Introducing New Capabilities of JFOLD Version 3 and Airbag Folding Examples

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Abstract

A software tool called JFOLD has been developed by JSOL Corporation to enable successful airbag folding using LS-DYNA®. This paper introduces some new capabilities of JFOLD Version 3 and demonstrates folding examples. JFOLD runs inside the powerful and popular pre-processor Primer. JFOLD Version 1 was released in July 2013 and has been continuously developed to make folding airbags quicker and easier.

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.

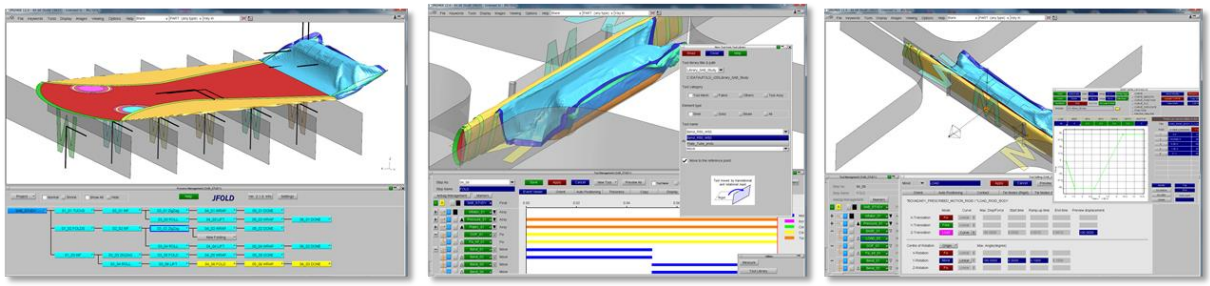

Figure 1: JFOLD's GUI: process management, tool management & tool setting panels

JFOLD's special benefits
- Intuitive and interactive operation: management of folding steps 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. 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 the user's own.

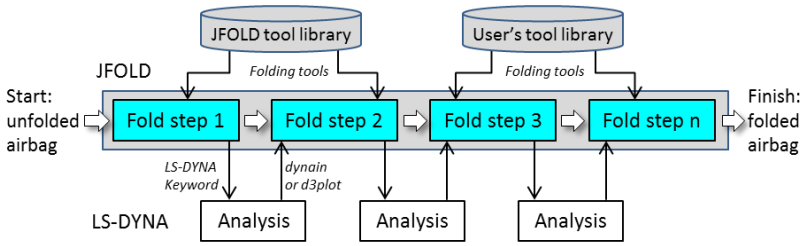

Figure 2: Schematic of one folding process using JFOLD

Project Sharing Capability
JFOLD data can be easily shared between companies, increasing project efficiency.

A typical inefficient scenario might exist as shown below:
- Airbag model development is done by supplier (folding and validation etc.)
- OEM receives model and wants to study changes in trim design, or package, or the influence of the final folds on deployment direction etc.
- OEM has to ask supplier to refold airbag adding cost and delays
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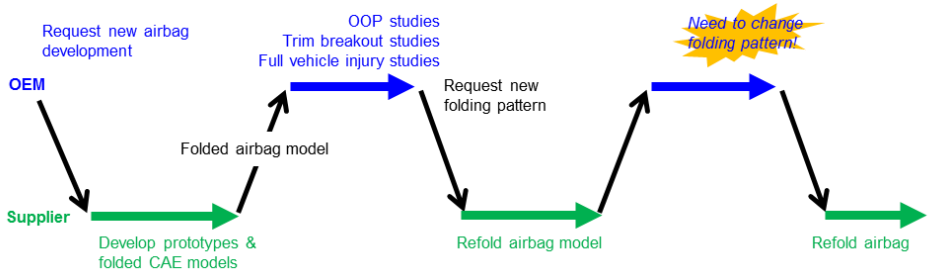

Figure 3: Inefficient scenario: only the creator can refold the bag

The solution: share folding capability with JFOLD:
- Supplier shares the JFOLD project data with OEM, including all steps needed to repeat the folding process
- OEM can easily modify the fold pattern to do own their studies - complete folding know-how not required (supplier does it the first time).
- Less burden on supplier – less project delays, saves cost and time
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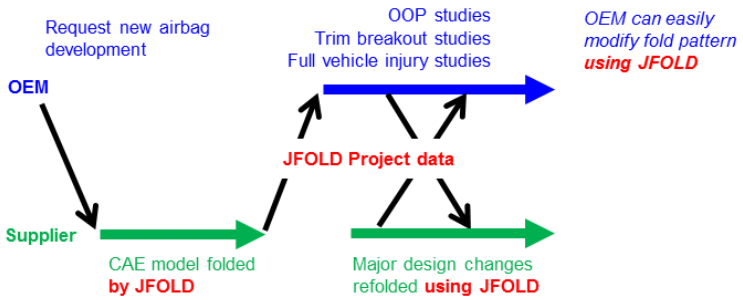

Figure 4: Efficient increased when both creator and user share JFOLD data

New Features in JFOLD Version 3

Moving tools using cables

With this new capability cables pull a tool into a desired location over time. The cables shrink to zero length over a defined time, like JFOLD's "stitching tool". The advantage of this method over BOUNDARY PRESCRIBED MOTION is that complex translations and rotations need not be defined. It also beats BOUNDARY PRESCRIBED FINAL GEOMETRY because tools move as a rigid body and can follow curved paths, as shown below.

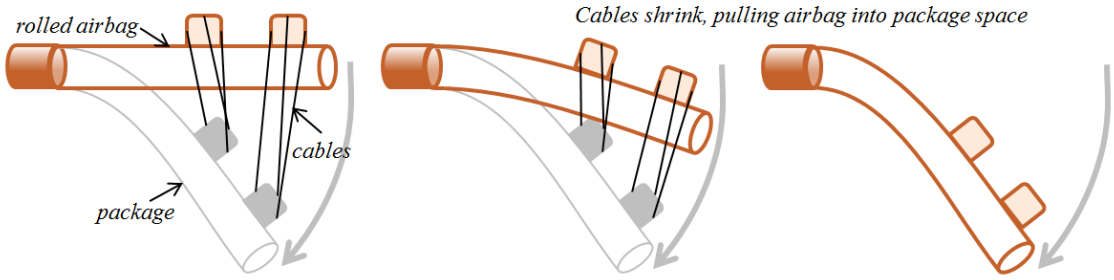

Figure 5: JFOLD Cables Tool can pull parts into place

Aligning airbag shell normals

Consistent shell normals are required when applying pressure to an airbag part during the folding process. In JFOLD Version 3 users can now align and reverse shell normals from within the airbag management panel.

