Rapid Development of Multiple Fold Patterns for Airbag Simulation in LS-DYNA Using Oasys Primer

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Abstract

The creation of folded meshes for airbag deployment simulations is a time consuming task. The fold pattern has a significant effect on the speed and shape of deployment of the airbag, and therefore should be modelled when prediction of deployment timing is required, as is the case with out of position analysis for FMVSS 208. To investigate changes in fold patterns or airbag shape involves repeating the entire airbag mesh process for each modification. This paper describes a new mesh-independent folding tool in Oasys Primer that can speed up the modelling process. The time required for each operation is quantified for a variety of fold patterns on a thorax bag. Finally, a driver airbag is inflated using LS-DYNA's ALE gas flow capability, and the deployment timing compared between mechanical and traditional zig-zag fold patterns.

Introduction

Analysis of airbag deployment has become a routine requirement in restraints system design. FMVSS 208 requires consideration of out-of-position occupants, who will be contacted by the deploying airbag before full inflation has occurred. For side airbags, it is important that the bag deploys into the space between door trim and occupant before that space is closed by intrusion of the door. In both cases, timing is critical and is strongly influenced by fold pattern as well as by the dynamics of the inflowing gas. With LS-DYNA's capabilities for modelling the gas flow (using ALE methods) has come increased emphasis on modelling the fold pattern accurately, and consequently the requirement to analyse many different candidate fold patterns.

Traditional methods of meshing and folding the airbag are unsatisfactory because of the time consuming process (often iterative) needed to design and create a suitable initial mesh for any given fold pattern. Further, the process must be repeated from scratch to change the fold pattern. The underlying problem, that of needing a special mesh to suit each fold pattern, has now been eliminated by mesh-independent folding in Oasys Primer, which leads to substantial time-savings compared to traditional mesh-and-fold processes. This is illustrated below using a thorax bag as an example.

There is an increasing tendency towards mechanical folding processes, whereby the fabric is packed into the module by machines; there is no defined fold pattern but the geometry and kinematics of the process determine to some extent the final distribution of material within the module. For example, the centre of the front face of the bag is often placed directly over the inflator to assist rapid deployment. Modelling of these processes is discussed. Differences in deployment timing, as predicted by LS-DYNA's gas-flow (ALE) capability, are demonstrated.

Traditional Meshing and Folding Methods

In the traditional method of folding an airbag (flowchart shown in figure 1) the user starts with the basic airbag shape and a list of the folds to be performed. The position of these folds on the unfolded airbag must be determined. This can be a difficult task, especially if the fold lines are not just at 0° and 90°. With this information the airbag then needs to be meshed. To ensure good folding, mesh lines need to be made along the fold lines and at fixed distances from the fold lines. These ‘tram lines’ give good thin folds without penetrations.

Once the airbag is meshed it can be folded. This can easily be done in Oasys Primer. There are several tools to help with mesh aligning if the mesh produced is not quite correct. If more major modifications to the fold pattern are required, the whole process needs to be repeated.

The major proportion of the time required to do several iterations is spent determining the position of the fold lines on the unfolded airbag and creating a suitable mesh in a pre-processor for folding.

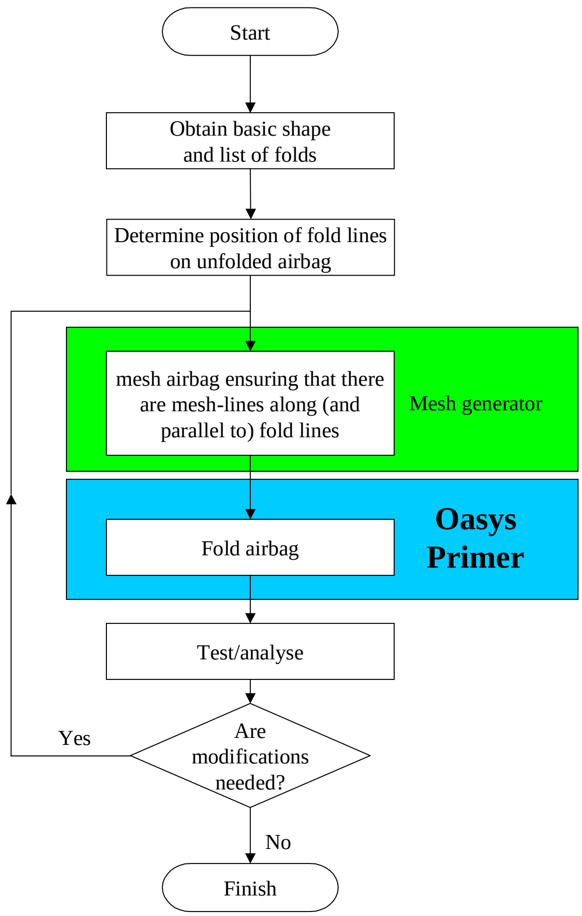


Figure 1: Traditional airbag folding flowchart

Modeling a Thorax Airbag Using Mesh-Independent Folding

The flowchart for creating a folded airbag model with Primer's mesh-independent folding capability of shown in Figure 2 below. To illustrate the mesh-independent folding method we consider a typical thorax airbag. The basic airbag shape is meshed using any generic meshing program or pre-processor. This mesh merely shows the outline size and shape of the airbag. Because the fold pattern is not considered, the meshing stage is very quick and the same mesh can be re-used for any fold pattern.

To start the mesh-independent folding process, the mesh is imported into Primer and Mesh-Independent Folding is selected. Primer splits the imported mesh into triangles.

