Session H2.3

CASE STUDY ON THE FE-MODEL AND GEOMETRY MORPHING IN STRUCTURAL ANALYSIS

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KEYWORDS - geometry morphing, FE- model morphing, morphing, design process, optimization

ABSTRACT - In order to minimize time and resources needed to develop new prototypes, designers use already built models and based on these they continue with the creation of the new one. Again, in order to minimise development cost, old parts, doors, bonnets etc., are modified in order to be used in new prototypes. There are also cases that for completed models some modification are needed in order to meet new requirements, (creation of embosses to control deformation) but minimal or no manual intervention is wanted either for the mesh or the boundary conditions.

This procedure, modifying an existing design in order to develop a new one or to meet specific requirements for some parts, can be achieved using ANSA Morphing Tool. With the morphing tool the engineer is capable of shaping his design according to his needs. Till now, ANSA Morphing Tool worked only on FE-models and in conjunction with the mesh reconstruction/regeneration capabilities of ANSA, it was possible to modify complete models with minimal or no user intervention. The only drawback of this procedure is that since geometry is not included in the morphing, the final shape can not be outputted and reused by the CAD software.

This present paper, ANSA Morphing Tool for geometry is introduced for the first time. The procedure of Geometry Morphing is presented for a number of cases, alongside with FE-model morphing for the same cases, starting from the initial geometry and concludes after morphing to the final model that also includes the new geometric definition which can be used by CAD software.

TECHNICAL PAPER -

1. INTRODUCTION

The creation of a new prototype is a procedure that requires both time and resources. In order to minimize time and the resources spend on it, before a prototype is actually built, a virtual prototype is first created. Using this virtual prototype, the CAE engineer is capable of running a number of tests on it, study its behaviour, and then according to his analysis propose any modifications if needed. Fig. 1 illustrates the complete circle made for a "virtual" prototype in order the initial CAD concept to be finally constructed. After the initial concept the product is designed in CAD. Using a pre-processor like ANSA, the prototype is meshed, analysis dependant forces and boundary conditions are applied and the solver input file is created. Following, the solution is obtained, and the results are analyzed using a post-processor (μETA). In the case that the results of the analysis are satisfactory, the production of the prototype is authorized and the part is built for the first time. On the other hand, if the results are not satisfactory then modifications are made to the part. The part is designed again, and the same process is repeated till the appropriate results are obtained. This whole process needs the cooperation of more than one departments (CAD – CAE), increasing in this way the complexity of the task, cooperation is in most cases time consuming and as a result this "circle" has proven to be slow and expensive.

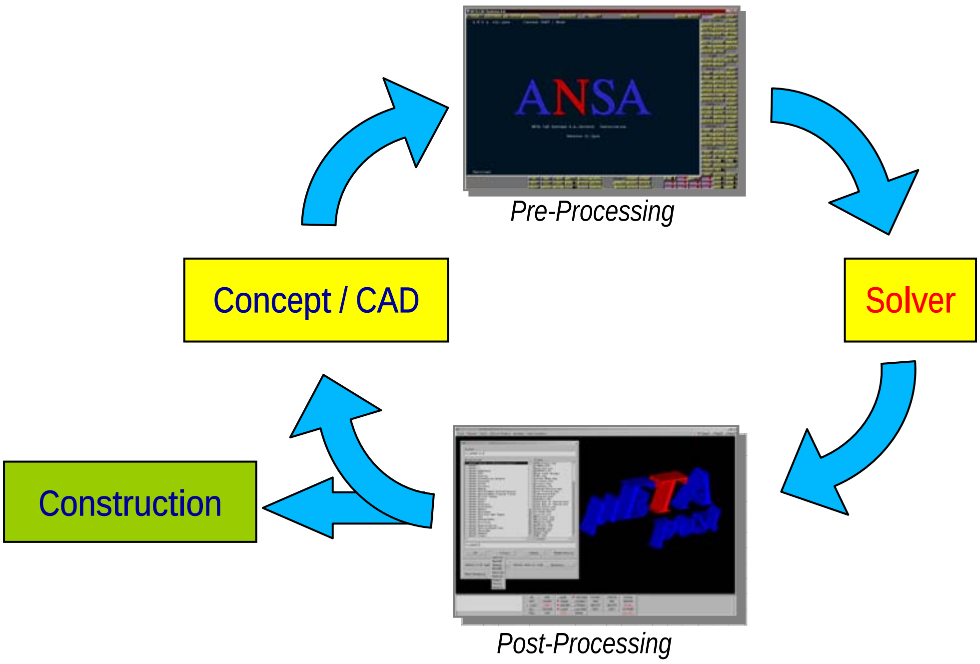


Fig. 1: The creation of a prototype.

In order to minimize both time and cost, most companies start developing a new prototype not from scratch but try to further develop / modify, a part that already exists. In other cases, again to minimize cost, companies try to make use of existing old parts in new assemblies with as few modifications as possible. This is the case of old rails fitted in new platforms or old doors to new frames.

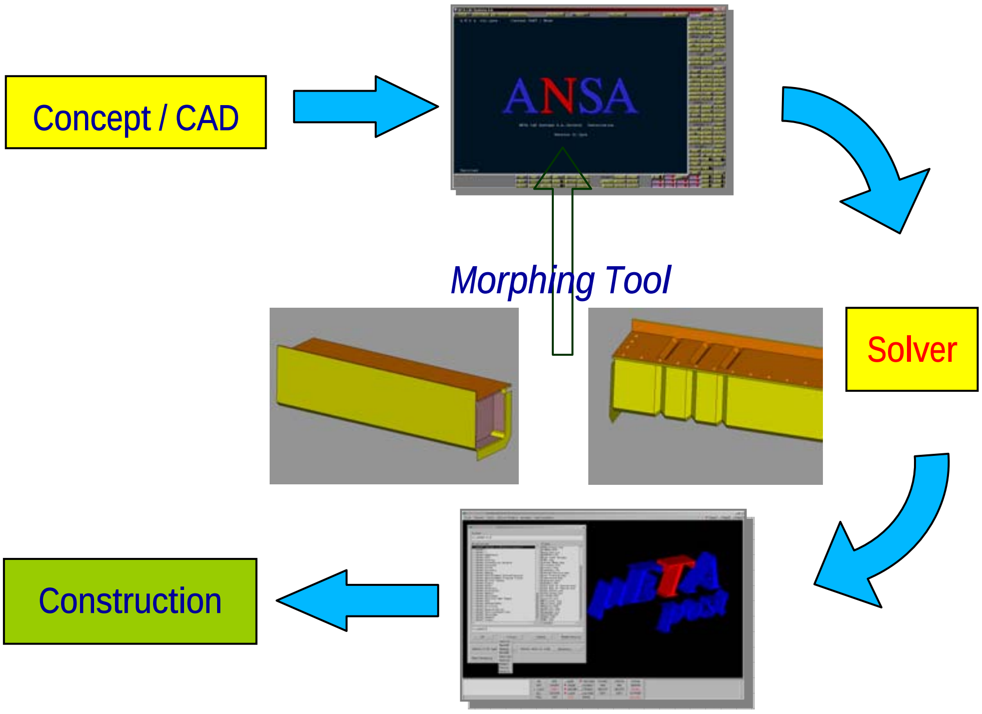


Fig. 2: The use of ANSA Morphing tool in part creation.

