Side Curtain Airbag Folding Methodology

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Abstract

In recent years, CAE simulations have been substantially improved as a result of the growing need to achieve full vehicle developments in a shorter time span while also attending the demand of cost reduction in such developments. One of the most critical components regarding the passive safety systems of a vehicle is the Side Curtain Airbag, therefore the necessity to involve this critical component in an agile product development process becomes compulsory. Consequently, when the validation using numerical methods of such component is performed, a full deployment of the airbag is needed to be evaluated and analyzed, having as a key objective the monitoring of its dynamic behavior caused by the effect of interacting with nearby components. In view of the foregoing, the folding process of the airbag plays a key factor in its whole operation.
This study describes a hybrid methodology to fold a Side Curtain Airbag by means of a geometrical and simulation-based routine, which can be defined entirely on LS-PrePost®, using the embedded tools in the occupant safety applications. This work aims to englobe the tools and steps followed in order to obtain, within a short period of time, a LS-DYNA® CAE model of the airbag, capable of representing efficiently and accurately a deployment, which might be used in early stages of numerical analysis for areas such as Interior Trim integrity and safe interaction.
Using this CAE methodology, a new scope of problem-solving techniques originates. Applying the novel approach described in the preceding paragraph, a folding scenario could be useful to control the dynamics of the airbag in order to achieve a faster deployment in a certain zone, to avoid an undesired interaction with the interior trim of the vehicle, or to simply evaluate the aperture time of the system overall. All this adds up to a feasible cost reduction alternative to the most common techniques that involve modifying and adapting geometries including supplementary components, that impact directly in the prime cost of a vehicle.

Introduction

As part of a complex and safety-related critical system the Side Curtain Airbag, like many other components in an automobile, needs to be submitted to a product cycle development, in which virtual and physical testing have a crucial role in its improvement. This continuous enhancement can only be achieved by several iterations in which the engineer's criteria and judgement provide the guidance to the final version of the component.

At the present time, most of the existing cycles in engineering are computer-aided, this reflects in accelerated processes which permits to have an optimized version of a product in lesser time. For the particular case of airbags, every change in its chambering design, attachment points selection, packaging strategy, amongst many

others; have a direct impact in the kinematics involved during its deployment, this means that for its proper testing, whether it's done physically or by simulation, a whole set up must be prepared in which folding and packaging have a crucial role.

This paper aims to address a folding approach which contributes to the (aforementioned) accelerated development of the Side Curtain Airbag aided with simulation tools.

CAD to CAE Considerations

The first input that a CAE analysis usually has is a CAD file, in this case a file of the flat layout of the airbag and its inner deflector would be enough to begin the preprocessing stage of the CAE process: meshing.

For a mesh that will be submitted to a folding process three basic aspects have to be taken into consideration:

1. Element size - Needs to be small enough to capture fabric creases and possible deformations that may arise with different folding techniques. Element size also has a significant importance when the unfolding takes place, as it could influence on the accuracy when trying to capture the profile the airbag makes when deploying.

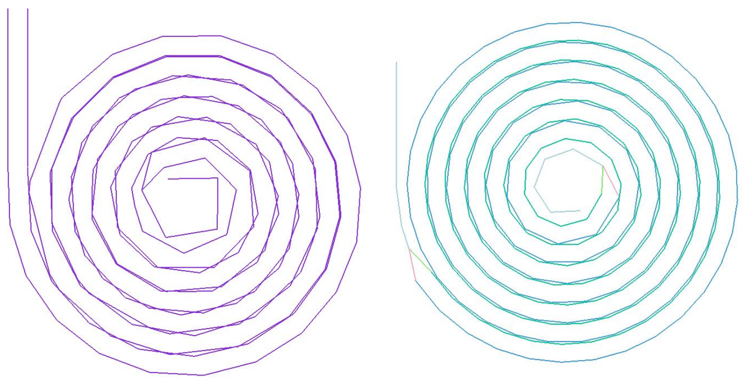

Figure 1 – Comparison between mesh sizes in a rolled airbag. Coarse (left) and fine (right) mesh.

