Airbag Folding with JFOLD
Latest Developments and Case Studies

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Abstract

JFOLD is a software tool for simulation based airbag folding in LS-DYNA®. Today's airbag deployment analysis demands accurate folding of complex designs, but this is often a very time consuming process requiring expert input. JFOLD's continuous development focuses on making the process simpler and quicker and to give the non-expert access to complex folding techniques. This is achieved through three core elements: intuitive user interface, built-in customisable tool libraries and realistic, state of the art examples and tutorials.

This paper describes two methods of folding a passenger airbag, including and a novel way to quickly flatten the bag from 3D to 2D.

To further reduce airbag development cycle times and cost, a new airbag morphing application is under development to help the user optimise the design in a virtual environment. This and other new features will be presented.

Introducing JFOLD

JFOLD is a software tool developed by JSOL Corporation that helps the user perform simulation based airbag folding. It runs inside Oasys PRIMER as a JavaScript, and uses LS-DYNA® to simulate each folding step. The JFOLD graphics interface is designed to be easy to use and intuitive, so only a basic knowledge of LS-DYNA or PRIMER is needed.

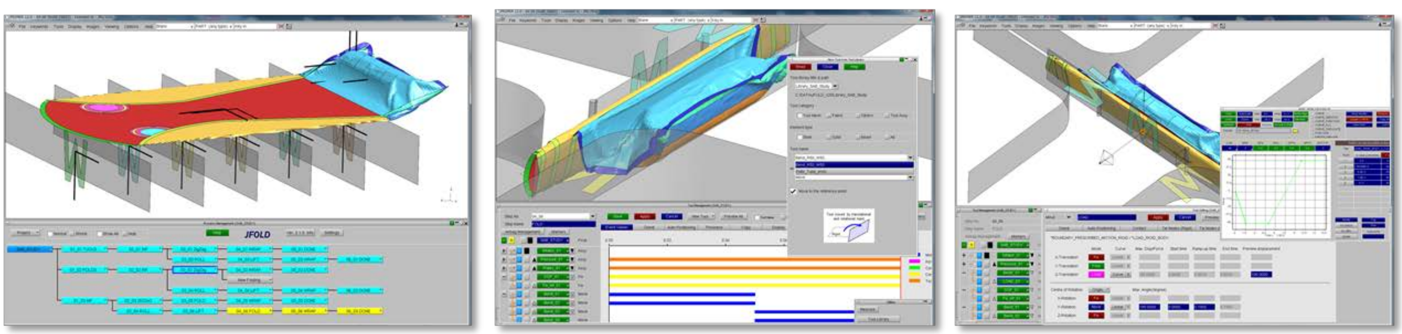

Fig.1: JFOLD's GUI: process management, tool management & tool setting panels

JFOLD's special benefits
- Folding steps managed using flow-chart graphics
- One-click auto-positioning of tools
- Reusability of tools
- Non-encrypted input files
- Free, state-of-the-art example models to use as templates

How it works

JFOLD manages the folding processes in a series of "steps". Each step uses one LS-DYNA analysis to deform the model like a real fold, stitch panels or relax fabric, etc. The airbag model is passed from step to step, using the deformed shape from the previous analysis. Folding steps can be modified, copied and branched off at any stage to investigate different folding patterns. “Tools” are used to deform the airbag and these can be copied across steps, imported from the built-in library or from the user’s own.

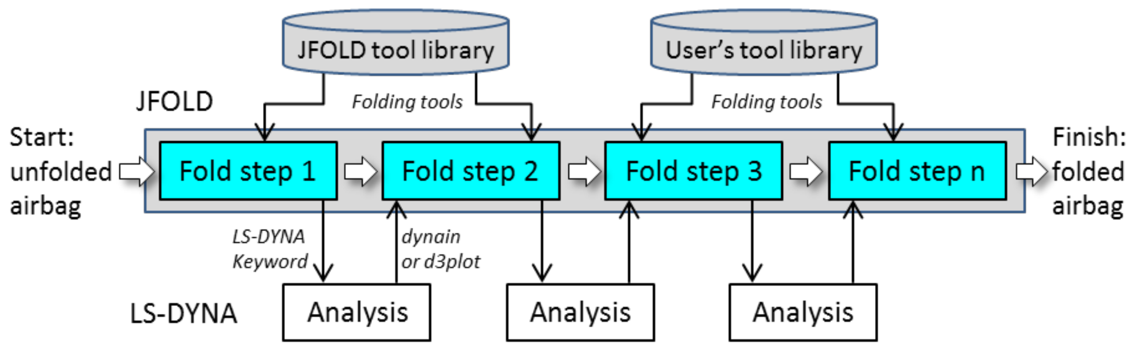

Fig.2: Schematic of one folding process using JFOLD

Tools available in JFOLD Version 4 Example Library

Category	Element Type	Characteristic (Action/tool type)	Extras
Tool Mesh	shell plates (11 sizes) solid plates (11 sizes) shell tubes (4 sizes)	Interchangeable action types: Move, Stationary, Load, Press, Roll, Fold, FinalGeom, dependent	Contact to airbag. Connected to airbag via extra nodes, rigid beams or tied contact.
Fabric	Non-mesh entities that are applied directly to airbag fabric	Pressure, LoadNodes, FoldLine (beams), Fix (SPC), Rigidify (NRB), Stitching (beams)	Many unique settings for each type.
Tool Assembly	Fold assy (3 sizes) Z-fold assy (4 sizes) DAB inflator	Special pre-defined action types	
Others	Inflator mesh examples (DAB, SAB, CAB, PAB) Cables	Inflators are FinalGeom type Cables are beams	

Table 1: Tools in JFOLD’s example library are grouped into four categories

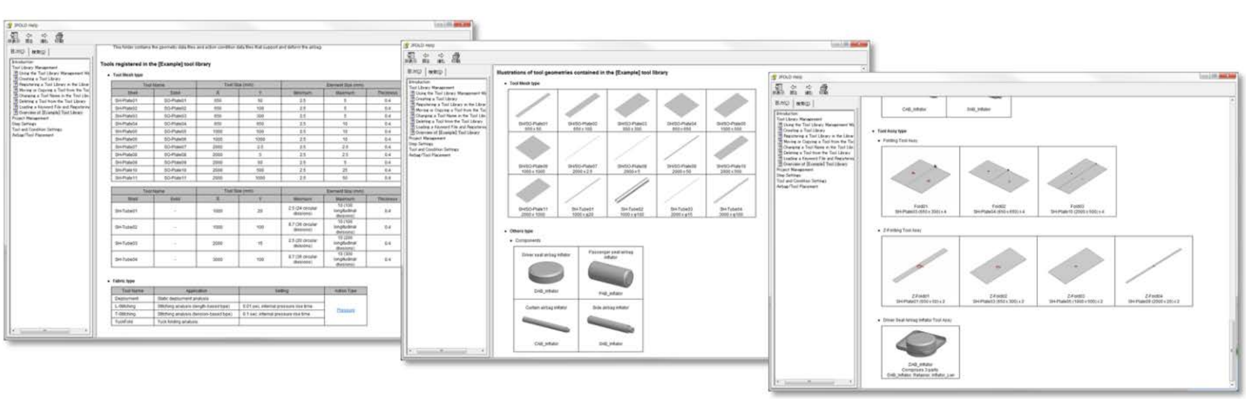

Fig.3: Example Library Tools are explained in the comprehensive on-line help pages