Tying airbag fabric to a tool using tied contact

With this new method tools can be "stuck" to airbag parts so that the fabric moves with the tool. The tied contact has the benefits of birth/death times for the sticking action, tools can be rigid or deformable and by default all airbag nodes within the adjustable contact thickness are tied to the tool.

Managing stress relaxation in the airbag fabric

Version 3 allows the user to control the timing of the stress-strain restoration ("relaxation") in MAT FABRIC. Stresses and strains during folding must be kept to a minimum to keep the correct size and shape. JFOLD creates AIRBAG REFERENCE GEOMETRY at the start of the folding process and during each step stresses and strains relative to the reference condition are restored using the TSRFAC curve in MAT FABRIC. This causes the shells to try and regain their original shape and "relax" to zero stress. In JFOLD Version 3, users can control the time over which the relaxation process occurs.

This feature can be used to "shrink" a wrapper or cover over the folded airbag at the end of the folding process, if the user imports the wrapper in an expanded condition with its own reference geometry. It can also be used to fit a curtain airbag into a complex package space as shown below.

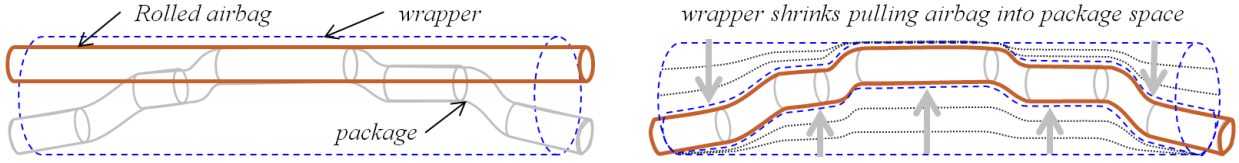

Figure 6: JFOLD shrink-wrap pulls a curtain airbag into place

Case Study: Driver's Airbag (DAB)

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]

Test Set 1 comprised pendulum data for a generic driver's frontal airbag folded using two different folding patterns: zig-zag and top-roll. The set also included inflator data, simple wheel and pendulum models, and enough information to develop a similar DAB model using the corpuscular particle method (CPM) in LS-DYNA.

The differences in pendulum acceleration for the two folded patterns were only significant for test cases where the module lid is fitted. Accurate module geometry and material data were not available so for this study we just used the no-lid test data to validate a baseline DAB model.

Objectives:

- JFOLD technical development – feedback to developers to improve future versions
- Create realistic examples to give to JFOLD customers to use as templates for their work
- Promote the capability of JFOLD using real-world examples
- Create a realistic baseline DAB model with which we can develop out-of-position (OOP) countermeasures and research new capabilities in LS-DYNA (future work)

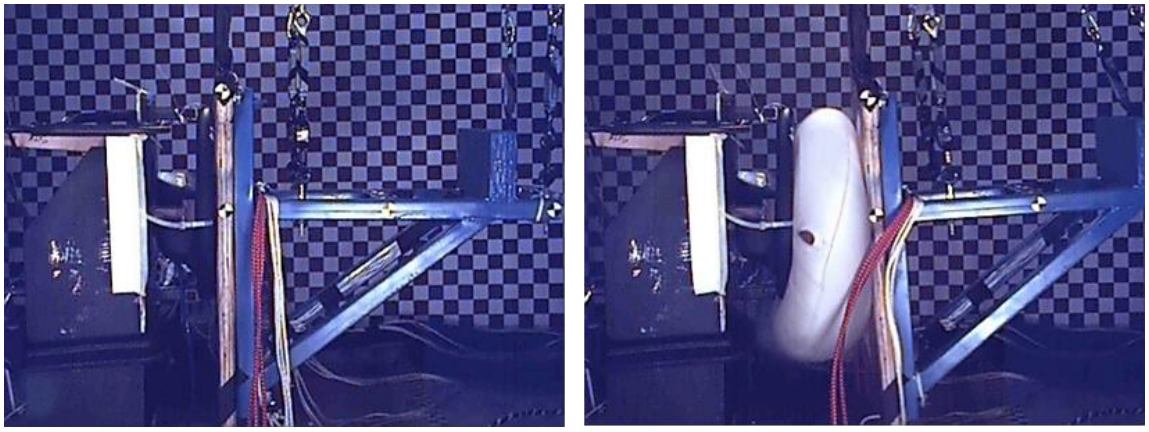

Figure 7: DAB Pendulum Tests from the USCAR Research

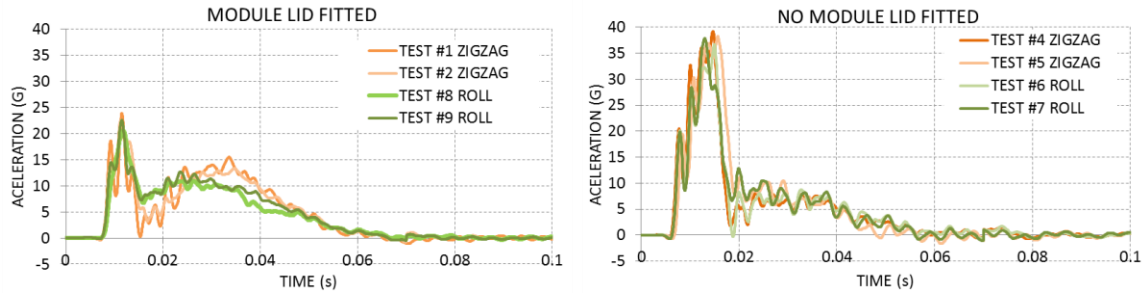

Figure 8: USCAR Pendulum accel. curves for tests with (left) and without (right) the module lid

Airbag Modelling & Folding

An existing generic DAB model was adjusted for size, 240mm tether length and vent diameter. The vents were not in the same location as seen in test film but considered good enough for this study.

