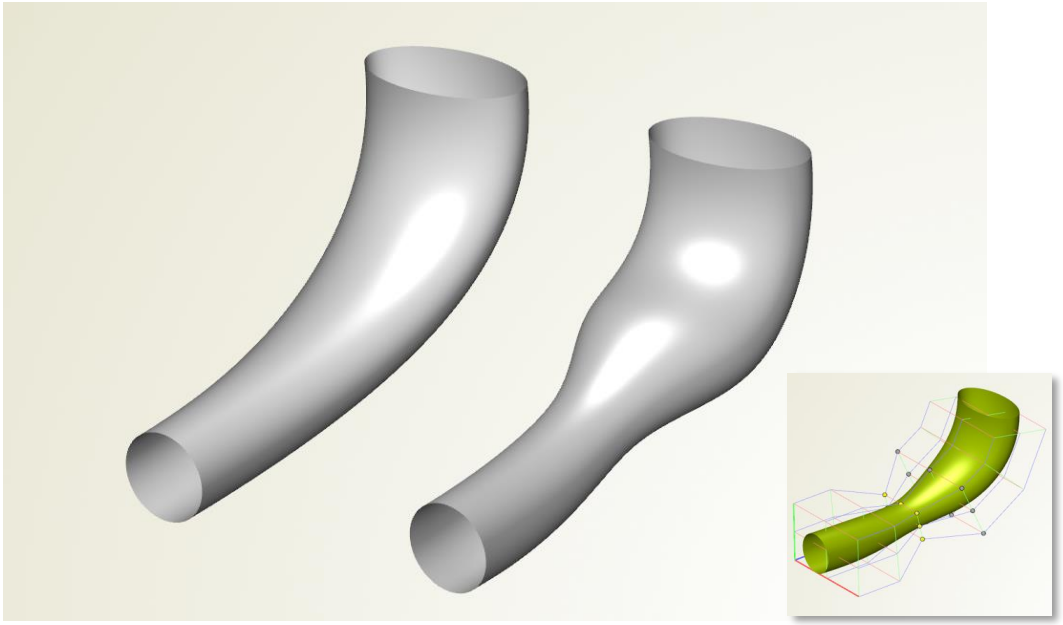
Free Form Deformation

With free form deformation it is possible to vary the shape of your geometry in an intuitive manner with just a few clicks. This tutorial will guide you step-by-step through the creation of a simple free form deformation. First we will create a deformation box around the geometry, and then set up some different operations for the deformation.



If you like to create the start geometry by your own instead of loading it from the samples, you can start with the "Sweep Transformation" tutorial before doing the free form deformation.

