

Creation of 3D geometry from topology optimization results, for thin-walled and casted parts

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1 Introduction

The use of topology optimization gives us the capability to create an optimal design for a product, taking into consideration a set of predefined constraints, under certain load cases to which it is subjected. However, its results exhibiting jagged and/or no well-defined boundaries, lead into difficulties, regarding the interpretation of these results into proper CAD geometry, which subsequently could be used downstream in the CAD based product development process or could be parametrized and further optimized. Moreover, the manufacturing process, that will be followed to build the parts or the structure, adds an extra variable and increases the degree of difficulty to the task of creating adequate CAD geometry.

Based on the above, we have distinguished two main techniques for performing this interpretation of topology optimization results into CAD geometry and we have developed the corresponding procedures based mainly on ANSA functionality.

The first one concerns mainly structures built up by thin-walled parts, e.g. vehicle BiW, or parts produced by extrusion, and the second parts manufactured by casting, or even by additive manufacturing.

2 Creation of CAD geometry for thin-walled structures and extruded parts.

2.1 Cross section and library of cross sections.

The basic entity for the creation of 3D geometry for this kind of structures is the cross section, which is supported in ANSA as a distinct entity. It can be created either from scratch by using 2D curves (Fig.1.a), or from already existing model/s by performing a “Plane Cut” on it/them (Fig1.b).

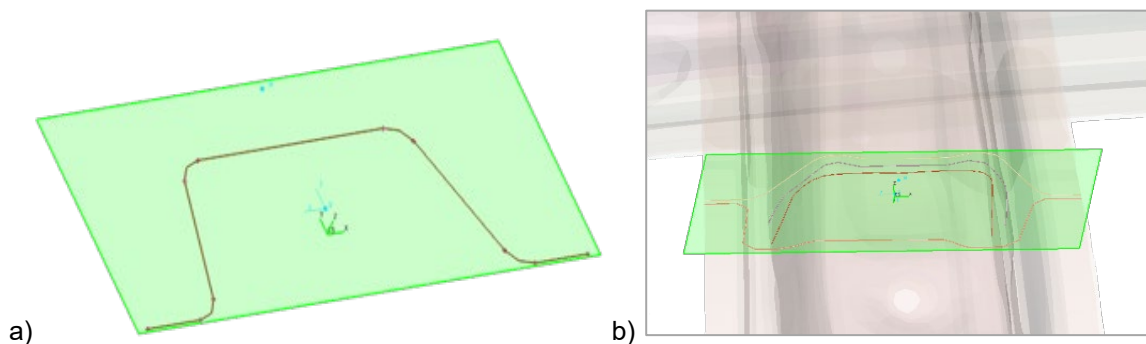


Fig.1: Cross section created by a) 2D curves, and b) by “cutting” an FE Model.

In the Cross Section Tool of ANSA the properties of a cross section (e.g. moments of inertia, area, etc.) can be calculated and stored as its attributes.

Furthermore, both individual cross sections and groups of cross sections with high degree of similarity, or from a certain area of the vehicle, e.g. the b-pillar, can be saved into a library, so as to be available for subsequent use. This library offers to the user the capability to store all his legacy cross sections, with their properties, in one database, in order to be able to choose from them in the concept phase of new designs (Fig. 2).

2.2 Parametrization of a cross section.

Each cross section can be parametrized in ANSA so that it can easily be adapted to the required size and/or be able to function properly in the context of a parametrical optimization regarding its geometry. Potential types of parametrization could be e.g. the width and the height of a cross section, or the width and the position of its flanges (Fig. 3).