New Developments in JFOLD Version 4

The latest version of JFOLD contains many user-interface and speed enhancements (copying tools is now 30% faster than v3). Other main additions include:

1. LS-DYNA submission to local processors

Each step can be submitted directly from within JFOLD's process management panel to LS-DYNA running on local processors. The analysis progress is tracked and the button changes colour according to the job and termination status. LS-DYNA executable and number of processors are defined in a new settings panel. (LS-DYNA license sold separately). In the future JFOLD will be able to run a chain of folding analyses automatically.

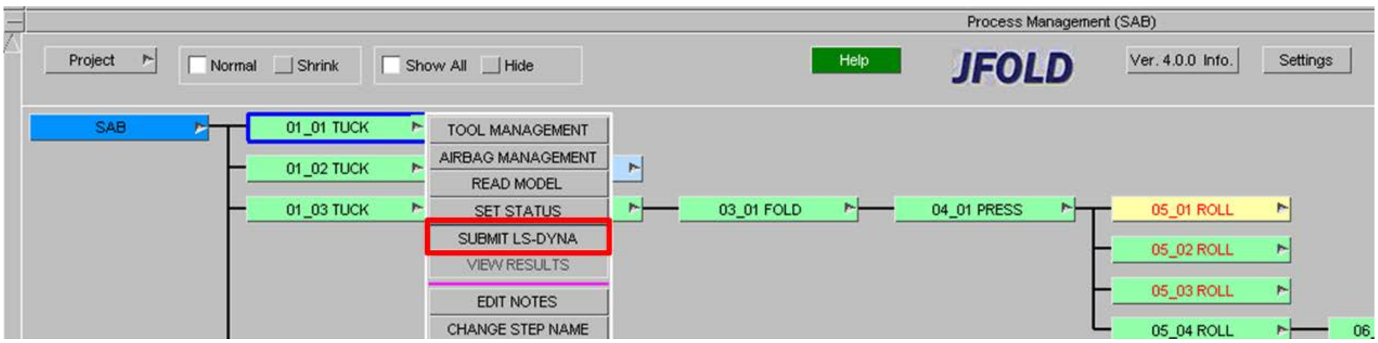

Fig.4: LS-DYNA submission to local processors available in JFOLD v4

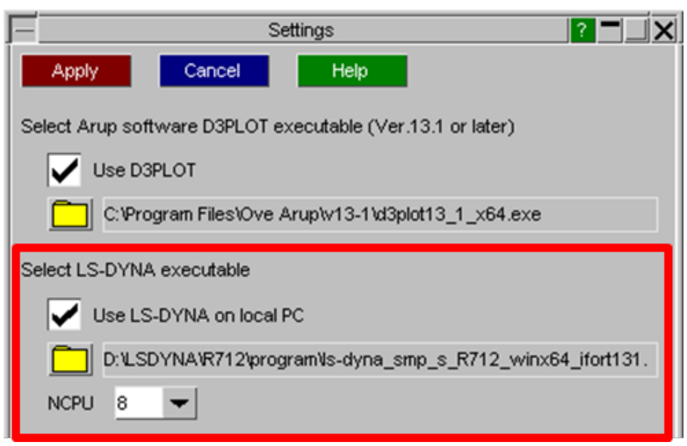

Fig.5: Local LS-DYNA executable and number of cores defined in the new settings panel

2. Deformable tool type

This addition to the tool mesh category supports *MAT_ELASTIC, *MAT_FABRIC and other deformable material types. For example a rigid tube is used to roll up a curtain airbag in one step, then changed to become a flexible core in the next step. This core keeps the rolled section of fabric stable when deformed to fit the vehicle. For *MAT_FABRIC tools JFOLD v4 can create and modify the *AIRBAG REFERENCE GEOMETRY for that tool, allowing "shrink tubes" shown earlier to be generated using tools rather than airbag components.

3. Folding Assessment Information

To help the user determine the success of the airbag folding analysis JFOLD v4 reports:

- The number of crossed edges (contact penetrations) that exist in the resulting airbag
- The % area change when compared to the reference geometry or previous state.
- Current volume of the airbag.

Case Study: Passenger Airbag (PAB)

In this study two techniques for folding a passenger airbag (PAB) are presented. PABs are usually three dimensional in construction and must be flattened during the folding process, usually according to a complex pattern of tucks and folds. This 3D to 2D step is one of the biggest challenges in folding airbag models. In the following pages we present a classical way of 3D-2D flattening; using plates to tuck the front and sides, and also a new much faster method using beams to define the fold crease lines.

Reference data

In 2011 the Occupant Safety Research Partnership (OSRP), a division of the United States Council for Automotive Research LLC (USCAR), made available on-line their 2006 research "Benchmark Problems for Evaluating OOP Simulation Capabilities of Occupant Safety Simulation Codes".[1] This data included in "Test Set 2" drop-tower and OOP test data for a typical passenger airbag. The airbag description and folding information was insufficient for accurate modelling but the overall dimensions and general folding pattern were used as a basis for this study.

Fig.6: Photos of the PAB from USCAR research in unfolded, partly-folded and folded states

Method 1: using plates and rollers (flattening process only)

As the shape of the PAB model was made up, no fold line information was available for collapsing the 3D structure to 2D. To get the inflated shape to fold flat without severe wrinkling a series of side tuck folds and stretching folds were performed. In all five steps (five analyses) were required. Previous experience guided the approach but still this process took a long time with much trial and error.

