Airbag Folding in LS-DYNA® using Generator4

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1 Abstract

Generator4 is a preprocessor that helps users modeling the most complex CAE designs, from geometry handling and meshing to simulation definition.

Characterized by its flexibility, this multi-platform software allows engineers to define calculations for the finite element solver LS-DYNA®, as well as for multiple other solvers.
Airbag modeling represents a great challenge for CAE Engineers, where complex processes with high accuracy demands are combined with short cycle times.
In order to ease up engineers work at the airbag optimization field, Generator4 includes the Pre-Simulation module.

Pre-Simulation module allows both experienced and average users to define airbag folding processes to be calculated with LS-DYNA®.
On the one hand, experienced users with good knowledge of the real folding process can describe and model the different simulation steps, empowered by the complete LS-DYNA® capacity. Also, it is possible to store the processes into templates with user selected key-parameters as variables.
On the other hand, non-experienced users can take advantage of the expert templates to adapt, actualize and start calculations of new airbag models. The procedure is realized just by adapting the variables, while guided by a user-friendly interface.

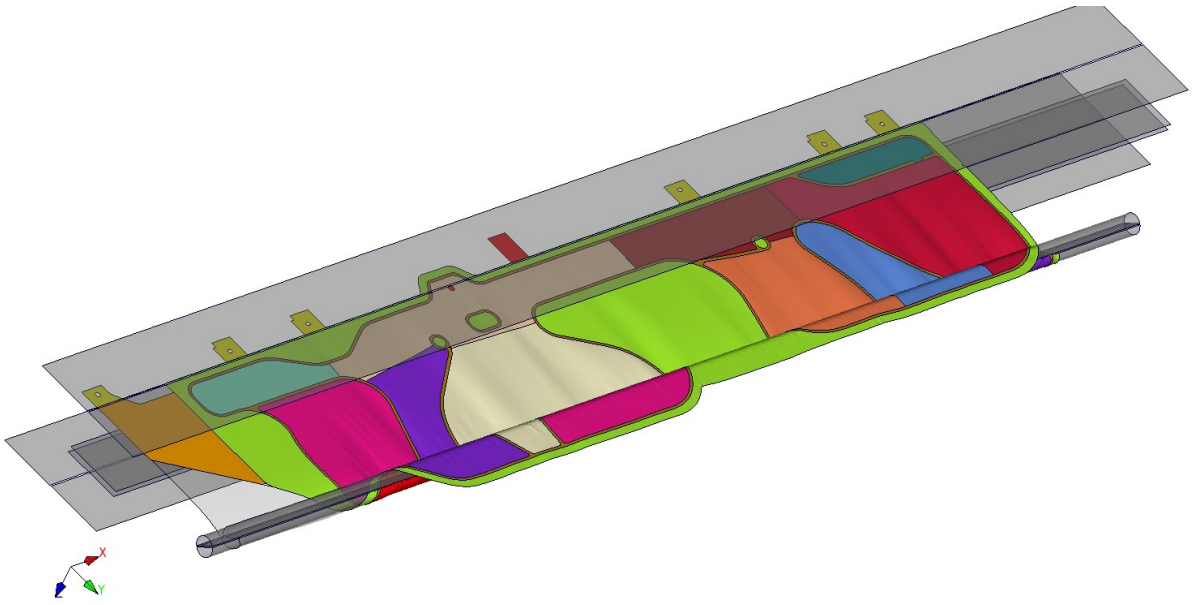

Fig.1: Airbag folding model defined with Generator4 and its Pre-Simulation module

Both methods will be shown at the presentation as well as the new improvements currently being implemented, such as built-in common process definitions and an even more intuitive graphical interface, so the definition of complex folding processes is within reach of everyone.

2 Introduction

The automotive industry already makes an intensive use of numerical simulation for the design and optimization processes of the different vehicle systems. The complexity of the models is increasing, and there is an *observable trend* towards the usage of this technique in a greater brand of areas.
One of the areas where the use of numerical computing is a fact, is the development and analysis of airbag safety systems.

High quality numerical analysis techniques id precisely deeply rooted in the GNS-mbH. Convinced of the great potential of the numerical simulation, the company was grounded in 1994 by a group of engineering analysis experts.

Initially focused on offering customer service in the fields of crash analysis, GNS has now more than 200 engineering analysis experts worldwide, providing high quality numerical analysis and support for a great range of engineering areas by using state-of-the-art finite element and boundary element codes.

Knowing first-hand the needs of the industry and engineers dedicated to Finite Element Modeling, GNS also develops its own range of dedicated software. The deep insight knowledge and years of practical experience, together with continuous internal testing by the company's own engineers, guarantee the maximum performance, functionality and robustness of the software.

3 Generator4 General overview

Generator4 was released in 2015, combining the car safety functionality of it's predecessor Generator2 with geometry treatment and mesh generation under a new user interface.
Among the different GNS products, Generator4 stands out in the field of vehicle safety, taking safety positioning as its very best.

Already tailored to meet the industry needs in safety fields such as FMH positioning, pedestrian safety or Dummy positioning, now focuses on offering a real solution for the demanding airbag folding processes.
The goal is to offer a flexible, dynamic and easy to use solution, that enables the definition of airbag folding processes for solvers like LS-DYNA (among others). All of it in a simple way, while keeping all the robustness and capabilities that the chosen solver has to offer.