For the above reasons, some years ago, the Morphing Tool was introduced in ANSA. Using the Morphing Tool the CAE engineer was able to make any modifications he wished directly to the FE model without having to return to the CAD department, saving in this way significant time. With the Morphing Tool, the engineer was able to make any needed modification, either to a specific area of his model or on the whole model and without losing the initial mesh of the part. In the case that the mesh after morphing did not meet the quality specifications set, the reconstruction function is used, and the mesh is automatically regenerated and corrected in order to meet the quality specifications. Since, forces and boundary conditions are not lost during morphing, the model is ready to be solved again, Fig. 2. This process can be fully automated if an optimizer is used in conjunction with the solver. The optimizer communicates with ANSA via the ANSA scripting language, control the morphing parameters and so the optimum solution is reached automatically.

Using ANSA's Morphing Tool inside an optimizing circle, the CAE engineer is capable of reaching an optimum solution for his model, fast, with low cost and with no or minimum interaction between different departments (CAD/CAE). Currently, the only drawback of this procedure is that morphing is only applicable on FE-models, meaning that the desired information derived from the optimization circle cannot be directly passed to the CAD department. So, the only way to get the information to the CAD department, is first to convert the FE-model to geometry and then output the geometry using a neutral format (*.igs, *.stp). Unfortunately, this conversion doesn't always produce good results, since in most cases information of fillets and other curvatures of the part is not retained in FE. For this reason, ANSA from version v12.2.x incorporates for the first time the possibility to use the Morphing Tool directly on geometry (Geometry Morphing).

2. ANSA MORPHING TOOL

FE-model Morphing

FE-model Morphing is conducted in ANSA using Morphing Boxes. Morphing Boxes can be reshaped by moving the Control Points that are located along their Edges. All entities shell / solid elements, 3D points, must be loaded in a morphing box in order to be morphed. The user can move the Control Points in order to reshape the boxes in two modes. The first one is the non-morphing mode, where the boxes are simply reshaped in order to better fit the model geometry. The second is the morphing mode, where the boxes are reshaped and their loaded elements are morphed accordingly.

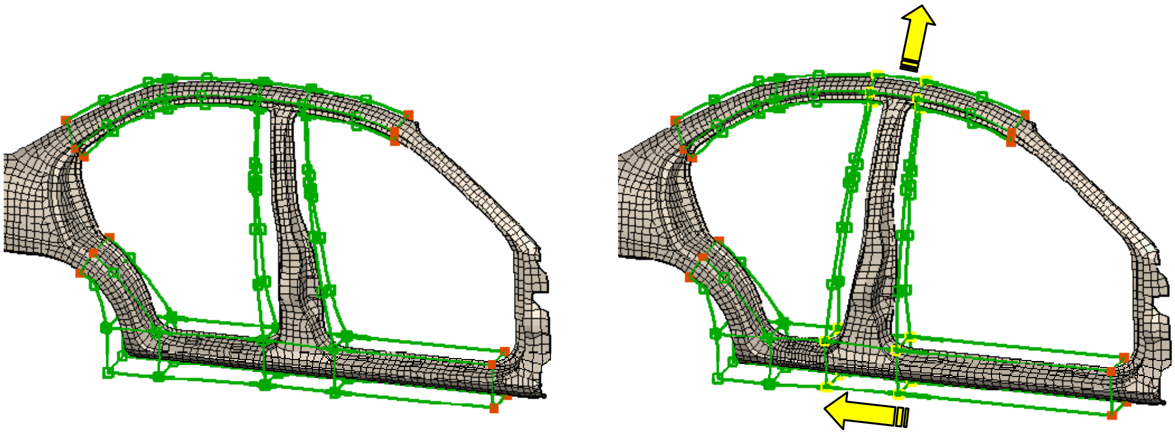


Fig. 3: Morphing Boxes follow the shape of the structure

One way to use the morphing boxes is to follow the shape of the structure. As shown in Fig. 3 moving or sliding of Control Points results in the morphing of the model in the desired direction. The second way is to create a single morphing box and then to split it into many with their edges fitted on the feature lines of the model, Fig. 4. By doing so, the surrounding boxes can act as buffer zones of the morphing action, thus ensuring continuity of the deformed neighbouring shell of solid elements. At the same time, the ability to move the fitted Morphing Box edge by exact translations, rotations or even snapping onto pre-defined target 3D curves, allows for highly controllable and precise modifications of the actual mesh.

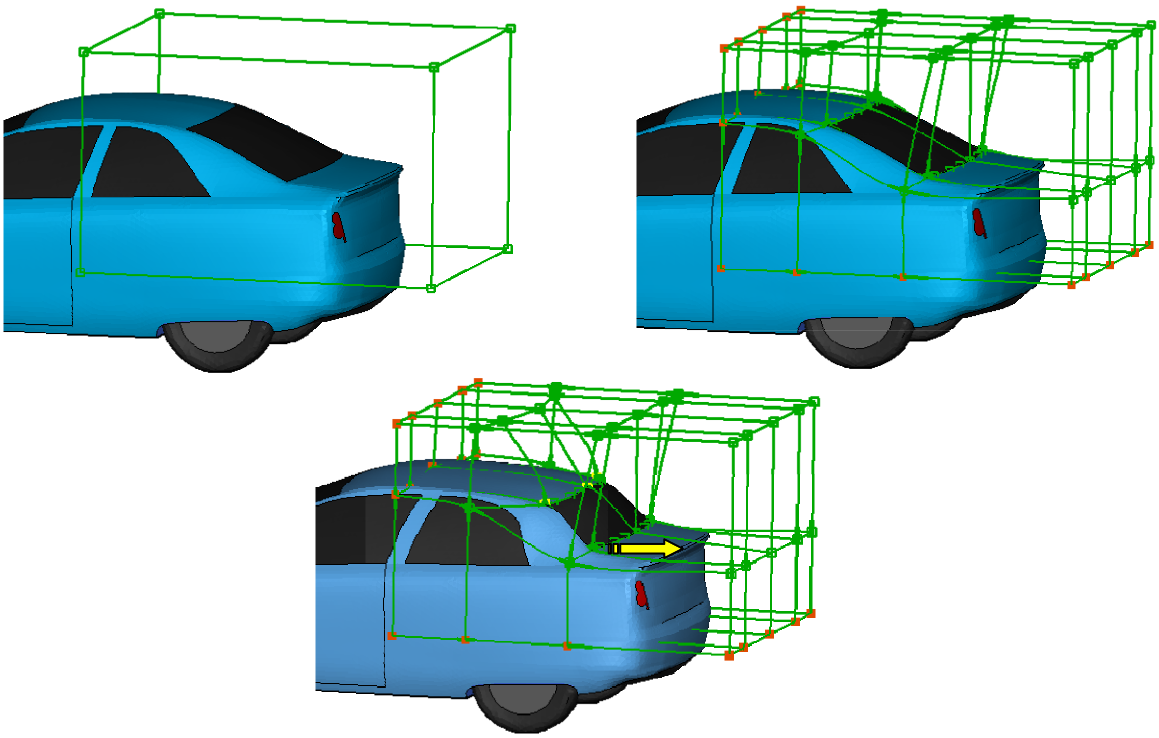


Fig. 4: A single Morphing box split into many.