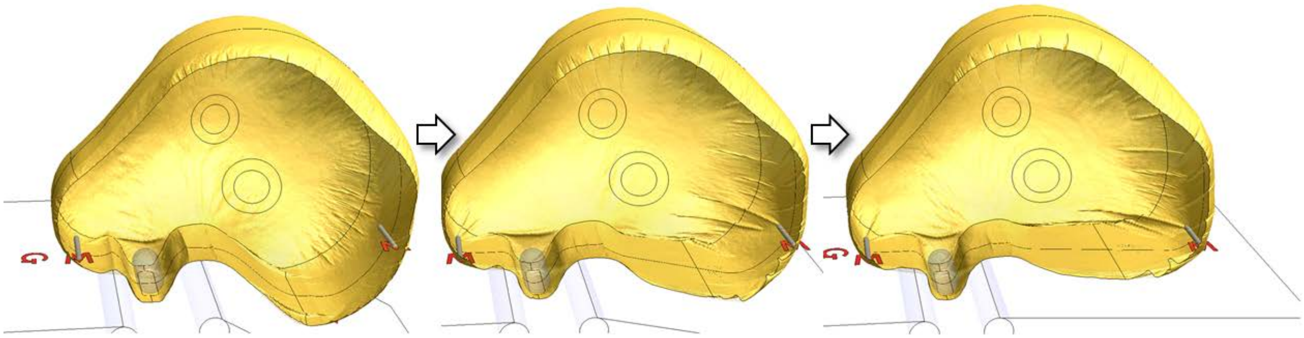

Fig.7: Step 1 – inner rollers & plates make the base flat

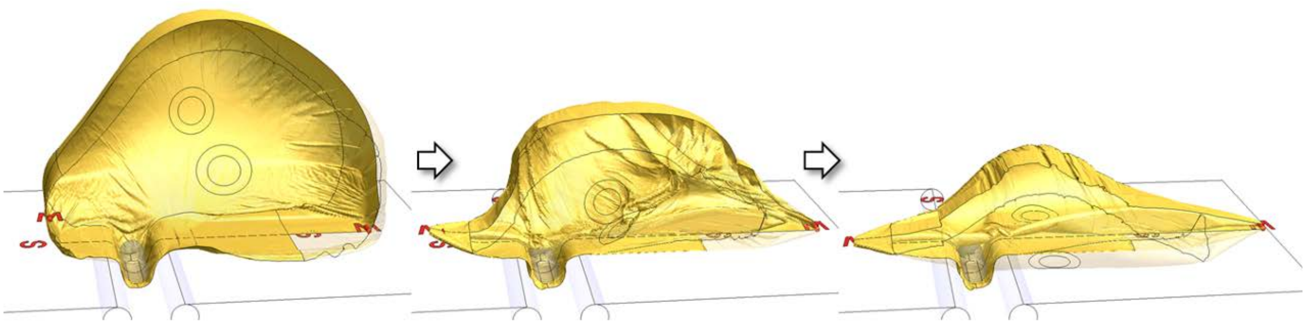

Fig.8: Step 2 – inner rollers stretch the bag while pressure pushes sides inwards

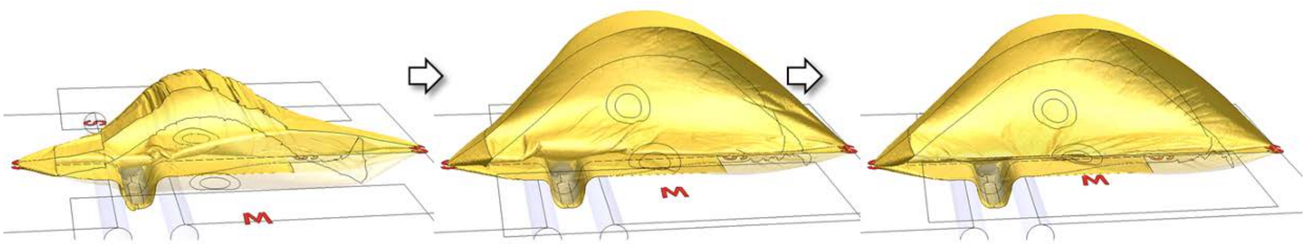

Fig.9: Step 3 – plates slide in to tuck the sides while pressure inflates the upper section

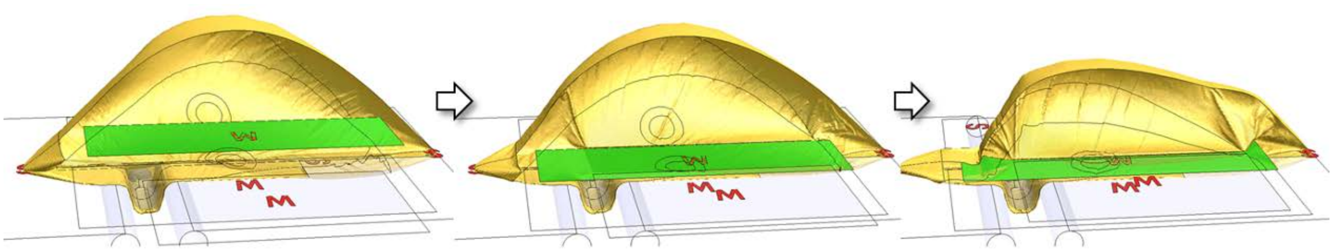

Fig.10: Step 4 – inner plate (green) presses the previous tuck while more plates slide in from the sides

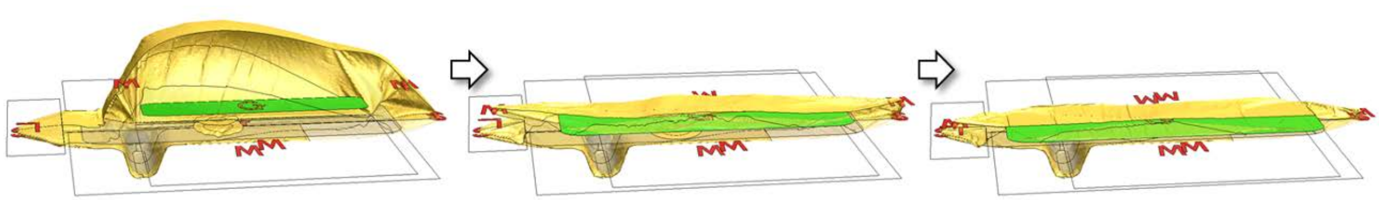

Fig.11: Step 5 – inner rollers used again to stretch the bag while pressure makes the last side tuck

Method 2: Using scanned fold lines (full folding process)

One objective of this study was to develop a faster and easier method of 3D-2D flattening. A new approach was considered that assumes most users have access to a real airbag with fold crease lines visible when unfolded. In our virtual model we took the crease lines from the example flattened in the steps shown earlier. The whole modelling process is included in this description.

Meshing from CAD

If the PAB geometry is very simple, CAD surfaces can be constructed in a 3D condition that enables the CAE modeller to mesh the parts already stitched up. However most PAB geometries are not simple and many users prefer to start by meshing 2D CAD surfaces of flat, separate fabric panels. In this method, seam lines are stitched together using beams between every node on matching perimeters. The mesh around the perimeter must therefore line up exactly for later merging of nodes. A good meshing pre-processor can achieve this without much effort.

