

Model Set up, Analysis and Results of the Inverse Forming Tool in ANSA

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Abstract

With an ongoing aim to reduce the time a model requires to be prepared, the sheet metal forming studies have evolved to catch up. This affects initially the die designers, who are requested to decide the manufacturing processes early in the design process as well as process engineers who aim to incorporate stamping results in further studies.

Feasibility analyses are one kind of such studies, performed to check whether a part can be created from a forming procedure. The blank shape is estimated and cost is estimated too. Through such an analysis, the results of thinning and work hardening are produced and are used in further structural studies.

In either case, simulation is utilized to analyze and validate these complex processes usually using one-step analysis methods. The Inverse Forming tool of the ANSA pre-processor implements such an inverse one-step method to address whether forming is feasible early in the design phase and associated costs. Additional LS-DYNA® entities are created for integrating pressing results in further analysis.

The current paper tests the model preparation, the data and minimum required information, the performance of the solver, as well as, the quality of the results. The automation capabilities and the strong advantages of the tool, render it as the ideal one-step solver.

Introduction

As the design cycle timeframe is reduced constantly, the demand for stamping results is transferred in earlier stages of the design process when geometry is not finalized yet but plays a significant role in design decisions. This increasing need is facilitated by usage of one-step method solutions.

One such method has been implemented for the Inverse Forming tool of the ANSA pre-processor. With an interface that focuses on user friendly interaction, and on minimum input information, the Inverse Forming is simple and intuitive.

The tool handles the final product mesh along with its material information and if available any addendum geometry. Information of final thickness, strains, wrinkles and splits, and the initial blank shape are then calculated and plotted, while any related LS-DYNA entities are created.

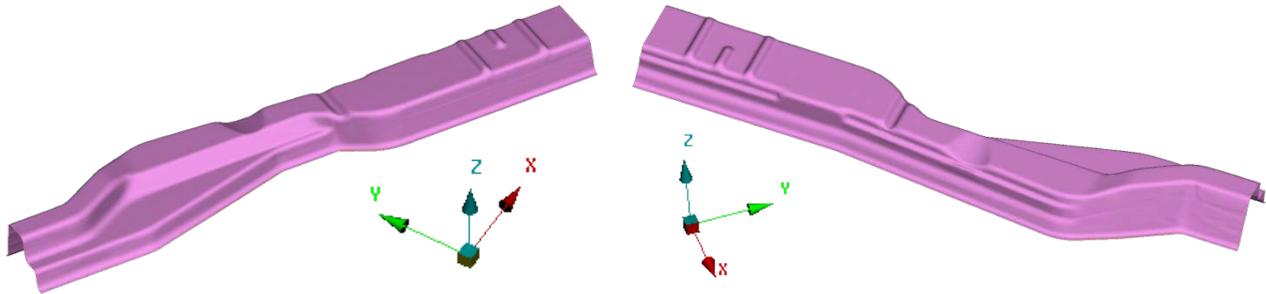
Model Set Up

For setting up the run, the basic required data are the shape of the workpiece and its material properties. If the blankholder is available, then it can be used too.

Prior to the solution, some final options are available for selection of the calculated results along with adjustments to the solver.

All this model set up is saved, allowing modifications and reapplication at any moment.

The BM3-01 sample file from the Numisheet 2011 [2] is used to illustrate this process.



Workpiece

The geometry of the workpiece is the essential information needed.

The Initial Thickness of the specimen contributes to the calculation of the final shell thickness at each node.

Property thickness can be used while multiple thicknesses of tailored parts are supported too.

The Friction coefficient introduces the influence of friction between the punch and the blank while the stamping direction vector which can be identified automatically, indicates the direction of the punch.

Inverse Forming
✕

Name:

x

y

z

Workpiece

Blankholder

Material

Results

Advanced

FLD Zones

Connectivity: Search:

Initial Thickness

Friction Coefficient

Nx

Ny

Nz

Set Direction

Invert Direction

Comment:

OK

Cancel

Blankholder

In case a Blankholder is available it can be used, along with the force with which it is applied.

Name: Inverse Forming

x: 0. y: 0. z: 0.

Workpiece Blankholder Material Results Advanced FLD Zones

Blankholder Search blankholder
 PassThrough

Blankholder Force
 50000.

Material

The Hollomon's workhardening law and the Lankford coefficients of the material are the last essential parameters for the calculation.