Pattern 1: Top-Roll

The USCAR tests used a less conventional top-roll pattern. (The more common reverse-roll pattern is demonstrated later in this paper.) A pressed, flat bag is first rolled up using JFOLD's *Roll Tool* assemblies, then pressed and rolled again into the middle. In both roll cases pressure is applied to the fabric to reduce wrinkling.

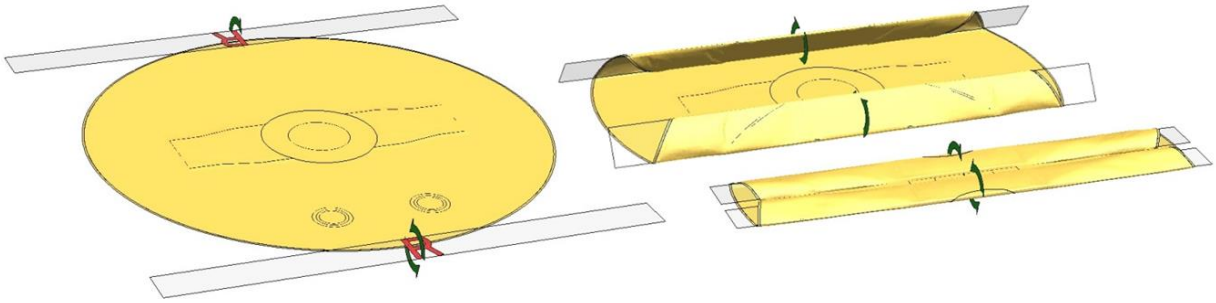

Figure 9: JFOLD roll folding using plates

For the second roll we use solid rods instead of flat plates – these provide a good contact surface and take up less space among the folded layers. The rods can be easily positioned to generate the correct roll width, although this can take some trial and error if the real tool width is not known. A process to assist this task is under consideration. Solid rods can be created by the user in JFOLD version 2, and will be available in the Example Tool Library from version 3.

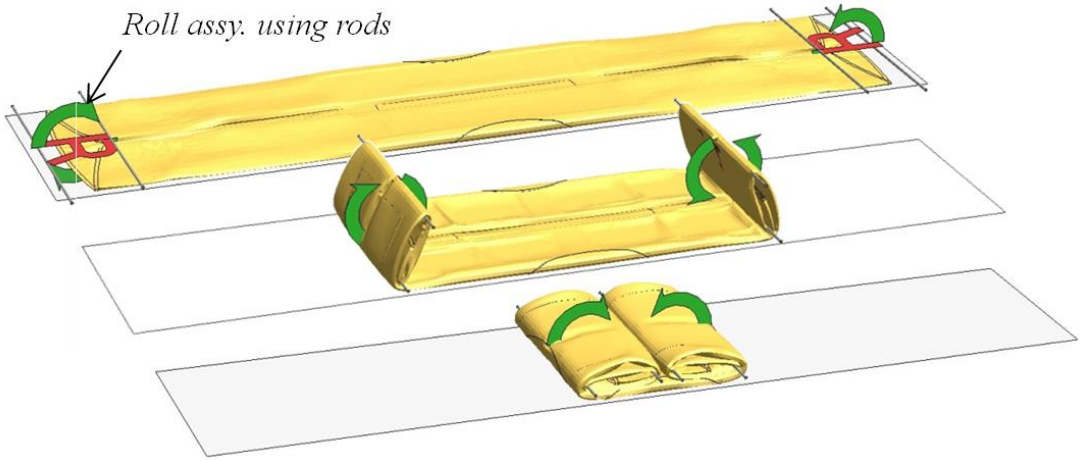

Figure 10: JFOLD roll folding using rods

The inflator is pushed into the folded bag while the wrapper is fitted. This combines two tasks and avoids premature unfolding. The wrapper can be added at any step. The inflator mesh can be imported or downloaded from JFOLD's Example Tool Library.

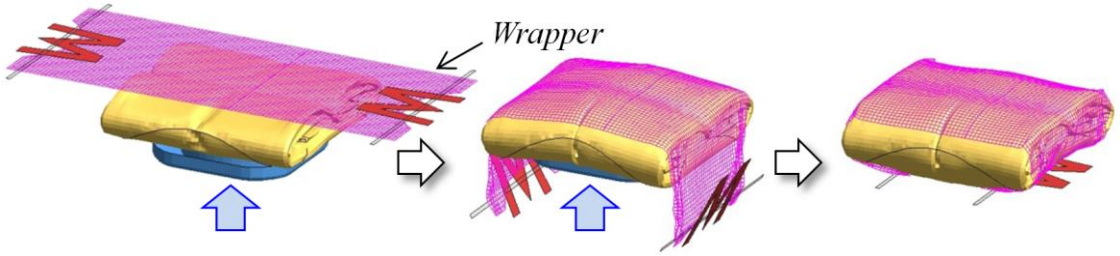

Figure 11: JFOLD wrapper and inflator fitting

Finally the module case is shrunk to real size, squashing the corners so the bag fits perfectly.

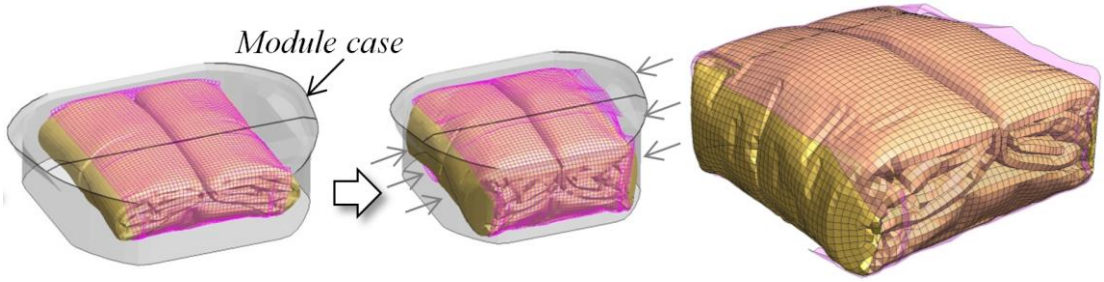

Figure 12: JFOLD fitting to the module case & final model (right)

JFOLD automatically creates reference geometry at the start of the process and stress relaxation is performed at every step, however high stresses and strains can still build up during folding, and these can cause severe wrinkles and distortion in the final model. The techniques shown in these examples have been refined to avoid high stresses from the start.

