate around the z-axis, so that these radii are calculated in the xy-plane.

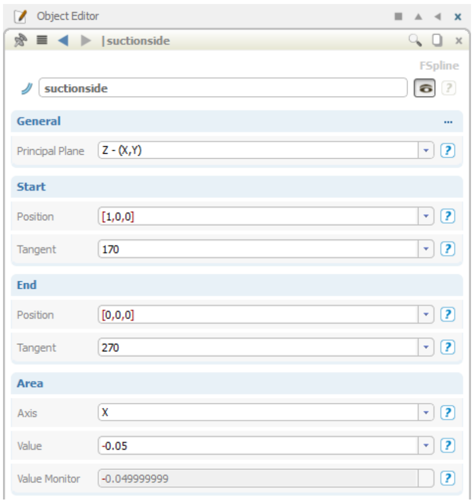
In our example, the y-coordinate of the stacking axis start and end positions is “0”. However, for other models with a 3D shaped stacking axis, this is not always the case. Therefore, we include it in the formulas above.

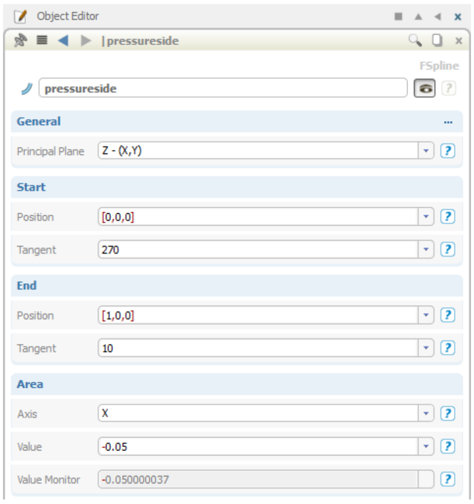
6 2D Blade Profile – Part 1

In this tutorial, we want to keep the focus on the complete blade design process. Therefore, we use a very simple 2D profile so that the overall tutorial is not too long. Compressor or turbine blade profiles are mostly designed by means of camber lines and thickness distributions. See the other CAESES tutorials for this topic. Basically, you can create your own 2D profile in this step, with all profile parameters that you need.

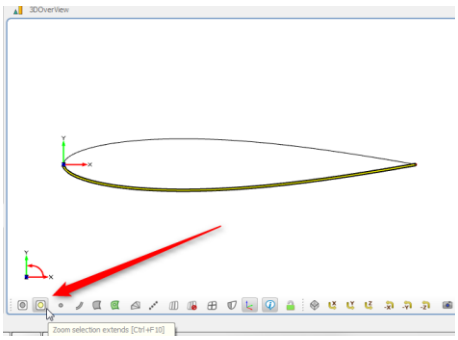
Here comes our simple profile:

- Create a smooth spline via *CAD > curves > f-spline curve*.
- Set the attributes as shown in the left screenshot below (curve name, start/end positions and tangents, area axis and value).





- Copy and paste “suctionside” and rename it to “pressureside”.
- Set the attributes as shown in the right screenshot above.
- While “pressureside” is still selected, press the button “zoom selection extends” at the *3DOverView* window.



✓ This shows the profile in the xy-view. Profile design in CAESES is usually done in the xy-plane. Therefore, a second window is helpful.

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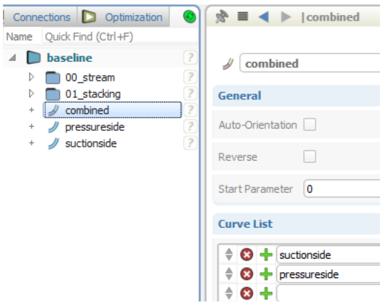
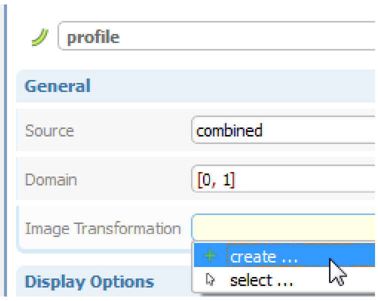
2D Blade Profile – Part 2