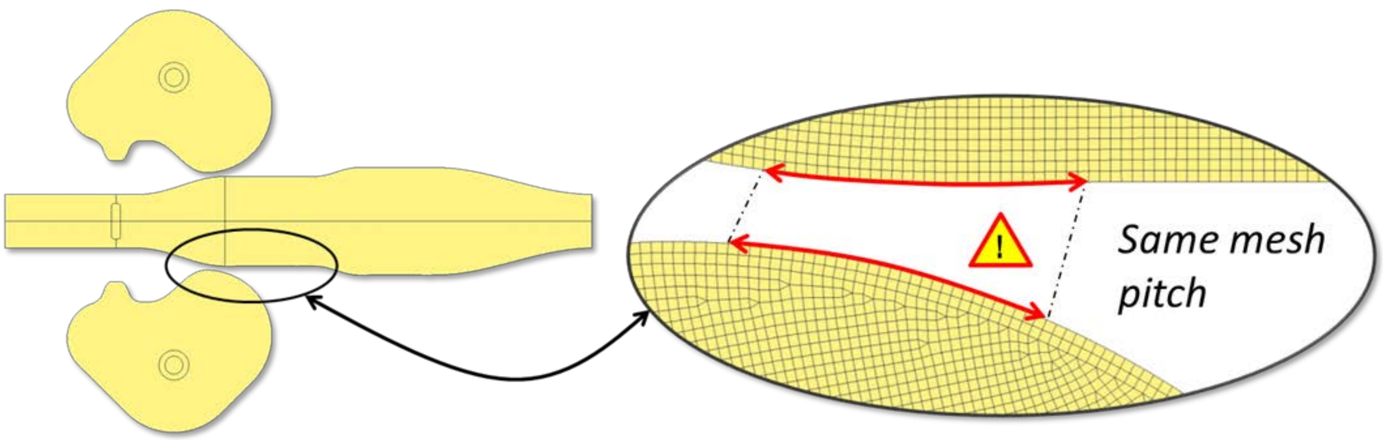

Fig.12: Creating the 2.5mm 2D mesh – perimeter mesh must match up

Transposing the fold line geometry

The next step is to open up the real airbag, scan the crease lines using a 3D measuring arm and convert those lines to beam elements of **MAT NULL** material. Again, good meshing software can achieve this very quickly. The beam elements can be independent of the fabric mesh, attached with a tied contact. Beam length should roughly equal the fabric shell mesh length.

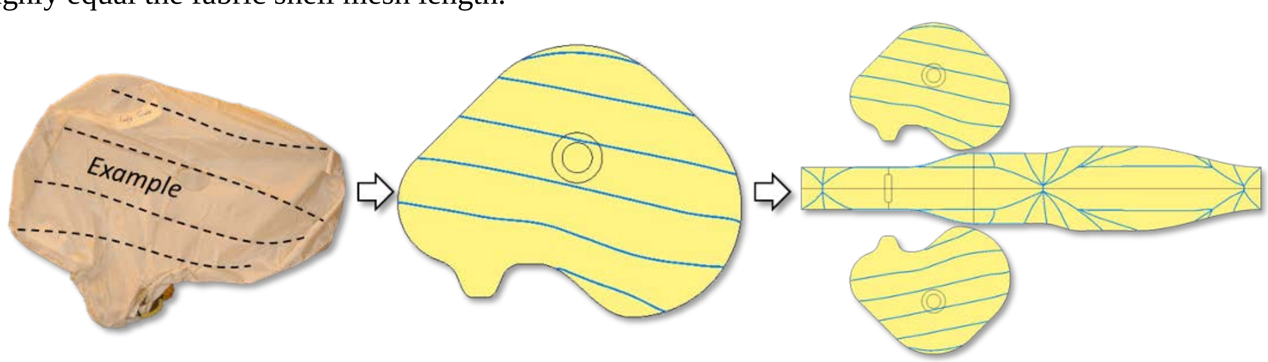

Fig.13: Transferring crease line geometry to the mesh surface as beam elements (example only)

Folding using JFOLD

Starting with the mesh of the flat panels marked up with the fold lines beams, the whole folding process can be performed in JFOLD very quickly with little trial and error.

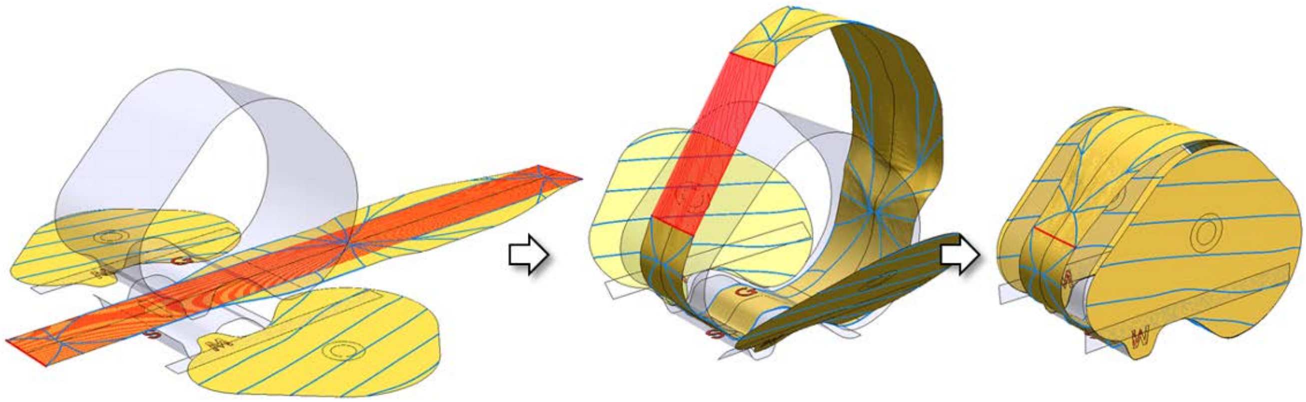

Fig.14: JFOLD Step 1 – Wrap and assemble the 3D shape from 2D meshed surfaces

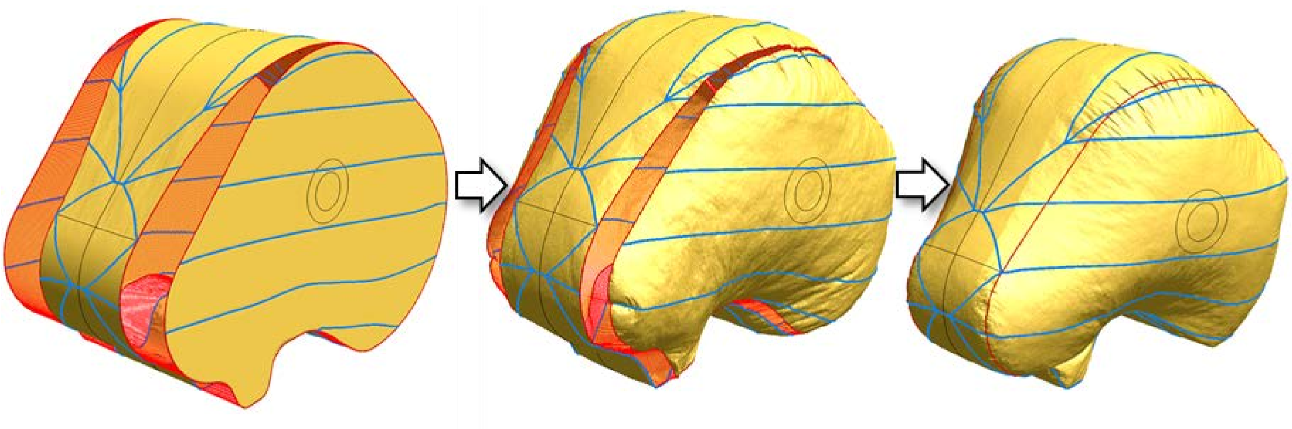

Fig.15: JFOLD Step 2 – Stitching the sides whist applying low pressure inflation

In Step 3 pressure is applied to fabric between the fold lines and load is applied to the fold-line beams so as to collapse the 3D shape. The simulation follows the established folding geometry of the real bag so requires only low pressures/forces and little wrinkling or stretching occurs.