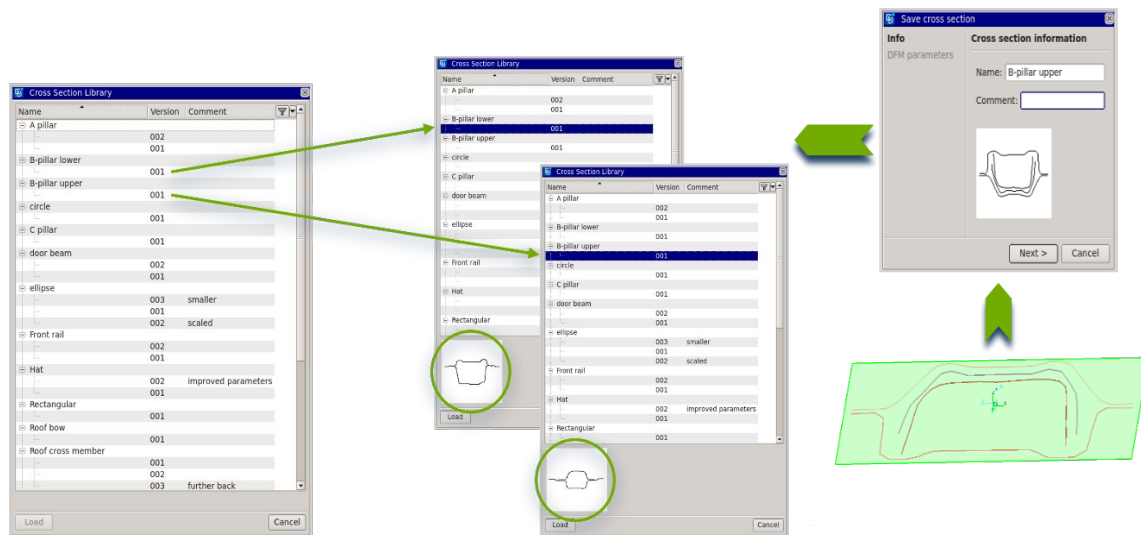


Fig.2: Cross section library.

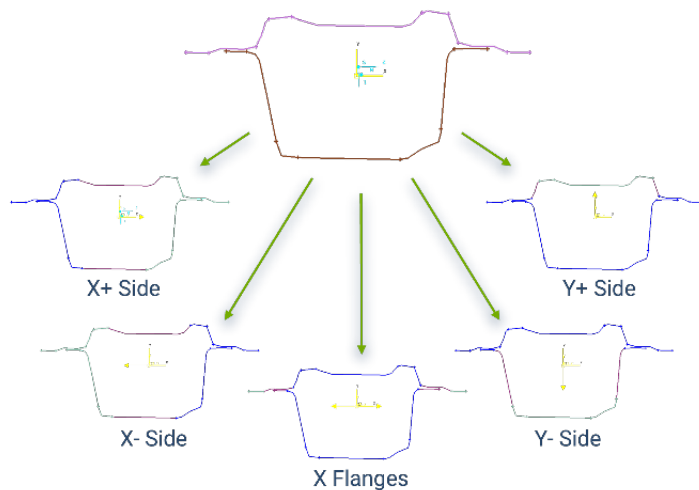


Fig.3: Parametrizing a cross section.

2.3 Creating the CAD geometry.

The example that we will use to exhibit the creation of the geometry is the b-pillar area of the results of a full BiW model subjected to topology optimization under multiple crash load cases (Fig. 4).

By selecting a cross section from the corresponding library, we can position it automatically upon the organic mesh model, adjust its orientation and size, and finally create the geometry in the form of 3D faces between the positioned cross sections (Fig.5).

In the same way - with the aid of cross sections - we can create automatically the geometry of the top part of the b-pillar, and subsequently connect automatically the two pieces, by creating a transition geometry between the two pieces, thus concluding the design of the whole b-pillar (Fig. 6).

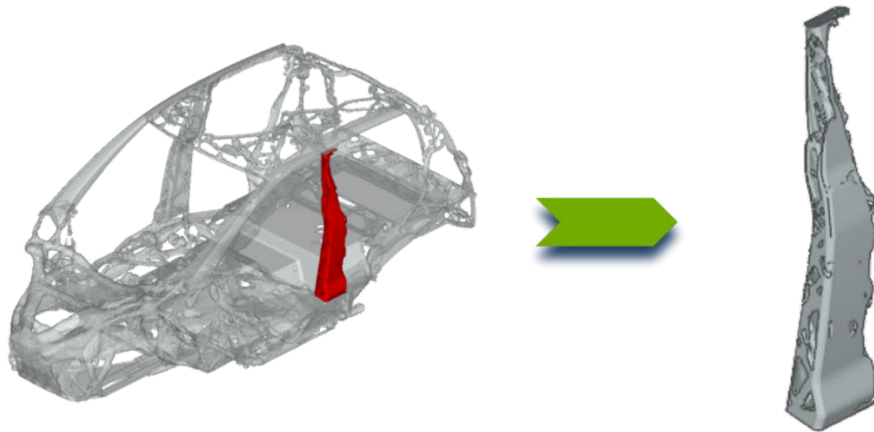


Fig.4: Test case : b-pillar area of the topology optimization results of a vehicle's BiW.