Name: Inverse Forming

x: 0. y: 0. z: 0.

Workpiece Blankholder Material Results Advanced FLD Zones

Hardening K Hardening n
 562.1 0.2

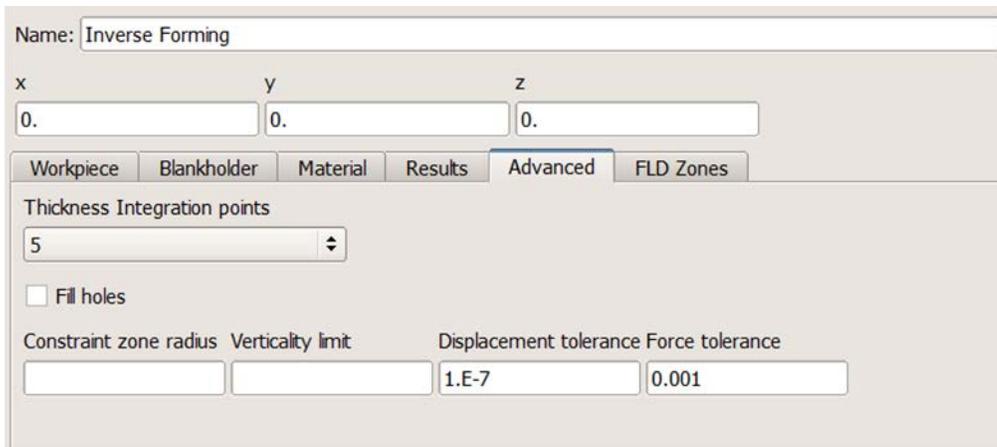
Calculate K,n User defined FLC Import FLC

R_0 R_45 R_90
 1.6 1.6 1.6

Alternatively, the Hollomon's workhardening law values can be calculated based on the workpiece's LS-DYNA material *MAT_024. This elasto-plastic material stores information of arbitrary stress versus strain curve from which the law parameters are derived. Alternatively, a stress – strain curve in a comma-separated values (CSV) file can be used too.

Advanced options

Further optional information include the definition of Thickness integration points to be taken into account and the option to Fill any holes of the workpiece.



Name: Inverse Forming

x: 0. y: 0. z: 0.

Workpiece Blankholder Material Results **Advanced** FLD Zones

Thickness Integration points: 5

Fill holes

Constraint zone radius Verticality limit Displacement tolerance: 1.E-7 Force tolerance: 0.001

Additional parameters are related to the tuning of the solver.

In case the solver does not converge, the Constraint zone radius will affect the zone that is automatically selected and treated as constrained.

On the other hand, if the workpiece has vertical flanges in relation to the initial blank, then the Verticality limit is the factor that needs to be adjusted instead.

The Displacement tolerance and Force tolerance affect convergence issues related to displacement of the nodes and force balance residuals respectively.

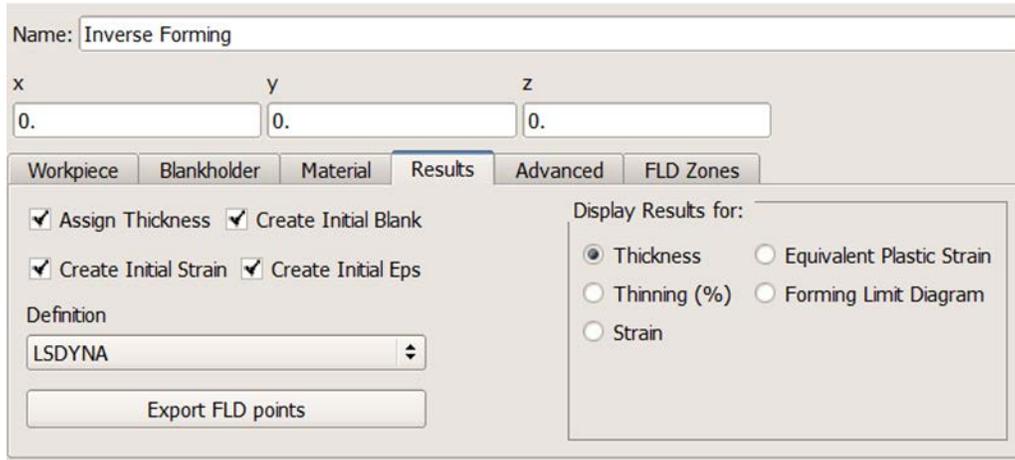
Solver

The Inverse Forming is a fast, robust, accurate and scalable one-step solver.

