JFOLD - Introducing A New Simulation-Based Airbag Folding System for LS-DYNA®

Shinya Hayashi

JSOL Corporation
2-18-25 Marunouchi, Naka-ku, Nagoya, Aichi, 460-0002, Japan

1   Abstract

Computer simulation is playing an increasingly important role in the design, development and application of airbag safety systems. As folding patterns and airbag structures become more and more complex, users are turning to simulation based folding solutions to generate accurately folded models in a short space of time. To meet this demand, a new software tool called JFOLD has been developed by JSOL Corporation to enable successful airbag folding using LS-DYNA. JFOLD's intuitive and interactive system guides the user through the folding steps using flow-chart graphics, interactive tool positioning/resizing, tool motion control, animation preview and so on. JFOLD runs inside the powerful and popular pre-processor Primer.

2   Introduction

The airbag is a vital component in the vehicle safety system to reduce occupant injuries during a vehicle collision. Modern vehicles with good NCAP ratings in vehicle crash safety have multiple airbag modules; driver, passenger and knee airbags for front impact, side and curtain airbags for side impact. Pedestrian airbags have also developed recently that inflate outside of the vehicle.

Airbags consist of a fabric bag, tightly folded to fit inside the steering wheel, instrument panel, front seats, roof side rail and so on. Immediately after a vehicle collision, high pressure gas inflates the airbag in very short time to cushion occupants from the vehicle interior. The way the airbag is folded can greatly affect its deployment speed and shape, and this can have a large influence on occupant protection performance.

Automobile and airbag manufacturers increasingly use computer simulations of airbag deployment to design and enhance folding patterns. However it is not easy to create the computer model of the folded airbag due to the lack of CAD data for the complex folded geometry. The often difficult task of airbag folding is usually accomplished by either a specialized pre-processor tool which orients the nodes to achieve the folded shape, or a simulation-based approach which deforms the airbag mesh in stages using analysis, replicating the physical folding process. The pre-processor method can fold simple patterns very quickly but can't create the complex folded shapes often used in modern airbag designs. The simulation-based approach requires preparation and calculation time but can be applied to almost any kind of folding pattern thanks to the physical, realistic nature of the folding process.

JSOL Corporation has developed a new simulation-based airbag folding system for LS-DYNA called JFOLD Version 1.0. JFOLD is a software tool that runs inside the powerful pre-processor Oasys Primer and also uses the post-processor Oasys D3plot. JFOLD is an integrated system that helps the user easily create input models for folding simulations and view simulations results. JFOLD doesn't include LS-DYNA solver – folding simulations are performed using the customer's own LS-DYNA licenses.

3   Simulation-based airbag folding & JFOLD general overview

As a simulation-based airbag folding system, JFOLD manages the set-up of various jigs (called tools) that move and deform the airbag mesh in an LS-DYNA analysis so as to achieve a folded shape. The location, shape and motion of each tool must be carefully set up then adjusted over a few analysis iterations to achieve the desired geometry for each fold. The final folded shape is usually obtained over a series of folding analysis steps: typically 5 to 10 for a simple airbag, many more for complex

fold patterns. After each successful fold, the geometry of the deformed airbag and some of the tools must be carried over to the next step. To carry out these tasks as quickly as possible then, the simulation-based airbag folding system must both manage the series of folding steps and also help the user to easily set up complicated tool motions.

JFOLD has an intuitive and interactive GUI system which guides users through the folding steps using flow-chart graphics and useful functions such as interactive tool positioning/resizing, tool motion control, animation preview and so on. Tools in JFOLD have three categories: *tool mesh*, *fabric* and *component*. "Tool mesh" types are typically plates but can be any shape, made from beams, shells or solids. Tool meshes are the same as the steel jigs used in an airbag folding machine which produces folded airbags in mass production. "Fabric tool" type describes input data that for example applies internal pressure or nodal constraints to the airbag fabric. "Component" types represent real parts like the inflator, airbag module case, seat and body structure that can be used to deform the final folded shape. In the following sections functions of JFOLD are explained in detail.