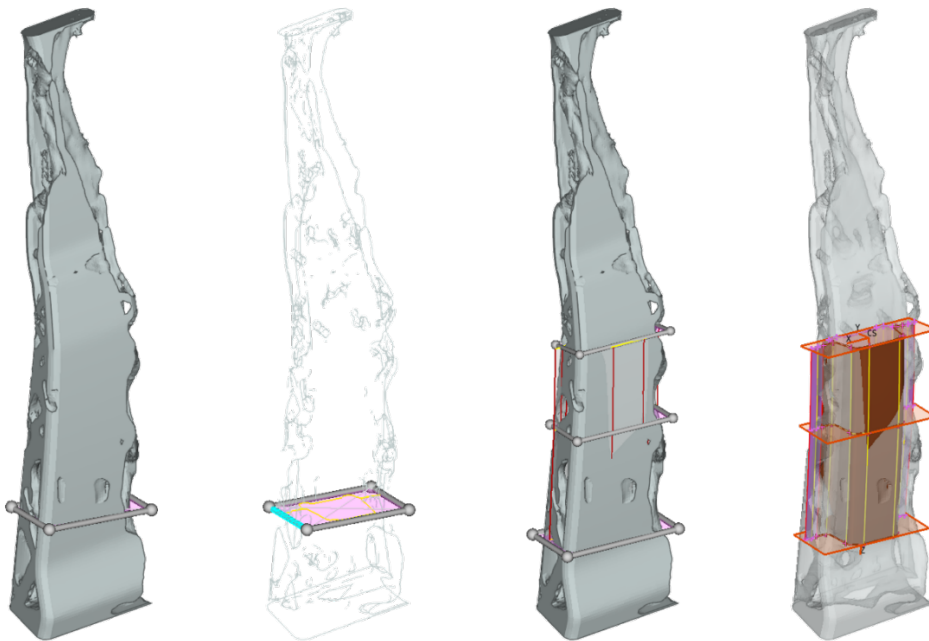


Fig.5: Positioning the cross sections on the organic mesh and creating CAD geometry.

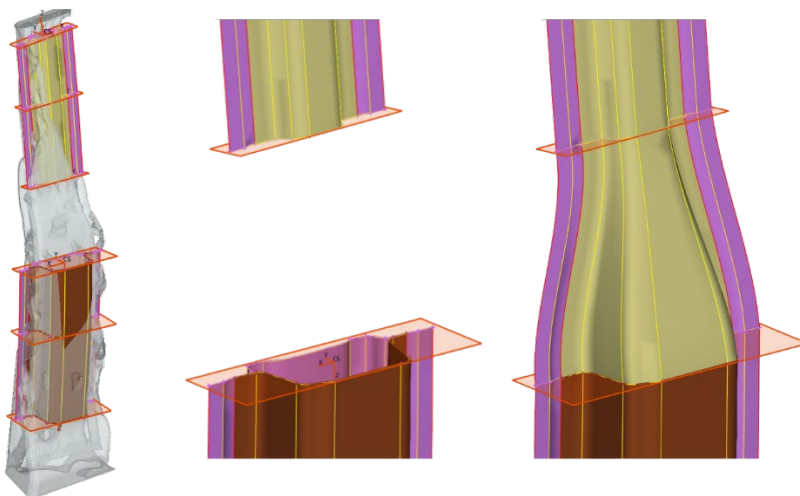


Fig.6: Creating the transition area geometry between the top and bottom part of the b-pillar.

2.4 Editing and fine-tuning of the created CAD geometry.

The geometry created in the previous steps can be edited with the appropriate tool, in order to capture better the “organic mesh” model shape, or to fine tune the transition area from the upper part to the lower. The advantages of this approach are : i) the geometry is updated, with no need to create it from scratch, ii) the visual inspection of the changes performed is always easily available by the “regeneration” of the faces, and iii) the tool greatly facilitates management and further processing of the big amount of cross sections created in the model (Fig. 7).