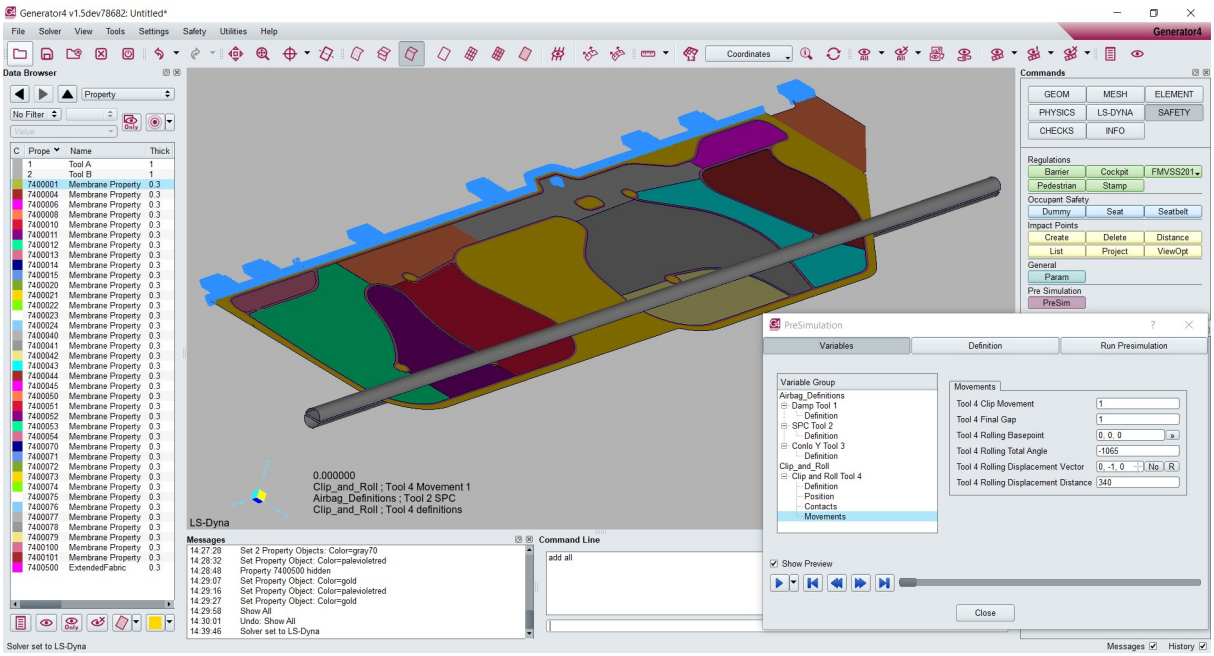

Fig.2: Generator4 overview

4 Industry requirements for airbag folding

One of the car components with the most significant impact on the vehicle safety systems are the airbags. They have become the most influential element when it comes to reduce the occupant damage during a vehicle collision.
Therefore, is one of the elements where the development teams focus their efforts.

Fig.3: Mounted driver airbag [1]

The current safety requirements already represent a great challenge for engineers and designers working for the vehicle development. And the market and regulation trends indicate that the complexity and requirements of these systems will be significantly increased in the near future.

4.1 Current Airbag modeling characteristics:

With such an influence on the safety ratings and the necessity of fulfilling the regulations, airbag models have become more and more complex.

When it comes to deployment kinematic analysis, several industry researches show a clear predominance of initial folding influence rather than used gas dynamics. [2]
Achieving the most accurate folded airbag models is not simple. There is no CAD data from already folded models and simple geometric approximations are not suitable to provide the required accuracy.

Furthermore, during the optimization phases, engineers need to perform modifications based on the unfolded geometry. For each model variant an accurate folded version will be needed.

As a consequence, precise simulations are carried on, reproducing the real folding sequence, in order to obtain folded models as close as reality as possible.
This simulation processes present the following characteristics:

1. Highly specific simulation processes, depending not only on the type of airbag (diver, side, curtain, torso bag, knee, 2D or 3D…) but also on the different folding techniques (rolling, folding, compressing, tucking…)
2. Solver dependency. Different solvers may require different approximations and techniques for representing the same process.
3. High technical difficulty. Currently, highly experienced professionals with deep knowledge on both the real folding process as well as the used solver, are required to define such models.
4. Externalized Processes. Due to previous aspects of the simulation, folding calculations are often carried out by specialized companies.
5. Time consuming process. Technical difficulties or long response times between companies, produce delays in the working flow.

4.2 Requirements yet to be fulfilled:

The industry requires supporting software to evolve, not merely to ease up current processes but also to change and re-define some of its current distinguishing aspects. With that aim, software in the field of airbag modeling has to fulfill several requests. Naming just a few of them:

1. Offer an agile and dynamic preprocessing methodology. Presenting an easy to learn and use graphical interface with great customization opportunities.
2. Multidisciplinary. Airbag geometry meshing, modifications and folding definition weithin the same platform. Using the same software and GUI for the complete process avoids format inconveniences along with work speed increment.
3. Solver independent. Multidisciplinary and distributed teams require a high flexibility when it comes to the used solver.
4. Multi-platform. As it is commonly required within big distributed teams.
5. On-site process. Confidential models and folding processes requires avoiding third parties handling the data.
6. Provide reproducible folding simulations, allowing the airbag optimization process.
7. Present highly automation capabilities. In order to directly obtain the folding process models, reducing implementations times and calculation errors.
8. Batch mode support. To use in combination with different automatic operations, locally or at HPC nodes.
9. Folding tools database. A preset of folding tools, user expandable, with access to all main parameters.
10. Clear and simple to overview fold process descriptions.

5 Philosophy for the Airbag folding capabilities from Generator4

Taking into account all the aspects analyzed in previous chapters, the Generator4 airbag folding capabilities are currently being expanded.

Airbag modeling in Generator4 is currently accessible by using the so-called Pre-Simulation module. The Pre-Simulation module from Generator4 is based on both flexibility and automation capabilities:

- Flexibility: To be able to handle all kind of models, processes and several finite element solvers.