Pattern 2: Zig-Zag

The second pattern tested by USCAR involves two zig-zag folds. Both can be quickly executed using JFOLD's *Z-Fold Tool Assembly*. These tools use varying forces to move, rather than prescribed motion, so the exact trajectories do not need to be calculated. In this example we also use *Fold Line Beams* to neatly fold the ends over.

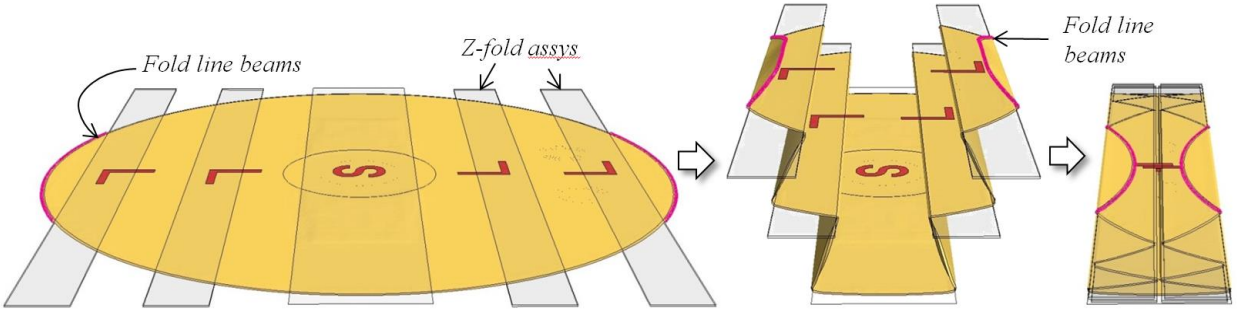

Figure 13: JFOLD zig-zag (Z-Fold) folding using plates & Fold Line Beams

For the second zig-zag we use solid rods again to cope with the thicker sections. In this step a larger area of fabric must be folded at the ends so *Move Tools* were used instead of *Fold Line Beams*. The *Move Tools* use the same forces as the *Z-Fold Tools*, but also have rotation.

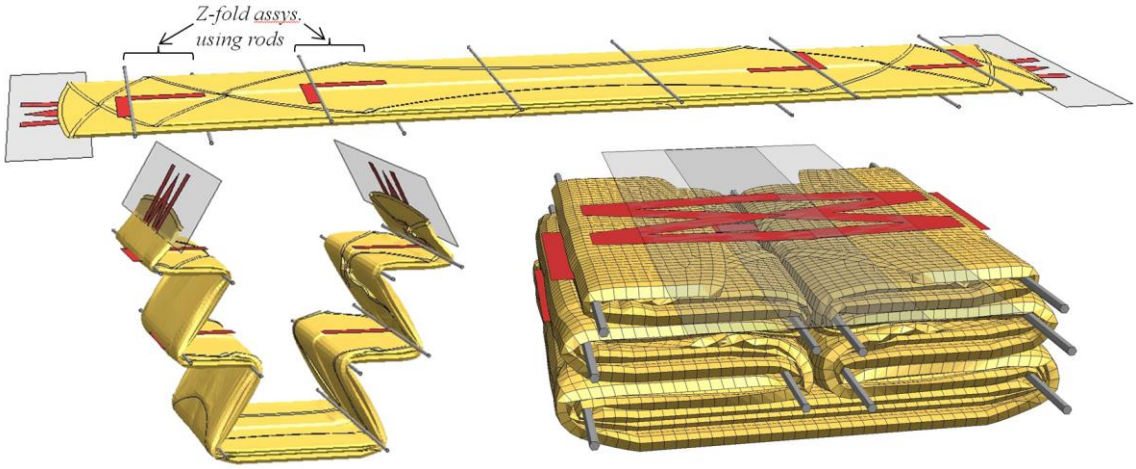

Figure 14: JFOLD zig-zag (Z-Fold) folding using rods

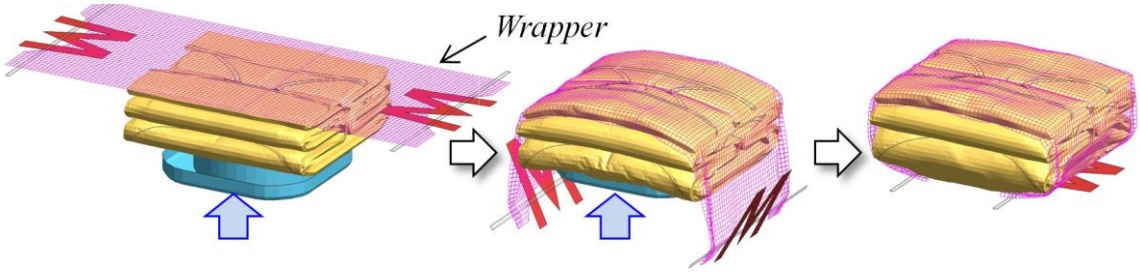

Figure 15: JFOLD wrapper and inflator fitting for the zig-zag model

Unfolded Airbag Model

The data set included pendulum tests performed on unfolded airbags so this geometry was also created using JFOLD. An inflator was pushed into the bag which was also in contact with a stationary steering wheel module.

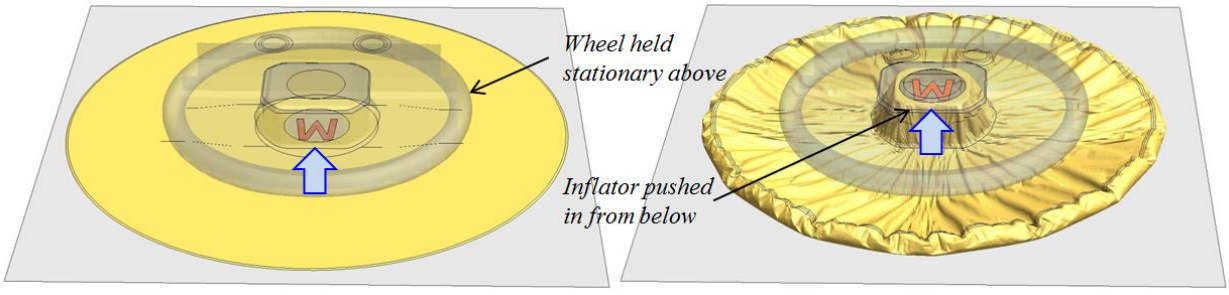

Figure 16: JFOLD generating the unfolded condition model

Deployment Analysis using the Corpuscular Particle Method (CPM)

First task was to correlate the model to the tests on unfolded airbags with and without vents and fabric coating.

