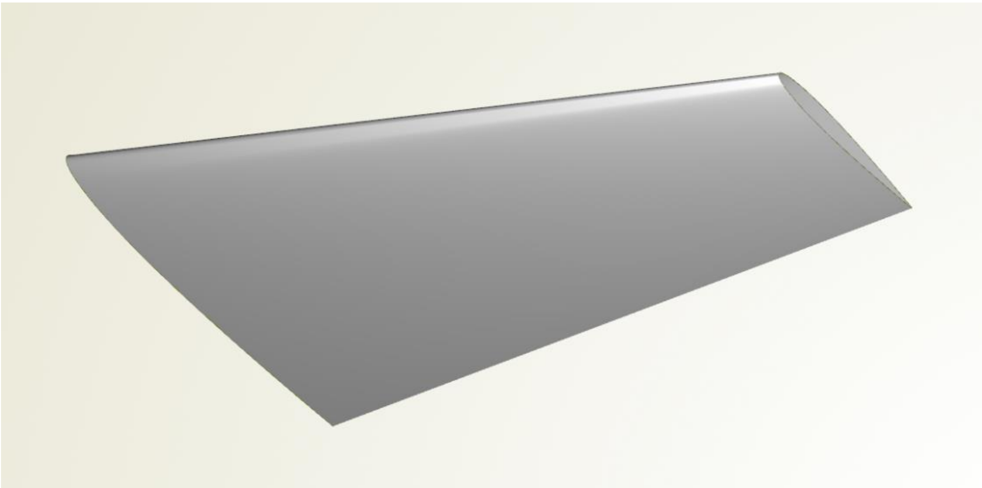
First Modeling Steps

Before you start with this tutorial, you can watch these helpful videos:

- 3D View
- Object Editor and Object Tree Part 1 / Part 2
- Visibility and Filters
- Basics of Parametric Modeling

In this introductory tutorial you will be guided step-by-step to create a parametric model of a simple airplane wing based on the well-known NACA profile. You will learn how to create, manipulate, and parameterize profile curves. The parameterizations will help you define and test geometric variants by changing typical design variables such as angle of attack (AOA), aspect ratio and wing sweep.



The prerequisites for this tutorial are simply to familiarize with the overview of the graphical user interface including object trees, viewing windows, mouse operations, general object types, etc.

By the end of this tutorial you will have a basic understanding of how to create parameterized geometries including curves and surfaces, which can later be used for automatic generation of design variants, CFD integration and design optimization studies.

CAESES Project

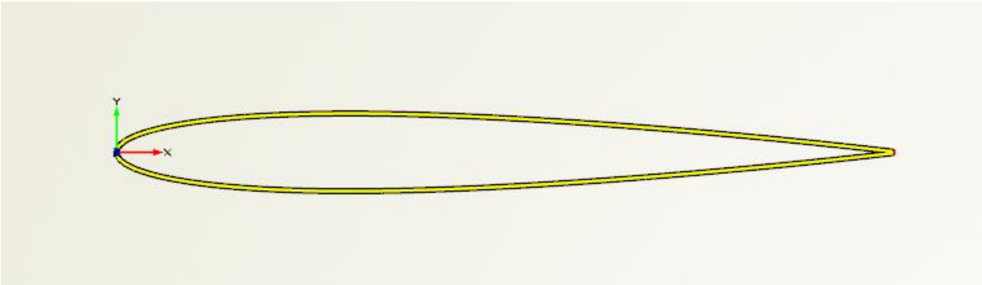
The resulting model can also be found in the section *samples > tutorials* of the documentation browser.

1

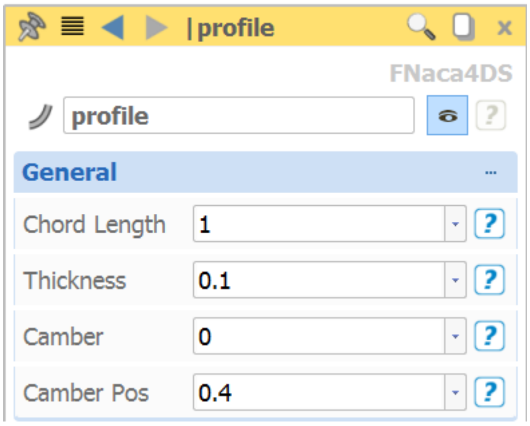
Profile Creation

In this example, the wing shape will be based on the NACA 4-digit-series profile. NACA profiles are commonly used in the industry to form the basis of wings, airfoils and other aerodynamic shapes.