- Automation: To speed up the process definitions, avoiding human errors while boosting engineer's creativity, allowing them to focus on the design process.

These two Generator4 distinctive characteristics provide a good basis to create the concrete and accurate processes required for any kind of safety processes such as airbag folding, out of a generic tool such as the Pre-Simulation module.

Generator4 provides this way an easy to use simulation-based airbag folding system, where the main workflow can be described as follows:

The unfolded model can be directly imported or even defined within Generator4, by using its geometry and meshing capabilities.
Based on this model, desired folding process can be defined. By setting-up diverse tools and its movements, all the different techniques can be achieved: rolling, folding, compressing, tucking… All the events defined to be taking place during the folding simulation are structured in different "Steps" and "Actions", so the user can get a good overview of the process being defined.
Once the routine is defined, it can be directly sent to be calculated either locally or remotely at any external calculation node.
As soon as the calculation is completed, the results are automatically imported in Generator4, so the user can adapt any definitions if needed and use the model for the deployment simulations.

As an example of the good automation capabilities, the complete described process can be automated and used for the automatic creation of different airbag variations, speeding up the optimization processes. The folding definitions itself can be stored in form of an XML file, and used for different models or even solvers, demonstration of its outstanding flexibility.

Next schema shows a general automated process for an airbag folding and later usage in a car crash simulation:

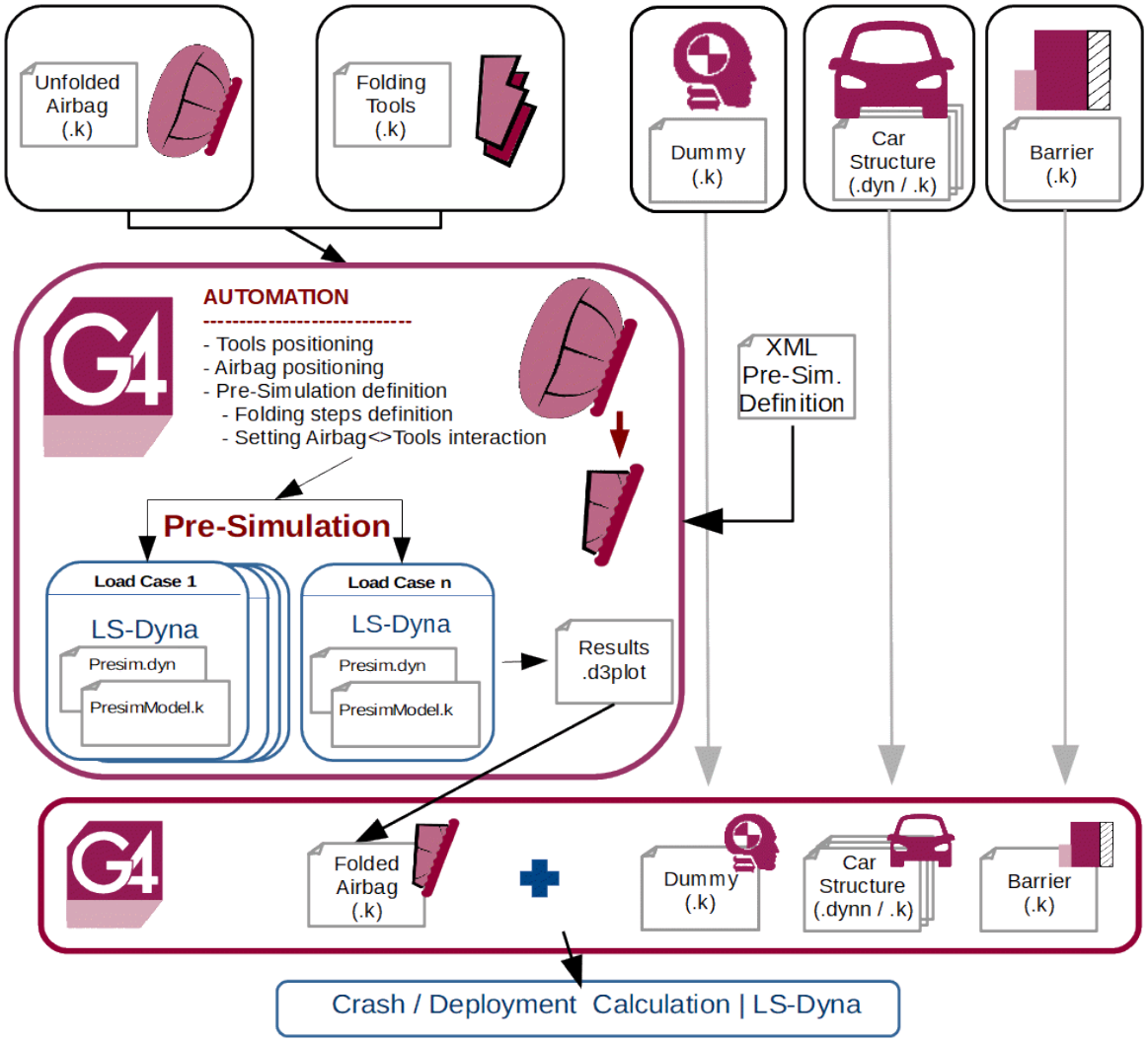

Fig.4: Example of airbag study process with Generator4

6 Airbag folding automation capabilities from Generator4

A fully automated folding process creation can be achieved in generator4 by using templates in the form of xml files. Thanks to the xml support of the Pre-Simulation module, all necessary information is stored in an accessible and comprehensible way.
Once a folding process is created by an expert, all the steps and actions can be directly translated into an xml file by Generator4.

Thanks to it, the defined process can be shared and made accessible for other engineers, so they can take benefit of the complex folding definitions made by an expert. Moreover, the process can then be applied to different airbag versions and models.
Template definitions are also editable by external scripts or software, making the Generator4 airbag folding solution a perfect candidate for automatic workflows integrated in SDM systems.