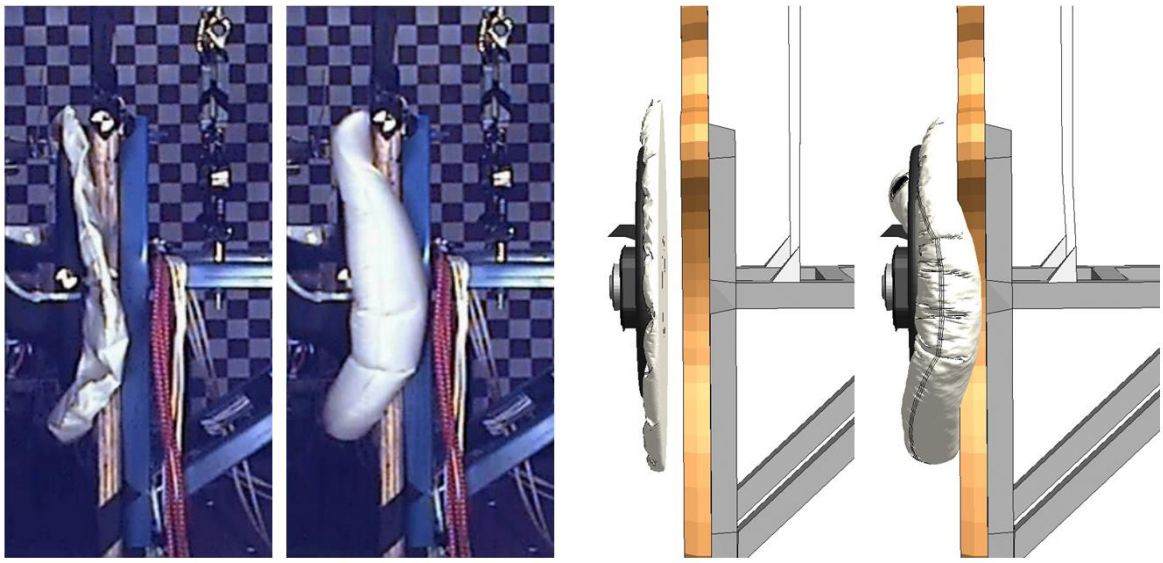

Figure 17: Pendulum tests on unfolded airbags, test (left) and analysis (right)

A reasonable correlation to test was achieved by tuning heat loss, leakage under the inflator and fabric porosity (all within realistic levels). Vents were assigned a soft material so they can stretch open under pressure. CPM's enhanced venting was also used.

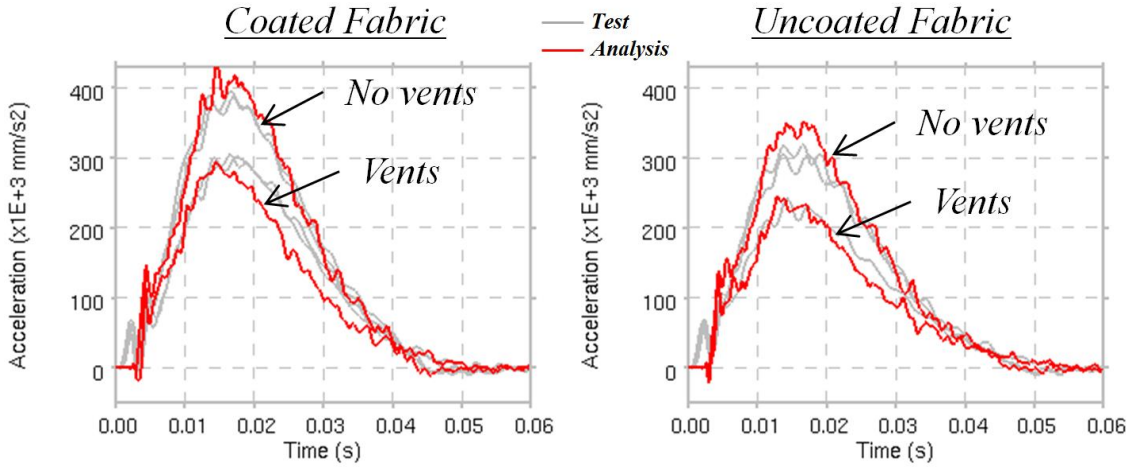

Figure 18: Pendulum acceleration for unfolded airbags

The second task was to simulate the folded airbag pendulum tests, without module cover lids. The airbag fabric node data was defined as an *INCLUDE file, so models of the zig-zag and rolled geometries could be analysed keeping all other input data the same.

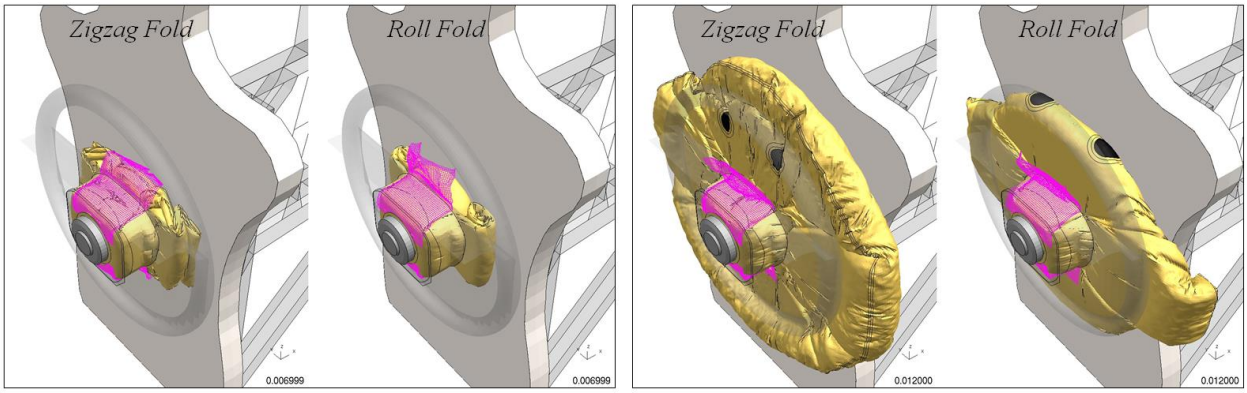

Figure 19: Deployment differences of zigzag and rolled airbags at 7ms (left) and 12ms (right)

Again, a reasonable correlation level was achieved with minimal tuning. This model is considered sufficient for future research, including the effect of module break-out (using the with-lid test data), designing OOP countermeasures, new folding patterns and so on.