4   Operation panels of JFOLD system

Fig.1 shows a screen grab of the JFOLD system. The upper window is the model graphics panel, showing an airbag and the tools used in a folding simulation step. The lower window is the JFOLD operation panel. Here the user controls the folding simulation flow-chart, tool setting, airbag definitions and so on. The operation panel is made up of the following three layers.
-    Top layer: Process Management Panel (PMP)
-    Middle layer: Tool Management Panel (TMP)
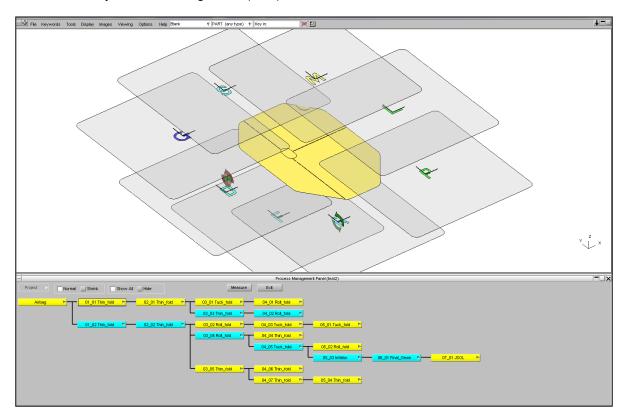-   Bottom layer: Tool Setting Panel (TSP)

Fig. 1: Model graphics panel (upper window) and operation panel (lower window)

4.1 Process Management Panel (PMP)

The Process Management Panel (PMP) is the top layer in the JFOLD operation panel and shows the hierarchy flow-chart of a chain of folding simulation steps. The *root step* at the furthest left side defines the airbag mesh model and each folding step connecting after the root step represents one folding analysis performed on the airbag model. Fig.2 shows an example of how the data is carried over between analyses: folding simulation result executed in the parent step is used as the input model in the child step. The PMP has useful functions to easily manage this carry over process, selected by mouse in the pop-up menu off each step:

- Append new step: creating new child step by carrying over the parent step
- Branch off new step: creating new branch step by copying another branch step
- Delete steps: deleting one step or all steps after the selected step
- Show / Hide mode: blank unimportant steps to keep the display clear
- Lock / Unlock mode: prohibits modification of locked (blue) steps
- View results: view analysis results of a selected step using post-processor D3plot

One of the most important capabilities of the PMP flow-chart system is that it can be used as new airbag design tool to quickly create various folding patterns. Fig.2 shows a chain of folding simulations that create three folding patterns A, B and C.
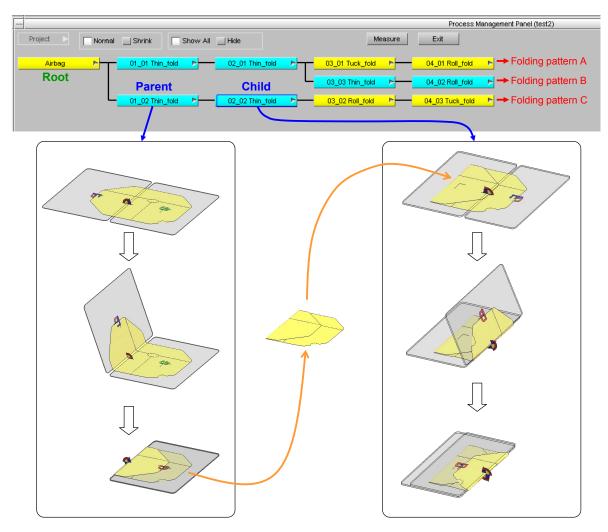

Fig. 2: Flow-chart graphics of PMP and an example of two folding simulations

4.2   Tool Management Panel (TMP)

The Tool Management Panel (TMP) is the middle layer in the JFOLD operation panel. TMP manages the visualization (blank / unblank / reverse / only / transparency) of all the tools and airbag, and also quick positioning and size scaling of selected tools. New tools are added to the step here, from the tool library or another existing step, and modified tools can also be saved back into the tool library.

Fig.3 shows the event viewer which draws bars to represent start and end times of motions and ramp-up time of loading for all tools. This provides a clear visual display to the user to aid tool set-up. Termination time of the folding simulation and output interval time of the results are automatically set according to the tool end times, but can also be input manually.

Fig. 3: Event viewer of TMP

4.3   Tool Setting Panel (TSP)

The Tool Setting Panel (TSP) is the bottom layer of the JFOLD operation panel. Tool definitions are set up according to each kind of tool. Positioning, motion, loading, contact definition to the airbag, tying nodes to the airbag etc. are all input here. Fig.3 shows an example of motion setting for the *move* type tool mesh. Also constrained definitions, boundary conditions, internal pressure and cable stitching can be defined for an airbag and component parts like inflators or airbag module case set up. Translation, rotation and resizing of tools can be performed graphically by mouse drag operation.