- Set the orientation to the XY-plane by clicking on the “Z”-icon at the bottom of the 3D view window.
- From the *CAD* pull-down menu (or from the *CAD* toolbar) select *curves* > *NACA-4DS curve*.
- Rename the created object to something representative such as “profile”.



You can see the profile now appears in the 3D view and the leading edge is placed at the origin of the global coordinate system. Note that for NACA 4-digit-series curves, the profile is not closed at the trailing edge, which you can confirm by zooming in to that region of the airfoil. We will close it in a later step.



The created profile shape is symmetric. We can modify the profile by changing the *camber* to “0.05” for example. This will change the profile so that the mean camber line is curved.

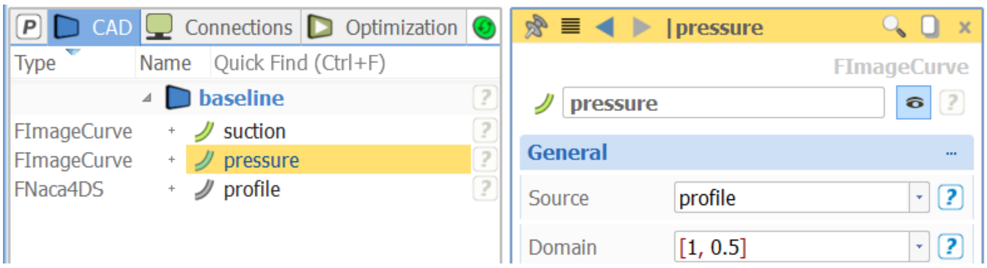
2 Suction and Pressure Side

The top surface of the wing is typically referred to as the suction side, whereas the bottom surface is referred to as the pressure side. In order to vary and manipulate the shapes it is convenient to split the profile curve to form separate curves for the suction and pressure sides.

- ▶ Select the profile curve from the previous step and choose *CAD > curves > image curve*.

Since the profile curve has been selected, the image curve creator checks the selection as a suitable input. In this case, it takes the profile curve and sets it as source curve for the image. Alternatively use the ALT-key, drag & drop or the pull down menu of the editor to enter the profile curve as input for the source.

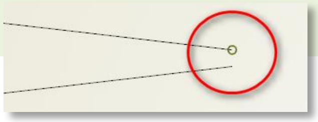
- ▶ For the *domain* field specify a range of “[0, 0.5]”. Change the name of the curve to “suction”.
- ▶ Use copy and paste (CTRL+C and CTRL+V) on the “suction” *image curve.*



- ▶ Change the domain of this copy to “[1, 0.5]” and change the name to “pressure”.
- ▶ Turn off the visibility of the original “profile” curve e.g. by toggling the icon to the left of the object name in the object tree. Now only “suction” and “pressure” are visible.

Remember: All curves are parameterized definitions and the domain of the curve is characterized along the parameter domain of 0 to 1, denoted by the parameter “t”. Thus in the above step, selecting a domain from 0 to 0.5 will select the upper segment of the profile. Also, the direction of the parameter domain is taken into account, and for instance is reversed if you make the selection from 0.5 to 0 within the image curve.

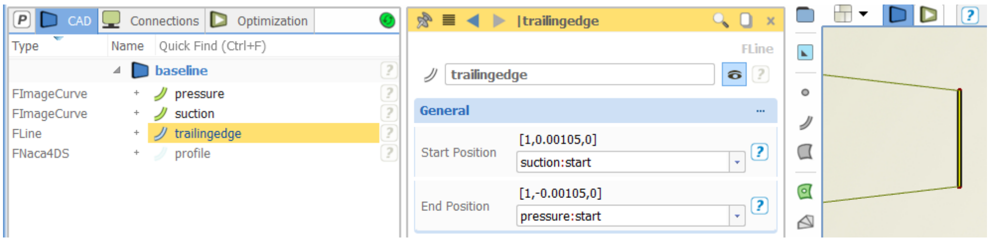
You can toggle the view icon to view the origin of the curve (i.e. t=0): Select a curve, open the category *Display Options* and click onto the icon. With the settings that we used, the origin of both the suction and pressure curves is at the trailing edge, which will become important when generating the surfaces (Step 7).