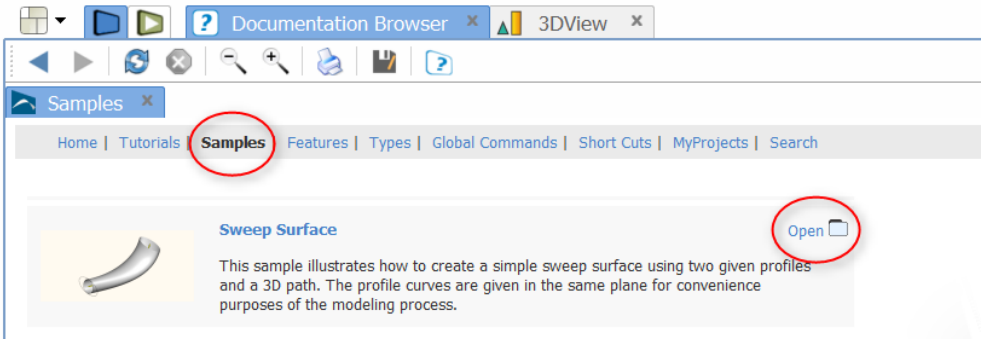
CAESES Project

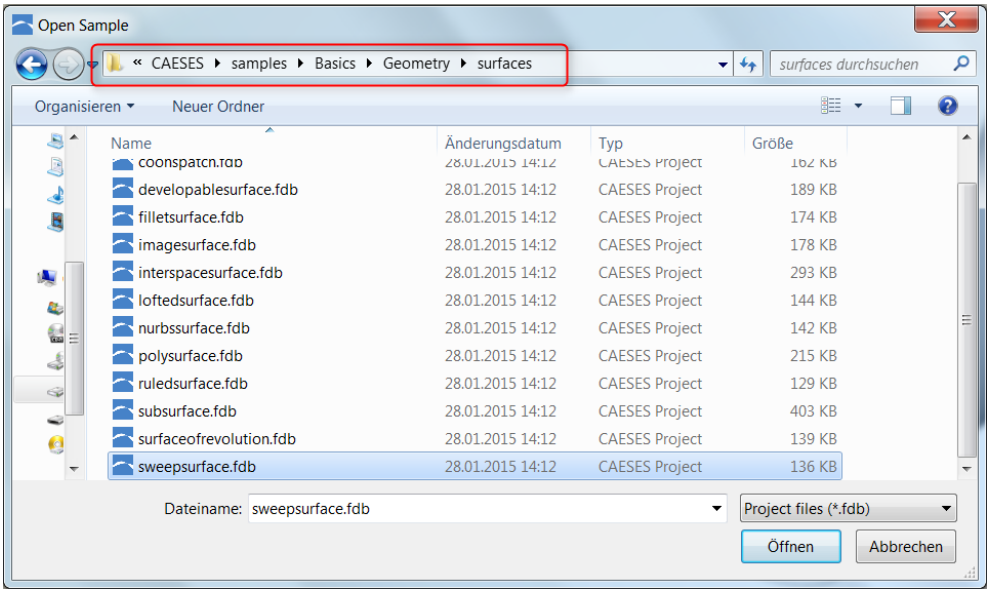
The resulting model can be found in the section *samples* > *tutorials* of the documentation browser.

1 Let's Get Started

In this step we will open the Sweep Surface sample and use this project file as starting point for this tutorial.

- Choose *file > open sample.*
- Open the project via *basics > geometry > surfaces > sweepsurface.fdb.*
- Save a copy of this project via *file > save project* so that we do not modify the original project file.
- Rename the sweep surface to "original_sweep".

