Highly Automated Springback Compensation of the Draw Die©

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1 Abstract

Achieving a sheet metal part within dimensional tolerance without the need for tool recutting is the ultimate goal of every forming simulation. Several key factors are essential to reach this goal: an accurate forming simulation with precise material descriptions, correct friction values, and an accurate binder model to determine the correct material flow and stress state of the part after forming. Additionally, an accurate springback calculation is required, considering the part clamped in the measurement device and the effect of gravity. With these results the new tool geometry has to be determined to compensate the springback of the sheet metal part.

This presentation will describe the implementation of a highly automated springback compensation process for the draw die in Ansys Forming and LS-Dyna. We will detail the iterative simulation process, the assumptions made, and demonstrate the user-friendly setup for defining this iterative simulation.

An example will be presented using the compensation of tools for a hood outer panel, with a thorough explanation of the results. The presentation will conclude with an outlook on future developments in springback compensation.

2 Introduction

In die manufacturing, springback has been a serious problem, especially for the use light weight materials. Lot of research efforts have been conducted to improve springbck prediction accuracy. New material models which address key issues such as nonlinear kinematic hardening, anisotropic hardening, and Youngs module during unloading have been developed and tested; smooth contact has been proposed to reduce contact noise; more advanced frictional model was also implemented. It is observed that good correlations can be achieved between prediction and test data. Due to springback prediction accuracy, LS-DYNA has built a great reputation in in stamping simulation.

To accurately predict springback is important, and it is more important to make use of the springback prediction and numerically compensate the dies before it is manufactured. There are many ways to compensate for springback. For example,springforward method was one of the popular ones. With this method, the residual stress after forming was mapped to the final deformed trim panel with a reverse direction. The deformed trim panel shape under the specified load of the residual stress is the compensation intent.

2.1 Compensation algorithm in LS-DYNA

LS-DYNA was the first commercial software to provide springback compensation. Since springback compensation is not a linear problem, and the geometrical deviation cannot be compensated within one try. So, an iterative compensation algorithm was proposed. If one iteration is not enough to bring down the deviation to be less than the acceptable tolerance, it is always advised to use more iterations. Usually, it is found that 2 to 4 iterations are needed for most of the applications.

In addition to iterative approach, a scale factor was also available. It is found that it is not effective to fully compensate the springback deviation by changing the tools in the opposite direction. A scale factor, which allows the user to decide the ratio of the shape deviation the part is compensated. The preferred scale factor is case dependent, and experienced users can always use the proper one to reduce the number of iterations. For most of the situations, the suggested scale factor is between 0.75 ~ 1.0.

One of the challenging issues in springback compensation is how to modify the binder and addendum. After trimming, only a limited part of the tool has direct relationship with springback of the blank part. The modification of the rigid tool outside the trimming curve must rely on extrapolation, which is an instable process and can easily result in un-smooth surface. To resolve this problem, several approaches were implemented to meet the requirement for each application. The commonly used ones are the followings:

1. Smoothly change the whole tools. The smoothness and the transition region of the modified surface will depend on the springback magnitude and the smoothing factor. If the springback is large, the transition region will be increased automatically. A larger smoothing factor will result in a smaller transition region. This method is used in places when the binder can be changed.
2. the option to keep binder fixed. In many of situations, it is suggested that we do not modify the binder during compensation process. Under this option, the smoothing factor has little effect. The smoothness of the modified tool depends on the magnitude of the springback and the size of the addendum region. If the springback is large, the transition region might not be smooth if it is not large enough
3. change the binder for the case when blank is on the binder.

To obtain a homogeneous gap between the rigid tools, an option to define the master side was also available. If both side of the rigid bodies are treated equally in springback compensation, the numerical error can result in a non-homogeneous gap between the die and punch. Usually, only one side (lower or the upper) of the tool will be chosen as the master side, and the modification of the other side (slave side) depends solely on the change of the master. In this way, the two sides are coupled and a constant gap between the two sides is maintained. If both sides are chosen as master side, the gap between the two sides might change and the gap might become inhomogeneous. The choice of master side will have effect on the final result in certain situations. At this time, when the punch and binder are chosen as the master side, the binder region will not be changed. Otherwise, when the die is chosen as master side the binder will be changed, since the changes extend to the edges of the master tool.