2. Folding lines – The position of the possible folding lines need to be taken on account as the mesh should be aligned as best as possible under that restriction, this is done in order to avoid warpage and large deformations of the elements, that could be causing intersections or other issues in the simulation when the folding takes place.

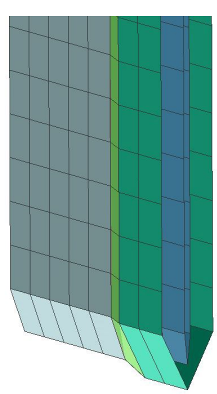

Figure 2 – Mesh aligned with folding line.

3. Mesh alignment – The mesh needs to be properly aligned to one axis, this is done in order to have the less deformation of elements possible when the roll of the airbag is done. The axis is usually the Global Z when the contour lines of the airbag are aligned with whether the X or Y Global axis.

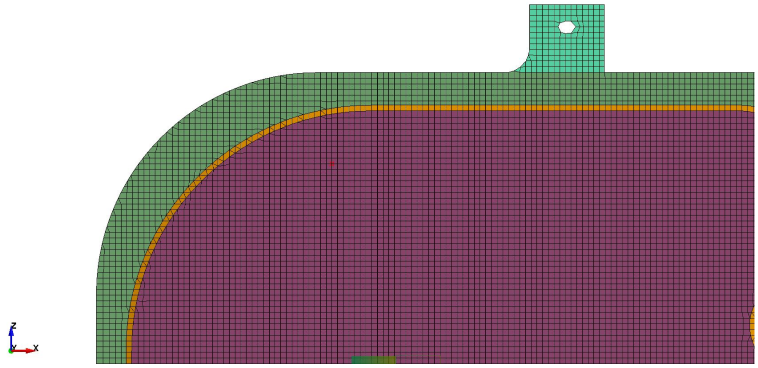

Figure 3 – Mesh aligned with Global Axis.

Having those two aspects in mind a proper mesh for folding can be achieved. This mesh should capture the chambers in which the gases will flow, so it should be a closed volume with only one inlet for the inflator.

Geometric and Simulation Folding

There are two different approaches when it comes to folding an airbag. The first one, the geometric approach is based on simple node translations under certain constraints. The main characteristic of this approach is that it does not require a simulation meaning, no computational cost or time are involved. These transformations are carried out instantly with the Airbag Folding tool on LS-PrePost, the user can modify certain parameters such as folding axis, distance between airbag layers, amongst others. Some of the folding types that can be performed with such tool are roll, thin, tuck, etc. It is worth mentioning that the tool avoids element penetration when performing such operations.

The second approach is done with a proper simulation, for this purpose the tool that LS-PrePost offers is Dynfold, which provides a GUI to set up a simulation-based folding. There are several possibilities that this tool provides some of them are:

- SPC Setup – For regions that require certain degrees of freedom.
- Loading Tools – Provides the possibility to load a used-designed tool and assign motion to it, such as translation or rotation.
- BPFG – Provides the possibility to upscale or downscale a box or other used-designed shape.

Dynfold also provides control cards that will regulate several aspects of the simulation such as contact and element deformation. The output that Dynfold offers is a set of include files that are arranged in such way that provides an easy mode to extract the resulting deformed airbag position in case it needs to serve as an input for a following simulation.

Having those two methods in mind, the CAE methodology proposed in this paper aims to use the best of both tools to come up with a quick and efficient process that results in a ready-to-run Side Curtain Airbag model.

CAE Workflow

A simplified workflow is depicted in figure 4. Once the meshing process has been completed the first step in the proposed workflow is to choose whether the Side Curtain Airbag has pre-folds, this means folding steps that might be after the roll, most Airbags of this type are only rolled and packaged in the designated space, but there might be some exceptions.