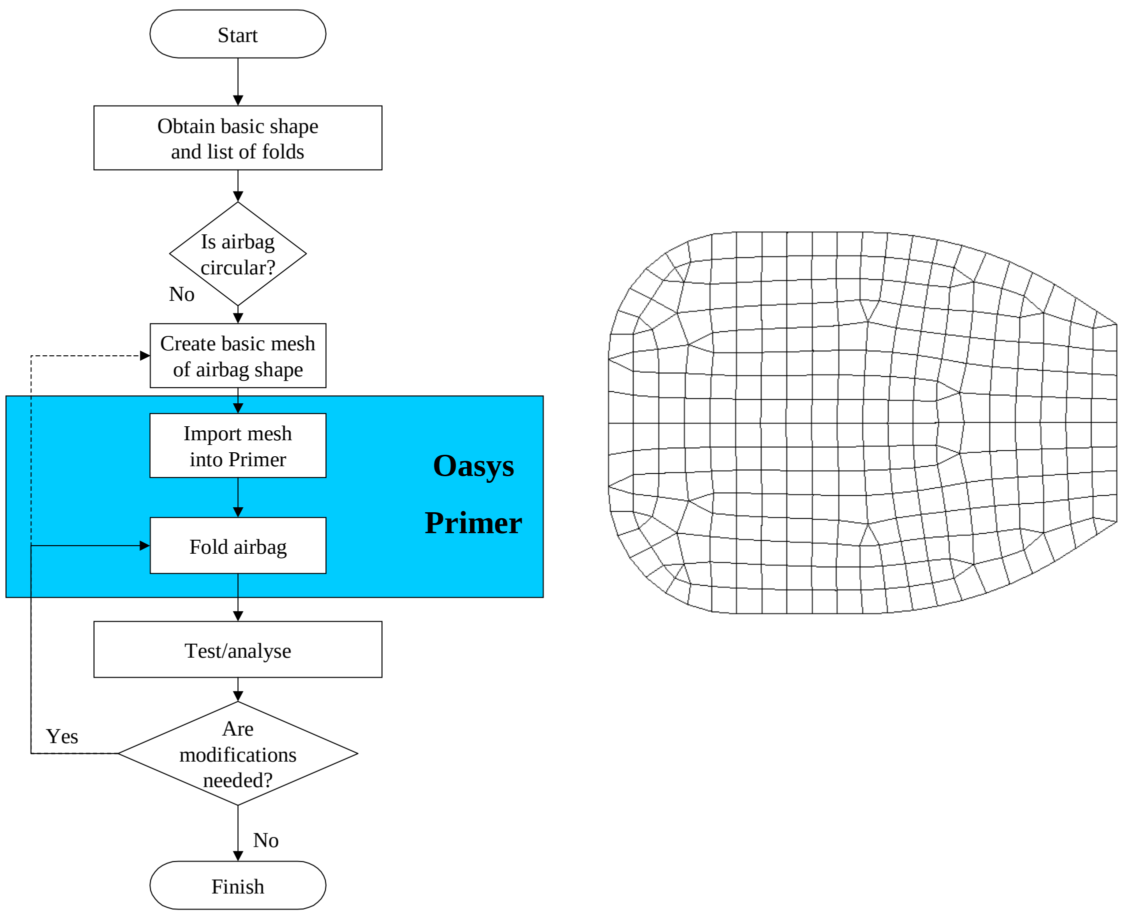


Figure 2: Flowchart for mesh-indpendent folding and typical imported mesh defining outline shape

Creating a fold

To create a fold using the mesh-independent method, the fold type, position and other parameters are chosen as normal (see figure 3).

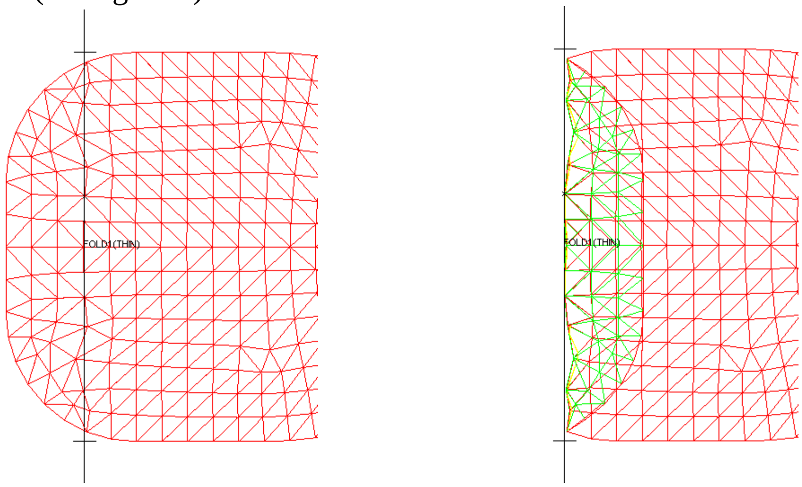


Figure 3: Fold without mesh-independent remesh in unfolded and folded state

Because the initial mesh lines are not aligned with the fold, some elements near the fold are inter-penetrating and the airbag model will not deploy cleanly. To overcome this problem, Primer remeshes the airbag as required to ensure a mesh suitable for folding (see figure 4). Now there are mesh lines along and parallel to the fold line.