Fig. 4: Motion setting for move type tool mesh in TSP

5   Action types of tool mesh

Fig.5 shows an example of the *move* type tool mesh. Tool meshes consist of structural elements, an *action mark* and a local coordinate system. The action mark tells us the action type of the tool mesh at a glance – for example the action mark "M" means "Move". The local coordinate system is used for specifying motion direction and positioning of the tool mesh. Fig.6 shows all action types for tool mesh implemented in JFOLD Version 1.0.
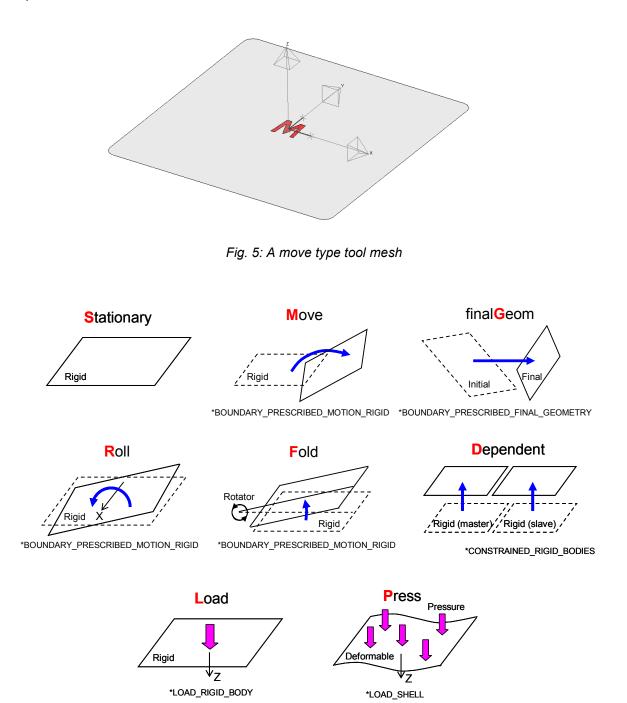

Fig. 5: A move type tool mesh

Fig. 6: Action types for tool mesh implimented in JFOLD Version 1.0

6 Introduction to some of JFOLD's useful capabilities

6.1 Preview of tool motion

The preview function of JFOLD animates the tool motion. Users can easily check the motion of selected or all tools using preview before executing LS-DYNA. The animation can be paused, stepped forward/back or played back at different speeds.

6.2 Tool library

The Tool library is a kind of database of tool meshes, fabric tools and components. New shape tools can be saved into the tool library using the tool registration menu. Multiple tool libraries can be created for each user, project or objective. Users need to select a tool library at the start of a JFOLD airbag folding project.

6.3 Auto-positioning of tool mesh positions

The auto-positioning function moves tool meshes automatically into the position until they contact the airbag model with a clearance of contact thickness. This function drastically saves time when position the tools.

6.4 Reusability of existing tools

Often the same shape tools are used repeatedly in folding simulations. In JFOLD a tool can be read from tool library as well as from another existing step. This tool reusability avoids the time needed to create the same tools again and again. Also by copying all tools from another step, a chain structure of folding simulation steps can be easily changed or reconstructed. This step chain reconstruction capability is an important function for JFOLD when used as airbag design support tool.

6.5 Switchable action type of tool meshes

When the folding simulation result of a parent step is carried over to its child step, the action type of each tool mesh is also carried over by default. In the child step a different action type is often needed because a different folding simulation is performed. Therefore a switchable action capability was developed. JFOLD can switch a tool's action type to another action type at any time. Fig.7 shows an example of switchable tool action capability. The tool mesh defined as a *fold type* in the parent step is switched into a *load type* in its child step, to keep the same mesh geometry. This function is a kind of tool reusability and saves users from creating new tool mesh.
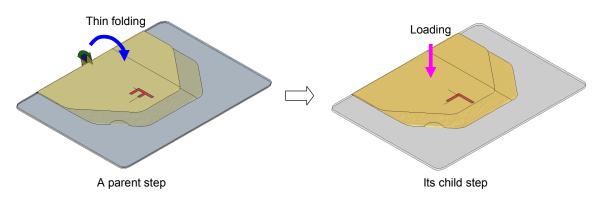

Fig. 7: Switchable tool action capability

6.6   Independency of node and element ID

In the development of a new airbag, the airbag design is frequently changed to improve its performance in reducing occupant injuries. In JFOLD, the newly designed airbag model can be read at the start of the flow process, in place of the previous airbag model design, and the series of folding simulations on the new airbag model performed again. This can create a similarly folded model of the new airbag. However in almost all cases the node and element ID of the new airbag model will be different from previous airbag model. If constraint conditions or contact parameters for the airbag model are dependent on node and element ID, users have to modify them manually after reading the new airbag model. JFOLD is developed under the concept of "node and element ID independency" to avoid such modifications, but this is not perfect in JFOLD Version 1.0 - users still need to modify some definitions after reading new airbag model. We will try to implement full ID independency in future versions.