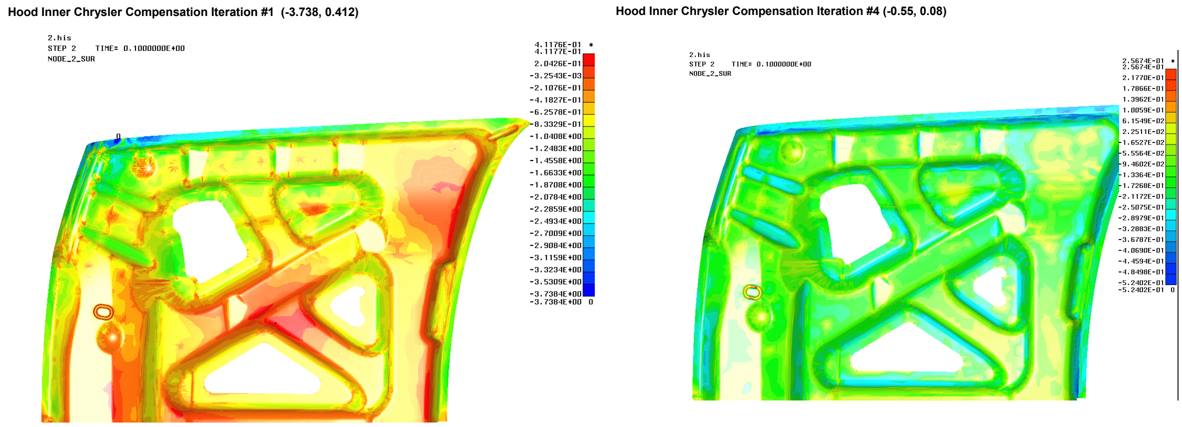
Sometimes it is found that compensation becomes saturated: further iterations will not reduce geometric error. When it happens, it is important to check the mesh quality for the rigid bodies. Reasonable fine mesh is needed, even for the rigid bodies, for effective compensation.

2.1 Case study: The Aluminum Hood Inner

Chrysler was one of the first ones to use LS-DYNA and numerically compensate springback for production parts. In the followings, one of the first case study was presented: Chrysler 300C hood inner done in 2002.

Springback prediction using LS-DYNA® was performed before construction. After comparing with historical springback data on a different aluminum hood inner, the compensation plan is decided based on simulation prediction. The draw die mesh is then morphed to incorporate the compensation

An iterative compensation algorithm was employed to demonstrate the convergence of compensation. The deviation from the design intent was improved from (-3.7mm, 0.4mm) with the original tool to (-0.55mm, 0.08mm) after 4 iterations , as shown in Figure 1a.



a) b)

Figure 1a: shows the deviation of the sprung shape with the original tool, and Figure 1b shows the deviation after 4 iterations

The iterative compensation method has proved to be an effective tool to reduce the geometric error due to springback behavior, and it has been quickly accepted in industry applications.

3 Springback Compensation function in Ansys Forming®

After springback compensation function was implemented in LS-DYNA, it was quickly supported by third-part user interfaces. Virtual compensation has become common practice in die manufacturing process.

After Ansys Forming® went to the market two years ago, we have got many requests to support springback compensation. As a result, we started to work on this function from the beginning of 2024 and will release it for 2025R1.

Just like Ansys Forming® other functions, springback compensation GUI is designed to be user-intuitive and easy to use. After user finish the traditional draw simulation, this function can be easily activated by clicking **Springback Compensation** from **Process→Advance**, as shown in Figure 2.

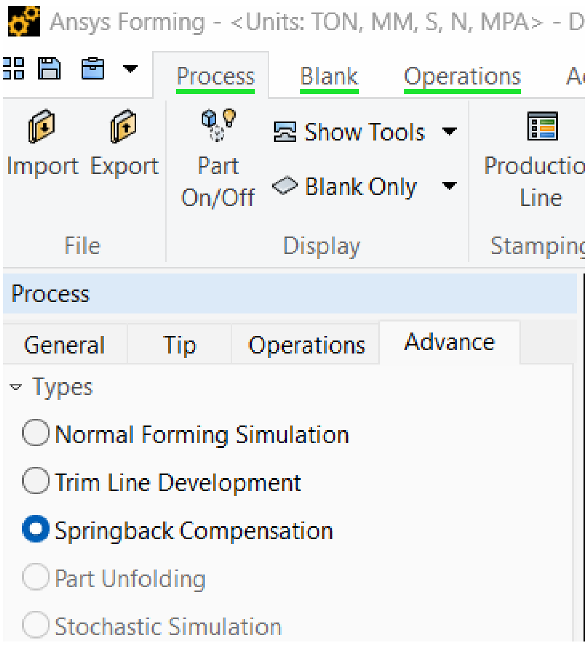


Figure 2. button to active springback compensation

When Springback Compensation is selected, the **Advance** button becomes active and user click it to access the pre-processing GUI, where user has option to define the maximum number of iterations; the convergence tolerance; the scale factor; which side to be the master side in compensation; target geometry, and the symmetrical conditions, as shown in Figure 3.