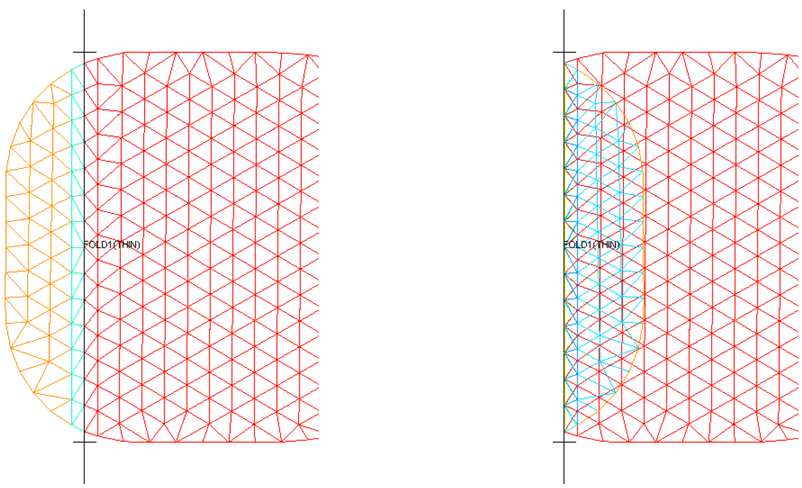


Figure 4: Fold after mesh-independent remesh in unfolded and folded state

As each fold is created, with Primer remeshes to suit the evolving fold pattern. The reference geometry (containing the unstressed size and shape of all elements) is automatically updated as each fold is remeshed.

Figure 5 below shows a second fold created at 45 degrees to the first, and the resulting mesh shown on the unfolded airbag.

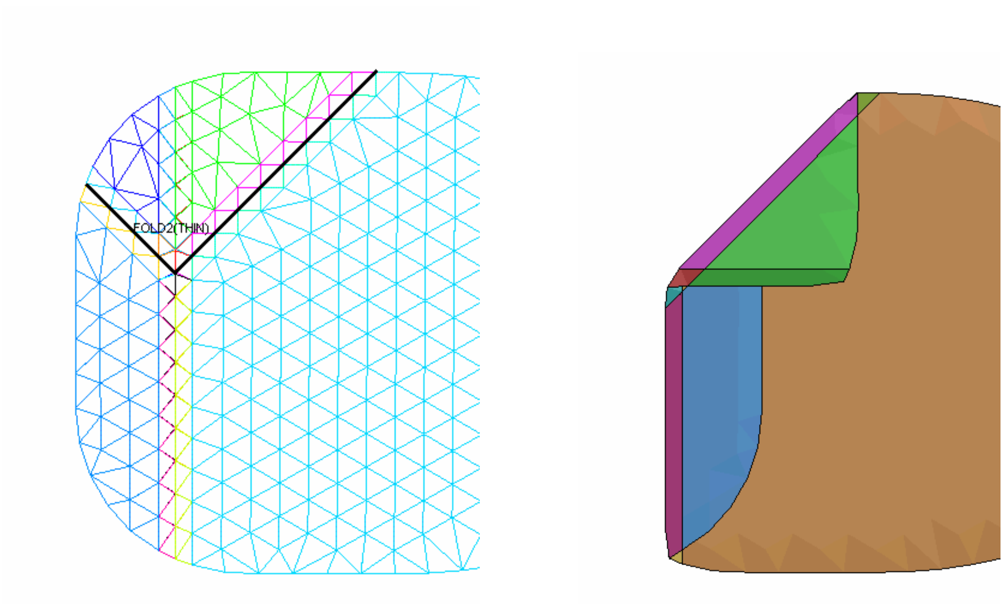


Figure 5 – Second fold at 45 degrees to first

To change a fold, simply delete it and create a different fold. The mesh is adapted to suit.