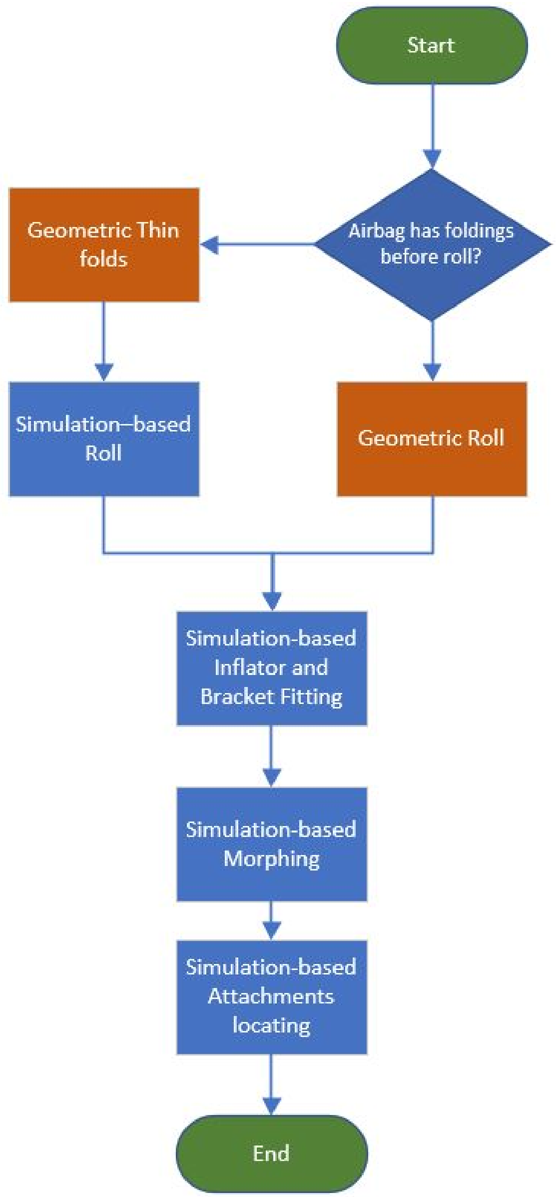

Figure 4 – Simplified Hybrid Folding Methodology.

Furthermore, it is worth mentioning that this proposed methodology might have some variants and general ideas might be adapted to certain folding designs or procedures. Therefore, for the next section of this abstract instead of explaining step by step the workflow, the advantages of choosing one method over the other will be detailed for each stage.

Geometric Folding Stages

The main advantage of the geometric folding approach over the simulated one is the lack of computational time, as mentioned before geometric folding provides an instant result with very good outcomes provided that the geometry discretization was done properly and with fine mesh parameters.

As observed in the workflow, the proposed steps to be carried out by the geometric approach where the following:

1. Roll – If no pre-folds are needed in the Side Curtain Airbag, the first step to be carried out is the roll. Most of the times the roll needs to be performed in order to have a deployment to the outboard direction of the automobile (towards the glazing not the cabin). After several simulations and comparisons, there were no major differences detected between the simulated and the geometric fold on a simple outboard roll.

   Choosing a geometric approach in this step provides a major advantage when sparing the computational time. A simulated approach would mean a lot of calculations spent on the self-contact of the airbag, this is because: as the roll is performed in the simulation more and more elements add to the space in which the airbag gets confined, meaning computations trying to keep the elements from intersecting.

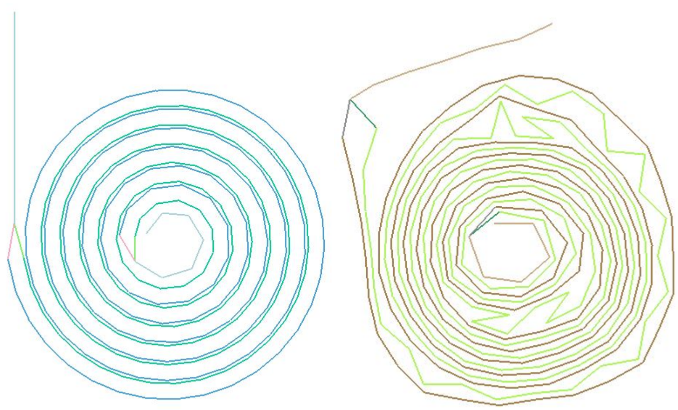

Figure 5 – Geometric (left) and Simulated (right) based roll.