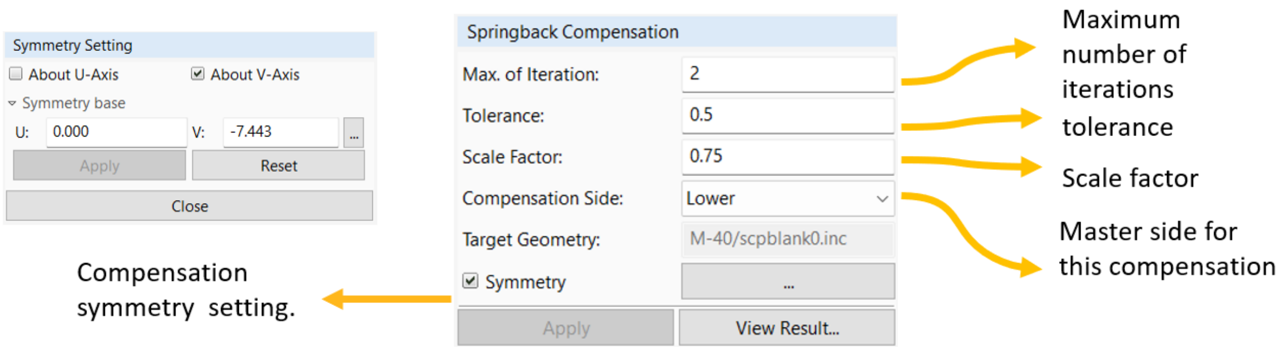


Figure 3. simple UI to pre-processing springback compensation

After the setting is defined as in Figure 3, user can click “Runner” to submit the job to run. Then running status will be shown in the GUI, which make it easy for user to monitor the job progress, as shown in Figure 4. When the job is running, the user can also view the result that have already finished.