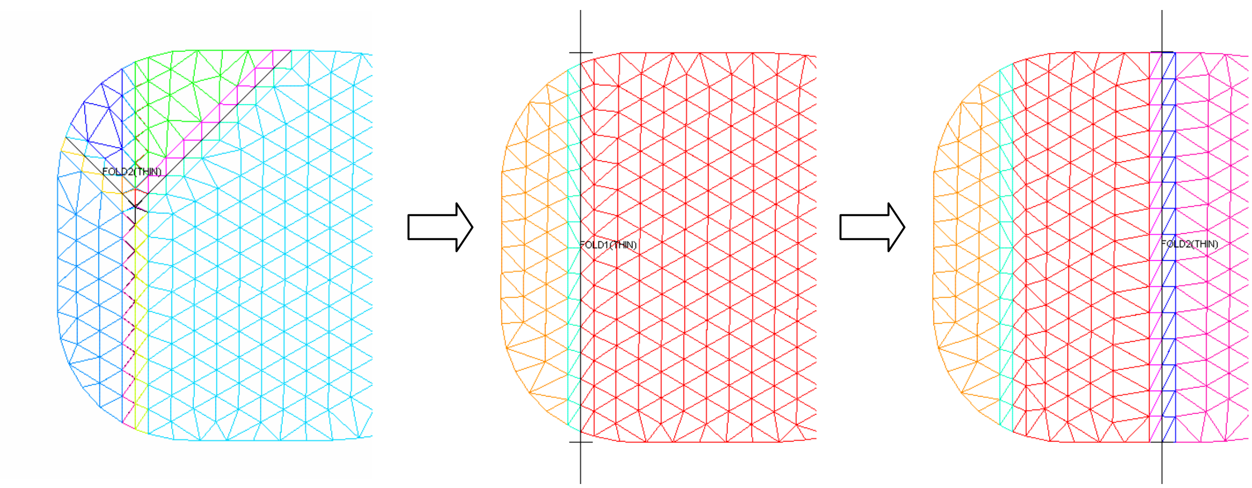
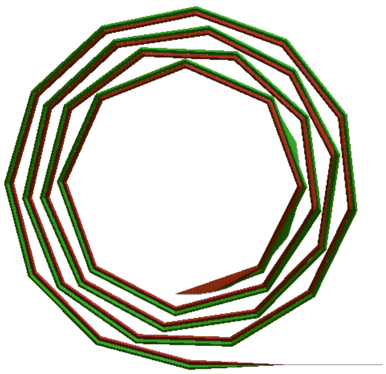
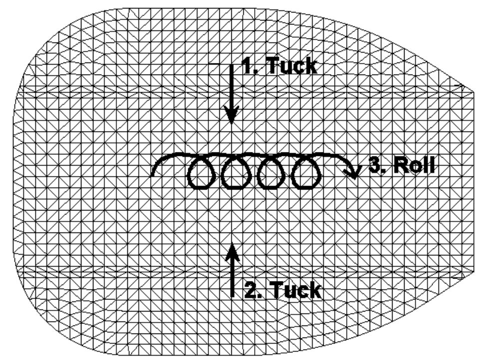
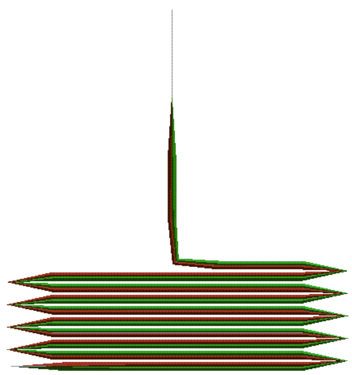
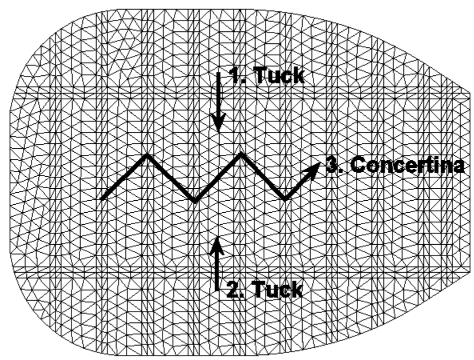
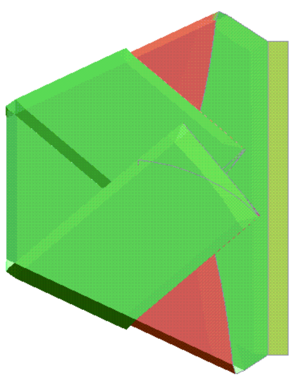
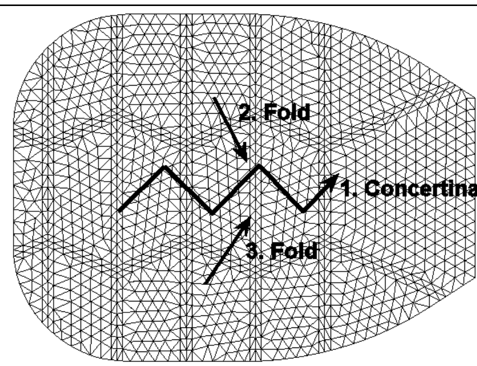


Figure 6: Changing a fold (viewed on unfolded mesh)

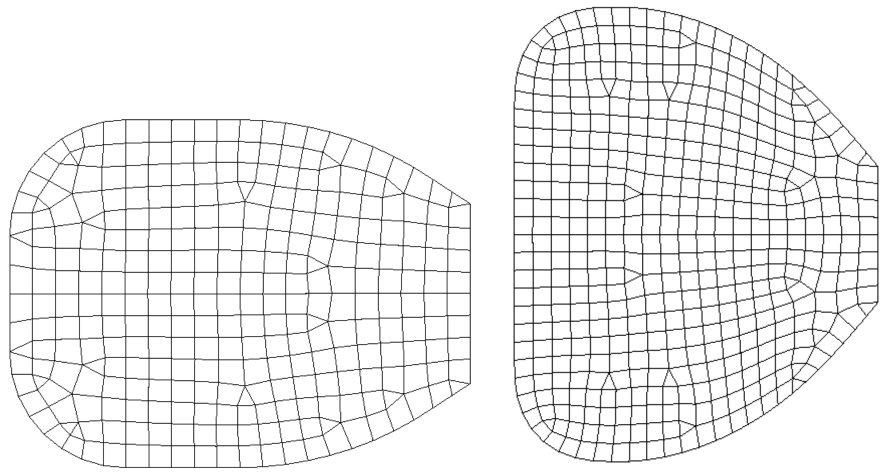
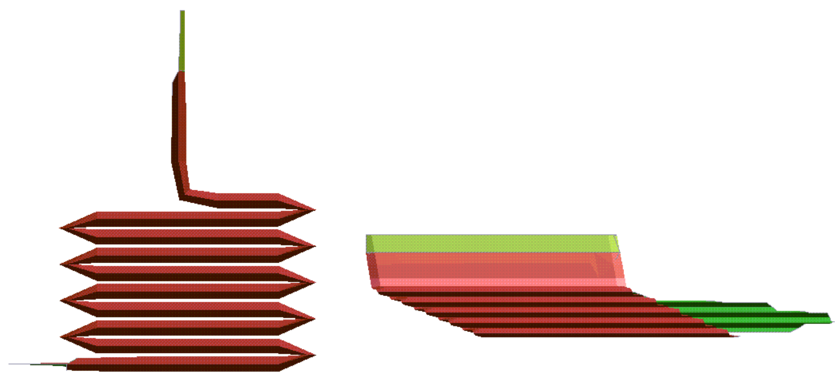
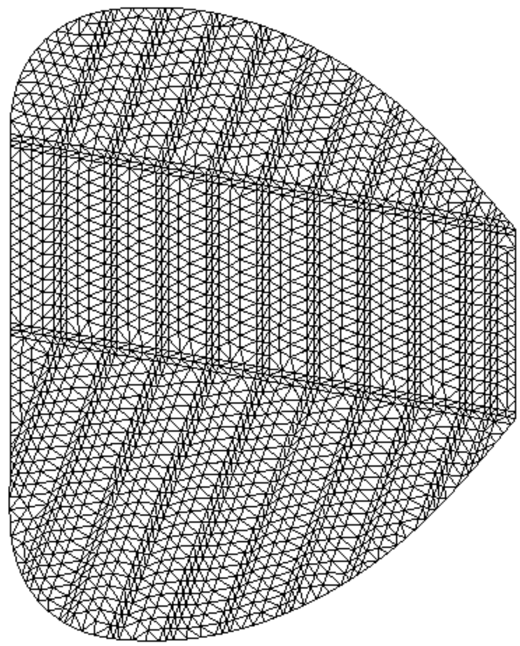
Examples of fold patterns