Based on the input simplicity requirements, the final workpiece shape is used as a basis. From there, the initial position of each node is calculated in order to predict the initial flat blank. The nodes are projected to the vertical plane of the stamping direction and then, adjustments based on Newton-Raphson algorithm follow so as to comply with the equilibrium of the final part. The calculation is based on the assumptions that proportional loading avoids the incremental integration of plasticity (Deformation Theory of Plasticity) and that simplified pressure-friction forces are used among the tools and the sheet in place of contact conditions. This way, obstacles of deformation history are overcome using a total or direct method [3] resulting in fast computational speed.

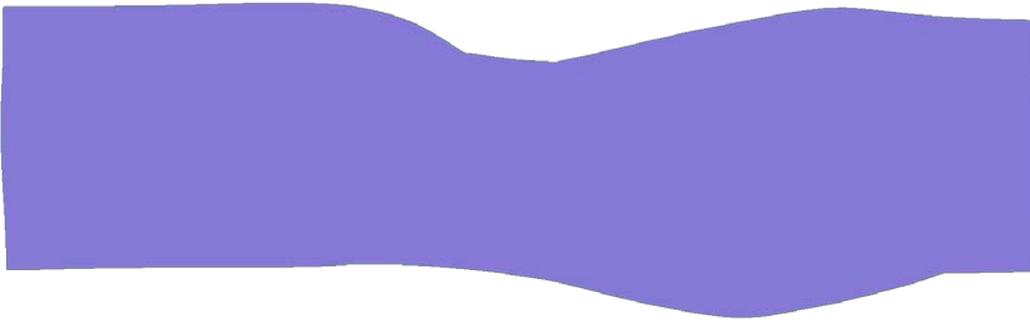
Results

After the run, visualization of the results is available through the tool.

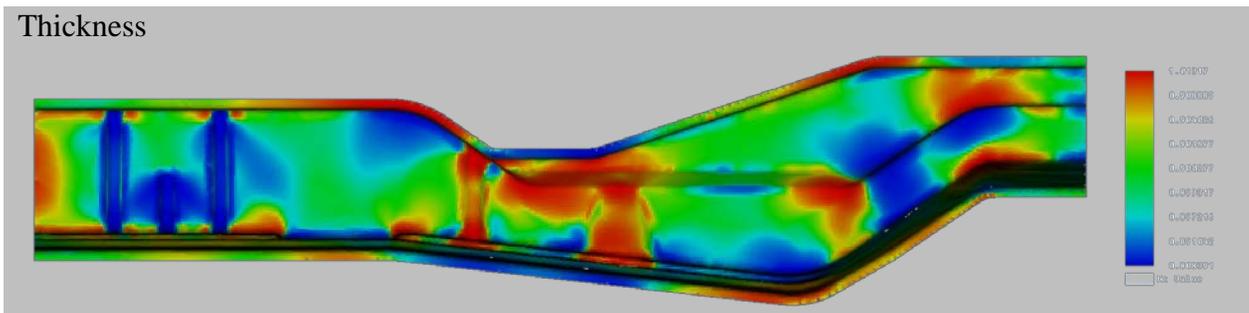


The initial strain and equivalent plastic strain are calculated and visualized while related keywords are created. The thickness for the final workpiece is assigned and the blank draw-in is also created. Additional results for thickness, thinning, strain and equivalent plastic strain are available while the Forming Limit Diagram (FLD) can be plotted and exported even on a user defined Forming Limit Curve.