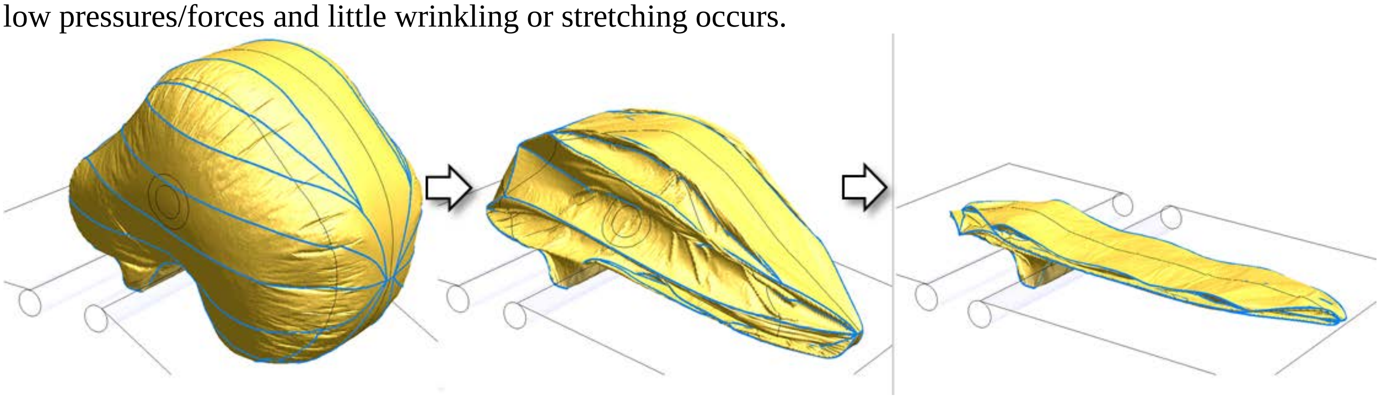

Fig.16: JFOLD Step 3 – Flattening the 3D bag into to a 2D folded shape

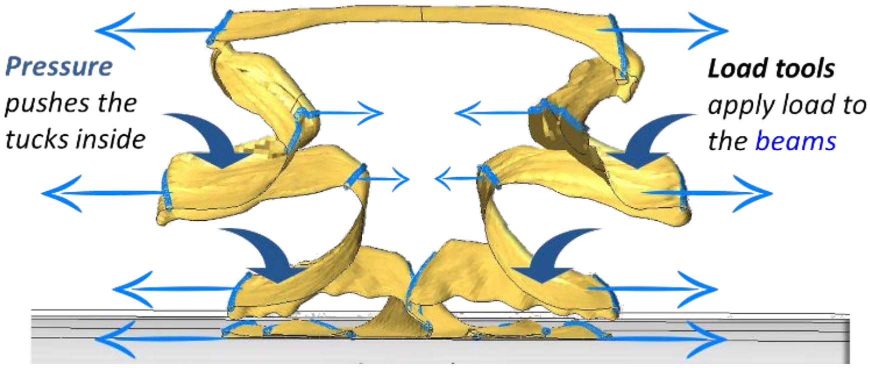

Fig.17: Cut section showing detail of the flattening process

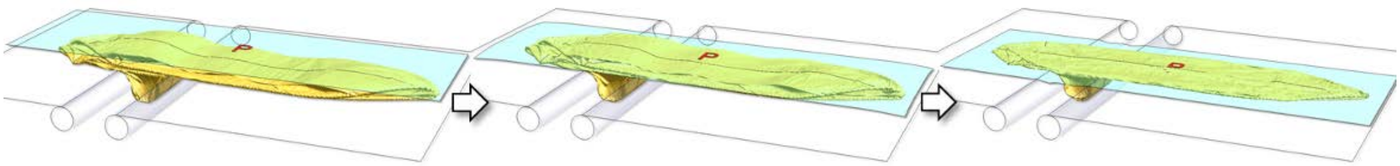

Fig.18: JFOLD Step 4 – Pressing to remove large gaps

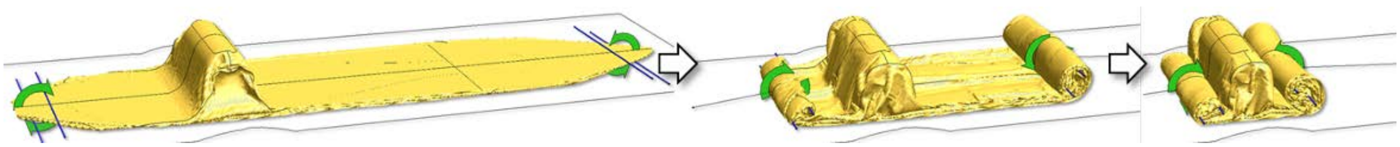

Fig.19: JFOLD Step 5 – Rolling up

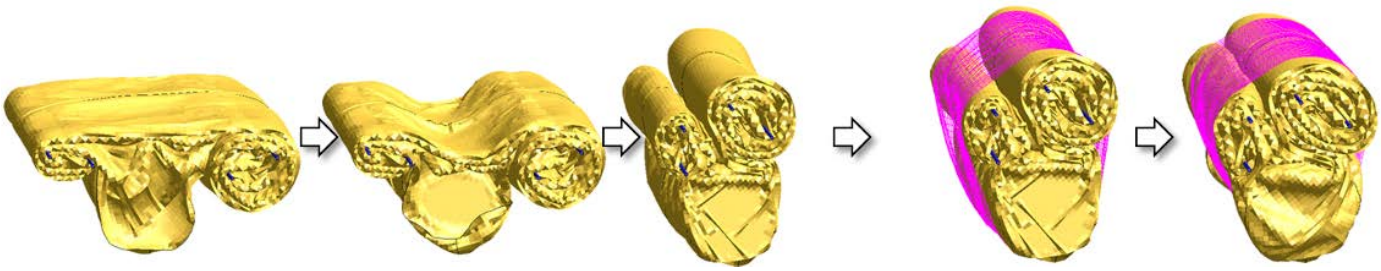

Fig.20: JFOLD Step 6 – Folding up the rolls and fitting the wrapper

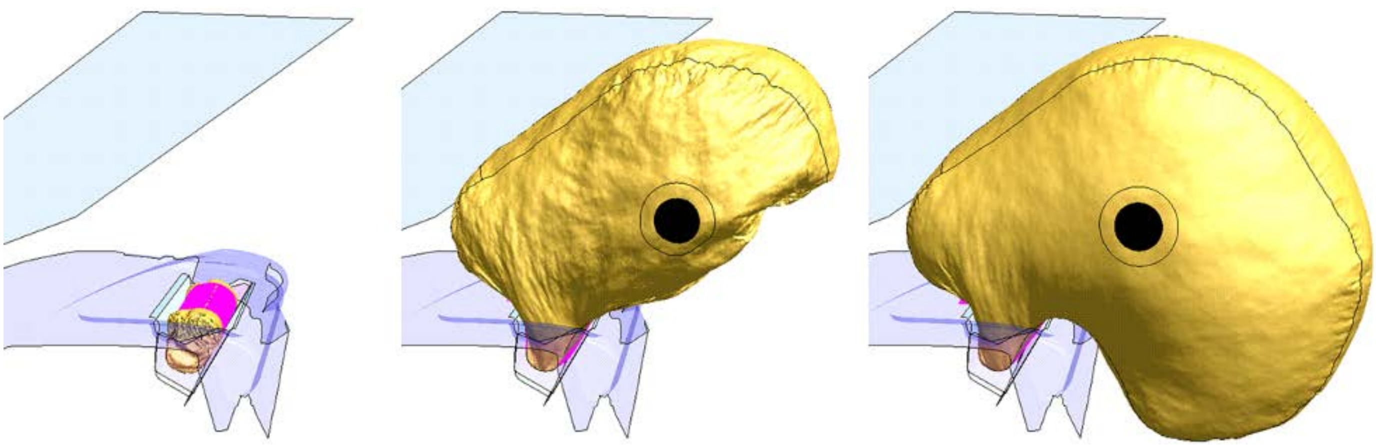

Fig.21: PAB deployment check using CPM

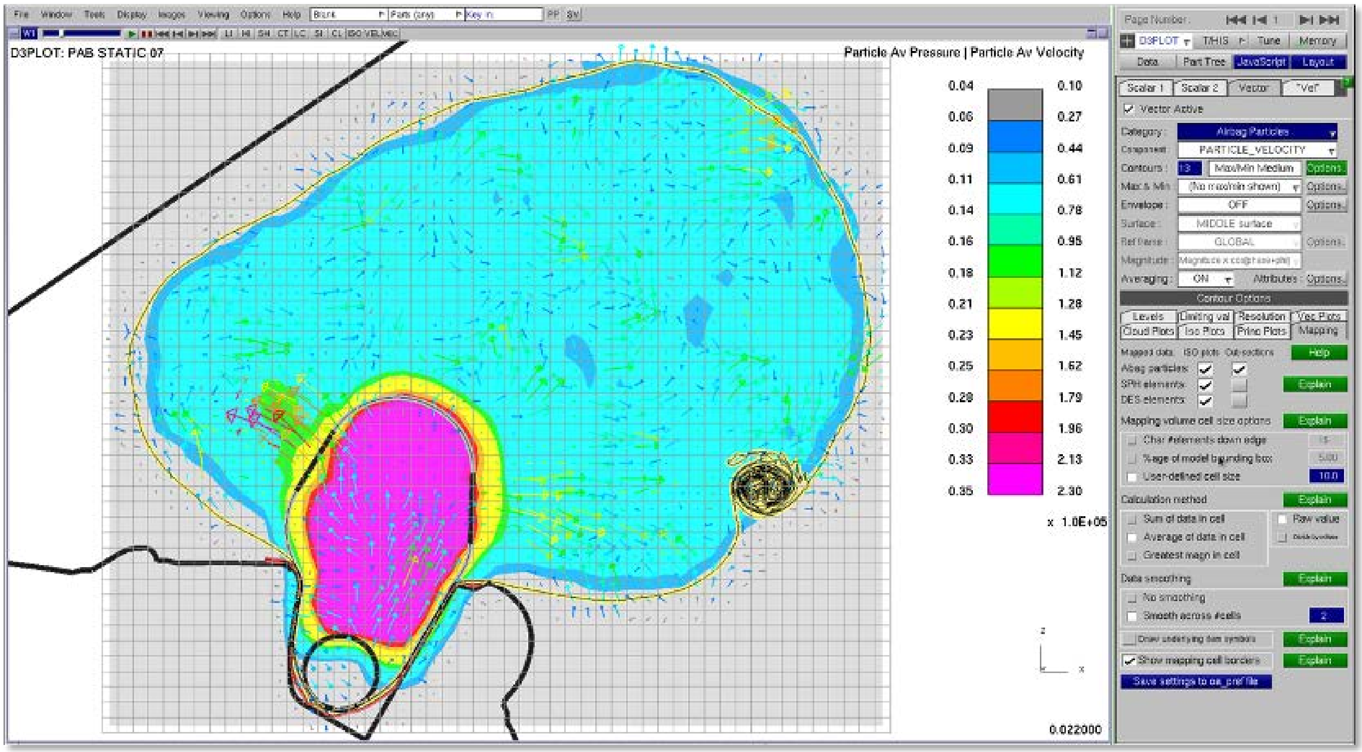

Fig.22: Visualising particle flow velocity and field pressure in a PAB with inner bag in Oasys D3PLOT

PAB Design Tool – Shape Morphing

Customers have requested the ability to morph the shape of the airbag to fulfil certain design criteria. This capability will be added to JFOLD in development phases from version 5 release.

After the stitching step in the previous folding process, models of the instrument panel, windshield and occupant can be imported as “tools” into a new JFOLD step. The user can then modify the shape of the inflated airbag interactively so as to make its deployed shape closer or further from the occupant or windshield.

This morphing process will use the interpolation feature of PRIMER’s scale & translate functions. The user selects an area of airbag to morph then drags the shape on the screen or inputs scale factors. The neighbouring area is stretched according to the selected interpolation function.