Geometry Morphing

Starting with version v12.2 ANSA Morphing Tool will also support Morphing on Geometry. Geometry Morphing incorporates a number of advantages:

- Can be applied on geometry. No mesh is required.
- Geometry Morphing is conducted in the same way as FE-model, by using Morphing Boxes.
- The user can use functions that work only on geometry like Reshape (automatically join macros to produce mesh of better quality), or have options applicable only on geometry Reconstruct (fillets treatment).
- Use of ANSA's Batchmeshing Tool after Geometry Morphing.
- Morphed Geometry can be output using neutral format to be used by CAD software (CATIA, NX, Pro/E).

As mentioned before, Geometry Morphing works under the same principles with FE-model morphing. The user creates boxes in the same way as before and instead of elements, geometric entities (faces) are loaded in the Morphing Boxes, Fig. 5. At the same time, it is also possible for a Morphing box to be loaded with more than one type of entities. This means that a box can be loaded with FE, faces as well as 3D points or other entities. By moving the Control Points of the box all the entities that have been previously loaded into it are morphed.

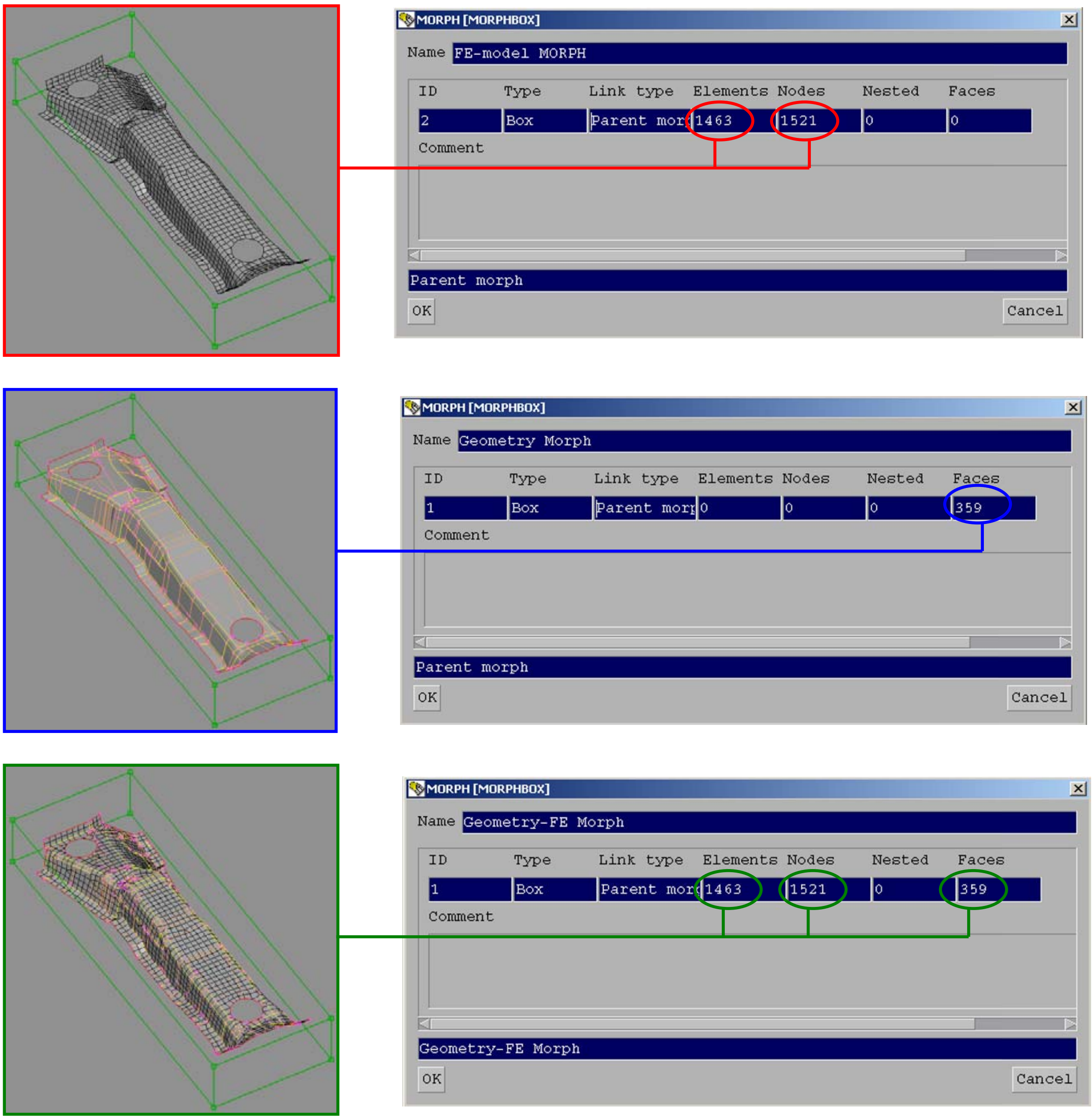


Fig. 5: Geometry morphing. Box Definition.

In ANSA the mesh created on a part, always resides on the CAD definition. In the case that a face being morphed has been meshed the mesh on the face is not lost, Fig. 6, but the mesh is being morphed as well. As stated above, in many cases in order to ensure that the changes made will only affect a specific area, the technique of using one box that has been split into many is used. With geometry morphing, where faces are loaded in the boxes, sometimes a face could be intersecting the common side of two boxes. In these cases, when the Control Points are moved and the box is morphed a cut is automatically created on the intersecting face. In this way the part of the face that belongs to the box being morphed follow the movement while the rest remain either at the initial position or follows according to any constrains between the boxes (of tangential constrain between the boxes). These cuts are made automatically and only in the cases that they are needed.