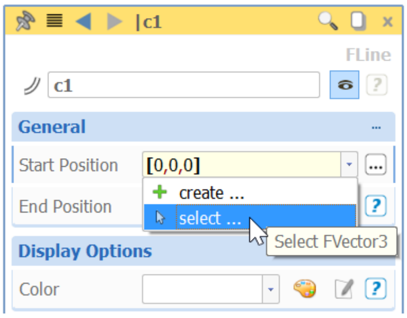
3

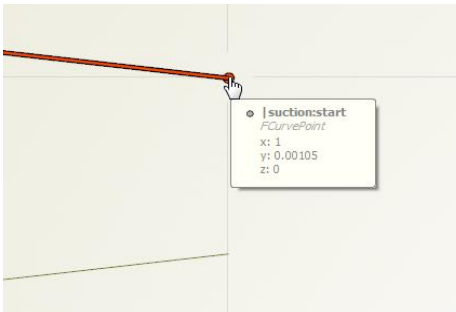
Trailing Edge Creation

As mentioned above, the NACA profile does not have a closed trailing edge so we will now close it manually by creating 2 points, and joining them with a straight line.



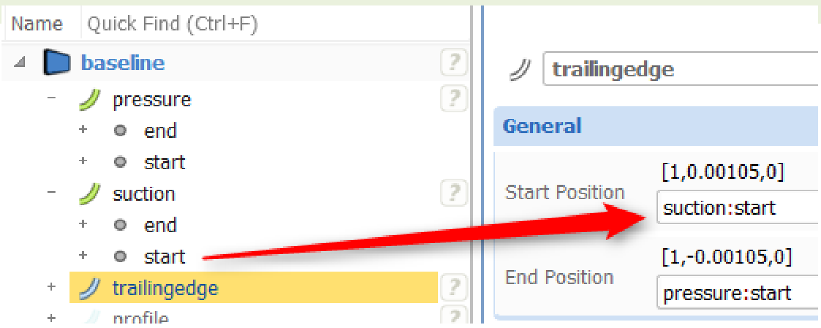
- Create a line via *CAD > curves > line* and name it e.g. “trailingedge”.
- From the pull down menu of the line’s start position, choose the “select” mode.
- In the 3D view, select the start position of the curve “suction”.





- Repeat this procedure for the end position of the line (i.e. select the start position of the pressure side).

✓ Instead of using the interactive “select” mode, you can also choose the start position via the object tree using drag & drop into the editor field.

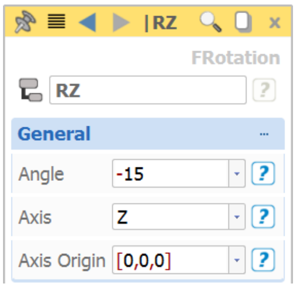


4

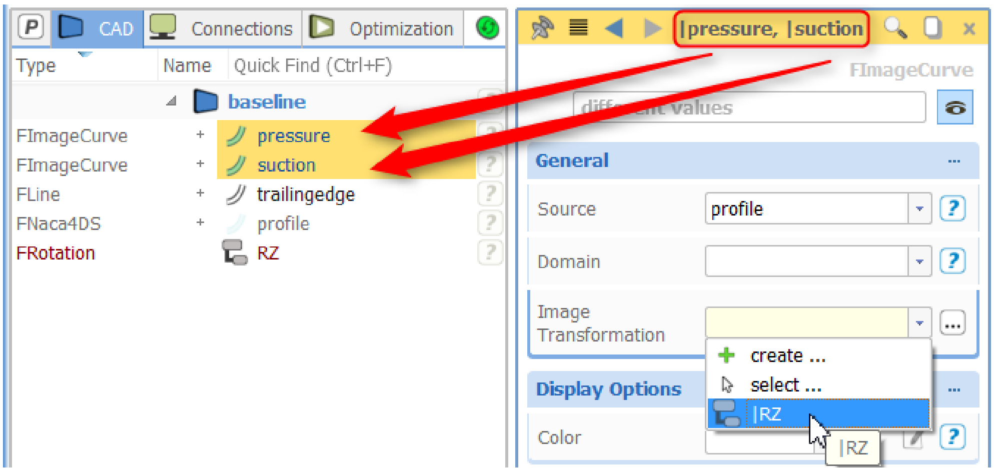
Angle of Attack

The angle of attack of the airfoil section can now be adjusted. In order to do this a rotation will be created:

- Create a rotation via *menu > CAD > transformations > rotation*.
- Rename the new object to “RZ”.
- Set the angle to “-15” and the principal rotation axis to “Z”.
- Select the “suction” and “pressure” curve at once using CTRL and in the *image transformation* field choose “RZ”.



In the 3D view you will see that the curves have rotated by -15^0. Note that the trailing edge is dependent on the curves “suction” and “pressure” so it will update automatically.



✓ Remember: The reference triad at the bottom left of the 3D view shows the orientation and standard rotations, which follow the right hand rule. In many commands the *axes* need to be specified via an index 0, 1, or 2 to represent X, Y, or Z axes. Image curves and images in general have an entry field for transformations. This is not the case for the NACA curve or line objects. That is one reason why image curves were created in step 2.

5

Root and Tip Profiles

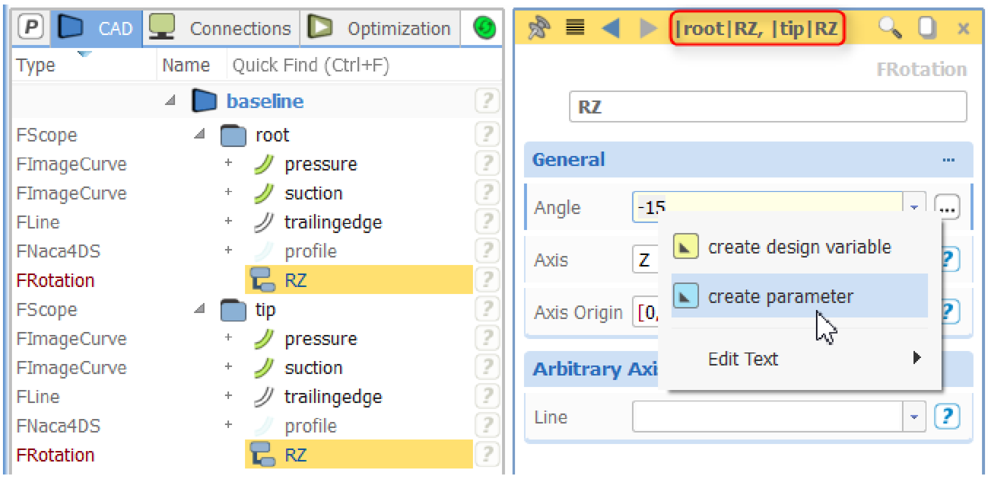
The steps above described the airfoil profile at the root of the wing (i.e. next to the aircraft body). For better object tree organization, we move everything that has been created so far into a separate scope.

- Select all curves and the *rotation transformation* and choose *CAD* > *scope*.
- Rename the newly created scope to “root”.
- Select the “root” scope and copy & paste it.
- Rename the copied scope into “tip”.

Finally, create a parameter for the angle of attack:

- Select the rotation object “RZ” from the root and tip scope while holding CTRL and, while the *angle* value is selected, right click and choose *create parameter.*
- Name the parameter “AOA” for angle of attack and set the value to e.g. ”-10” for a quick test.

The parameter “AOA” is used for both profiles and can be changed manually.



✓ Scopes are like sub-folders in your project that are used to organize and manipulate the object tree in an easy way. For example you can toggle the visibility of the entire folder, copy & paste it, etc. If objects are selected and a scope gets created, all selected objects are put into the new scope automatically as a short cut.

6

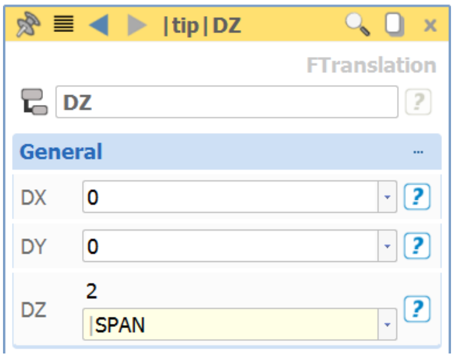
Translate the Tip Profile

As a result of the step above, there now is a new tip profile. Currently the tip is identical and in the same position as the root. Translate the tip profile along the spanwise direction (i.e. z-direction) by creating a new transformation.