A further advantage of the templates usage, is the support of self-defined variables. The Pre-Simulation module from Generator4 supports the definition of any desired variables and automated processes within the xml-file. These variables are then shown in an automatically generated dialog, allowing the user an interactive definition of the values to be defined.

Some advantages of this method are:
- Complex and accurate simulations can be defined by an expert, while non-experts can take advantage of it.
- Complete folding processes can be used for different airbag models, just by adjusting references.
- Processes can be applied to models, independently of the used solver
- Processes can easily be adapted just by modifying variable values
- Simple overview of key-parameters
- Separation between modifiable parameters and complex concrete solver definitions

In brief, Generator4 allows a faster creation of folding model-variations with less modeling errors.

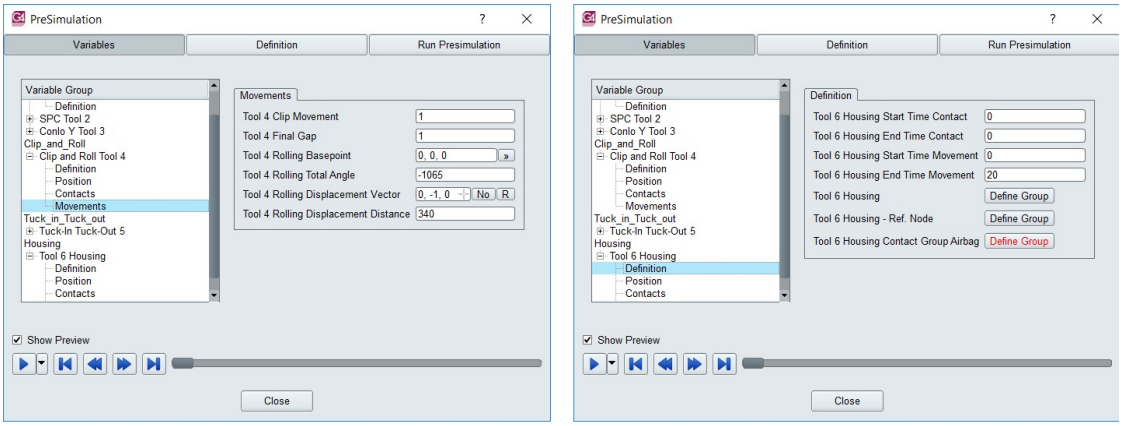

Fig.5: Example of tool variables definition in Pre-Simulation module

7 Practical cases:

7.1 Driver's Airbag folding process. Definition from scratch.

Defining an airbag folding process can be easily done in Generator4 by using the Pre-Simulation module. This module can be accessed from the safety command-group and consists of a plain dialog with 2 tabs.
The first tab is reserved for the process definition itself and the second one for the initialization of the settled calculations with an external solver. This can be seen at the following image:

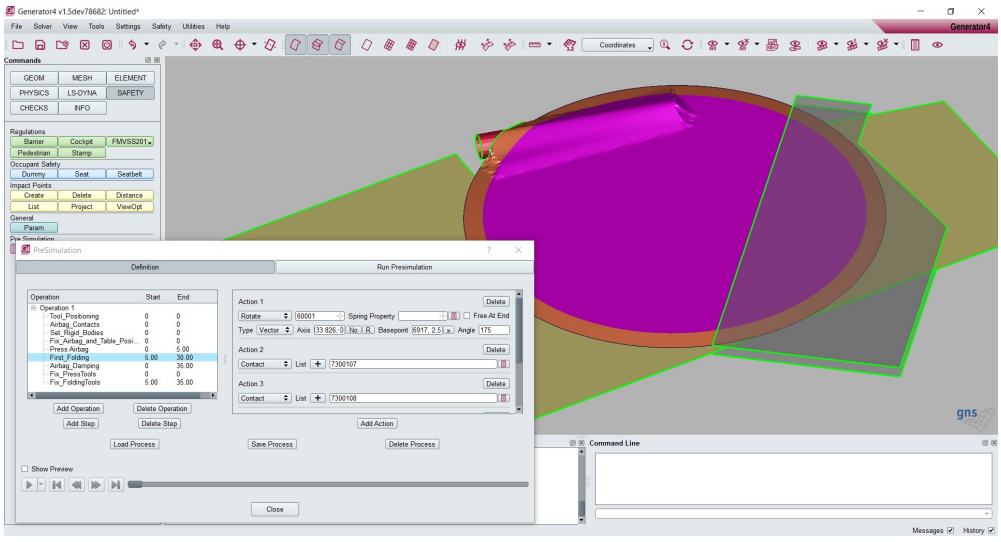

Fig.6: Pre-Simulation module in Generator4

Within the dialog, the user can create different Operations and Steps. Designed to structure and organize the folding operations, the Steps carried out within each Operation contain in turn any desired number of actions.
Actions are themselves defining the different operations taking place during the step time fringe. For example, tool movements or boundary conditions are defined with them.
A predefined list of action types is included in the dialog and can be directly used from the GUI.