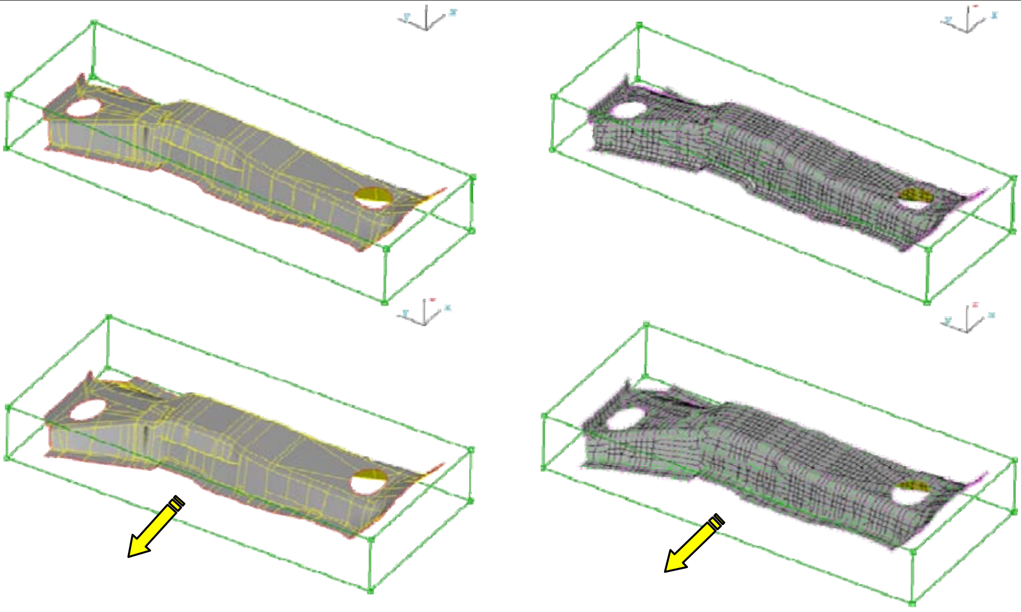
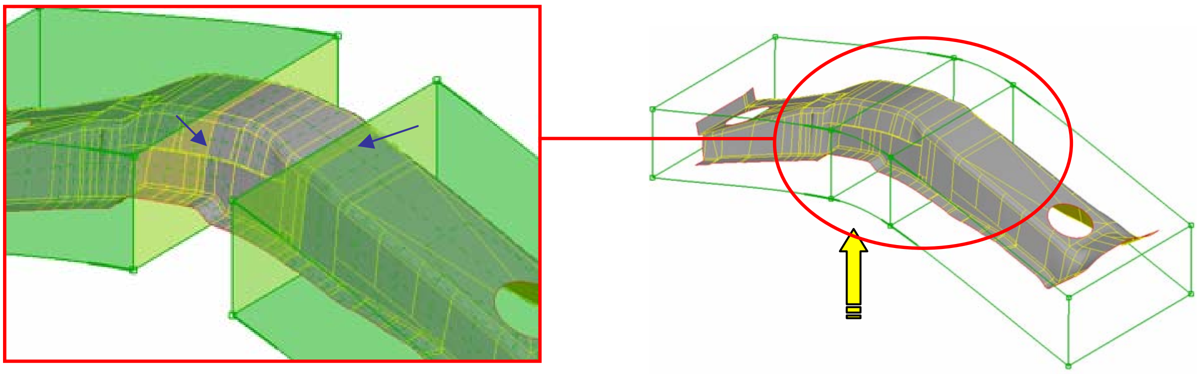
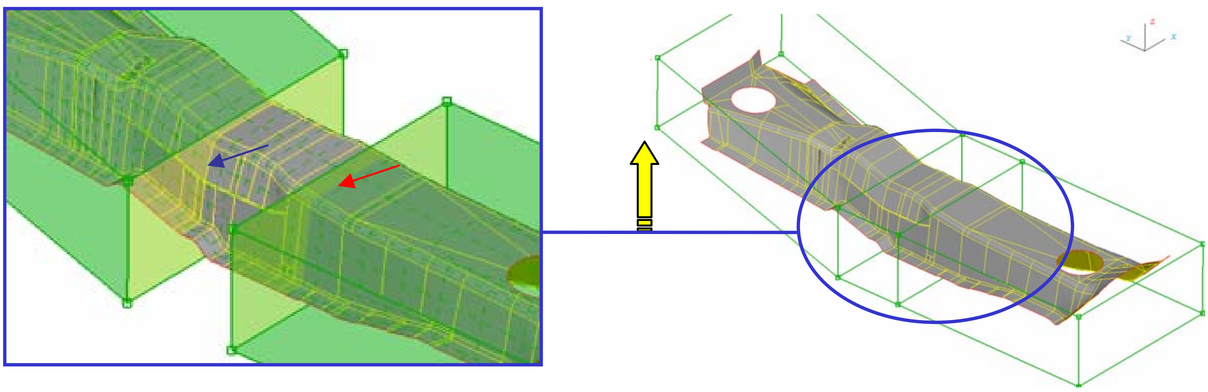


Fig. 6: During Geometry morphing the mesh on the faces is not lost,
but it is morphed at the same time.

Fig. 7a, b, show Geometry Morphing applied on a rail. In Fig. 7a, all three boxes share a tangential constrain. Moving the central Control Points upwards results in the automatic cutting of the faces, indicated by the blue arrows. On the other hand, in Fig. 7b there are no constrain between the boxes. In this case the Control Points on the left side are moved upwards, and since there are no constrains between the boxes, only the contents of the left box are affected. So, a cut on the faces is automatically created at that point (blue arrow), while on the intersection of the right and middle boxes with the faces no cut is made.



a) Middle Box has tangency constraints with both boxes.



b) Middle Box does not have any tangency constraints with the other boxes.

Fig. 7: Boxes that intersect with the geometry, depending on continuity requirements can automatically perform cuts on the faces.

3. STUDY CASES

To better evaluate Geometry Morphing a number of different test cases have been analysed and are presented. The part under investigation was a complete door assembly, which consists of 12 different parts, Fig. 8. For this assembly three different cases have been addressed.