Primer can be used to investigate several different fold patterns quickly. Three examples are shown below, created using the mesh-independent folding methods. The time taken to create each airbag mesh is given

Description of fold pattern	**View of folded airbag**	**Position of fold lines on unfolded airbag**
Tuck in edges of airbag and roll up **Time taken:** approx 5 minutes		
Tuck in edges of airbag and 'concertina' with thin folds **Time taken:** approx 10 minutes		
'Concertina' thin folds, then 2 thin folds at an angle **Time taken:** approx 10 minutes		

Example of changing geometry

As well as changing the fold patterns easily, Primer can also be used to investgate the effect of a different airbag shape.

Original (left) and new trial (right) thorax airbag shapes. Time taken to remesh airbag shape in meshing pre-processor with basic mesh: 10-15 minutes	
Trial fold pattern 2 angled thin folds followed by a 'concertina'. Time taken approx 10 minutes	
Position of fold lines on undeformed mesh.	

Comparison of Mechanical Folding Versus Concertina Folding

A driver airbag is modelled in Primer first by a mechanically-created ‘star fold’, then with a concertina fold pattern achieved with the mesh-independent folding method. Differences in deployment behaviour are presented.

Mechanical folding simulation

Mechanical processess for folding driver airbags are becoming popular, as they can often lead to cleaner deployments than more traditional concertina fold patterns. The centre of the front face of the airbag lies directly over the inflator, and can be propelled outwards as soon as the module cover opens, without first needing to unfold multiple layers of fabric.

Oasys Primer has a parameterised ‘star fold’ capability that can rapidly create a folded mesh of an airbag with minimal user input. An initial mesh is not needed. Figure 7 shows the panel in Oasys Primer used to create the star fold pattern. Figure 8 shows a typical mesh created by Primer in the unfolded and folded states. This fold pattern most closely approximates the result of a mechanical process with “paddles” that move radially inwards while the bag is partially inflated. It also roughly approximates the result of other mechanical processes that lead to most of the fabric being randomly packed around the sides of the inflator, while the centre of the front face lies directly over the inflator.