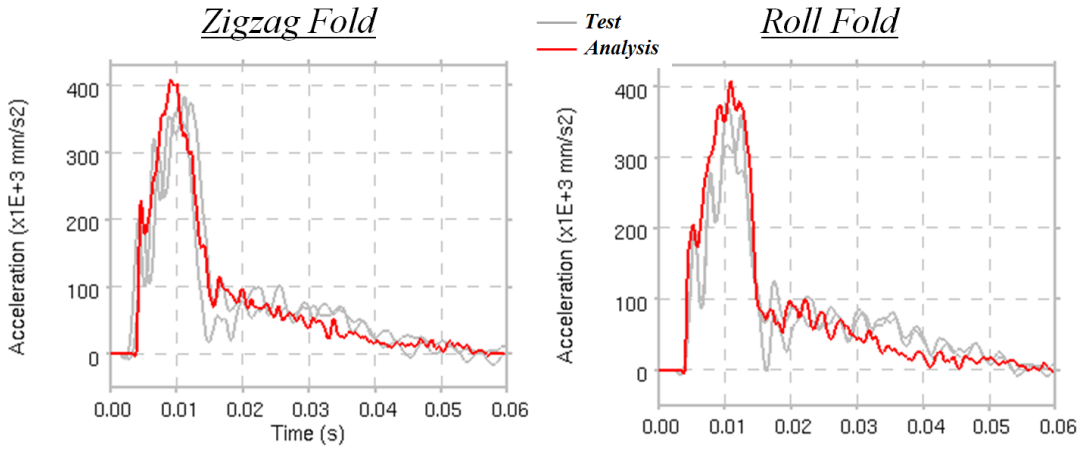

Figure 20: Pendulum acceleration for folded airbags (no lid)

Other Folding Examples Using JFOLD

DAB Standard Reverse Roll

This pattern is commonly found in production and will be included in the data made available to JFOLD customers.

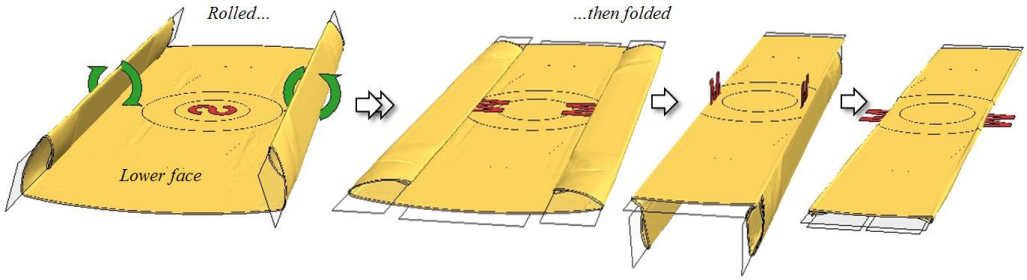

Figure 21: JFOLD roll folding using plates

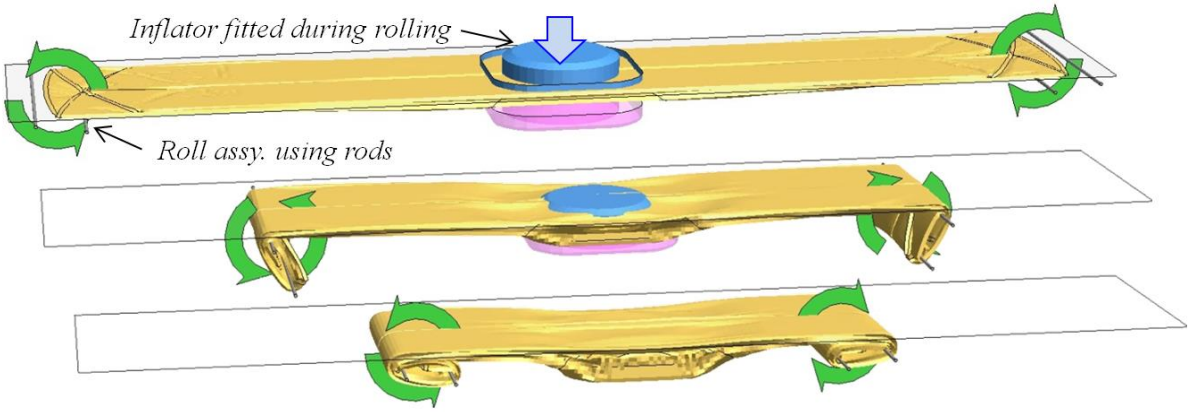

Figure 22: JFOLD roll folding using rods

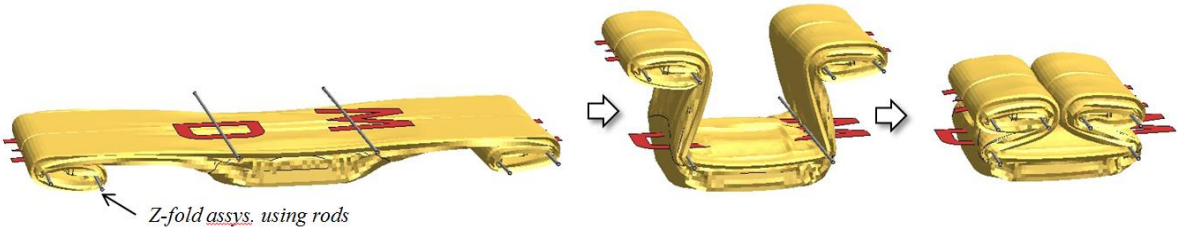

Figure 23: JFOLD Z-Fold using rods

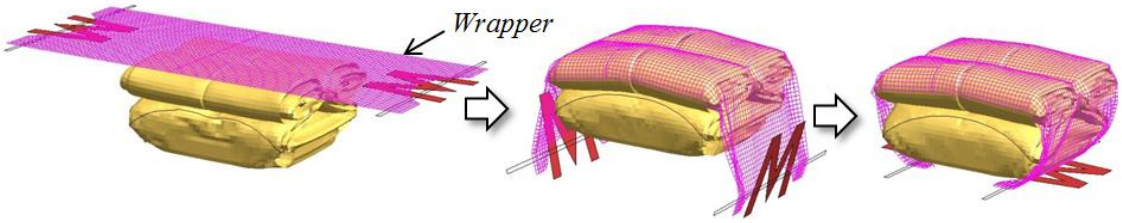

Figure 24: JFOLD wrapper fitting

Side Airbag (SAB) Tuck Folding (*For more details see [2]*)