   Both rolls have no elements intersecting, however the elements have a better distribution in the geometric approach which seems closer to reality as most airbag manufacturers make the rolls automatically with a machine. It also needs to be taken under consideration that when the roll gets packaged the distribution of elements gets compromised, so there is almost no difference when deploying a geometric against a simulated done roll.

2. Simple thin fold – Thin folds are a very simple operation, similar to the roll; the geometric approach provides very good results when folding a Curtain Airbag. In this case, some of the spared time also comes from the preprocessing, as thin folds most of the times require fixing the parts or regions of interest, this can be time consuming several sets of nodes need to be employed.

Simulation Folding Stages

Simulation based techniques provide access to more complex folding procedures at the cost of computational time. These stages are mostly dedicated to detail the model and package it in its designated space. The stages covered with this approach can't be performed geometrically, so a set up time must be considered also.

1. Inflator and Bracket fitting – This simulation gets the bracket and the inflator to its final position. During its transformation, contact is defined between the airbag and such components in order to have a deformed mesh resultant of that interaction.

   In this simulation, several considerations need to be taken into account:

   a) The primary tool for this step is the Boundary Prescribed Final Geometry LS-DYNA card. Using this card, the components position in its intended location avoiding intersections with the layers of fabric in the airbag by defining a contact between them.

   b) By this step it is likely that some simulations or geometric foldings have been already performed so a deformed mesh of interest is the input. Having this in mind there are some regions of the airbag that need to remain as they are, as time was already spent in achieving the desired form, so Single Point Constraints or SPCs are useful in this step. These can be useful to allow some degrees of freedom in a local or global coordinate system.

   The combination of movement with controlled degrees of freedom needs to be treated carefully as undesired outcomes might surge, such as over stretched or warped elements.

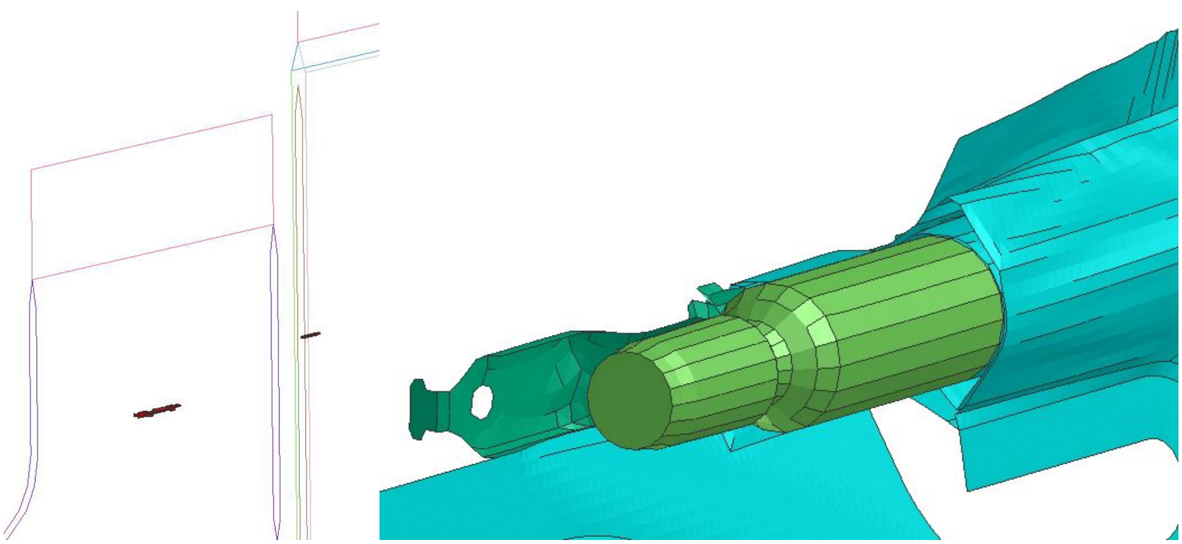

Figure 6 – Usage of Boundary Prescribed Final Geometry card to locate components.