- Create a translation via *menu > CAD > transformations > translation*.
- Rename it to “DZ” and set the dz-value to “2”.

Note that this value is relative to the chord length which had a default value of 1. Thus the span is 2x the chord length.

- Move the “DZ” object into the tip scope via drag & drop.
- Add another parameter “SPAN” for the dz-value (see previous step, parameter “AOA”) and set the value of the parameter to “2”.

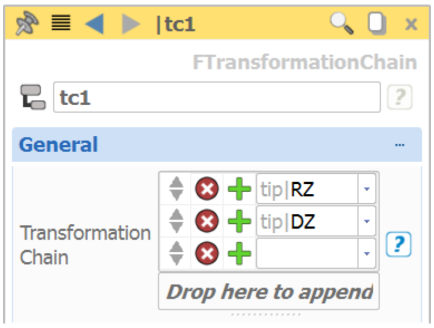


✓ Since we would like to create new objects within the “tip” scope, we can use the middle mouse button to select the appropriate scope “tip”. The folder turns yellow to indicate that it is the active folder and newly created objects will appear in this folder. Otherwise you can always drag & drop objects into any folder at any time.

7 Modify the Tip Profile

The “Tip” profile will now have 2 transformations. Since we can only put 1 transformation definition into the suction and pressure curves *image transformation* field, we need to create a *transformation chain*.

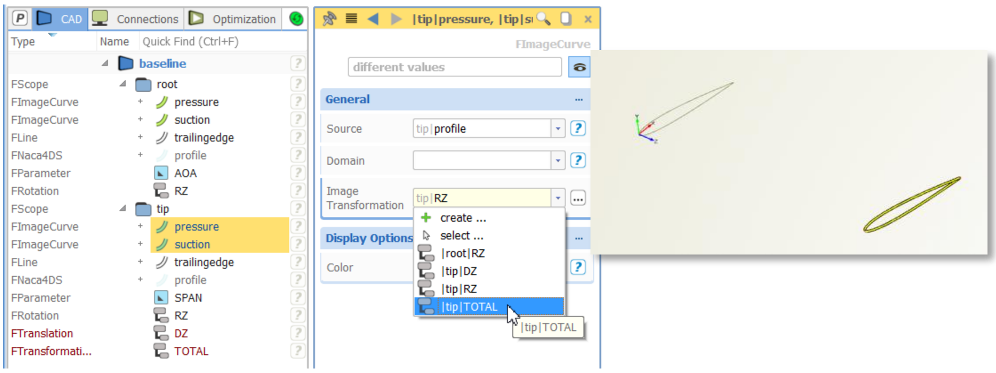
- First, select the rotation “RZ” of the tip scope.
- Secondly, keep CTRL pressed and select the translation “DZ” too.
- Create a transformation chain via *menu > CAD > transformations > transformation chain*.



In the field for *transformation chain* the two transformations are automatically entered due to the previous selection.

- Rename the *transformation chain* to “TOTAL” and move it into the tip scope.
- Select the “suction” and “pressure” curve of the tip and replace “RZ” with “TOTAL”.

The tip profile will now appear at a spanwise offset from the root profile.

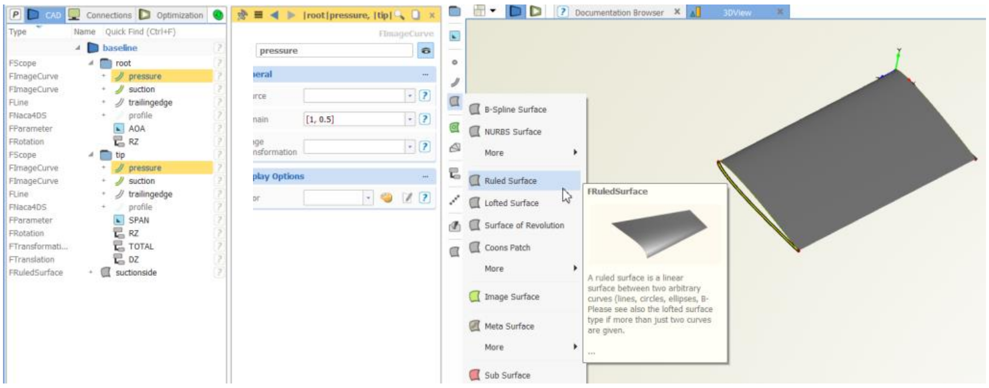


8

Wing Surfaces

Next we will create the wing based on the root and tip profile using a ruled surface.