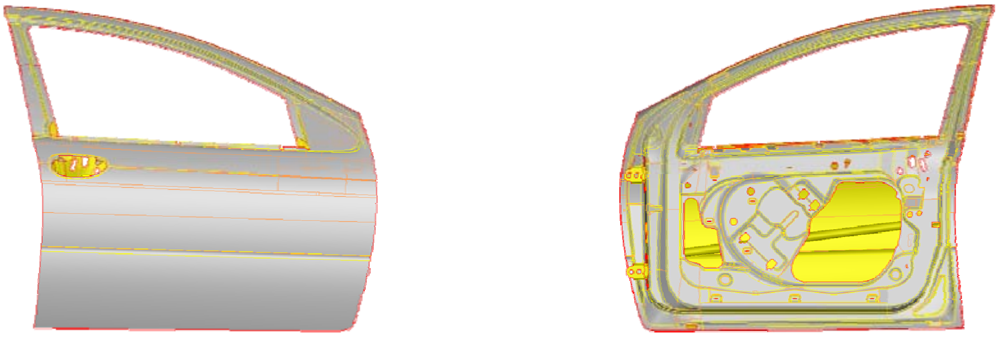


Fig. 8: Door assembly used for Geometry Morphing

The cases simulate the actual problem of trying to fit an existing door assembly either to a new outer design, or to a new frame. These are:

- Case A: Fit the door's outer frame to a predefined surface
  - A1: The inner frame should keep its initial position
  - A2: The inner frame alongside the rest of the parts should follow the outer frame.
- Case B: Fit the door's outer frame to specific cross sections

Setting Up – Morphing the assembly

In order to morph either an FE-model or geometry the procedure the user should follow is exactly the same and can be summarised in few simple steps, Fig. 9:

- Create a morphing box that includes the whole assembly (door).
- Split the initial box to smaller boxes, in order to have better control of different areas / features and isolate specific areas.
- Optionally the user can add control points to the edges of the boxes or have it done automatically. Since the control points are those that actually will coincide with the target curves more points will lead to better results.
- Create initial curves for the source geometry.
- Fit morphing boxes edges to the source curves.
- Create target curves from target surface.

After this stage the model is ready to be morphed. Morphing is conducted by selecting the appropriate morphing function and then fitting the boxes edges which reside on the initial curves to the target curves, or simply by moving Control Points.

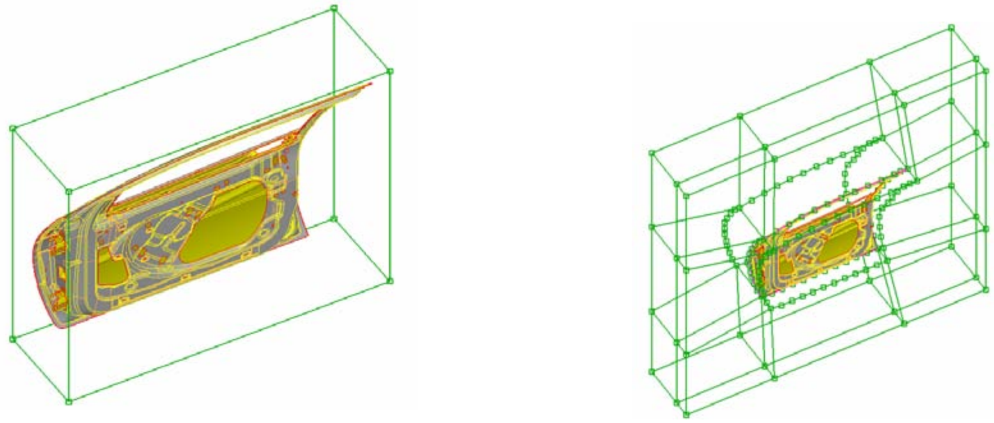
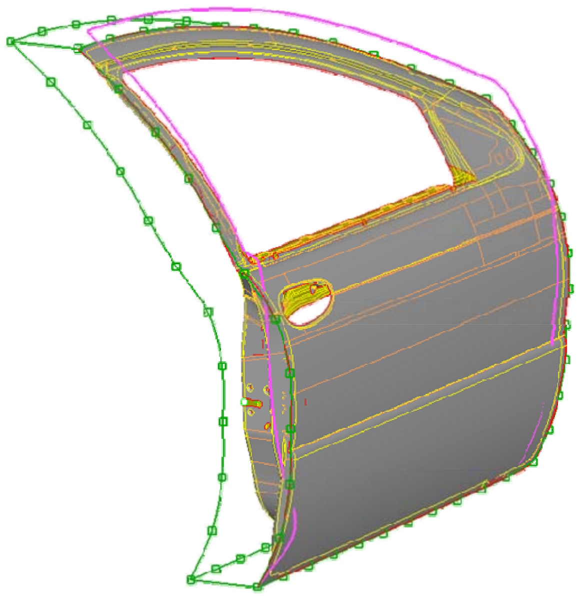


Fig. 9: Door assembly used for Geometry Morphing

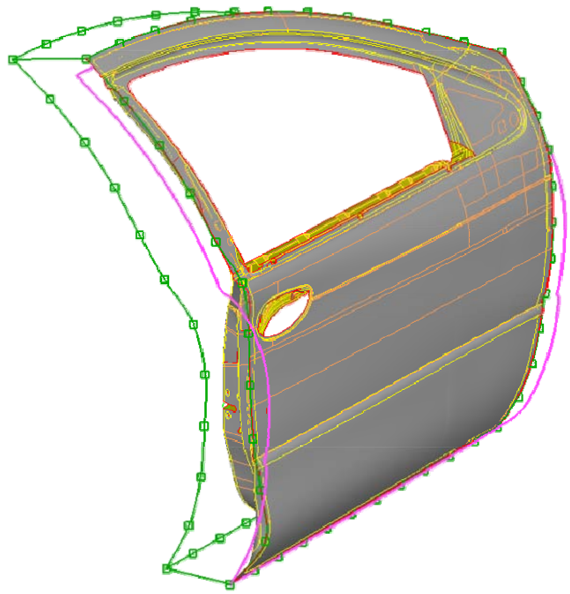
<u>Results</u>

For case A1 the morphing function Edge.Fit has been used. This function modifies the shape and position of elements that are loaded on a Morphing Box by fitting a box's edge on a target 3D-curve. The assembly before and after morphing is shown in Fig. 10. In Fig. 10a the target curve are coloured in magenta, while in Fig. 10b the morphed assembly is shown with the initial unmorphed position coloured this time, in magenta.

For the A2 case the Master-Slave Fit function has been used. With this function the edge of the morphing box is selected to be fitted on the target 3D-curve. At the same time a one or more edges of the morphing box can be selected to follow as slave the movement of the first selected edge. In this way all entities inside the morphing box are morphed in a uniform way. The results of Geometry Morphing on the door assembly are shown in Fig. 11 for the Master / Slave Fit function.