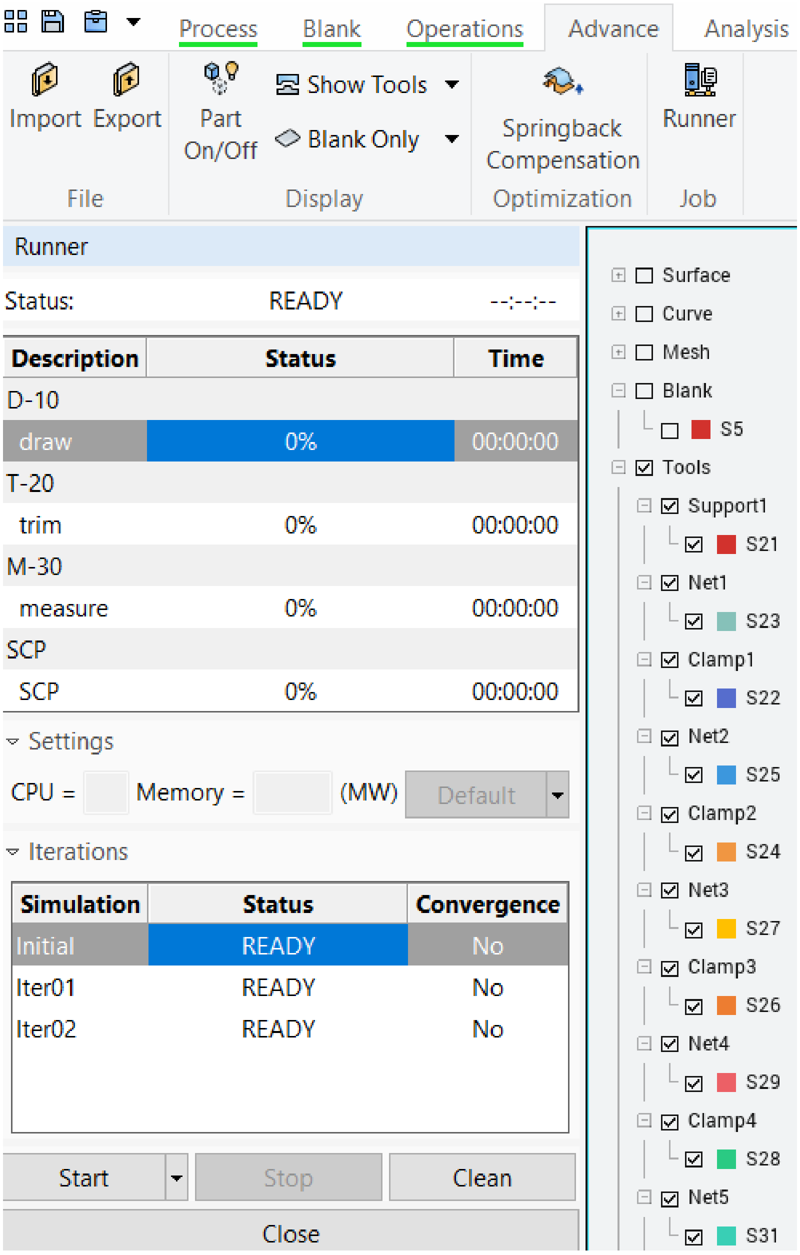


Figure 4. GUI to run the iterations for springback compensation

When click "View Results" as shown in Figure 3. Users can easily post-process the compensation results. It is possible to view the forming result, the updated tool at each iteration.

After the geometrical error is smaller than the tolerance, the iteration can be stopped. The updated rigid tool can be output in different coordinate system.

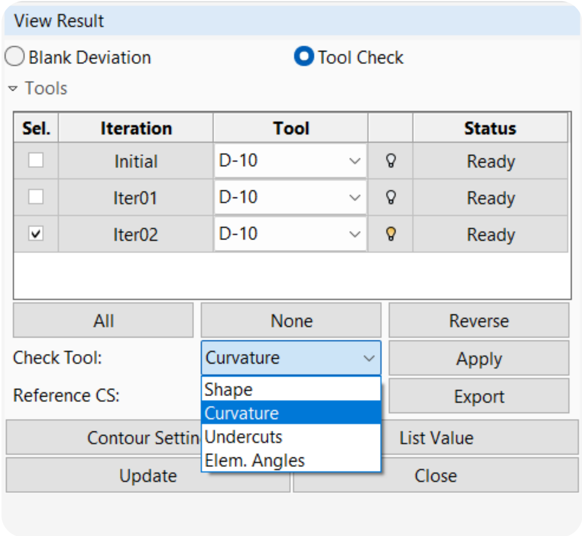
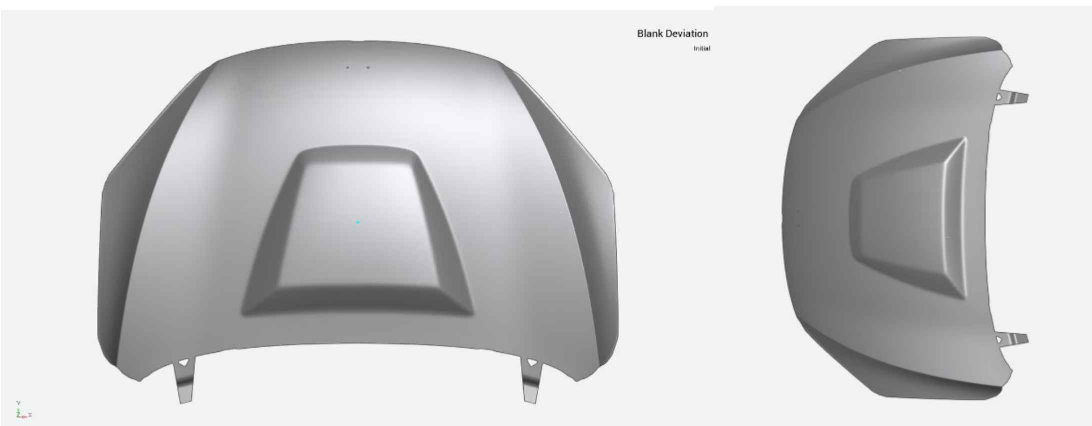


Figure 5. post-processing springback compensation

After each iteration, the tool geometry is updated, as a result, the corresponding trimming curve also need to be updated. Otherwise, the new part boundary will not match the target boundary. With Ansys Forming®, all the trimming curves will be updated automatically based on the die geometry change. In this way, the boundary of the sprung part will conform to the design intent.