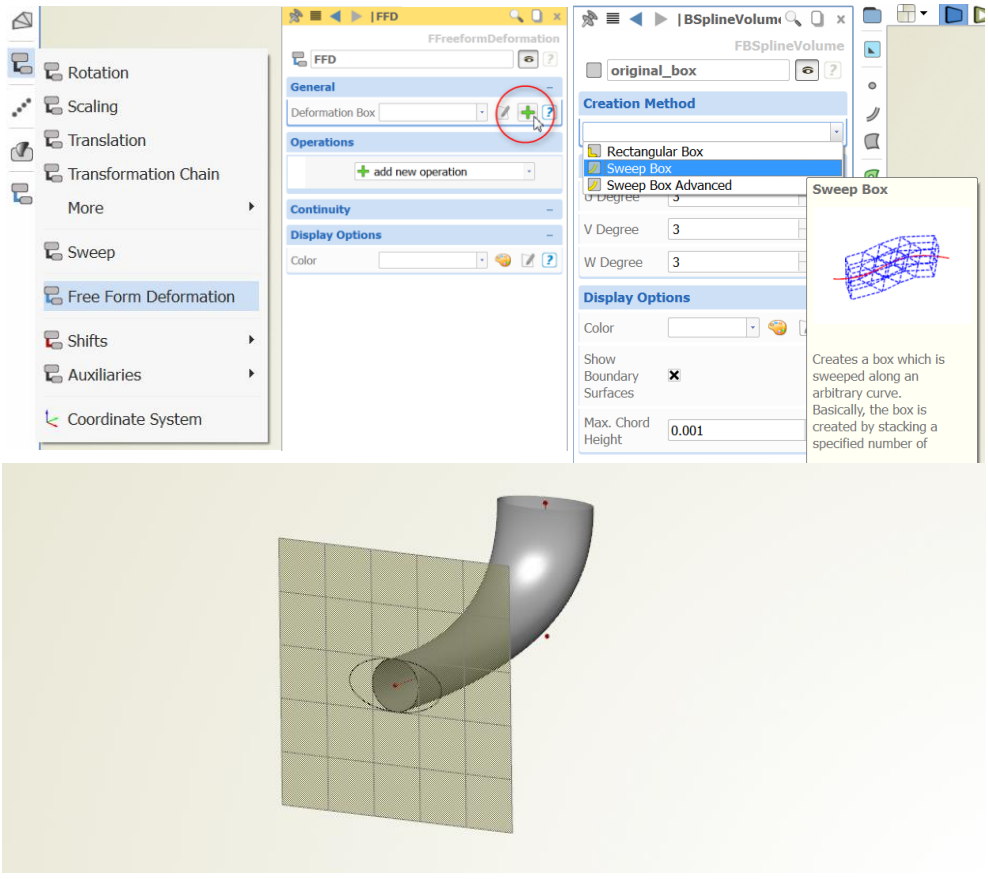




2 Deformation Box Part 1

In this step we will create a deformation box around the sweep surface. First we have to create the free form deformation, which then will help us to get such a deformation box (more accurate, in CAESES it is called a BSpline volume). After setting up the box, we will go back to the free form deformation.

- Choose *CAD > transformations > Free Form Deformation.*
- Rename the new object to “FFD”.
- Click on the green “+” button to create a new *bspline volume.*
- Rename the volume to “original_box”.
- From pull-down menu of the attribute *Creation Method*, choose *Sweep Box.*



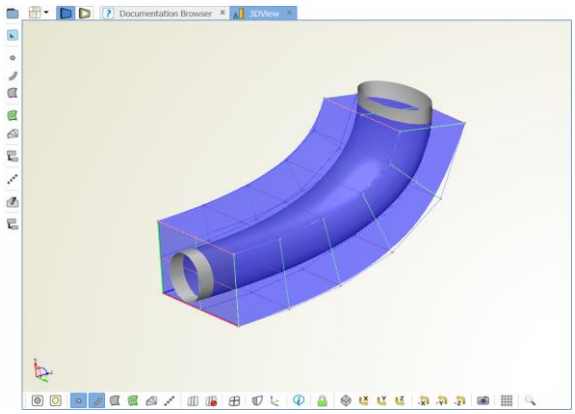
3 Deformation Box Part 2

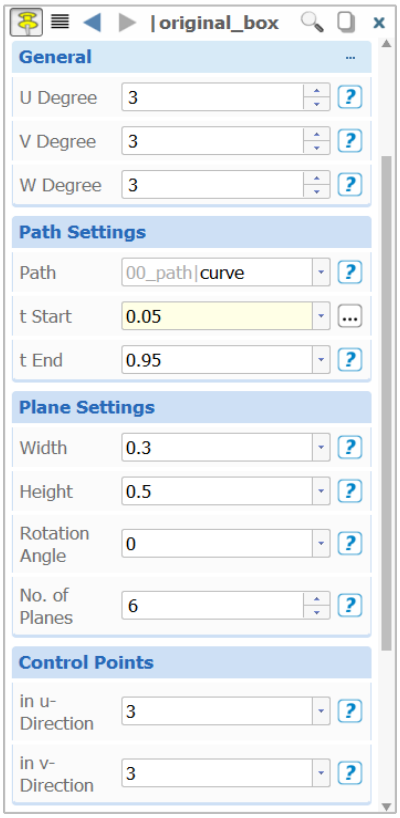
In this step we configure the box so that the target surface gets reasonably surrounded by it.

- Drag & drop "00_path|curve" into *Path*.

Set the values as follows:

- *t Start* to "0.05".
- *t End* to "0.95".
- *Width* to "0.3".
- *Height* to "0.5".
- *Number of Planes* to "6".
- *Number of Control Point in u-Direction* to "3".
- *Number of Control Point in v-Direction* to "3".