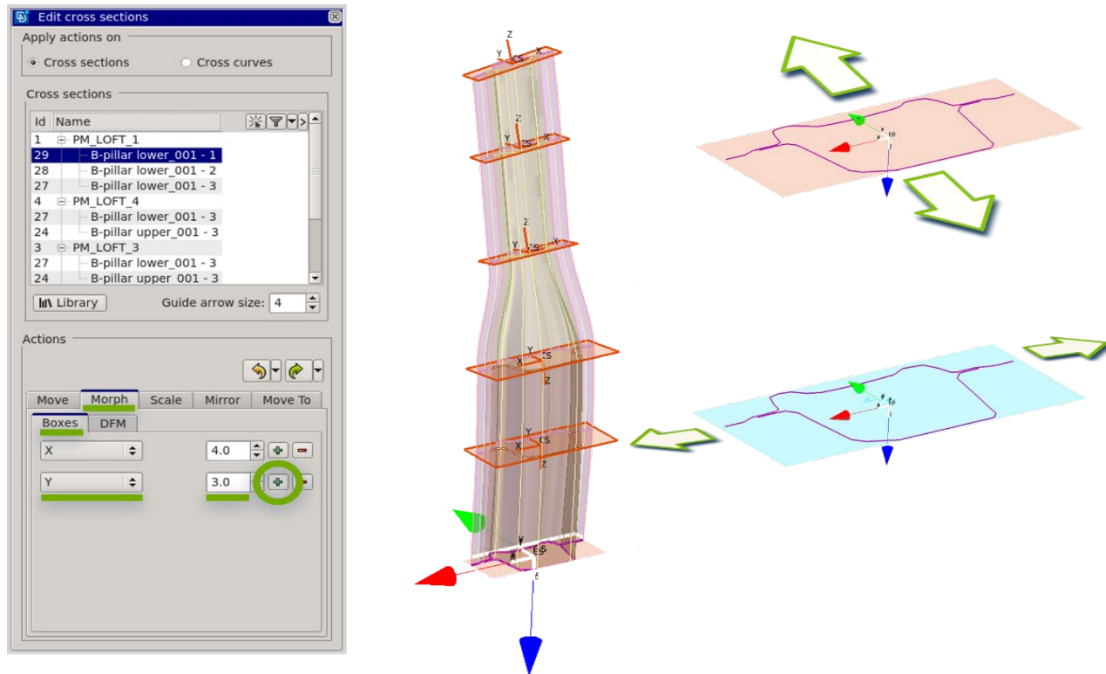


Fig.7: Tool for editing/altering the geometry by changing its cross sections.

2.5 Changing the configuration of a cross section.

The configuration of a cross section can be altered easily using simple ANSA functionality. A task example, in this case, is the addition of a reinforcement part to the already created b-pillar geometry with our pervious process. We just need to alter only one of the cross sections out of which the geometry of the part is defined (Fig. 8.a). The rest are updated semi-automatically, and by “regenerating” the original b-pillar geometry, we end up with a b-pillar reinforced with a new inner part (Fig. 8.b).

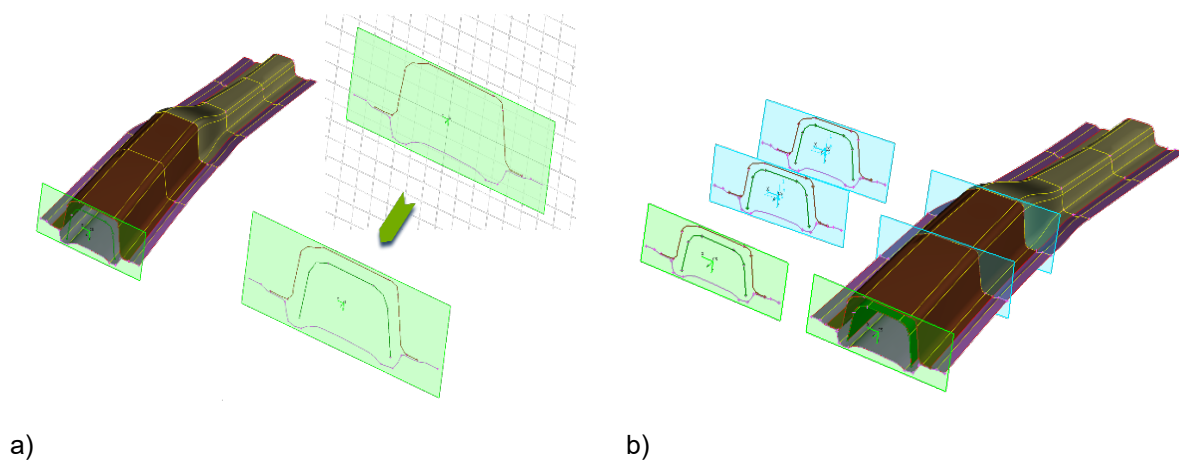


Fig.8: a) Adding a reinforcement to the b-pillar cross section, b) “regenerating” the CAD geometry.