For the surface generation process, we need a single profile curve. Let's put the two curves together and introduce a scaling for chord length:

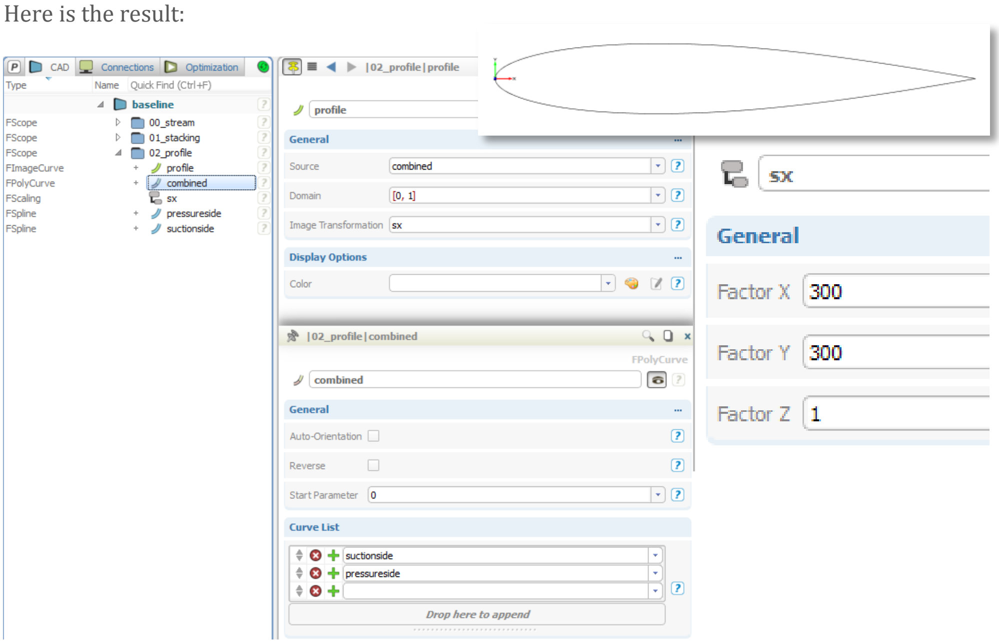
- Select "suctionside" and "pressureside".
- Choose *CAD > curves > polycurve*.
- Rename the new curve to "combined".



- While "combined" is selected, create an image curve via *CAD > curves > image curve*.
- Rename the new curve to "profile".
- For the selected "profile", create an image transformation via *transformations > scaling*.
- Set the name of the transformation to "sx".
- Set the value of *factor x* and *factor y* to "300".
- Select all curves and the scaling object "sx", and create a new scope.
- Set the scope name to "02_profile".



Here is the result:



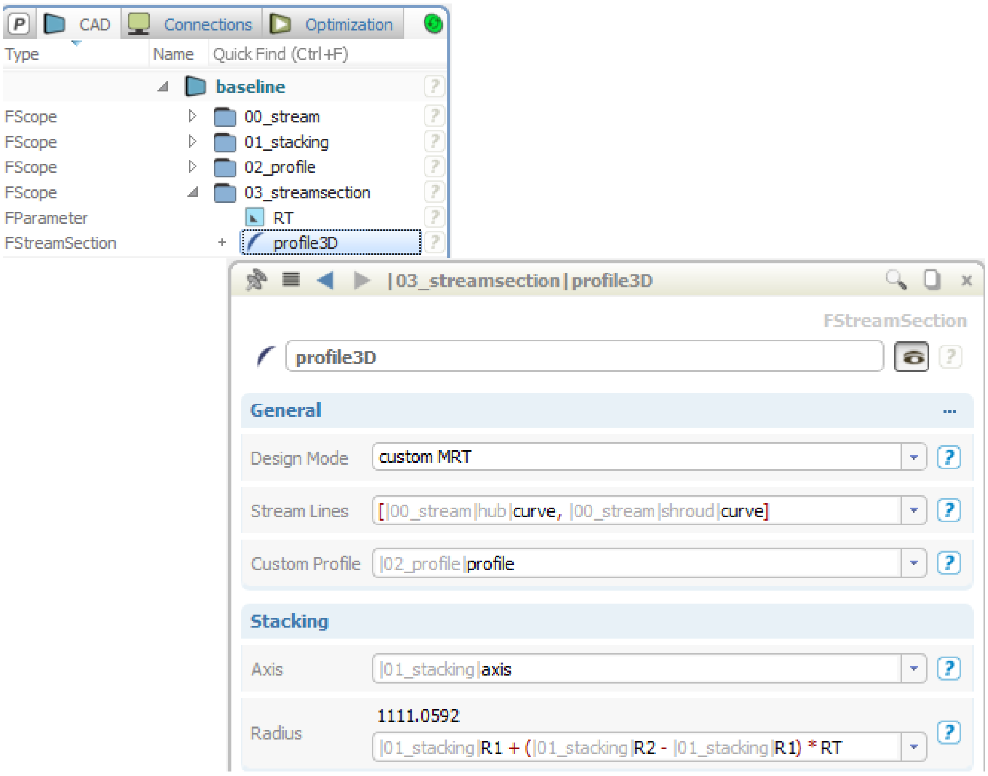
8 Stream Section Setup

The new profile need to be transformed into the 3D space. This is the job of the *stream section* curve type.

- Create a new stream section via *CAD > blade > stream section*.
- Set the name to “profile3D”.
- For the *design mode*, choose “custom MRT”, i.e. we consider a custom profile in the (m,r*Θ).
- Drag & drop the hub and shroud contour curves into the field *stream lines*.
- Set the “profile” from the previous step as *custom profile.*
- Set the stacking axis i.e. enter the line from your project.
- For the stacking *radius*, set the expression

  `01_stacking|R1 + (01_stacking|R2 - 01_stacking|R1) * 0.5`
- For the value “0.5”, introduce a parameter and call it “RT”.

  This is the one you can change now in the range [0,1] to move the section along the stacking axis.
- Select “profile3D” and “RT” and create a new scope, call it “03_streamsection”.



9 Encapsulate 3D Profile – Part 1

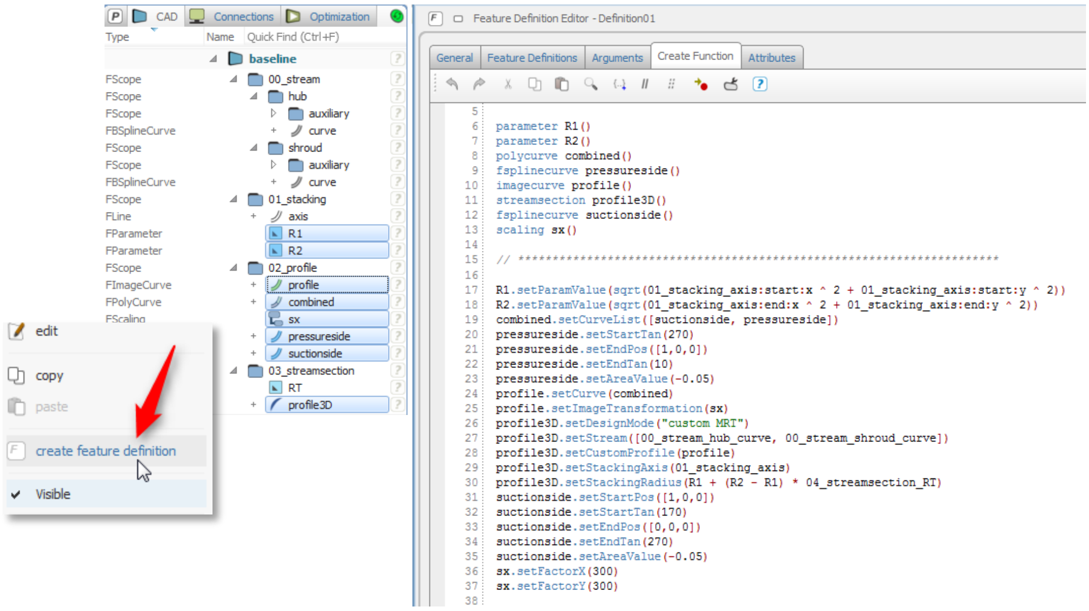
For generating a blade based on the *meta surface* technique, we first need to put our 3D profile into a feature definition:

- Select the objects that need to be put into the feature definition i.e.
  - "R1"
  - "R2"
  - All objects in "02_profile"
  - "profile3D"
- While the objects are selected, choose "create feature definition" from the context menu.

✓ Note that we do not select "RT", this is *input*, the same counts for stacking axis, hub and shroud curves. These objects should be modeled outside of the feature definition.

The parameters "R1" and "R2" could also be *input* to the feature, but we include them here to keep the feature *input interface* simple, i.e. it is just stacking axis, hub and shroud.

For more information, see the tutorials that cope with feature definitions.



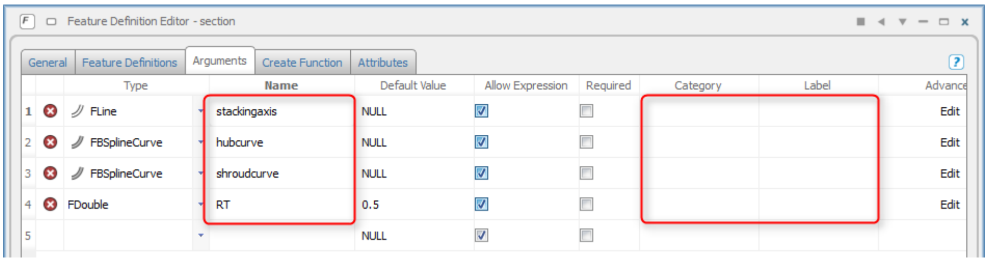
- Set the name of the feature definition to "section" (*General* tab of the dialog).
- Press the *Apply* button.

10 Encapsulate 3D Profile – Part 2

We quickly want to rename the auto-generated arguments so that they are easier to read. This again shows how you can customize features.

- Click on the *arguments* tab.
- Set shorter names for the arguments, as shown in the screenshot.
- Remove the auto-generated *Category* and *Label* names.

✓ Categories and labels are not needed for our simple example. If you have more input arguments, then this way of customization is helpful to organize the user interface of the feature.

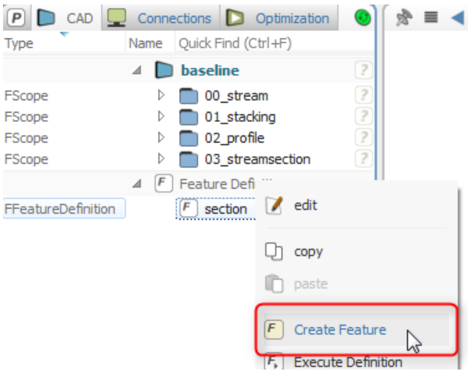


- Press the Apply button and close the dialog.

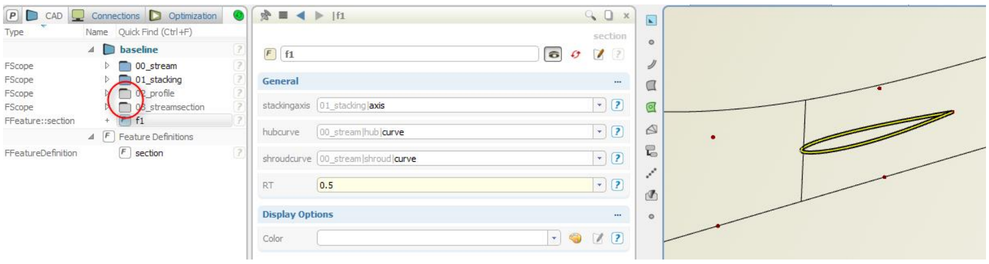
✓ The previous steps (interactive modeling of the 2D and 3D profiles in the tree) are actually not required. With some experience, you can directly start with a feature definition for defining your own turbine and compressor profiles.