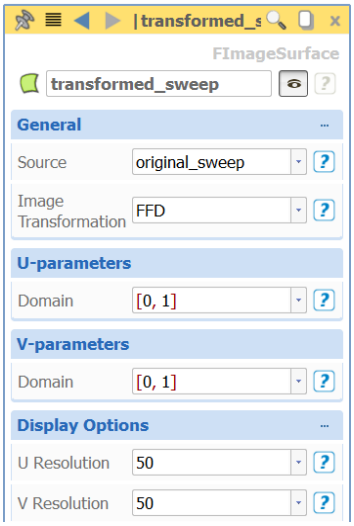
- Set the "*original_box*" to invisible – we will now continue with the free form deformation object.

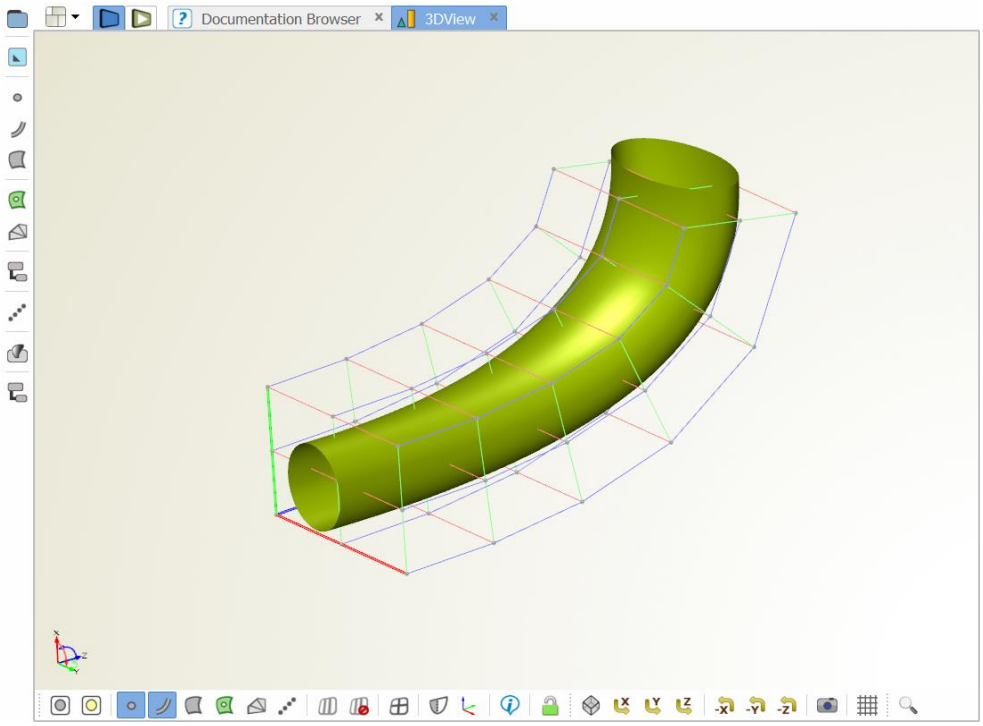
✓ The deformation box should go along a centerline, like the sweep path in this example, or surround your whole geometry to prevent buckling after the deformation. We will later set continuity conditions for the boundaries of the box.

4 Image of the Sweep Surface

For changing the shape of the sweep surface, we need to make an image of the initial surface.

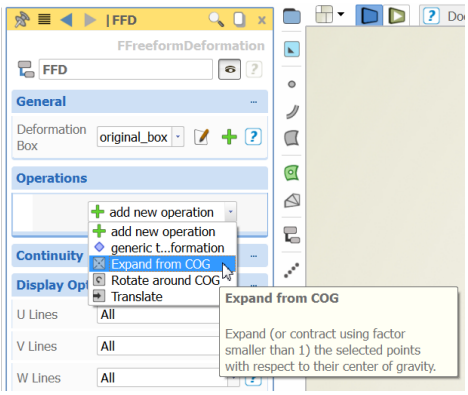
- Create an image surface of "original_sweep" via *CAD > surfaces > imagesurface.*
- Rename it to "transformed_sweep".
- Set "FFD" as *image transformation*.
- Increase the *U* and *V resolution* to "50".
- Set the "original_sweep" surface invisible.





5 Free Form Deformation Part 1

In this step we will setup the continuity conditions and add operations to deform the geometry.



- Select the free form deformation "FFD".
- Click on *add new operation* and choose *Expand from COG*.