2.6 Example of a BiW geometry.

In the following picture you can see the results for our BiW using the above process and tools.

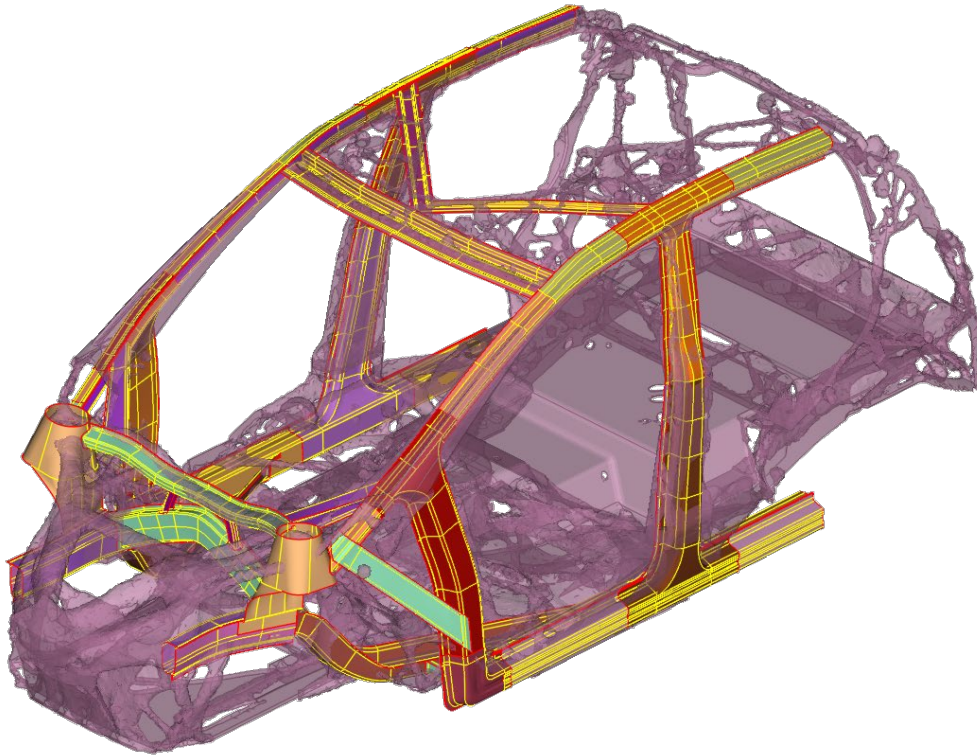


Fig.9: CAD geometry of a BiW created upon the results of topology optimization.

3 Creation of CAD geometry for casted and additive manufactured parts.

The procedure in this case follows a different path, although it can be combined at certain steps with the functionality used in the previous method. The example that will be used in this case is a simple beam. Due to the symmetry of the model we will process just one quarter of it (Fig.10).

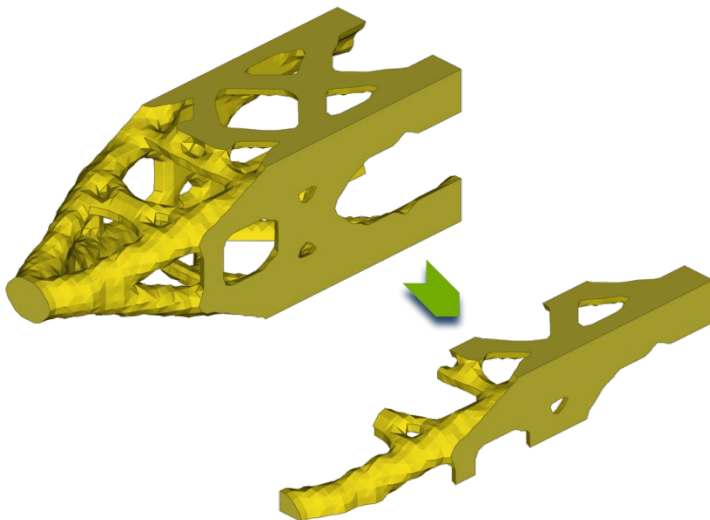


Fig.10: Test case for casted parts : topology optimization results of a beam-like part.