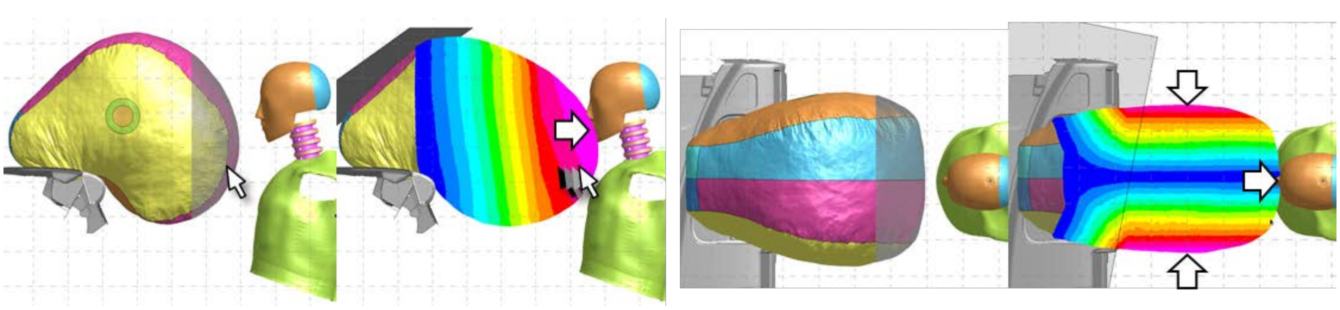

Fig.23: Shape modified by dragging or scale factor input in PRIMER’s orient interpolate function

JFOLD will calculate airbag volume and distance to the various "tools" (occupant head, chest, windshield etc.) and report the data during this process.

Once satisfied with the morphed shape the user can check that the deployed bag will achieve this condition by saving the step and running LS-DYNA. The results are then read into the next step where JFOLD again reports volume, distance to tools and also contact forces. The final deployed shape can also be visually inspected in JFOLD and results of the deployment in Oasys D3PLOT.

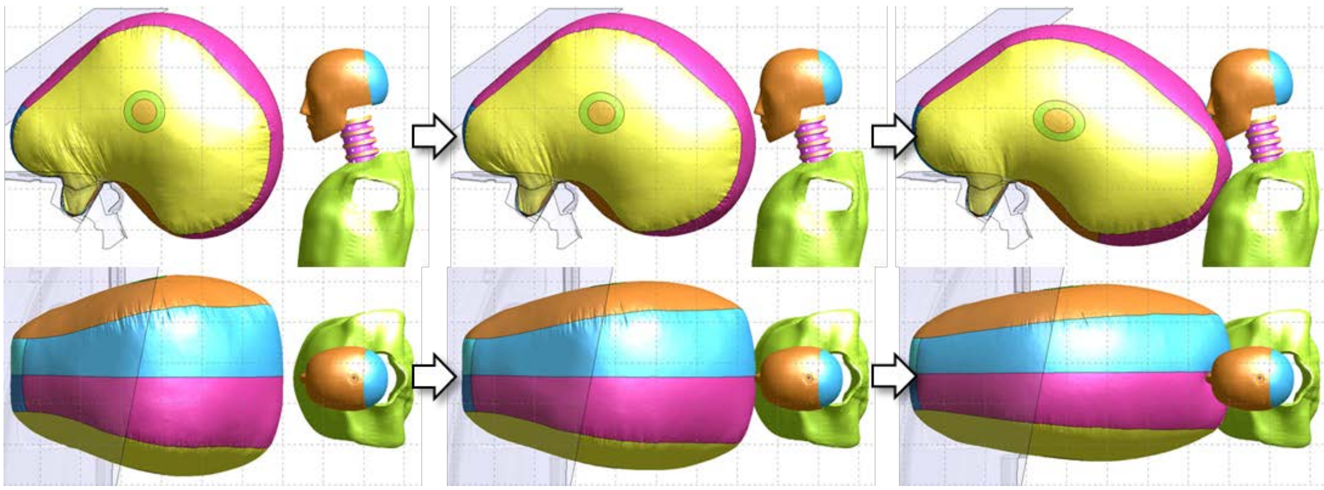

Fig.24: Checking the new shape using 20kPa inflation in LS-DYNA (Oasys D3PLOT)

If all criteria are not met the user can return to the previous step or easily copy the data to a separate new "branch" for further adjustment. If all criteria are met, JFOLD can then generate new 2D reference geometry for the new PAB design using an LS-DYNA analysis to morph the fabric in a constrained 2D condition. Crease line beams can be included in this process and the panels do not need remeshing. However this approach will not work if the shells have been locally highly distorted out of the plane of the panels.

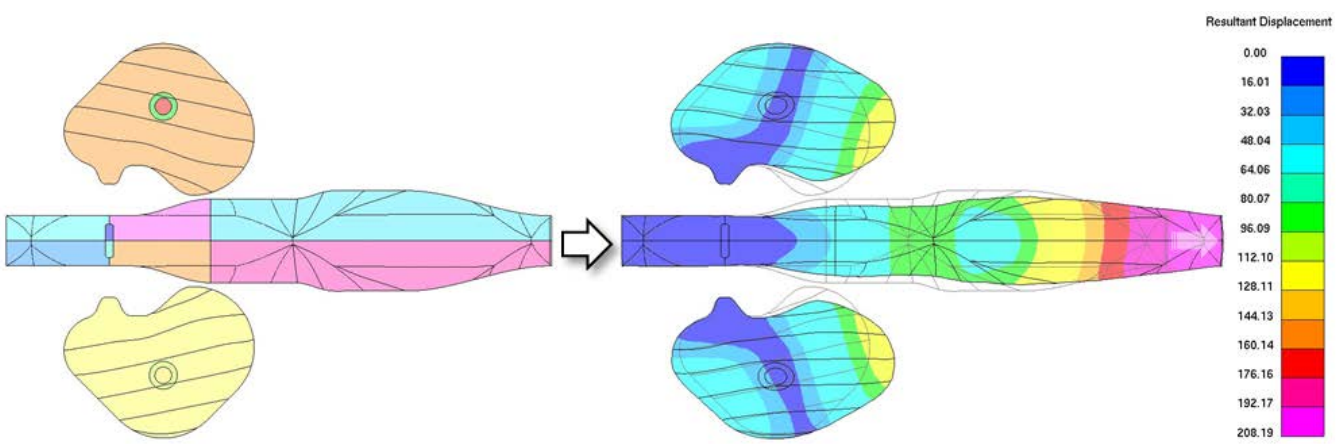

Fig.25: Using LS-DYNA to morph the 2D reference geometry into the new size/shape

The new 2D mesh can then be quickly refolded using the same tools and steps as performed earlier, albeit with adjustments for the new size/shape (e.g. one more roll may be needed if the airbag is longer than before).

This shape morphing capability will be gradually enhanced over time, for example options to avoid morphing the vents, or functions to scale the size of the vents.