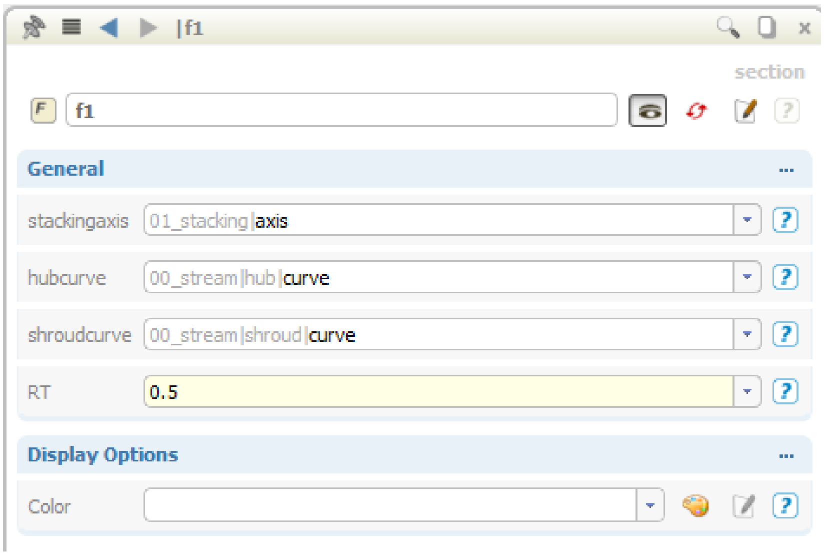
11 Testing the 3D profile

Before we generate a first blade surface, we want to check whether our feature definition works as expected.



- Create a feature from our new definition, see the screenshot.
- Set the input data so that the 3D section gets visualized in the 3D view.
- You can change the "RT" value, to see how the section gets generated along the stacking axis.
- Switch the scopes "02_profile" and "03_streamsection" to invisible by clicking on their scope icon in the tree – we do not need them anymore.