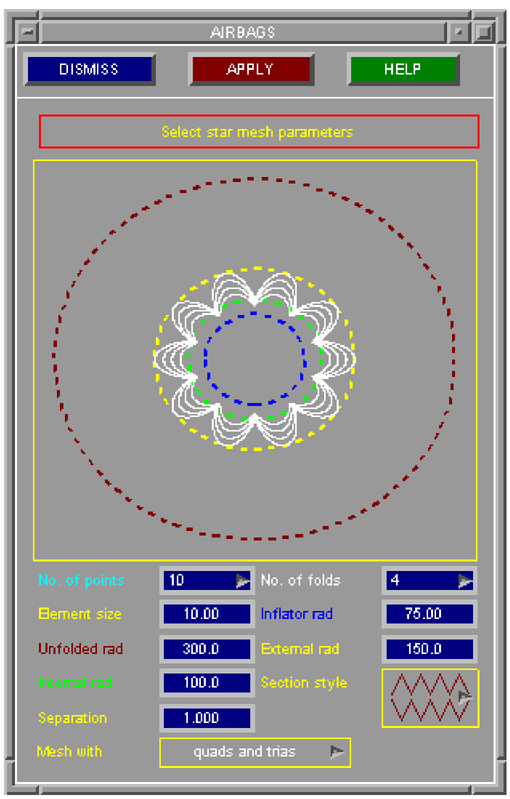


Figure 7: ‘star fold’ creation panel in Oasys Primer

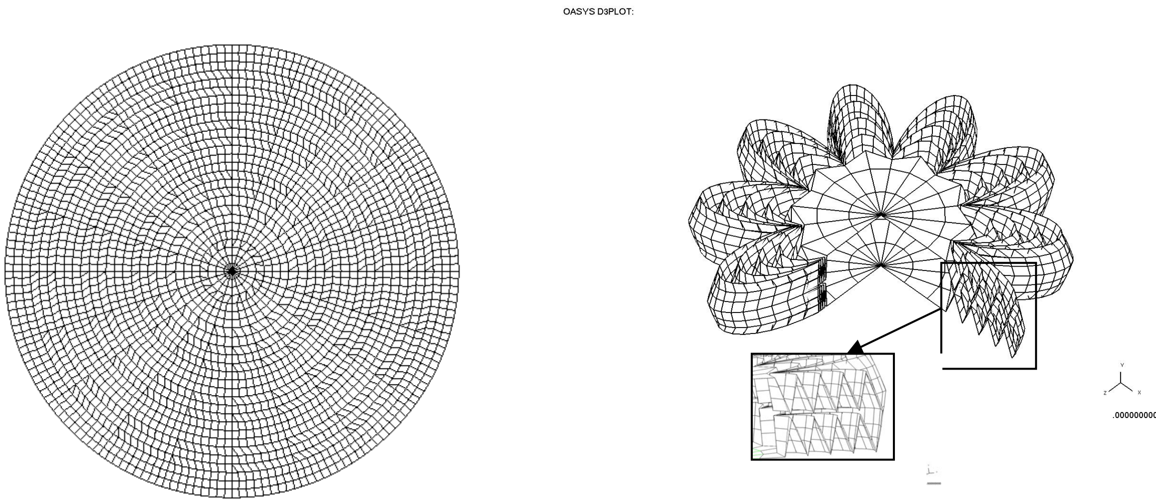


Figure 8: 'Star fold' mesh created by Primer in unfolded and folded states

The airbag shown here can be created in approximately 5 seconds on a typical workstation. The advantage of this process (Figure 9) is that the whole operation is done within Primer. Creating several meshes to investigate the effect of the number of folds or points can be done easily - there is no need to return to a meshing pre-processor to create a new mesh.

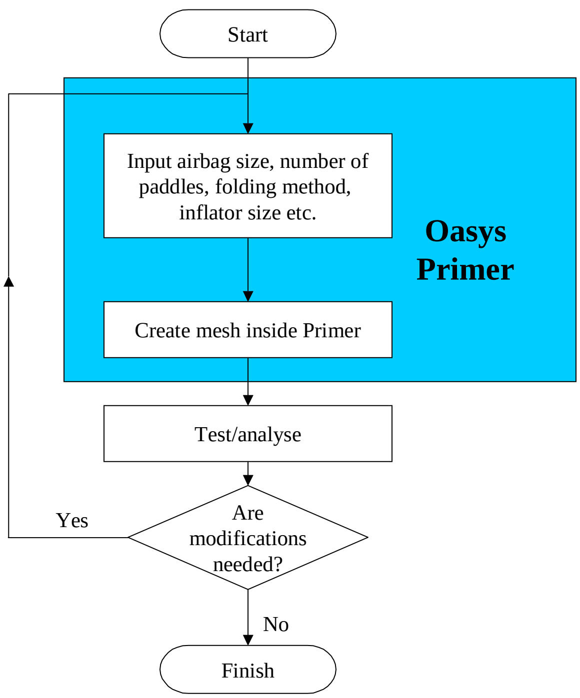


Figure 9: Flowchart for mechanical folding in Primer

Concertina folded driver airbag using mesh-independent method

The mesh-independent method was used to fold the driver airbag into a concertina fold pattern. The folding method is similar to that illustrated for the thorax bag above, except that there is no need for an initial mesh for circular airbags. The initial menu and the mesh created by Primer are shown in Figure 10. The folded airbag and unfolded final mesh are shown in Figure 11. The folded mesh was created in approximately 20 minutes.