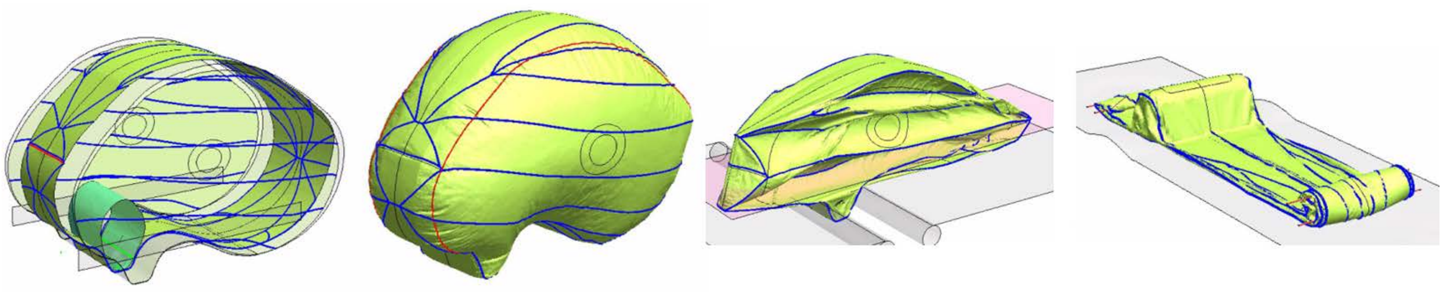

Fig.26: Refold new geometry using same steps as before

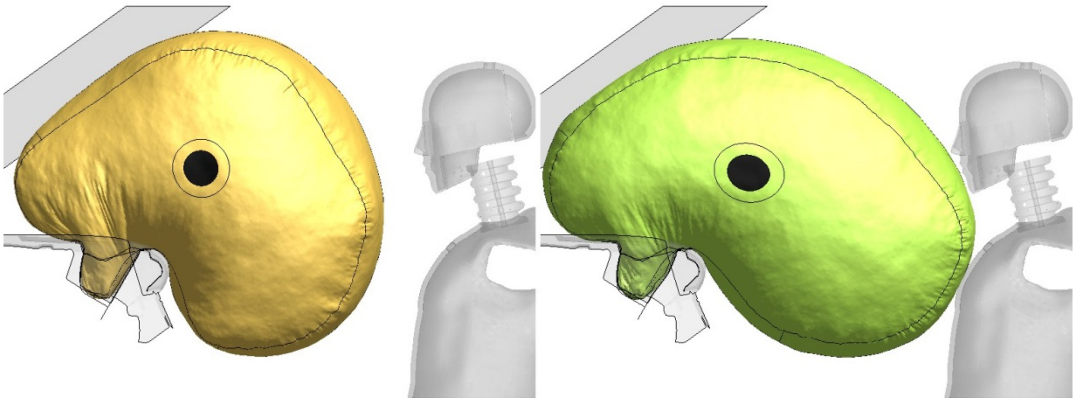

Fig.27: Original PAB compared to morphed shape (CPM) - Design improved ✓

JFOLD Examples & Tutorials

High quality realistic examples and tutorials are one of JFOLD's special benefits. As of February 2018 the following data is available free to JFOLD customers (supported in JFOLD v4):

Airbag Type	Example data	Tutorial
Side airbag (simple)	✓	✓
Side airbag (realistic)	✓	✓
Driver's airbag	✓	
Curtain airbag	✓	
Passenger airbag	✓	

Table 2: Example and tutorial data available for JFOLD v4

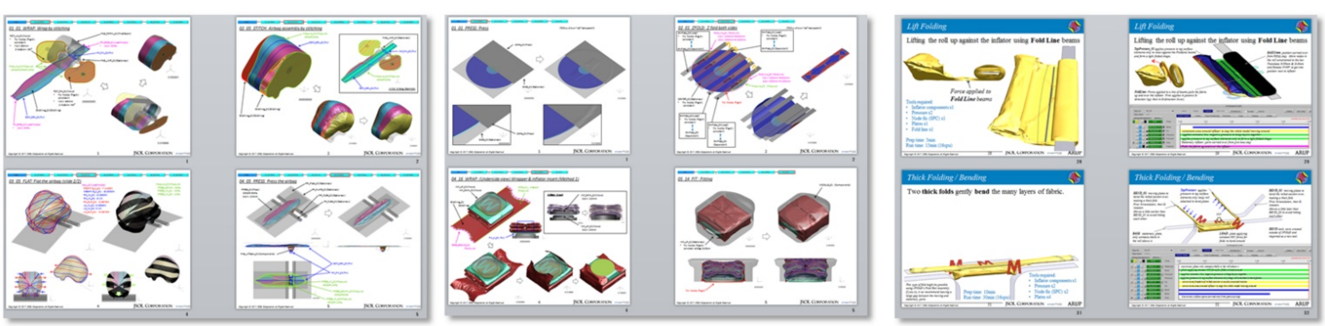

Fig.28: Examples of the tutorials and example models available to JFOLD customers

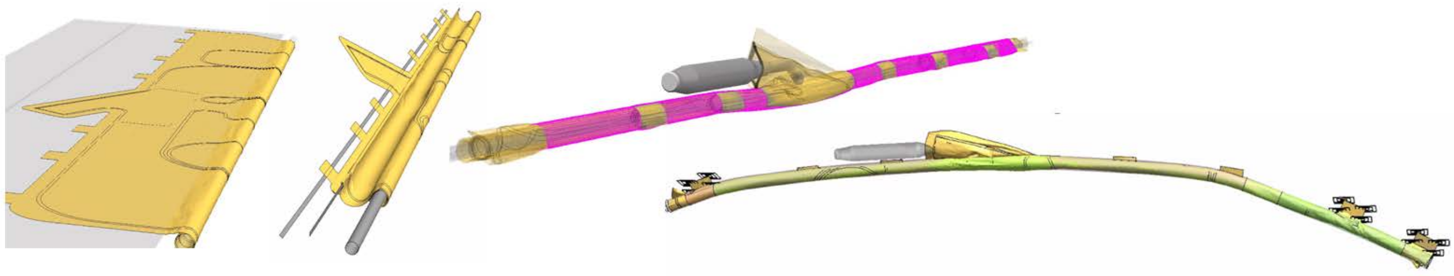

Fig.29: New Curtain Airbag Example (released with JFOLD v4)

Summary

This paper has introduced JFOLD capabilities though case studies and discussed new developments for future versions. The world-wide release of the latest Version 4 was in February 2018. Please ask your local Oasys distributor for a free trial version.

References

[1] USCAR OSRP Safety Simulation Working Group, "Benchmark Problems for Evaluating OOP Simulation Capabilities of Occupant Safety Simulation Codes", Problem version 8/15/2006
https://secure.uscarteams.org/secure/osrp/data/Test-HTML-Pendulum.html

The data used in this case study was provided by the Occupant Safety Research Partnership of USCAR (OSRP), which assumes no liability for its use, or for the analyses or conclusions that derive from its use.

[2] Taylor, R., Hayashi, S., Yagishita, S.,: "Introducing New Capabilities of JFOLD Version 3 and Airbag Folding Examples", 14th International LS-DYNA Conference 2016, Detroit, USA