6.7   Stitching tool to make 3D shaped airbag from separated fabric sheets

The stitching tool functions of JFOLD can be used to create 3D shaped airbag models such as passenger airbags. The user starts with separated, usually flat sheets of fabric mesh.   The number of elements along the edges where the fabric is stitched together must be the same. The stitching tool automatically scans the edges of the fabric sheets and generates discrete beams connecting pairs of edges using only a few mouse clicks. Fig.8 shows the example of discrete beams generated by stitching tool functions.
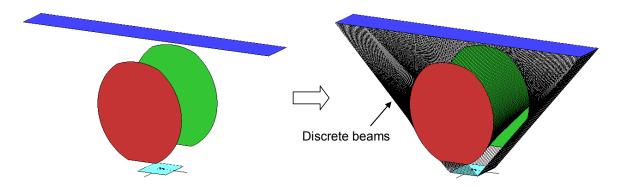

Fig. 8: Discrete beams generated by stitching tools in JFOLD

Next, as shown in Fig.9, a stitching simulation is performed by LS-DYNA. During the simulation the lengths of the discrete beams gradually become zero while a pressure is applied outward on the fabric sheets. After the analysis, JFOLD merges every pair of nodes connected by a discrete beam. Consequently the stitched 3D shaped airbag model is completed.
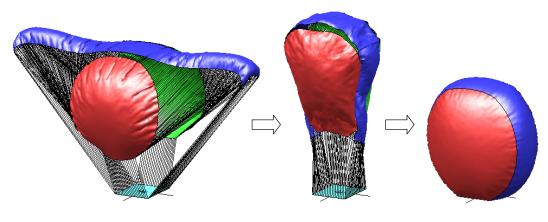

Fig. 9: Stitching simulation

6.8   Inserting a inflator part

Fig. 10 shows how the airbag can be deformed using an LS-DYNA analysis to make space for the inflator. The inflator model is read in from JFOLD's tool library and scaled to fit inside the narrow gap. JFOLD sets up all the required data to perform the analysis. Using a similar process, the folded airbag can be squashed and relaxed to fit inside a module case.
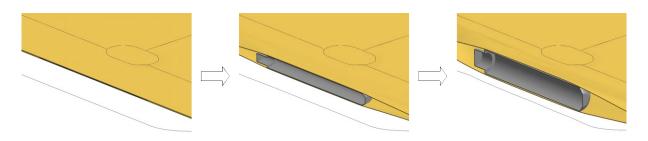

Fig. 10: Inserting a inflator model into the airbag model

7   Folding example of a passenger airbag model

Fig.11 shows an example of one step from a 3D shaped passenger airbag model folding process. Tool meshes push the side walls to flatten the 3D shape into 2D.
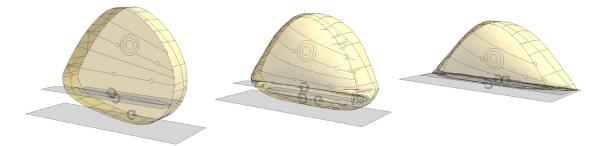

Fig. 11: Passenger airbag folding simulation performed by JFOLD

8   Release plan

Folding example models will be included in the JFOLD install package. JFOLD will be released in Japan in June 2013; worldwide release is planned for the end of December 2013.

9   Future development plan

JSOL will continue to develop and upgrade JFOLD. The following developments are planed in next or future versions:
- New functions according to customers' requests
- Usability improvements to the GUI system
- Enhancements to the tool library management system
- Node and element ID independency
- System to automatically submit a chain of existing folding simulations
- Continued development of a completely new type of folding method that will drastically reduce folding time and cost

10   Summary

JSOL Corporation has developed a new simulation-based airbag folding system for LS-DYNA called JFOLD Version 1.0. JFOLD will be continuously enhanced to enable users to develop airbags more efficiently.

11   Acknowledgments

The author shows grateful appreciation to the software developers of Oasys Primer for their continued cooperation, and wishes to thank all co-workers of JSOL Corporation in the JFOLD development team.