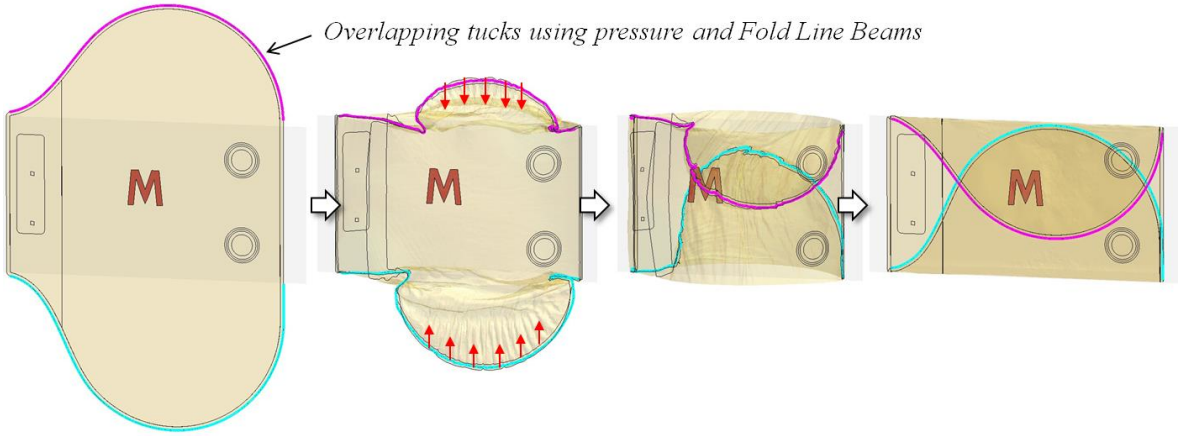

Figure 25: JFOLD tuck folding using Fold Line Beams and pressure

Side Airbag Zig-Zag Folding

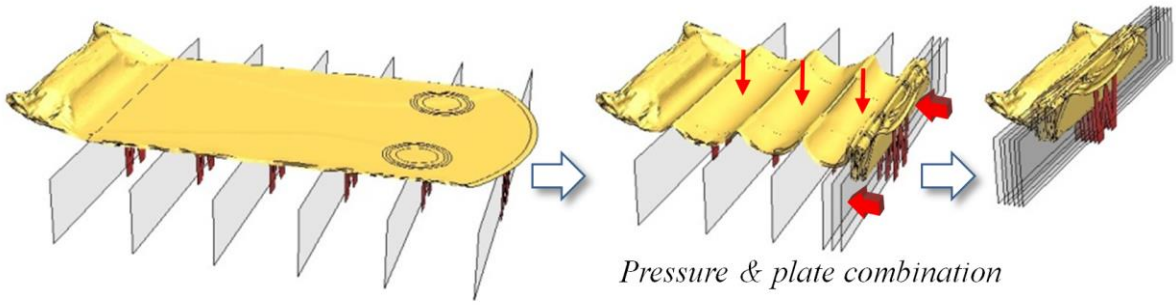

Figure 26: JFOLD zig-zag folding using plate and pressure combination

Curtain airbag (CAB) Roll & Zig-Zag Folding

Using the same contact thickness and materials, the 5mm mesh (top images) forms a larger diameter roll than the 2.5mm model (bottom images) due to geometric constraints. In most cases a smaller (e.g. 2.5mm) mesh gives a better result.

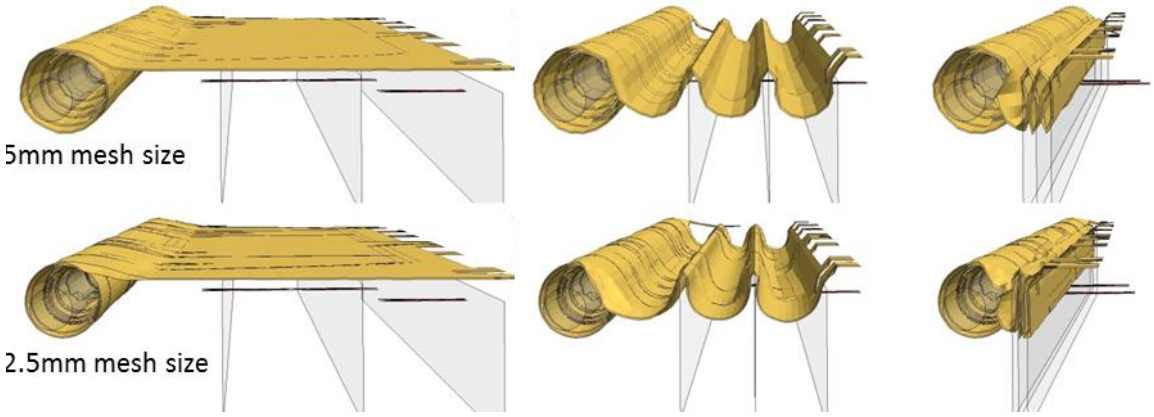

Figure 27: Folding curtain airbags of different mesh size

Curtain airbag Twist Folding

Some curtain airbags require a twist to ensure a clean deployment over the b-pillar or c-pillar trim. JFOLD can be easily used to tune the twist angle and area using a simple *Move Tool*.