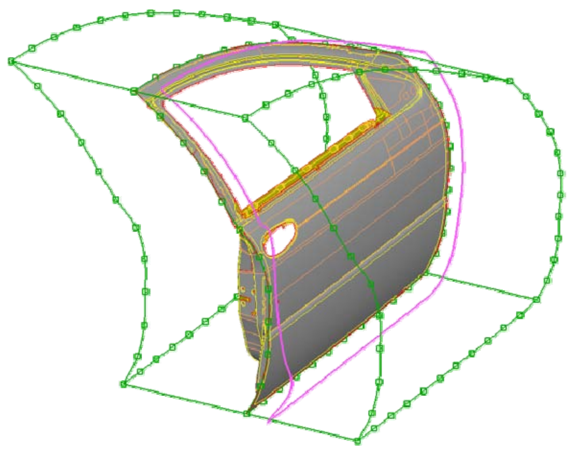


a) Before Morphing

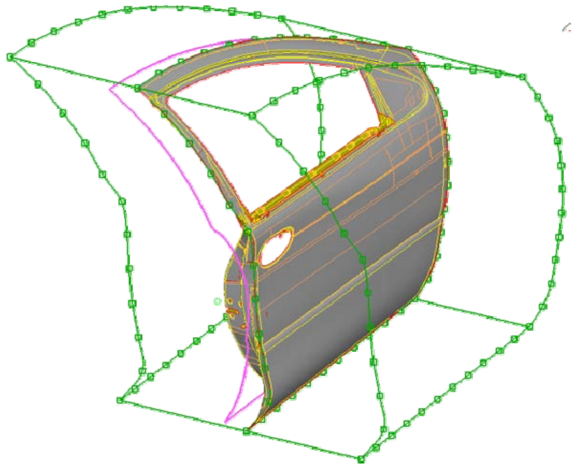


b) After Morphing

Fig. 10: Case A1. Edge Fit function in geometry morphing



a) Before Morphing



b) After Morphing

Fig. 11: Case A2. Master-Slave function used in geometry morphing

Fig. 12 and Fig. 13, show the difference between the results obtained using the two functions used for Geometry Morphing. Using the Edge-Fit function, the inside panel of the door assembly is almost not affected at all form the morphing process, while with the Master-Slave fit, where the second edge of the box follows the movement, it follows the trends of the target curves. Continuing in Fig. 13, at the front part of the door in case A1 (Edge-Fit) the hinges where left at the original position while in A2 (Master-Slave) the hinges were morphed.

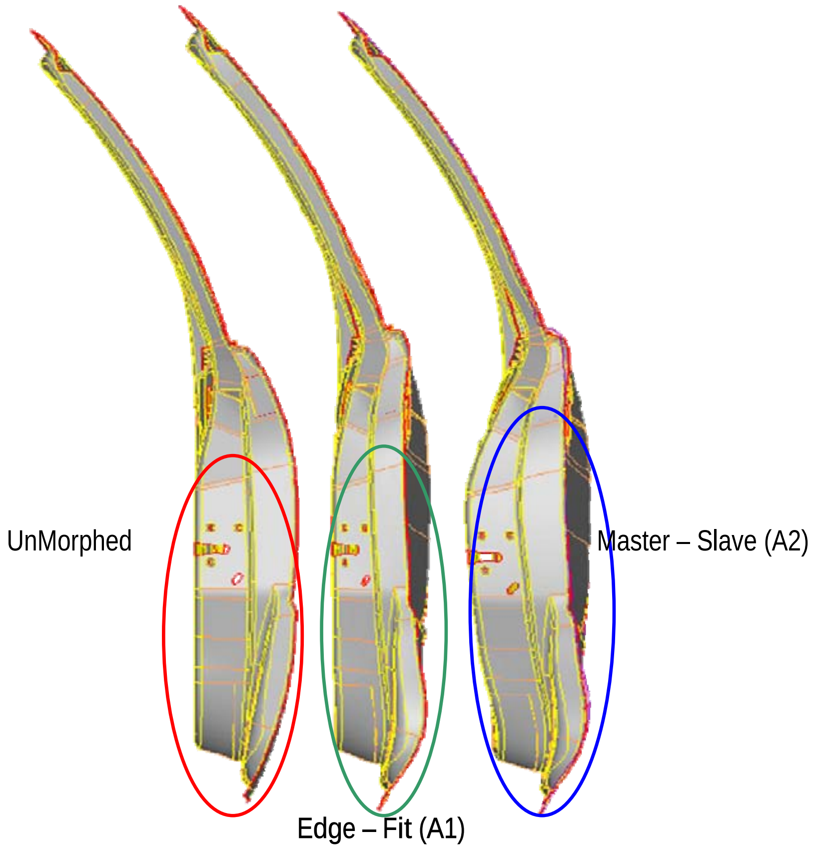


Fig. 12: Geometry Morphing, Case A1, A2 Rear View

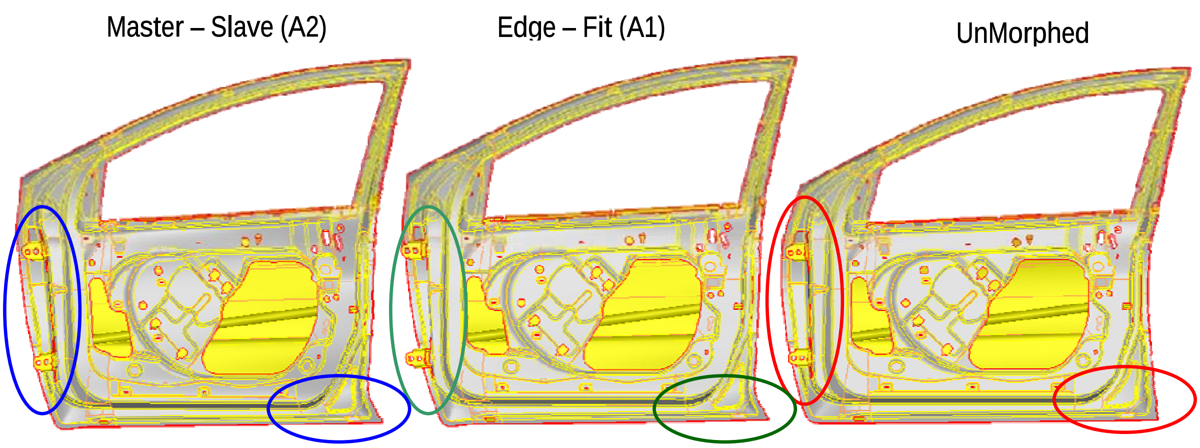
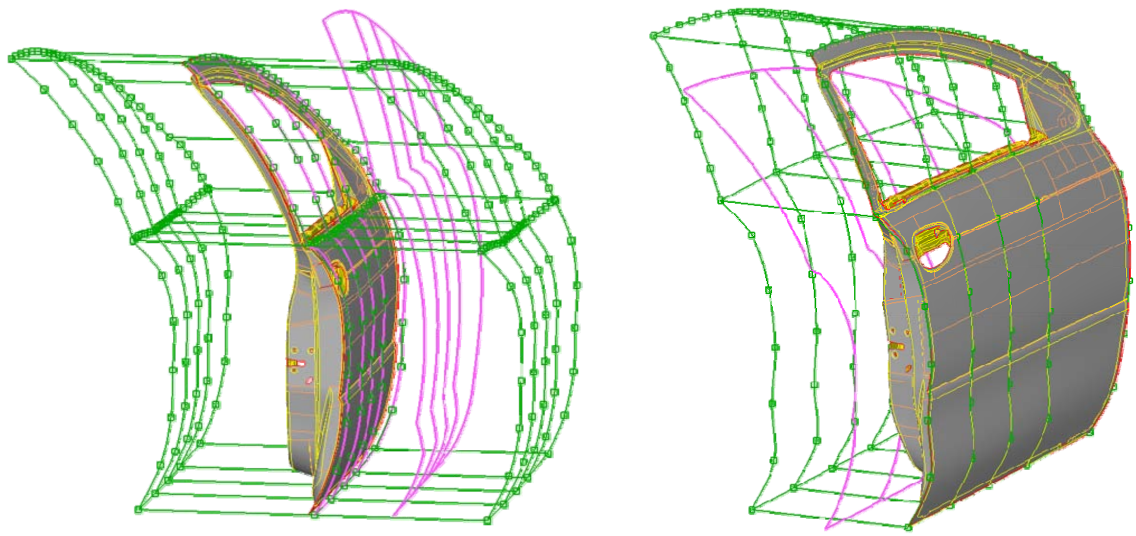