Now you can see all selectable points for the operation. We will change the continuity for the boundary conditions of the deformation.

- Click on the *continuity* tab to show these additional options.
- Choose *Tangent* for *w min (blue)* and *w max (blue).*
- Filter the points, curves and surfaces to see all points (lower buttons at the 3D view).

✓ The thick colored lines on the edges of the deformation box represent the u, v and w directions, and this also indicates the origin of the box. This local coordinate system refers to the deformation box and not to the global x, y, z-system.

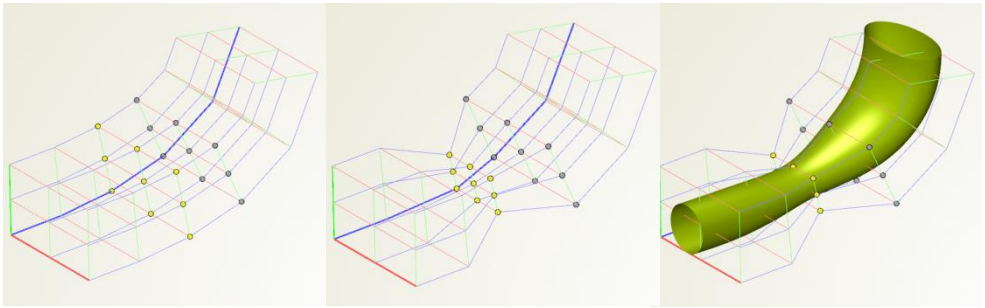
6 Free Form Deformation Part 2

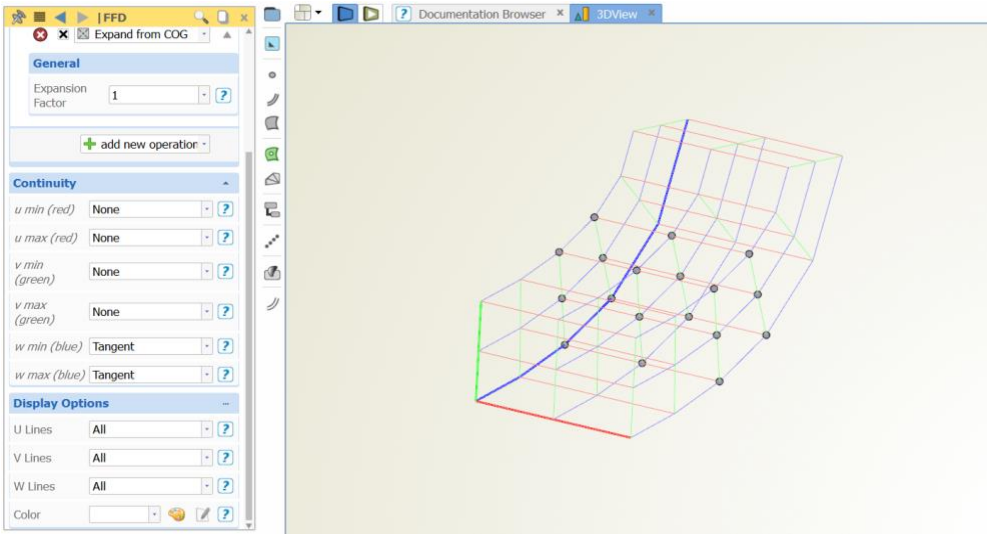
We continue with the free form deformation setup.

- Select all the points of the first plane by clicking on them like shown in the picture below.

When you click on the points, they will be activated for the operation and turn yellow. Grey points will not be included in the operation.

- Set the *Expansion Factor* to "0.5".
- If you like, deselect the surface filter to take a look at how the surface has changed.