- Select the “suction” curves from both the “root” and “tip” scope.
- Create a ruled surface via *menu > CAD > surfaces > ruled surface*.
- Rename the new surface to “suctionside”.
- Repeat this with the “pressure” curves.



✓ Surfaces are defined in a parametric space denoted by U and V, in such a way that the normalized surfaces are represented in a U and V domain from [0,1]. For the ruled surface created, the u-direction is along each input curve, whereas the v-direction is in the loft direction, which in this case is from the pressure side curve at the root to the pressure side curve at the tip.

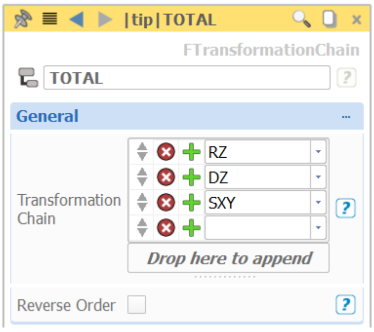
✓ Remember: It is important to always consider the order of input commands and the directions of curve and surface definitions in CAESES. Recall that in step 2 we defined the image curve’s domain to be [1,0.5] which means that the curve runs from the trailing edge of the original NACA curve at t=1 to the leading edge at t=0.5. If we reverse the order to [0.5,1] the surface generation would be done incorrectly. Try to change the domain to see it yourself.

9 Spanwise Variations

So far, you can change the angle of attack and the spanwise length. Next we will change the model to include variations along the span of the wing. For example, aircraft wings typically have shorter and smaller profiles at the tip, compared to the root profile.

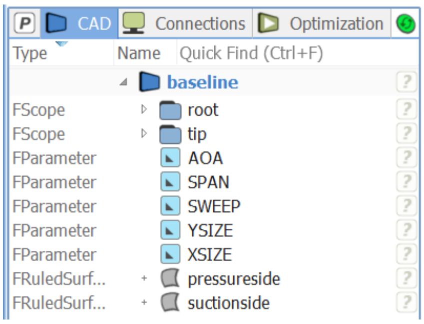
- Choose *CAD* > *transformations* > *scaling* and rename the object “SXY”.

Since the profile was created in the XY-plane you can for example make the chord length and thickness half of the value at the root by entering “0.5” for *factor X* and *factor Y*.



- The scaling must be added to the *transformation chain* “TOTAL” object of the tip scope i.e. “[RZ, DZ, SXY]” (e.g. drag & drop “SXY” from the tree into the list).
- Create parameters again for the discrete values “0.5” for both scaling factors and call them “XSIZE” and “YSIZE”, respectively.

Viewing the wing from the top, you can see that the leading edge is in a straight line. If you want to have a wing with a swept leading edge, then you can do so with another transformation.



- Go to the *CAD* and select *transformations* > *translation*, and rename the object “DX”.
- For the dx-value enter “0.5” so that the tip profile gets shifted in the positive x-direction by 0.5.
- Create a parameter “SWEEP” for the dx-value.
- Add the new “DX” transformation to the “TOTAL” definition: i.e. “[RZ, DZ, SXY, DX]”.
- Move the transformations “SXY” and “DX” into the tip scope.

✓ Remember: The order specified in the transformation chain is important because the transformations are in relation to the global coordinate system. If you change the order of the transformations then you will get completely different results.

10 Conclusion

This introductory tutorial outlined a quick and easy method to create a parametric model of a wing. By changing the parameter values, it is easy to modify the profile, chord, span, angle of attack, sweep, etc. Further parameters and transformation can be added to make the wing parameterization more complex. The variations along the span can be changed with non-linear functions as well. The procedure utilizing functional variations will be described in advanced tutorials which will outline functional curves, *curve engines*, and *meta surfaces*.