Figure 6 depicts the outcome of this step, some stretched elements on the bracket zone can be observed as a result of an over constrained model, this needs to be avoided to the extent possible.

2. Packaging space morphing – This step as the roll step can be done with both approaches however the geometric approach which is carried out with a Mapping tool in LS-PrePost, according to our study tends to present some issues. The Mapping tool asks for eight lines, these lines act as a Bounding Box for the initial straight routing of the airbag and the final deformed routing of it, four lines each. Obtaining these lines from a CAD file can sometimes be complicated as the CAD represents a cylindrical body and retracting those lines can be time consuming, it is noteworthy that these lines also have to be the exact same length as the airbag on the contrary that could also be a probable cause of element stretching or even element compression. Also, the eight-line mapping tool, tends to stretch elements in the changes of trajectory of the routing, this adds complexity to the task and decreases accuracy.

   For those reasons a simulated approach is much better over the geometric one according to our study, in addition to that the simulated method provides the exact final position that is to be occupied by the airbag. The only downside for this approach is the high computational cost, as it is the second to last step, all the final components are already fixed in position and the roll has already been performed, so a lot of interaction takes place and the simulation struggles with all the elements contacting one another.

   For this simulation some particularities need to be considered:

   a) As some regions are not to be affected, it is useful to define areas of interest for the contact, for example the whole inflator zone might need to be excluded from this contact, as that region has already been deformed to our interest.

   b) Similarly to the inflator and bracket fitting step, the main card to be used in this step is the Boundary Prescribed Final Geometry, but instead of upscaling a downscaling need to be performed as the airbag will be fitted on to the packaging space.

   c) As some parts are already fixed, it is useful to model them as rigid bodies, instead of defining a set of nodes to create SPCs. However, most of the elements in this step is to be left with no constraints as they will take their final position.

Figure 7 – Downscaling packaging pipe with Boundary Prescribed Final Geometry in order to route the Side Curtain Airbag.

3. Attachments positioning – This final step of this methodology covers the location of the airbag's fixing points. It is usually an easy procedure, the only potential problem that might emerge is regarding the disparities between CAD and CAE sometimes the attachments are modeled with different dimensions from one another so it might be hard to obtain an exact position in which the attachments need to be located.

   For this simulation the only aspect to be taken care of is the stretching of the elements, by this stage most of the elements are already in their final position, so typically a large set of constrained nodes is used to control this; however if there is not enough fabric left for the attachments to reach its designated location elements tend to stretch if the SPCs are not defined carefully.

   Boundary Prescribed Final Geometry is also used in this step to assign final position coordinates for the attachments.