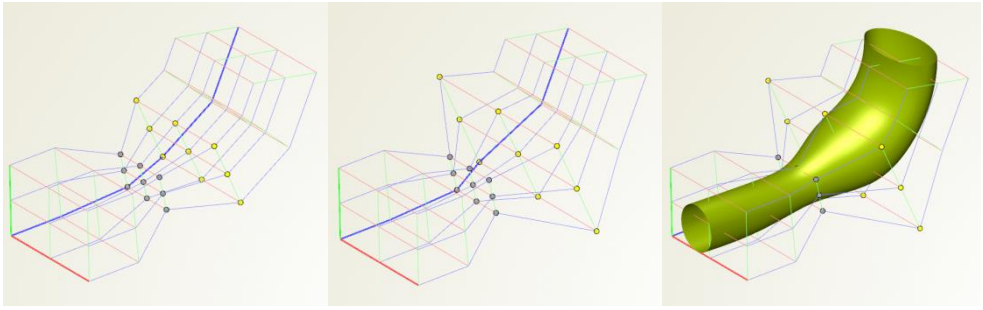


✓ By selecting all points at once, you can switch the selected points for the operation.

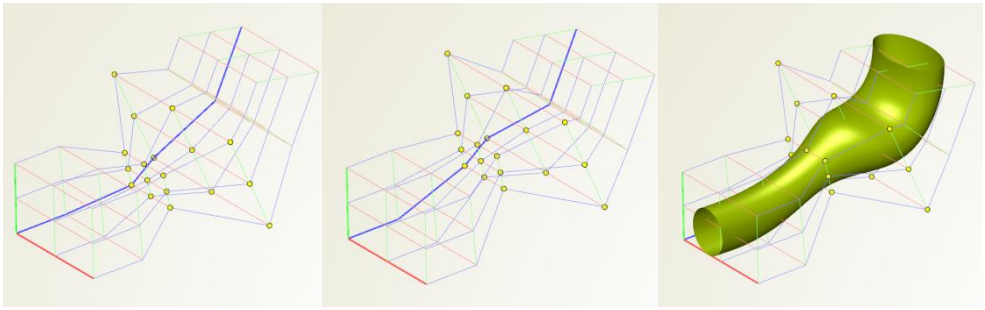
7 FFD – Add Two Operations

Now we will add a second operation to the free form deformation.

- Create a new operation *expand from COG*.
- Select the points of the rear plane.
- Set the *Expansion Factor* to "1.5".



- Create a new operation *generic transformation.*
- For the argument transformation, create and set a new translation.
- For the translation, set *dx* to "0.1".
- Select all points.



- Make the "FFD" transformation invisible so that you receive the following view:

✓ There are also other continuity conditions like *Position* and *Curvature*. You can change the conditions and selected operation points to see what influence it has for the deformation of the geometry. Any geometry outside of the box is not included into the deformation, hence setting useful boundary conditions is important for a solid geometry.

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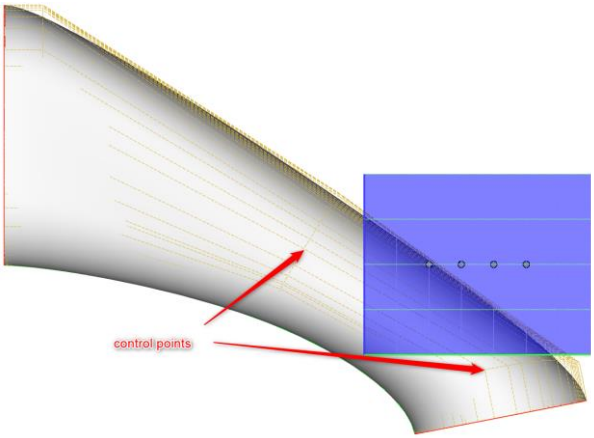
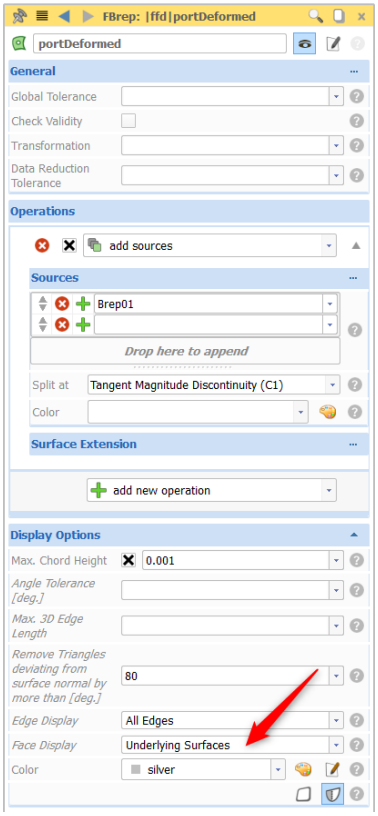
Appendix: Applying Free Form Deformations to Breps