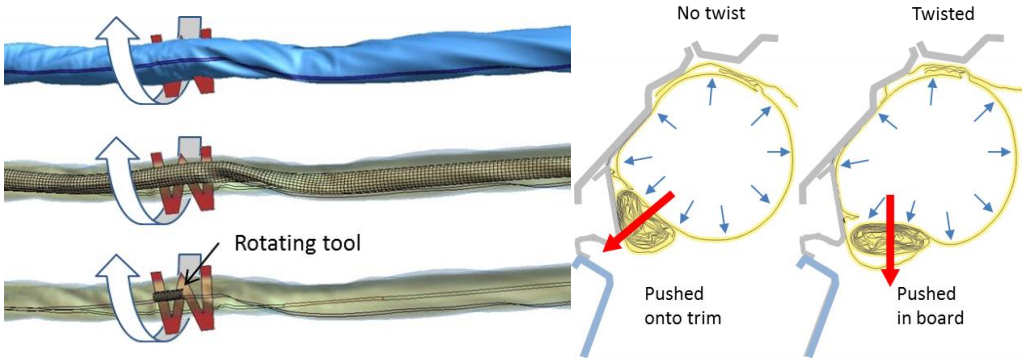

Figure 28: Curtain airbag twisted using JFOLD's Move Tool deploys away from trim

Passenger Airbag (PAB)

Tools that make PAB folding easier are in high demand and form a large part of our next research. The example below show how a 3D shape can easily be created from 2D design data using stitching beams in JFOLD.

In the first step, *stitching beams* are used to wrap the edge panel and *Move Tools* are used to lift up the side panels.

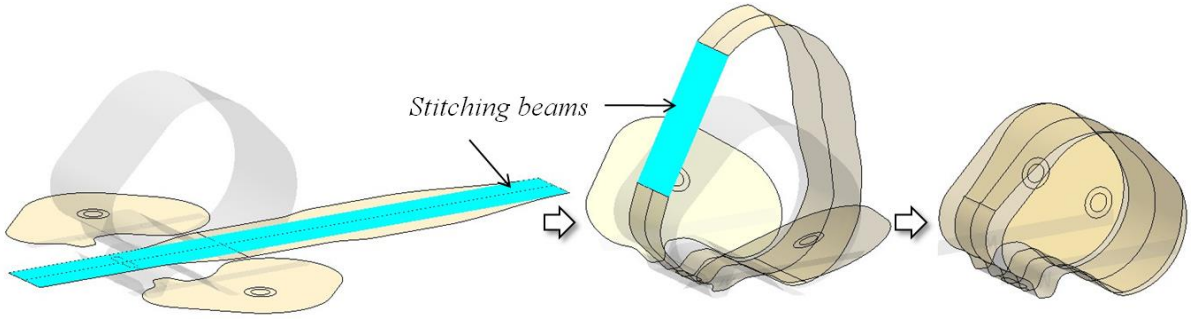

Figure 29: Forming a 3D PAB and using JFOLD

In the second step stitching beams are used to pull the seams together. These can be created with just a few clicks on each edge. Pressure is used to fill out the bag volume.

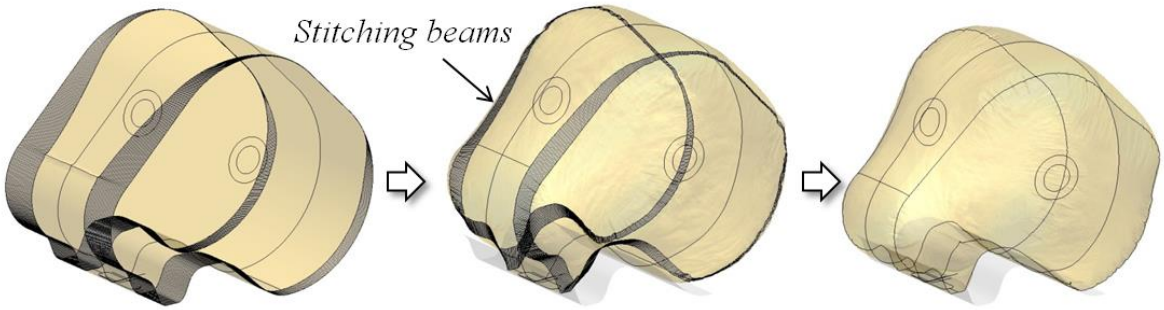

Figure 30: Stitching the panels together using JFOLD

The folding pattern needed to flatten a 3D airbag is unique to its shape, and often requires bespoke tool shapes and motions. Methods to help this process are under development.

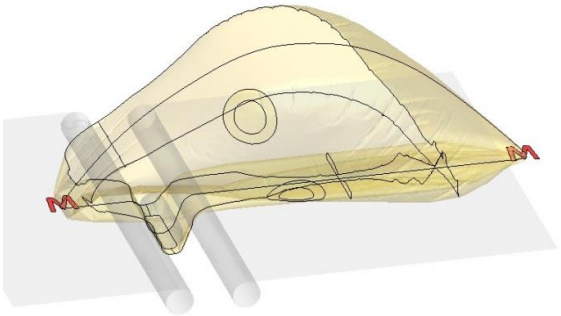

Figure 31: Methods to fold flat 3D shapes are under development

JFOLD Version 3 release plan

JFOLD Version 3 is planned to be released in summer 2016. The Version 3 release package will include the following:

1. A powerful folding software tool, continuously improved based on customer feedback
2. Realistic example models and JFOLD data to give you a head start folding typical airbag types, updated with our latest techniques for fast effective folding: driver (DAB), side (SAB), side curtain (CAB) and passenger (PAB)
3. A translation tool to convert Version 2 data into Version 3 format
4. A self-guiding tutorial to learn the basics
5. A comprehensive built-in help manual

References

[1] USCAR OSRP Safety Simulation Working Group, "Benchmark Problems for Evaluating OOP Simulation Capabilities of Occupant Safety Simulation Codes", Test Set 1: DRIVER FRONTAL AIRBAG PENDULUM TESTS, 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.,: "Using JFOLD & LS-DYNA to Study the Effects of Folding on Airbag Deployment", 10th European LS-DYNA Conference 2015, Würzburg, Germany

[3] Hayashi, S., Taylor, R.,: "Simulation-Based Airbag Folding System JFOLD Version 2 -New Capabilities and Folding Examples", 13th International LS-DYNA Users Conference, Detroit, 2014

[4] Hayashi, S.,: "JFOLD – Introducing A New Simulation-Based Airbag Folding System for LS-DYNA", 9th European LS-DYNA Conference, Manchester, 2013