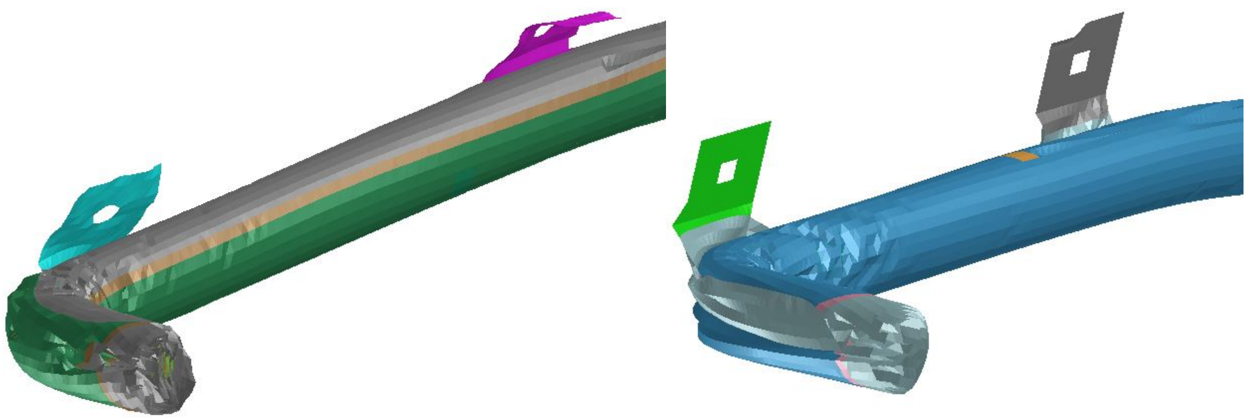

Figure 8 – Attachment positioning.

Conclusions

The folding approach for airbags provides an interesting way to manipulate its kinematics without the need of adding, subtracting or modifying surrounding components or even the airbag itself. The impact of the airbag folding over its deployment speed and energy might be useful when there is need of several problem-solving proposals. Additionally, it is a low-cost alternative as no extra components or expensive tooling are needed. Therefore, the development of a proper CAE methodology that covers this process is of the utmost importance.

This development opens a new area of opportunity to Ford Motor Company, bringing with it the opportunity to have a more collaborative workflow with third-parties which are experts on the field. This also provides possibility to have design direction even from early product development stages, to try different study cases in order to propose new folding patterns, to evaluate packaging spaces, among many others.

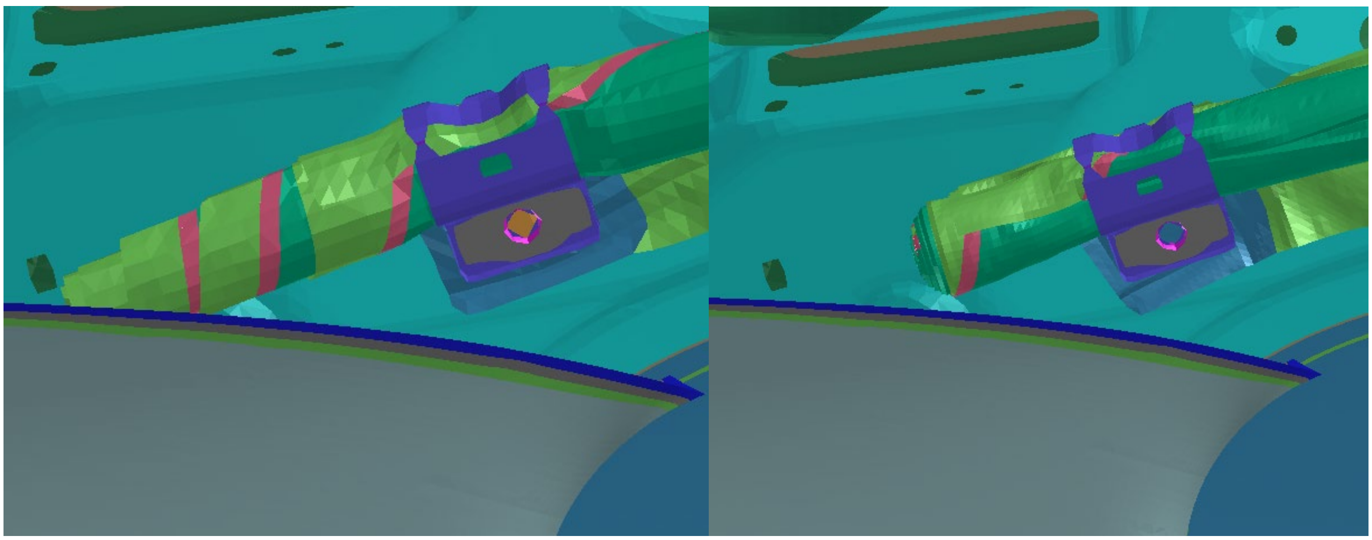

Figure 9 – Level of detailed captured after re-folding an airbag. Right image was the final model.

References

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