4 Springback Compensation example: a hood outer

After the implementation, many benchmarks have been tested. In this paper, a hood outer was chosen to demonstrate the capability. This forming process consists of a drawing process (D-10), two trimming process (T-20 and T-30), and one clamping process (M-40). In this case, the draw happens in the press coordination, and the clamping is performed in the car position. So, the compensation is performed based on two different coordinate system, as shown in Figure 6



6a) draw panel (in press coordinate system) 6b. clamping in car position

Figure. 6. Hood inner forming and springback in two coordinate system

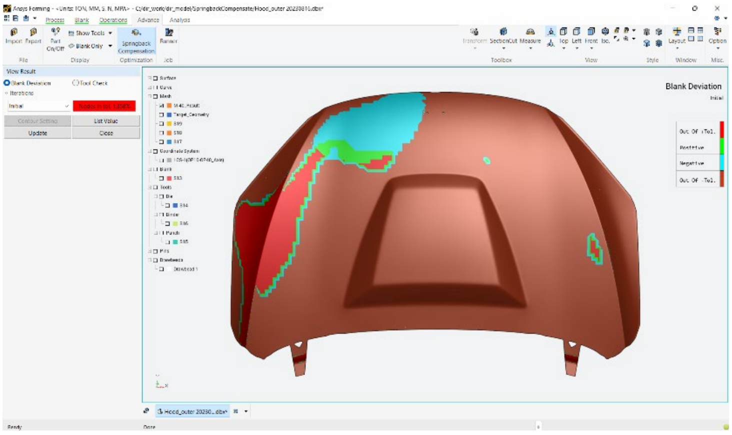
In this study, the scale factor is chosen to be 0.75 to show the iterative process, though we know that a value of 1.0 can reduce the iteration number. In the clamping simulation, gravity is also applied to the part.

With the original tool, the number of points within tolerance is very small, and with each iteration, more and more points are within tolerance. Table 1. Shows the number of nodes within tolerance with each iteration.

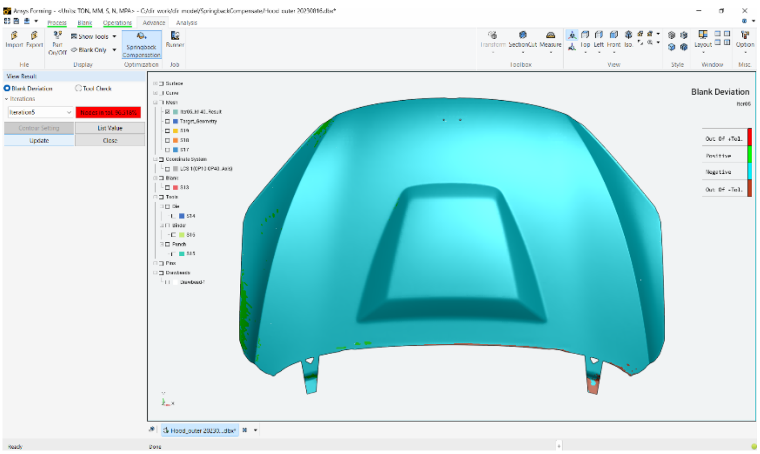
	Original tool	Iteration 1	Iteration 2	Iteration 3	Iteration 4
% of nodes in tolerance	1.4	26.2	43.0	48.3	96.7

Table 1. Percentage of nodes within tolerance increase with each iteration

The corresponding deviation map is shown in Figure 7, where is seen that after compensation, all the surface nodes are within tolerance.



7a) deviation map before springback



7b) deviation map for after the fourth iteration.

Figure 7. Deviation map for the sprung panel before and after compensation.

5 Future work

The initial implementation, there are some limitations. For example, the current release will only be good for draw die compensation. It cannot be applied to forming process with flanging and/or restriking stages. More functions are needed to make it complete.

1. Springback compensation will be extended to all the tools in different forming operations, including flanging, restriking, trimming tool.
2. Local compensation, which allows compensation to be done within a limit region.
3. Modify the CAD surface based on the compensated tool mesh, and maintain the continuity as in the original CAD surface.

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6 Summary

Numerical springback compensation is critical to reduce the die re-cut in die manufacturing process. Ansys Forming ® provides a robust and user-friendly solution to address this issue. With this function, compensation can be performed on different coordinate systems, and the corresponding trimming curves will be updated. The new tool geometry and the trimming curve curves can be output at different coordinate system.

7 Literature

Y. Hu, M. Nagarajarao, and X. Zhu, “A springback Compensation Study on Chrysler 300C stamping Panels using LS-DYNA@”. SAE 2008-01-1443