3.1 Smoothing the original surface of the topology results model.

As we can notice in the previous Fig. 10, the tessellated surface of the model is heavily irregular and jagged. The smoothing takes place with the “Sculpting Tool” of ANSA where the intensity of smoothing and the size of the affected area can be controlled (Fig. 11).

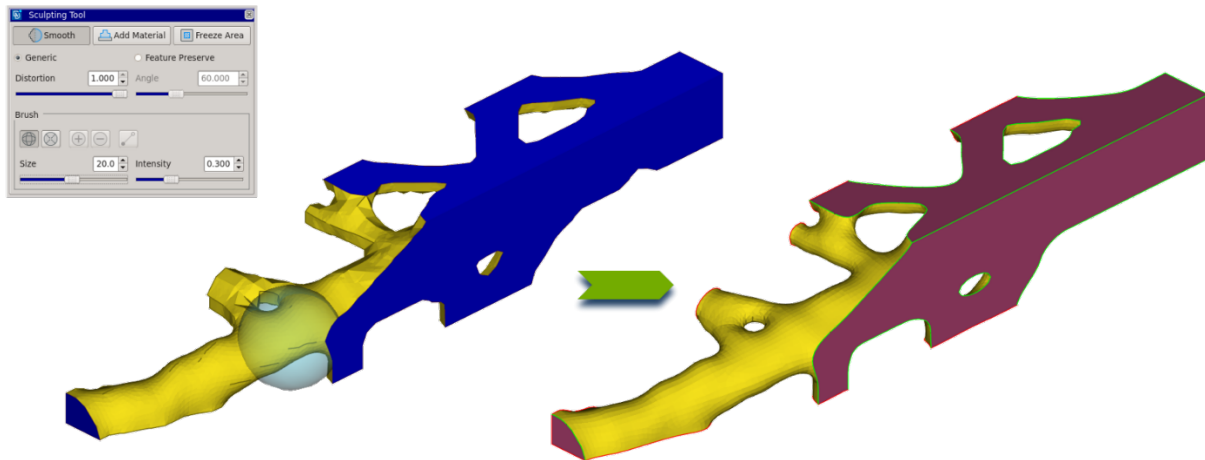


Fig.11: Smoothing the tessellated surface by using the “Sculpting Tool” of ANSA.

3.2 Fine adjustment editing.

In case the results of the previous step are not satisfactory, we can use either geometry-creation and morphing techniques of ANSA or the cross-section tool of our first methodology, in order to achieve the desired shape (Fig.12).

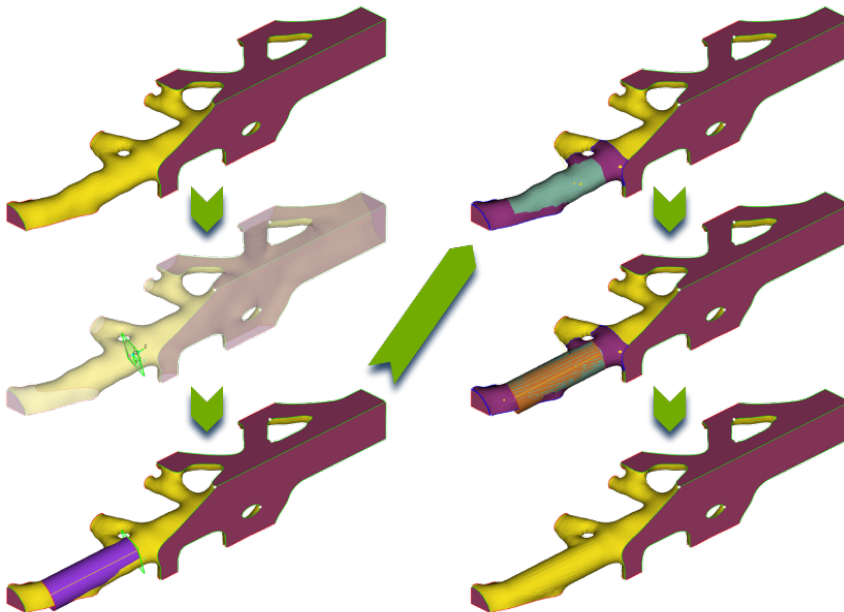


Fig.12: Manual editing of the smoothed surface using ANSA techniques.