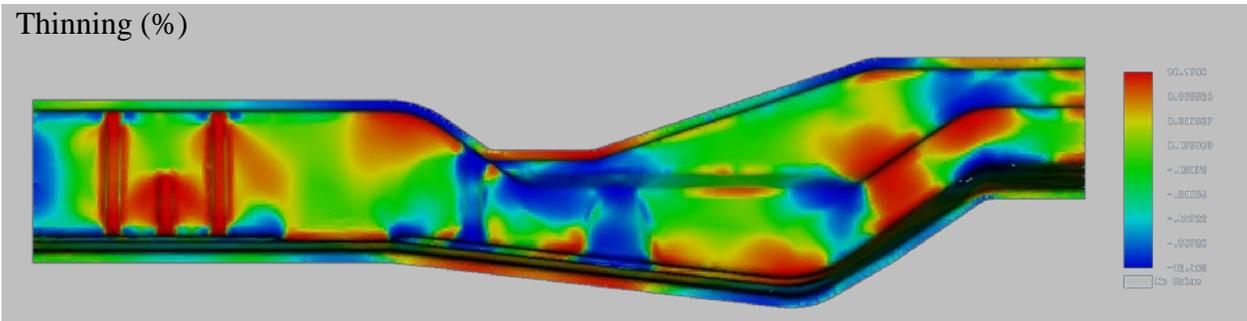
Blank draw



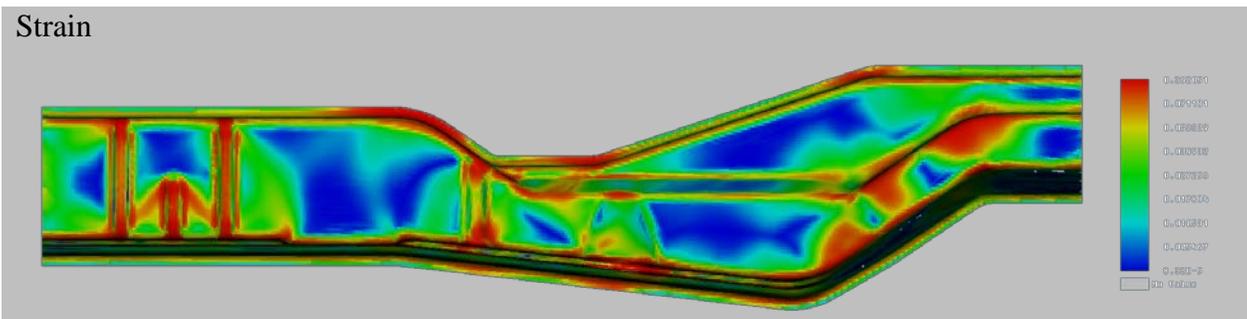
Thickness



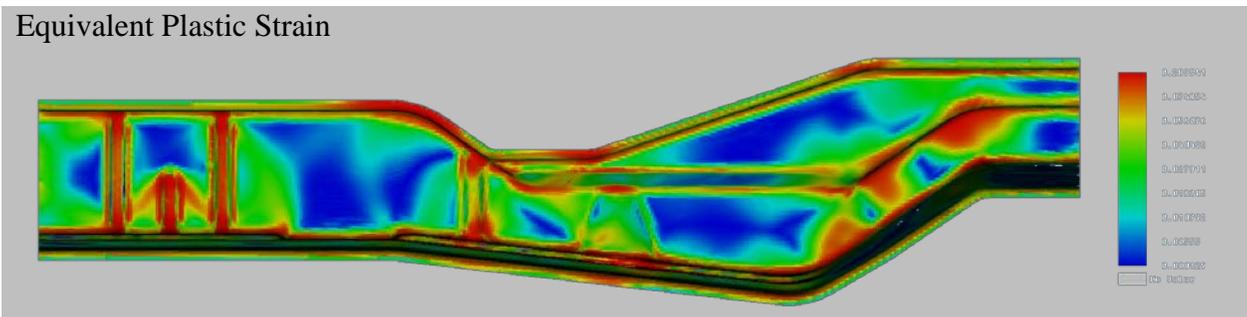
Thinning (%)