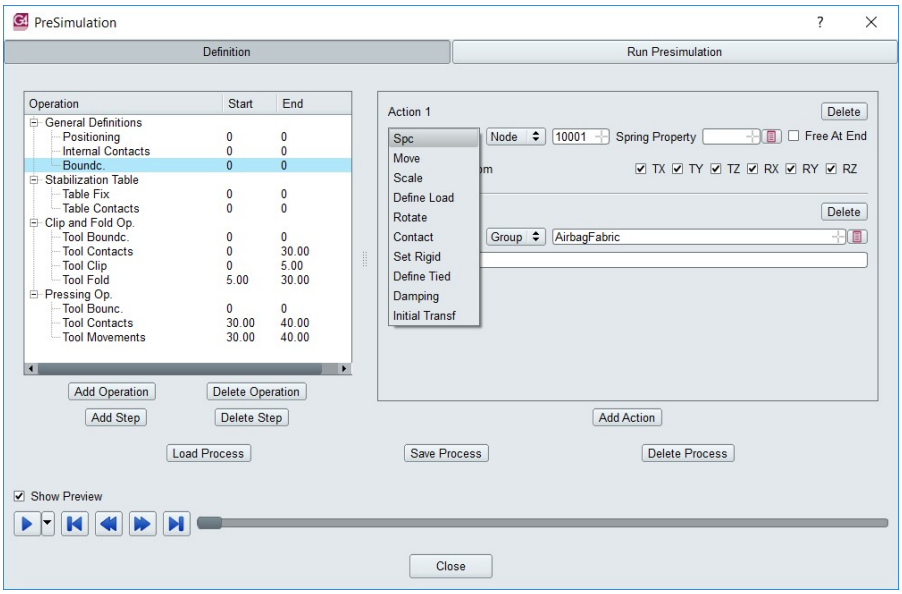

Fig.7: Steps structure and offered actions

The nature of the process to be calculated is completely flexible, as well as the used steps and defined actions structure. This way, the process can be adapted to each customer's request.
The necessary parameters and model references can be directly introduced at the dialog. Aside from that, graphically picking is also possible with the aim of making the definition process more agile for the user.

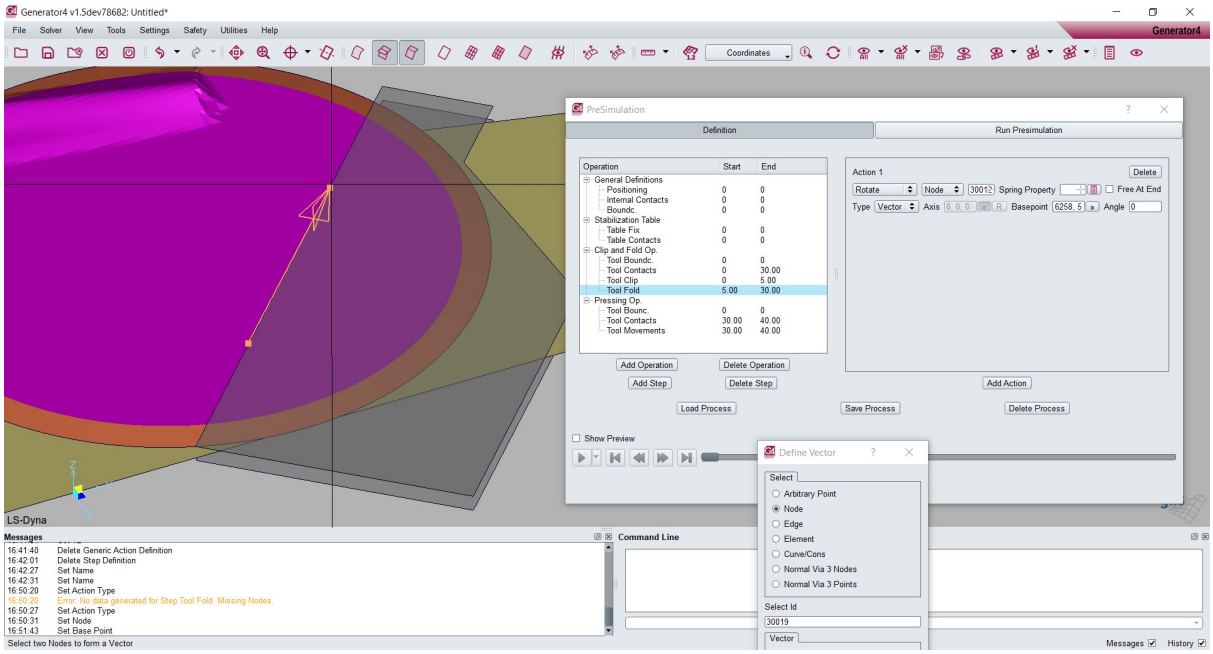

Fig.8: Interactive definition of several process actions

Once the different airbag folding operations are defined, the calculation can be initialized within Generator4 by using the “Run Presimulation” tab.
As shown in next image, the calculation is done with an external solver (LS-DYNA® at the present example) either locally or on a HPC cluster.