FFD which are applied to Breps, do not transform the surface itself. It moves the underlying NURBS control points, which define the geometry. This method makes it more robust and fast, but in some cases there are not enough control points to achieve the desired transformation. Therefore, we have to add control points, apply the FFD and afterwards remove some control points again.

Visualize the underlying NURBS control points:

- Expand the *Display Options* of the Brep.
- Change the *Face Display* mode to "Underlying Surfaces".

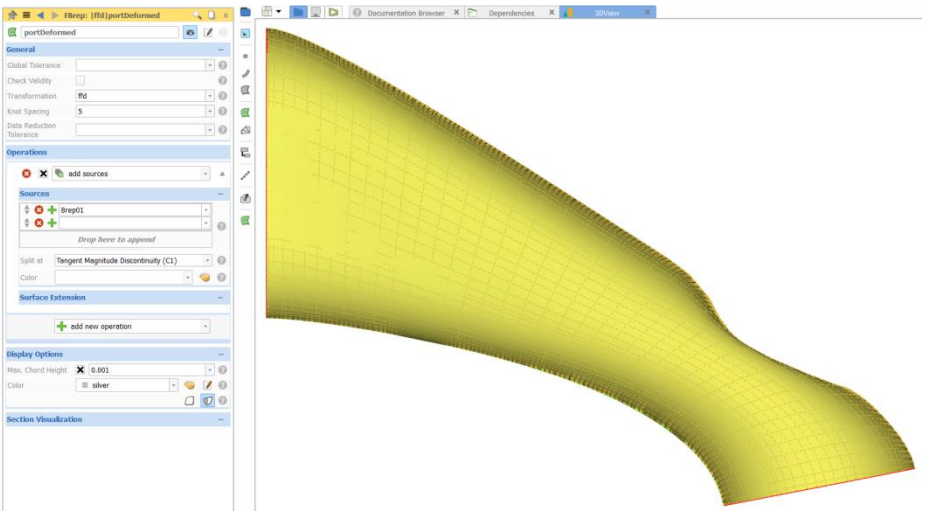




In the image above, you can see that there are several control points in circumferential direction, but only three sections in sweep direction. The blue box of the FFD does not include any control point. That's why there wouldn't be any effect of the FFD on the Brep. Hence we have to add more control points which can be done without changing the shape itself.

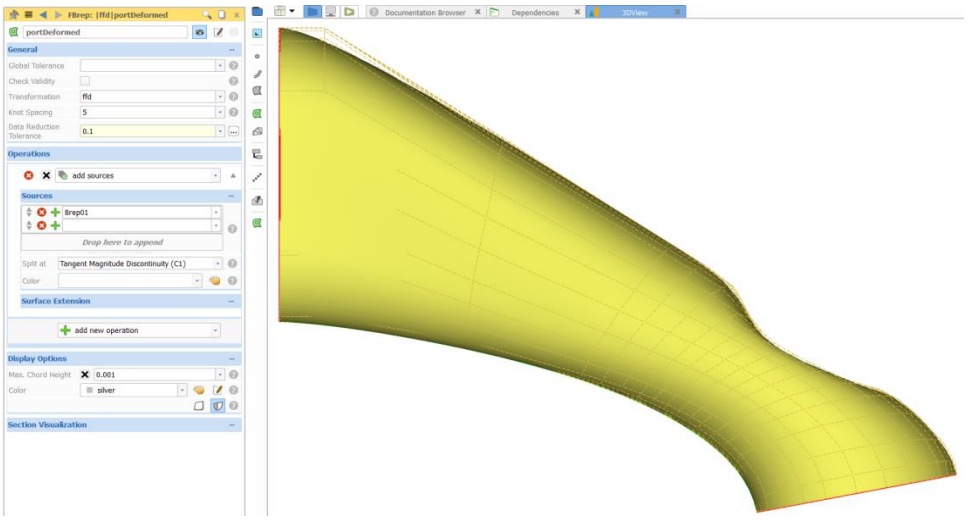
Here is how you add more control points:

- Set the FFD object to the transformation field of the Brep.
- Now a new field appears with the name of “Knot spacing”.
- Set an appropriate value. Note that this value is an absolute length.