3.3 Split the model into patches.

The final smoothed model is split into patches by the user, according to his judgement, using simple and easy to use ANSA functions e.g., Plane Cut (Fig.13).

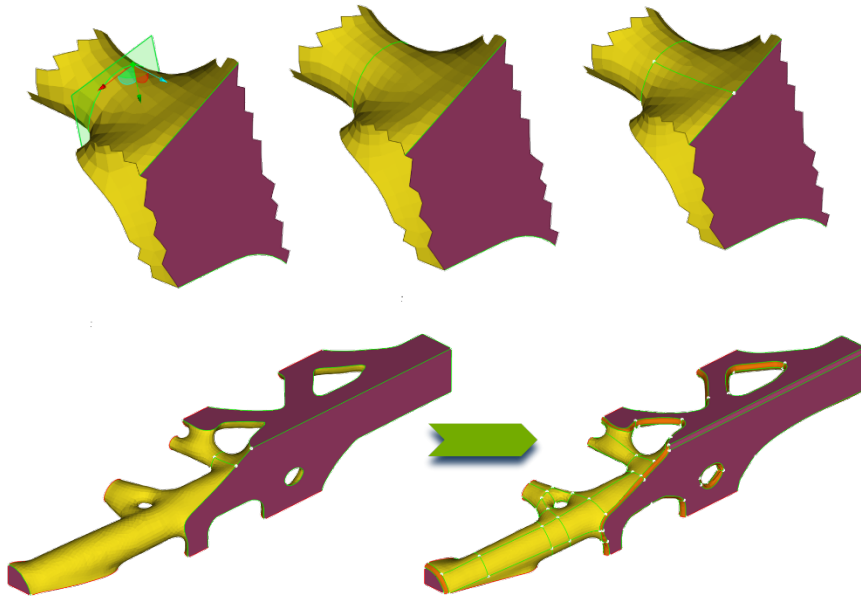


Fig.13: Splitting the model into quad-shaped patches.

3.4 Create the CAD geometry faces.

The creation of geometrical faces from patches takes place, taking into consideration how close the user wants to be the smoothed mesh to the resulting geometry, by using a sampling technique (Fig.14).