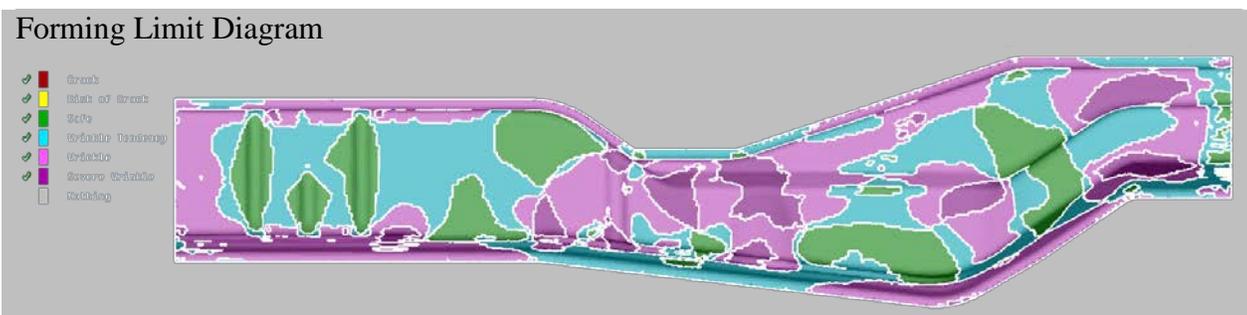
Strain

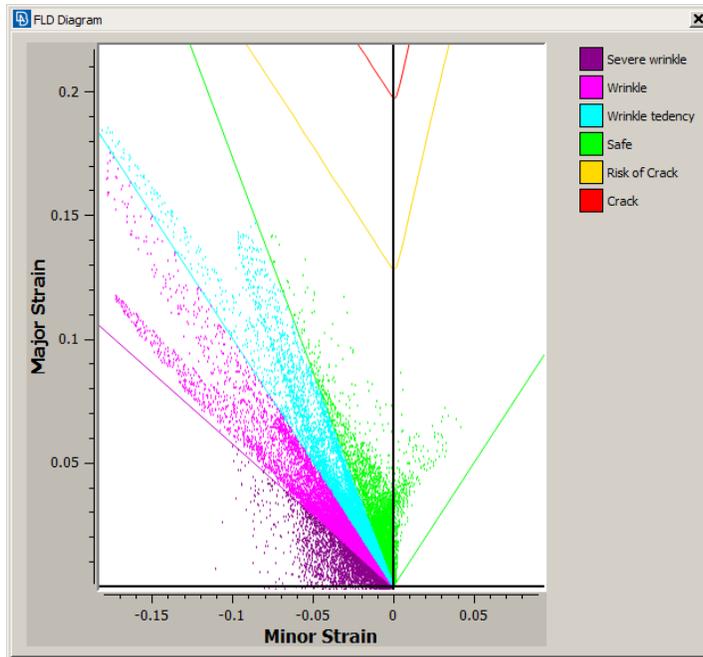


Equivalent Plastic Strain



Forming Limit Diagram





Along with the FLD plot, the area percentage of each FLD zone is available to judge if a further study is needed.

Name:

x: y: z:

Workpiece | Blankholder | Material | Results | **Advanced** | FLD Zones

FLD Zone Areas:

Crack Area	Safe Area	Wrinkle Area
<input type="text" value="0."/>	<input type="text" value="14.670707943069349"/>	<input type="text" value="43.918205652567714"/>
Risk of Crack Area	Wrinkle Tendency Area	Severe Wrinkle Area
<input type="text" value="0."/>	<input type="text" value="31.609157707714235"/>	<input type="text" value="9.80192869664839"/>

LS-DYNA Output

The tool creates the LS-DYNA keywords to represent any calculated results. Specifically the *INITIAL_STRESS_SHELL is used for assignment of any calculated stresses while the *INITIAL_STRAIN_SHELL is used for assignment of strain values. In a similar manner, the thickness of each element at its nodes is referenced using the *ELEMENT_SHELL_THICKNESS keyword.

Conclusions

The ANSA Inverse Forming tool uses a one-step solution method simple to setup and fast to run. It creates LS-DYNA keywords for the calculated final thickness, stresses and strains.

The initial conditions and thickness calculation incorporate the thinning and work hardening manufacturing results from stamping in the structural performance improving the predictive accuracy for Crash, Structure, NVH and Durability analysis.

The tool predicts also the initial blank shape of a stamped part based solely on its final product mesh.

This way, early manufacturing feasibility associated with the part's geometry is supported along with material cost estimation as the prediction of the blank shape is accurate for any user's choice at early concept stage assisting in minimizing the material scrap.

References

- [1] 2017, October. ANSA version 18.0.x User's Guide, BETA CAE Systems SA.
- [2] Proceedings of Numisheet 2011. Available at: <http://www.numisheet2011.org/index.html?Pagenum=53>
- [3] Duffett, G.A., Forgas, A., Neamtu, L., Naceur, H., Batoz, J.L. and Guo, Y.Q., 2005, August. Use of the Inverse Approach for the Manufacture and Decoration of Food Cans. In AIP Conference Proceedings (Vol. 778, No. 1, pp. 731-738). AIP.
- [4] Hallquist, J.O., 2007. LS-DYNA keyword user's manual. Livermore Software Technology Corporation, R10.0.