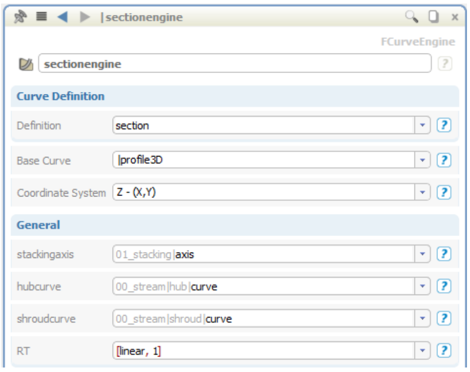




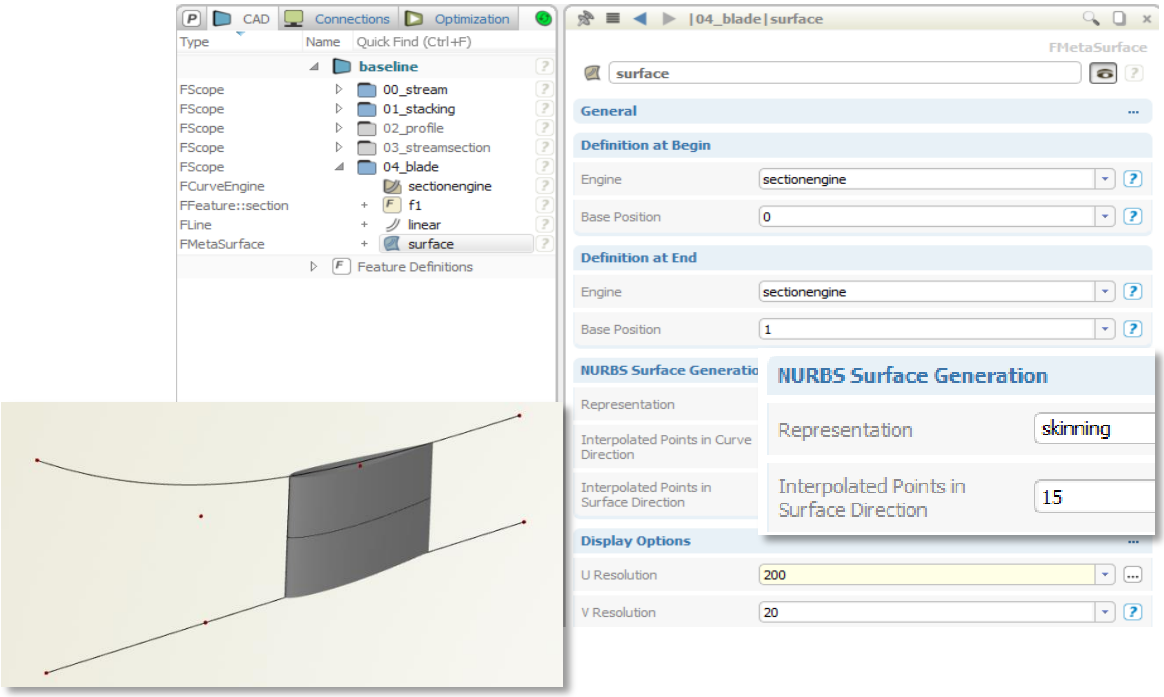
12 Creating the Blade Surface

We simply have to connect the profile and a linear function for “RT”. This is typically done with *curve engines* and *meta surfaces*.

- Create a line via *CAD > curves > line* with *start position* [0,0,0] and *end position* [1,1,0], call it “linear”.
- Create a curve engine via *CAD > curves > curve* engine, call it e.g. “sectionengine”.
- Choose the “section” to be the *definition*.
- Choose the “profile3D” as *base curve*.
- Set the axis and hub and shroud curve, as well as drag & drop the linear function into *RT*.
- Keep this engine selected, and choose *CAD > surfaces > meta surface*, call it “surface”.



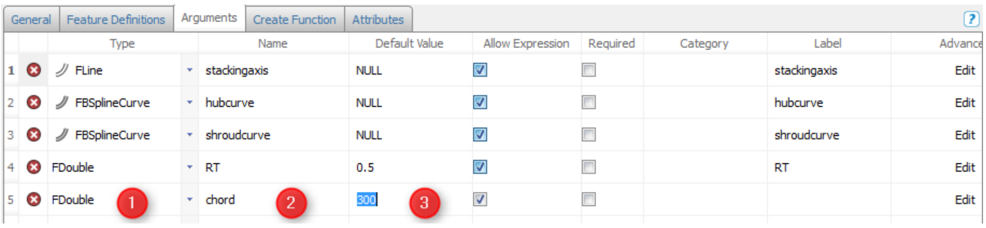
- Increase the surface *u-resolution* of the blade to “200”, for a smoother visualization.
- Choose “skinning” as the method for NURBS surface generation.
- Select the engine, the linear function, the blade surface as well as the testing feature and create a new scope, call it “04_blade”.



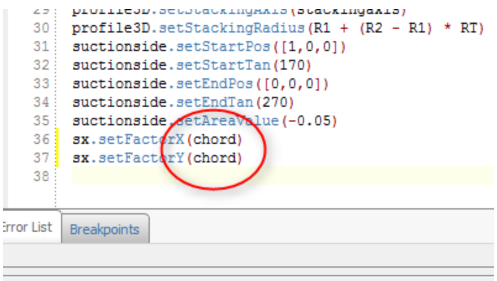
13 Introduce Chord Length

So far, our blade shape is constant in radial direction (“spanwise”). For a start, we introduce a chord length that changes the blade spanwise.

- ▶ Double-click on the feature definition “section” to edit it.
- ▶ In the *arguments* tab, introduce a double value “chord” and set the default to “300”.



- ▶ Click on the *create function* tab.
- ▶ Replace the scaling value with our new chord argument.
- ▶ Press the *Apply* button and close the dialog.