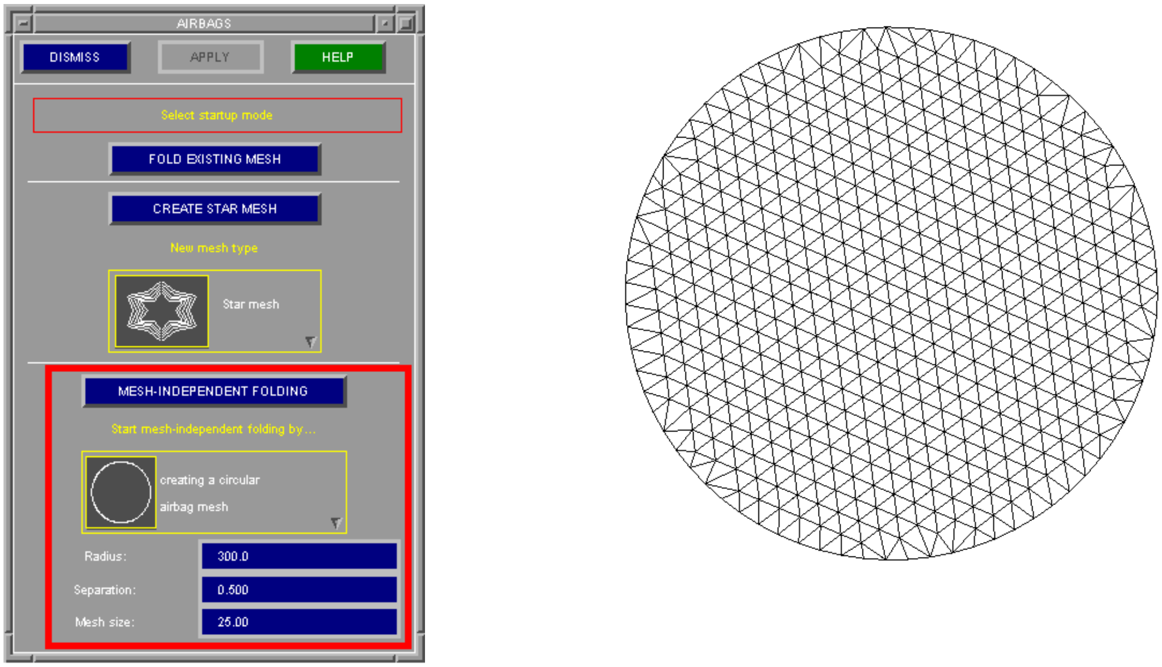


Figure 10: Creating circular mesh-independent airbag in Primer

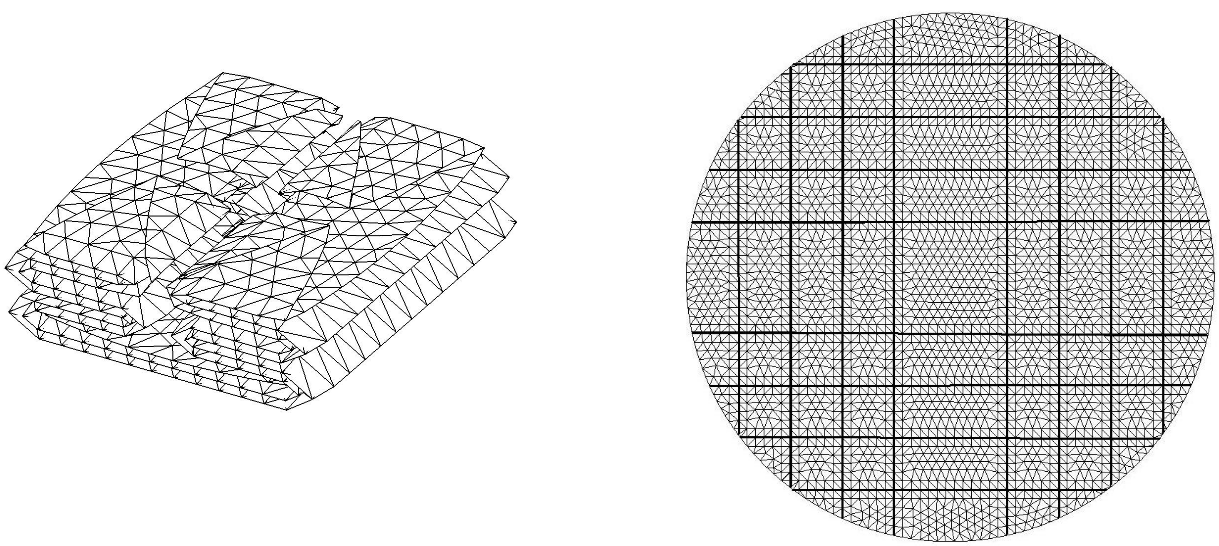


Figure 11: Concertina-folded driver airbag (reference geometry shown on right)

Effect of gas flow simulation on deployment of concertina-folded airbag

The concertina-folded driver airbag model was deployed first using the traditional control volume approach (*AIRBAG_WANG_NEFSKE_JETTING). In this method, the gas dynamics are approximated by jetting forces that account for the change of momentum of the gas jet as it strikes the fabric. The pressure is assumed to be uniform throughout the volume of the airbag; this does not reflect the early stages of deployment, when the folds may act as barriers to gas flow and hence the pressure is non-uniform. This in turn may lead to unrealistic airbag shapes during deployment.

The same airbag model was then deployed using LS-DYNA's fluid flow capability. The surrounding air and internal airbag gas are represented by an Eulerian mesh consisting of two-phase material (air and internal gas), defined using *ALE_MULTI-MATERIAL_GROUP. Gas inflow conditions were defined in this simulation using *SECTION_POINT_SOURCE; it would be more convenient in future to use *SECTION_POINT_SOURCE_MIXTURE, which requires input similar to *AIRBAG: curves of mass flow rates and temperatures versus time for each gas constituent. The fabric elements are coupled to the gas mesh using *CONSTRAINED_LAGRANGE_IN_EULER. The simulation took approximately 1 hour on a 12 CPU linux cluster using LS-DYNA 970 MPP. Figure 12 shows typical gas velocity vectors during deployment.

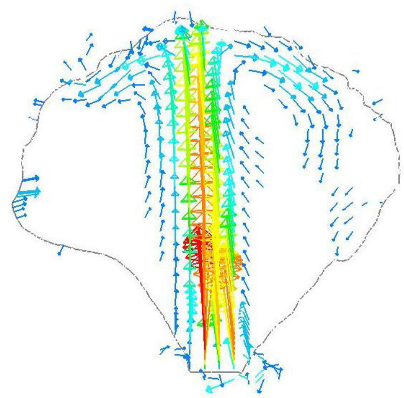


Figure 12 – Gas velocity during deployment

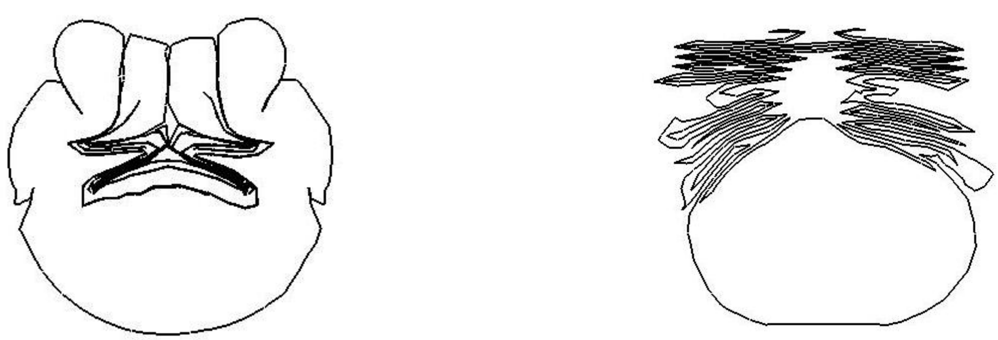


Figure 13 – Control Volume (left) versus Euler gas flow (right) – Section through unfolding airbag

Figure 13 compares the partly-deployed airbag models using control volume and Euler gas flow analysis methods. The gas flow analysis method correctly predicts that some regions cannot inflate initially, because the folds prevent the gas entering.