In the image above you can see that now the knot spacing is denser than before and the applied FFD has a smooth effect on the geometry. After we applied the transformation, we can now reduce the number of control points again, in order to enhance the processing speed of the Brep for further operations. Here is how you reduce the data again:

- Set the *Data Reduction Tolerance*: It will reduce the amount of control points so that the geometry deviation is less than the specified tolerance value. I.e., large values might change your geometry.



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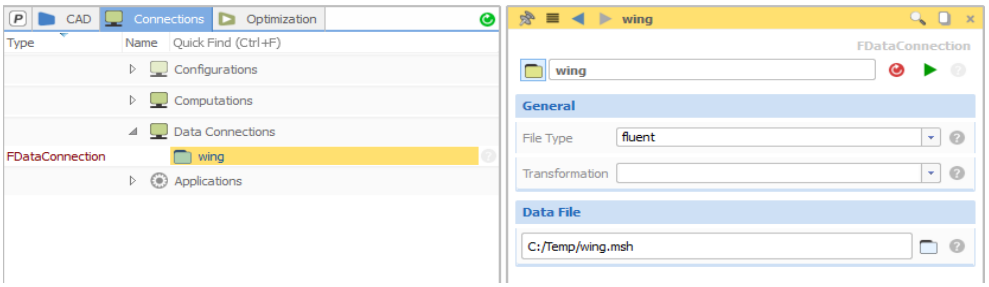
Appendix: Volume Meshes

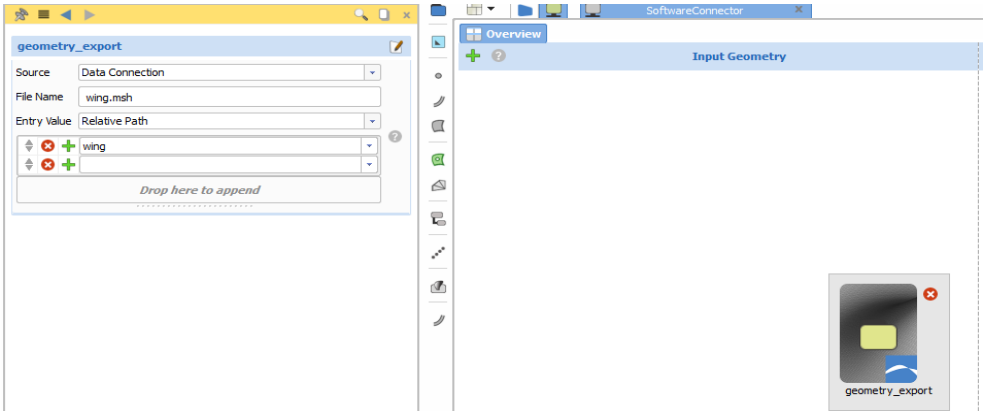
FFD can also be applied to volume meshes, to either manually change the mesh, or to run fully-automated shape optimization. Currently, only ANSYS Fluent meshes are supported, but further formats are under development. If you need a specific format, please feel free to get in touch with us (info@friendship-systems.com).

In order to automate the deformation process, you have to do the following steps:

- Create a data connection via *file > data connection > ANSYS Fluent*.
- In the connections tab, a new object shows up where you can set the mesh (*.msh).



- Create a software connector via *connections > software connector*.
- Create a new input geometry. For this entry, choose “data connection” as source, set a name and drag & drop the data connection into the list:



- Configure the software connector with all other information that is required to run the external tool chain (e.g. the scripts to run the CFD analysis in ANSYS). See the software connector tutorials for more information.
- In order to automatically change the mesh during optimizations by means of a FFD, set this FFD object at the data connection in the object tree.