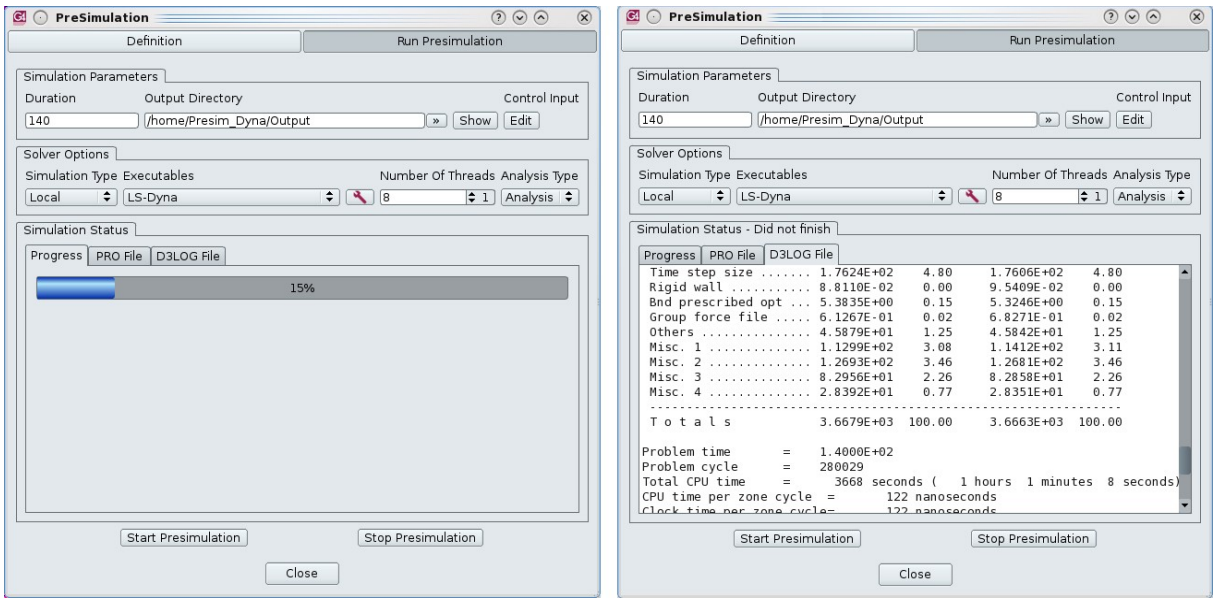

Fig.9: External calculation track in Generator4

Once initiated, the calculation can be tracked in Generator4. Calculation progress as well as the D3LOG files are to be seen at the module. Furthermore, the model is still available during the simulation time, so the CAE engineer is given the possibility to continue working with it.

After the calculation is completed, Generator4 automatically imports the results. New airbag shape as well as pre-stresses caused by the folding process are available.

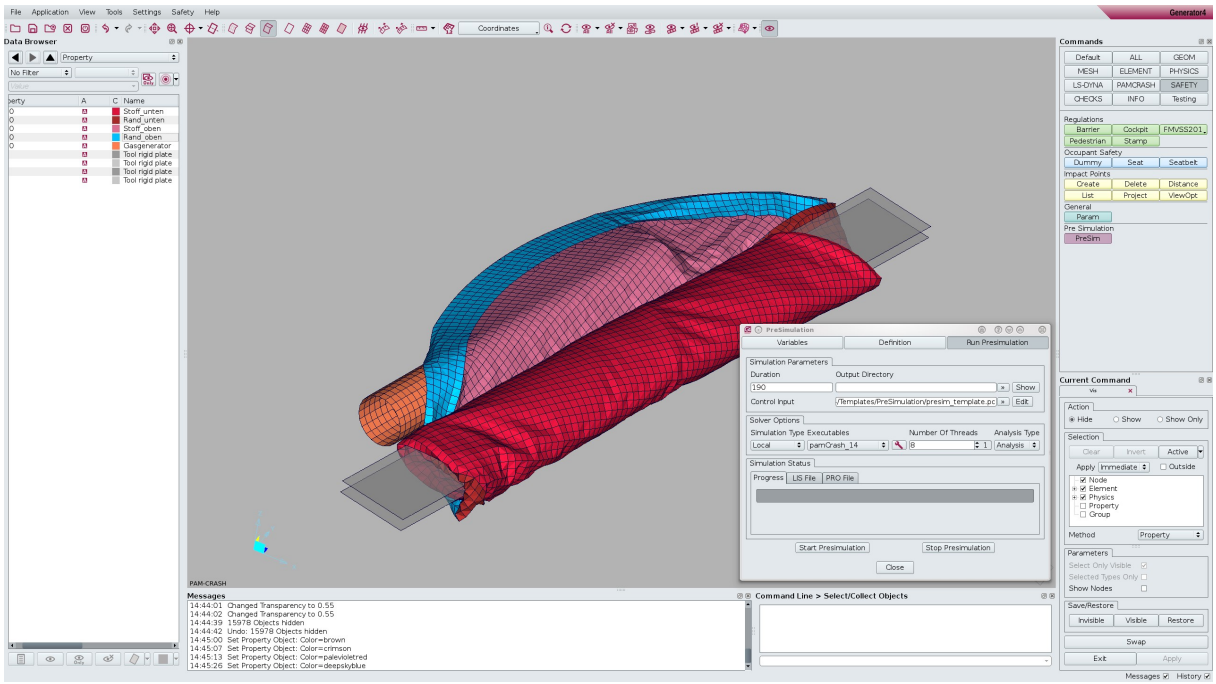

Fig.10: Imported results after airbag folding simulation

By using this method all different kinds of processes can be defined, such as the one shown in next image, consisting of different folding operations, pressing processes and rolling actions.

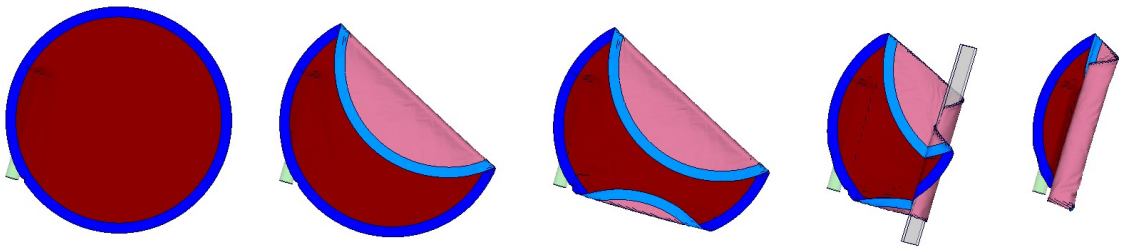

Fig.11: Airbag folding process defined with Generator4 and its Pre-Simulation module

7.2 Curtain Airbag folding process. Definition using the embedded Tools library.

The models and folding methods in daily practice, present nevertheless much more complex workflows, where a definition of the calculation model from scratch is much more costly in terms both of time and know-how.
In order to facilitate the definitions in these cases, Generator4 also offers a library of predefined processes and tools.
Among these tools, the user can find the processes most commonly used in different dubbing processes such as: Clip, Folding, Housing, Rolling, Compressing, Guiding Planes and Bars, Stabilization Plates, Tuck-In Tuck-Out…

These definitions can be imported into the model and be directly used simply after adjusting the variables of the same to the desired model.