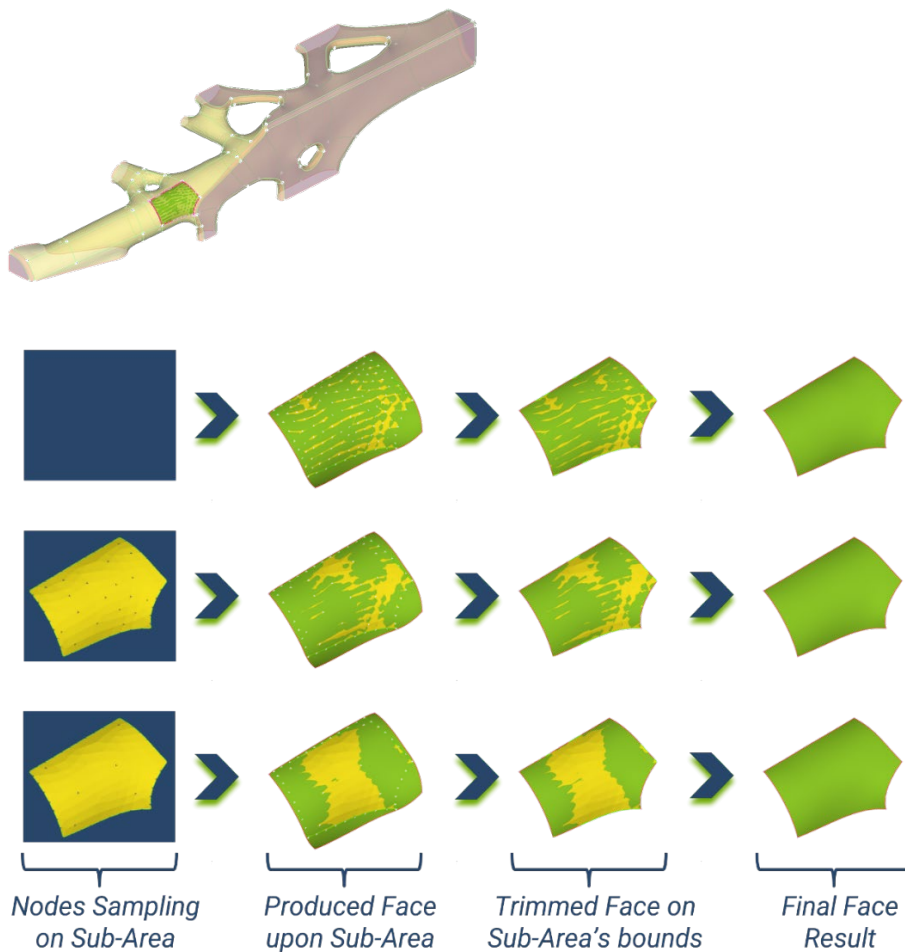


Fig.14: Creating the same face with different node density sampling.

3.5 Final CAD geometry.

After having created the CAD geometry of one quarter of this part, we can create the whole, just by copying it symmetrically with respect to two planes (Fig. 15).

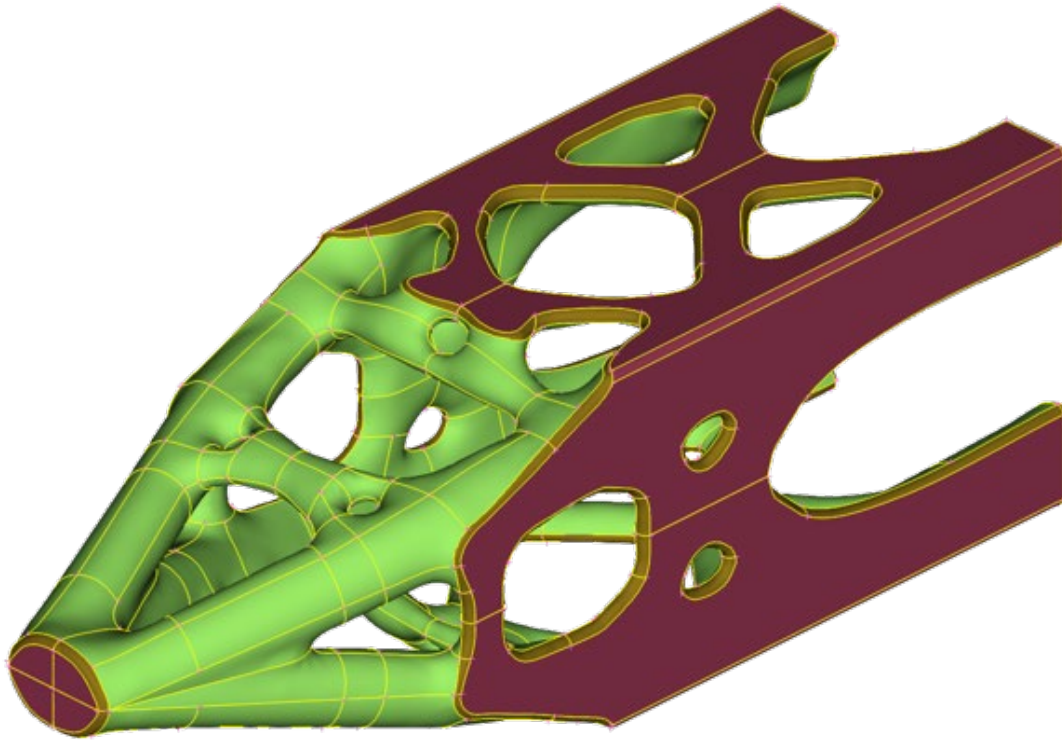


Fig. 15: Final CAD geometry of our test case.

4 Summary.

Based on ANSA standard functionality we have created processes that facilitate the creation of CAD geometry from topology optimization results for the two aforementioned types of structures. Regarding the thin-walled structures, the added capabilities of cross section library and cross section parametrization, and the tool for handling and altering the cross sections participating in the geometry definition, result in a fast and efficient way of creating their CAD geometry. Regarding the casted and additive manufactured parts, the process and recently released ANSA functionality contribute to the solution of the problem. Further development is being conducted towards the full automation of these processes.