Fig. 13: Geometry Morphing, Case A1, A2 Side View

According to case B scenario, the door assembly should be fitted to specific cross sections. This case is addressed in the same way as the A2 case. Only here since there are more than four target curves more morphing boxes have been created so that more edges would be fitted. In this way the user specifying more target curves has a better control on specific areas. The unmorphed assembly with the target curves can be seen in Fig. 14a while the final morphed door with the initial curves in Fig. 14b. In this example at the position of the cross sections, cuts have been made automatically during Geometry Morphing on the faces, in order to better be fitted to the target curve, Fig. 15.



a) Before Morphing b) After Morphing

Fig. 14: Case B. Master-Slave function used in geometry morphing, in conjunctions with a number of cross-sections.

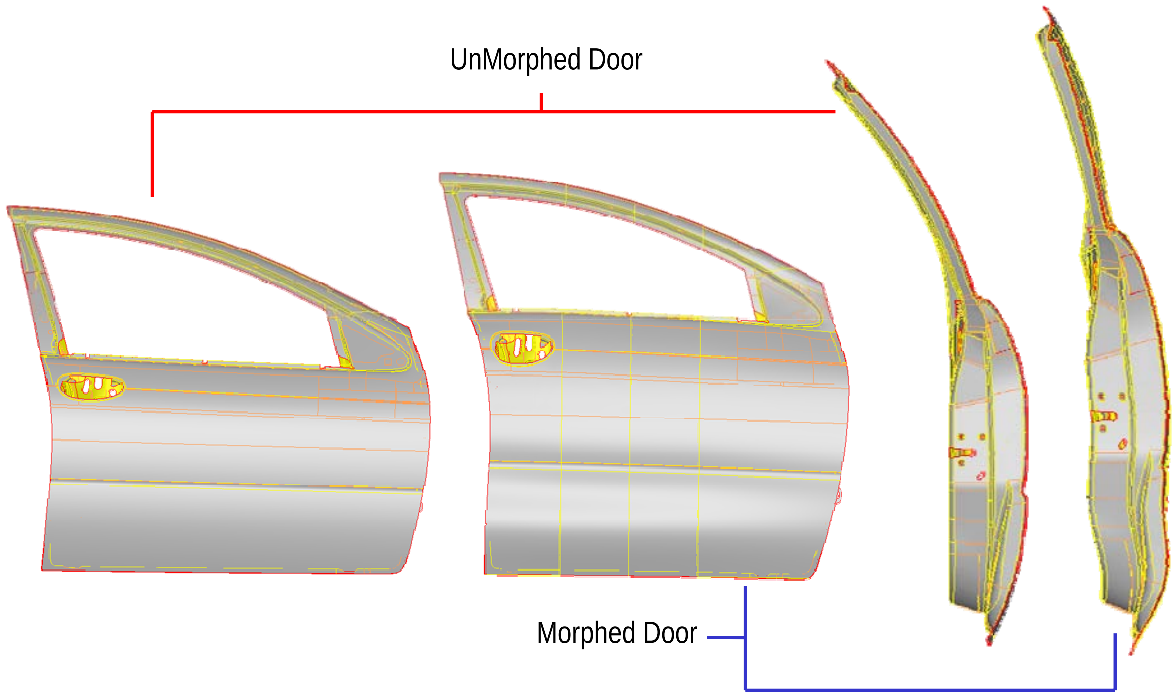
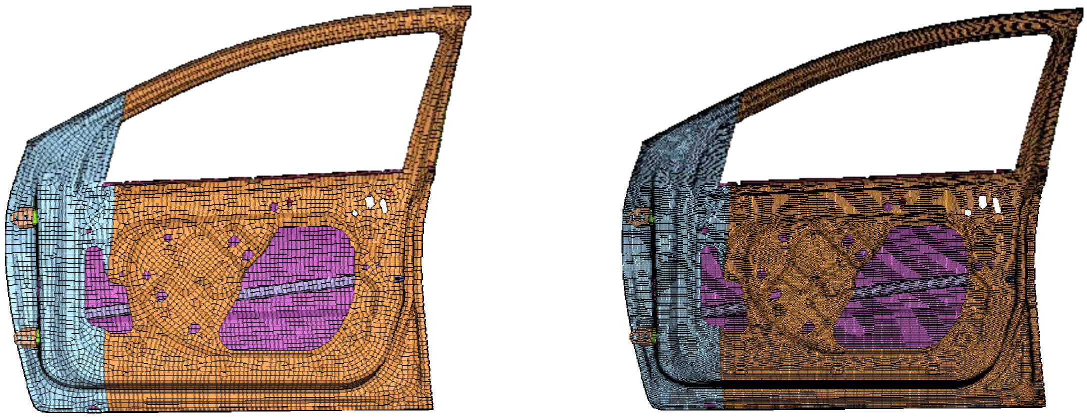


Fig. 15: Geometry Morphing, Side and rear view of case B.

4. COMPARISON TO FE-MORPH

For reference, the assembly under investigation has been meshed with a coarse (mean element length 12 mm), and a fine (mean length 5 mm) mesh. Following, the mesh was released from the geometry and two FE-models of the assembly where created, the first with 14 846 elements (12 mm) and the other with 91 931 elements (5 mm), Fig. 16. These models where morphed in the same way as with the geometry cases. Morphing (FE-model / Geometry) were conducted using an AMD Athlon 64 Dual Core Processor 5600+, with 4 GB of RAM. The times needed in each time to complete the operation are summarized in Table 1.