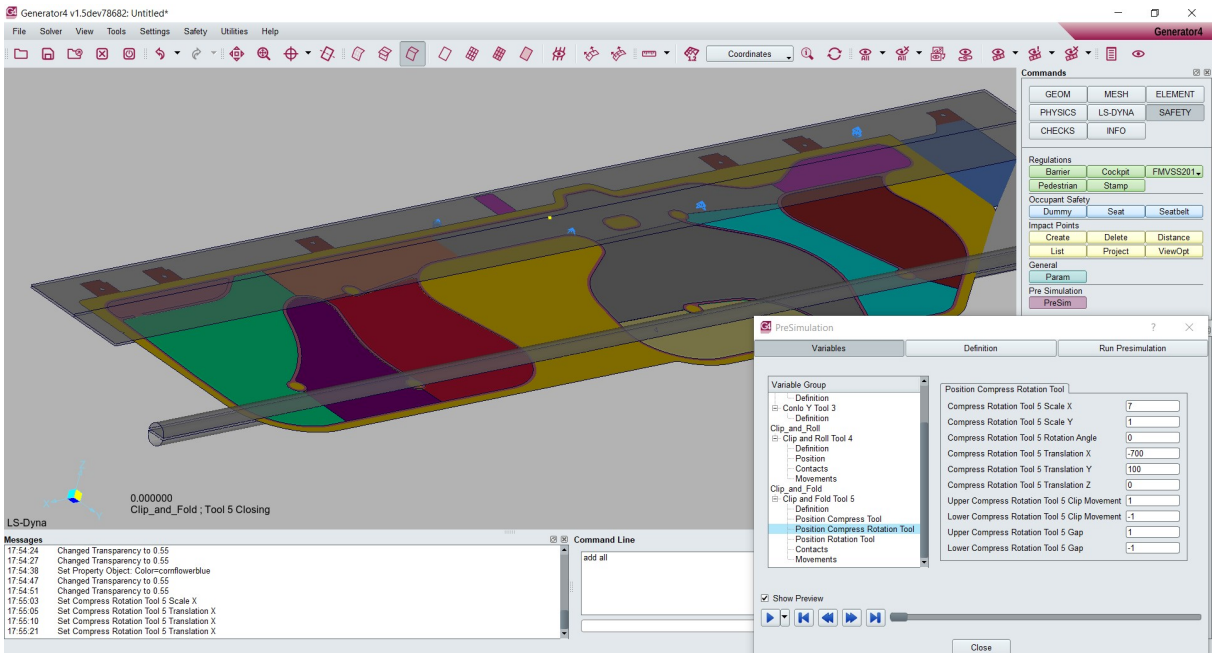

Fig.12: Variable definitions from one of the offered predefined tools.

Moreover, the offered tools use an easy XML format defining the different physic and mathematical conditions as well as the parameters that should be offered as a variable at its dedicated tab. This

means also, that the tools can be enhanced by each user to best fit its personal needs and processes if necessary.

As a result, it is possible to create complex folding processes with ease and avoiding definition or modelling errors, such as the curtain airbag example shown at the next image:

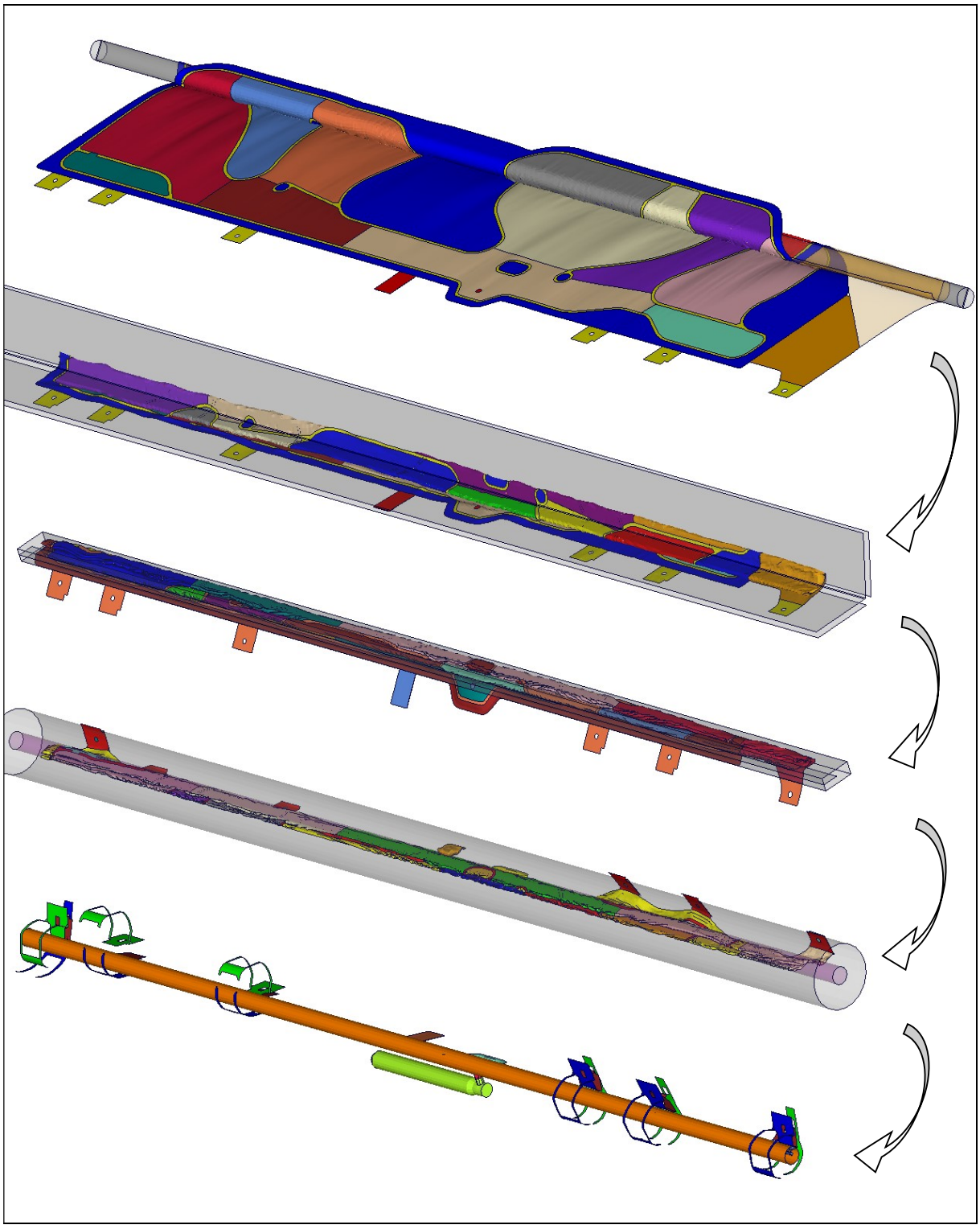

Fig.13: Curtain airbag folding process defined using Generator4 offered tools.

8 Current enhancements

In order to improve the airbag folding capabilities of Generator4, the following improvements are planned for the future versions to come:

- Introducing parametric process steps, using predefined tools: Together with the software, a complete tool library will is provided, as well as a predefinition of the most commonly used folding steps. That way, only the concrete airbag model parameters will be needed to implement a complete folding process. The described library is being enlarged to fit a wider range of processes.

- Enhance suitability of pre-defined xml processes: The xml support will be enlarged in order to offer a greater flexibility. For example, by introducing post-processing scripts to be started automatically once the folding simulation has terminated successfully.

- GUI improvement: An evolved user interface is planned in order to make the process definitions easier for any kind of user. Orientated at the deep forming software OpenForm, it will make non-experts also able to define complete folding processes with ease.[3]

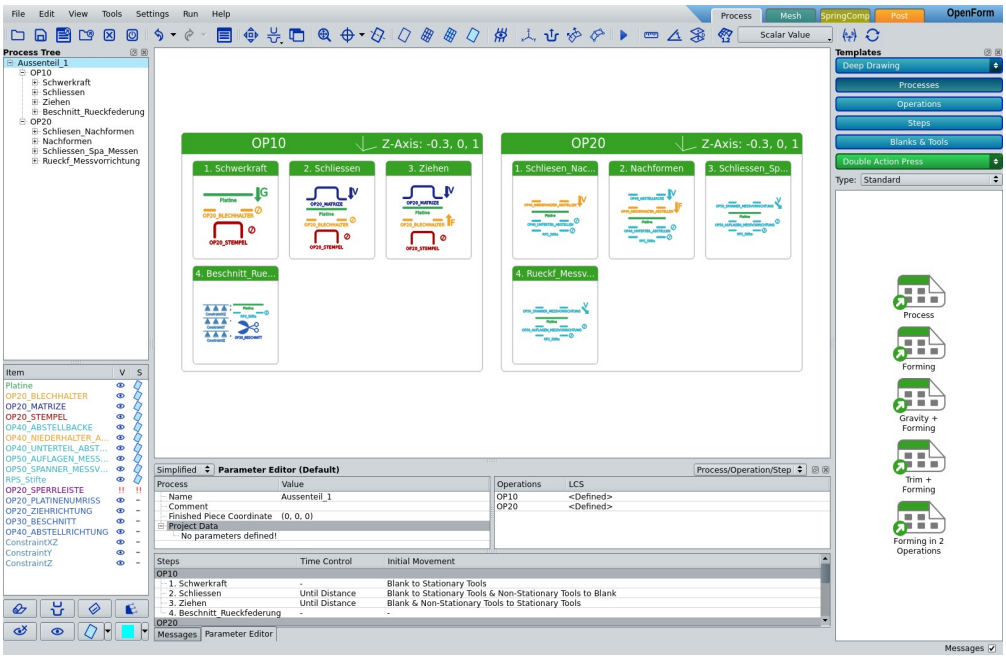

Fig. 14: User friendly layout from GNS software OpenForm

9 Summary

The capabilities from the GNS pre-processor Generator4, combined with the powerful finite element solver LS-Dyna®, make it possible to set up and run the complex airbag folding processes that the industry requires.
The Pre-Simulation module from Generator4 presents one intuitive yet flexible GUI for the model definition.
Experienced users with good knowledge of the real folding process can describe and model the different simulation steps while non-experienced users can take advantage of the expert templates to adapt, actualize and start calculations of new airbag models. The procedure is realized just by adapting the variables, while guided by a user-friendly interface.
Its template capabilities and its own session language, make it possible to define and run complex airbag processes with successfully and close to reality results within minutes, helped by a powerful pre-visualization of the tools movements.

10 References

[1] https://commmons.wikimedia.org/wiki/File:Driver_Airbag_stored.JPG

[2] *Dr. Aschenbrenner, L., Volkswagen AG: "Airbag Pre Processing – Handcraft or Software aided Model Creation?", Automotive CAE Grand Challenge 2018, Hannau, Germany.*

[3] GNS-mbH OpenForm manual guide.

[4] GNS-mbH Generator4 manual guide.