Effect of fold pattern on deployment of ALE airbag

The mechanically folded (star-fold) airbag was also deployed using the same Euler gas flow modelling method and gas input; the airbag fabric is a 600mm diameter circle in both cases. Deployment is compared in Figure 14 below.

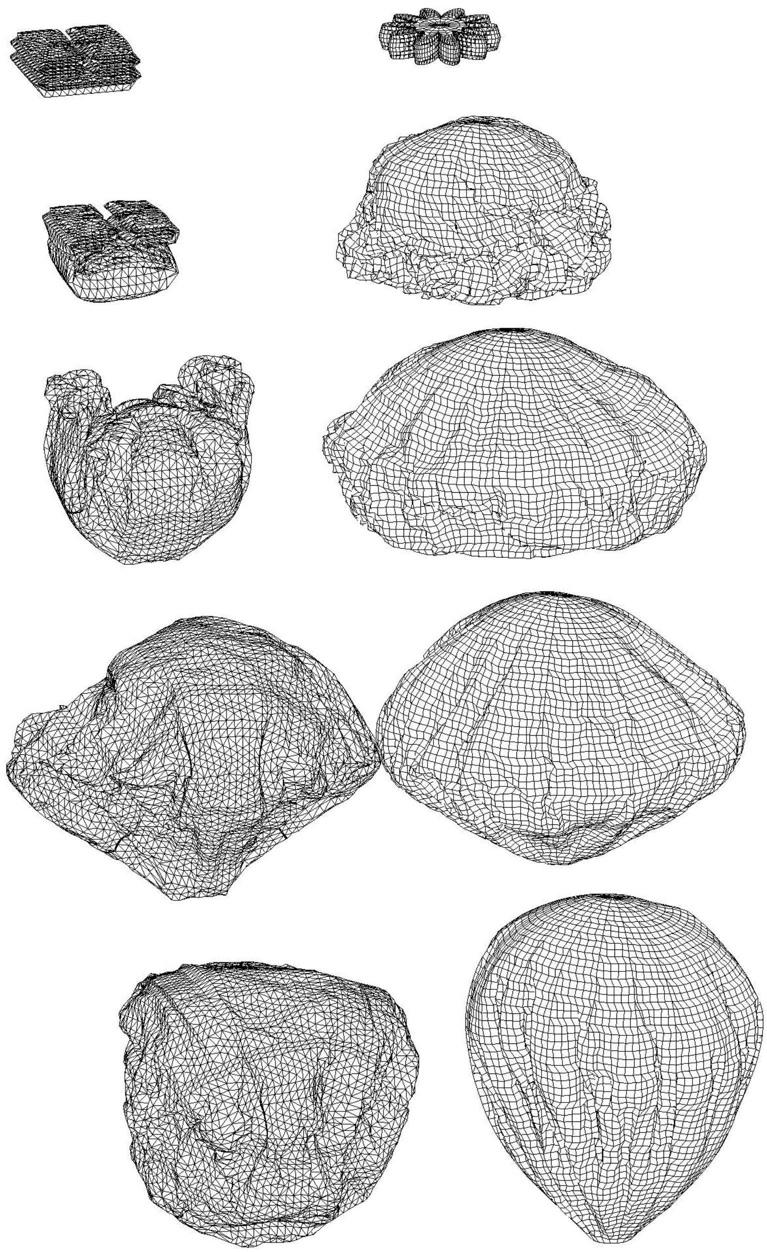


Figure 14 – Concertina versus mechanically folded airbags, deployed using identical Euler gas flow input data in LS-DYNA 970

The mechanically folded airbag shows a generally cleaner deployment, with less initial delay than is shown by the concertina folded airbag – the delay is caused by the need to unfold the fabric before the gas can fill the airbag. More energy has been used to unfold the fabric of the concertina-folded airbag, resulting in a slacker appearance, less pressure, and less motion towards the occupant. These differences in deployment behaviour could potentially lead to differences in occupant injury.

Conclusions

Oasys Primer can used to quickly create fold patterns for airbag simulations in LS-DYNA. Two different methods are available: a simulation of a mechanical 'star' fold and mesh-independent folding. An airbag with a star fold can be created in OASYS Primer in a couple of minutes. Mesh-independent methods in Primer can be used to dramatically speed up the process of creating and modifying fold patterns on airbags. In most cases a folded airbag mesh can be created within 10-20 minutes. Both methods create meshes suitable for deployment using either the control volume (*AIRBAG) or the ALE capability of LS-DYNA.

Fold pattern should be included in airbag simulations because the deployment sequence, and hence occupant injury predictions, can be affected. Euler gas flow methods are best suited to modelling the early stages of deployment. These can be undertaken in reasonable turn-around times: about one hour for the examples shown on a linux cluster running LS 970 MPP.