14,846 elements   91,931 elements

Fig. 16: FE model of door assembly

Table 1: Statistics of FE-model and Geometry Morphing

		Case A1, A2 M/S-Fit /Edge-Fit (min:sec)	Case B M/S-Fit (min:sec)
FE-model, 12mm	14 846 elements	0:03	0:03
FE-model, 5 mm	91 931 elements	0:10	0:10
Geometry	2 410 faces	1:05	4:30

The time needed for the FE-model morphing is merely seconds, depending on the number of elements of the model. On the other hand, for cases A1 and A2, the time needed to morph the geometry rises to one minute. Continuing for case B while the FE-model morphing needs the same time as in cases A1 and A2, for the Geometry Morphing the time needed rises to 4:30 minutes. This excess time needed compared to geometry morph of cases A1 and A2 is due to cuts that are being automatically created on the whole assembly.

5. CONCLUSIONS

In this case study it has been shown that from ANSA's version v12.2.x morphing will be available also for geometry with very satisfactory results. At the same time any mesh that resides on the geometry is not only kept but it can also be automatically reconstructed after the Geometry Morphing finishes. As expected, Geometry Morphing needs more time compared to an FE-model, but all the information about the morphed geometry can be returned to the CAD software, (Fig. 17) without having to transform the FE-model to geometry. At the same time, since geometry is not lost, important information of the parts, like fillets, holes, curvatures, are retained. Continuing, the batch meshing tool of ANSA can be used, taking advantage of its filters, special defeaturing and treatment capabilities in order to create a mesh of high quality.

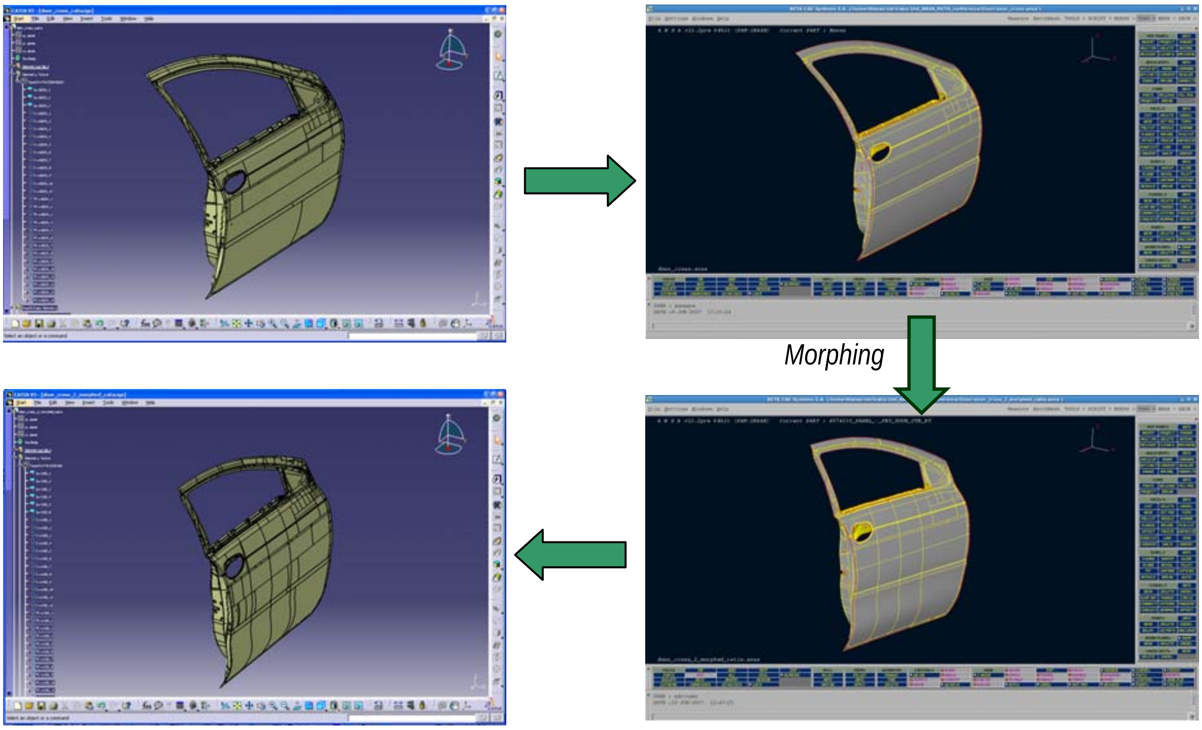


Fig. 17: Completing the CAD-CAE-CAD circle.

The time difference observed between Geometry and FE-model is currently too big to be ignored, in order to substitute FE-model morphing with Geometry Morphing inside an optimization circle. What is proposed though, is the following. First a good quality mesh should be created, and following the mesh should be released from the geometry thus creating a FE-model. Then, create an optimization circle between a slover/optimizer and ANSA Morphing tool on this FE-model. From this procedure the optimum modifications of the parts can be obtained alongside the final movement of the control points of the boxes. The next step is to use the information of these morphing boxes and apply the same morphing using this time morphing on geometry to the initial part. By this way, the obtained optimized modifications are passed to the geometry. Then, output the geometry using a neutral format so that it could be used by CAD software. In this way the optimised solution is finally returned from the CAE to the CAD department saving both time and resources.

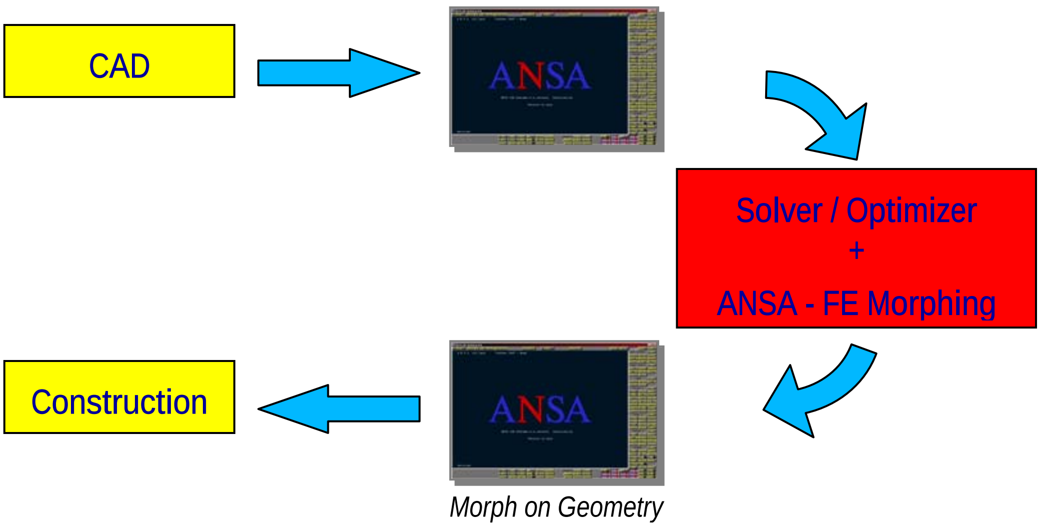


Fig. 18: Proposed solution combining both FE-model and geometry morphing.