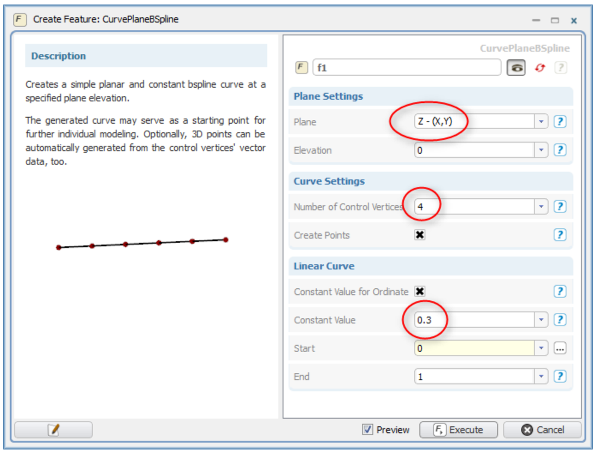


14

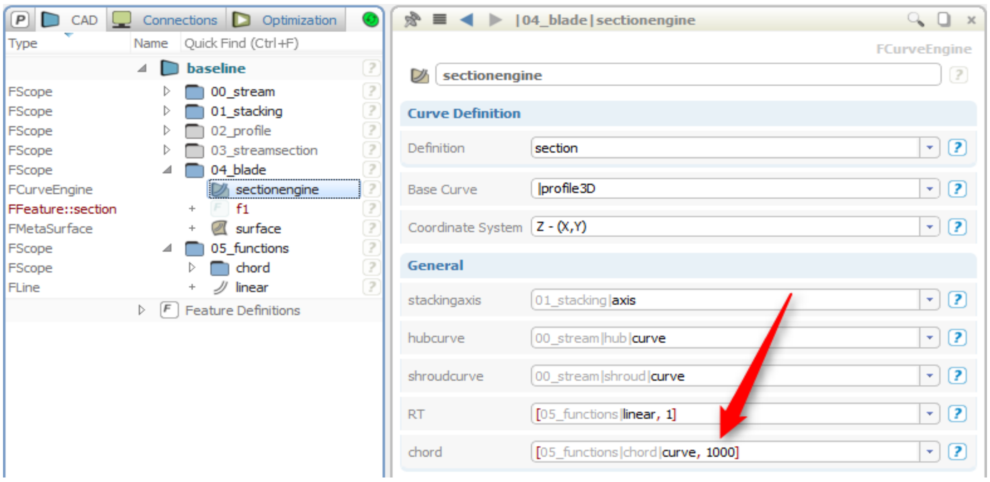
Introduce Chord Length Function

We create a radial function which describes the chord length change in spanwise direction.

- ▶ See also step 2 again: Create a bspline curve – now in the xy-system, with 4 points – where the ordinate value is set to “0.3” (we will consider this function in a normalized system).



- ▶ Rename the scope from “f1” to “chord”.
- ▶ Drag & drop the new curve (not the scope!) into the corresponding *curve engine* field of “sectionengine”.
- ▶ Set the factor for ordinate scaling of this function to “1000” (0.3 then actually means 300).
- ▶ Change the values of the curve points to see the blade changes in the 3D view.
- ▶ Create a new scope called “05_functions” and put the scope “chord” and “linear” in there.



15 Outlook

This tutorial shows the basic steps to create a parametric blade surface. Since the shape is still very simple, here are some next steps that you can directly try out after you have finished this tutorial:

- As a natural next step, you might introduce a rotation (“stagger angle”) for the 2D profile in the feature definition by adding a *rotation* object and a *transformation chain*. For this angle, you can again create a radial distribution as shown in the previous step.
- Introduce parameters and functions for the area values of the profile’s fspline – they are currently set to “-0.05” i.e. constant in radial direction.
- Visualize hub and shroud surface by using two surfaces of revolution.
- You can dive deeper by using *breps,* to create radius-based fillets along the hub. It is recommended to browse through the brep tutorials to find out more about this topic. There are also example projects provided in CAESES.