A New Concept on Stamping Die Surface Compensation

Li Zhang, Jin Wu & Dajun Zhou
Theme Development Department
Advance Stamping Manufacturing Engineering
DaimlerChrysler Corporation

XinHai Zhu
Livermore Software Technology Corporation

Abstract

This paper classifies existing die compensation methods into two general categories, geometry-based method and springforward method. To meet the challenge of increased application of AHSS and its associated severe springback problems, we propose a new concept by using the tooling mesh of design intent as reference during compensation iterations. Incorporation of this concept into these two original methods enhances the efficiency and accuracy of compensated die surface. The enhanced geometric method minimizes the "wrinkle" effect caused by traditional methods done on the blank mesh. The enhanced springforward method improves the convergent rate to a specified tolerance. The proposed scheme can start compensations on a die with either design intent surfaces or already modified surfaces. It is also capable to incorporate actual panel scan data into compensation process to achieve high compensation accuracy.

References

M. Boyce, "Finite Element Simulations in Mechanics of Materials and Deformation Processing Research", ABAQUS Users' Conference (1994)

L. Wu, C. Du, L. Zhang, "Iterative FEM Die Surface Design to Compensate for Springback in Sheet Metal Stampings", Numiform'95 (1995)

L. Zhang, F. Cheng, et al., "Springback Compensation in Die Surface Geometry Using Simulation Methodology". pp.98-103, IBEC'95 Body Assembly & Manufacturing (1995).

LS-DYNA Keyword User's Manual Version 970, Livermore Software Technology Corporation (2003).

A New Concept on Stamping Die Surface Compensation

The 8th International LS-DYNA Users Conference
May 2004

Li Zhang, Jin Wu & Dajun Zhou
Theme Development Department
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XinHai Zhu
Livermore Software Technology Corporation

Outline

* Overview of Traditional Springback Compensation Methods

* New Concept on Springback Compensation

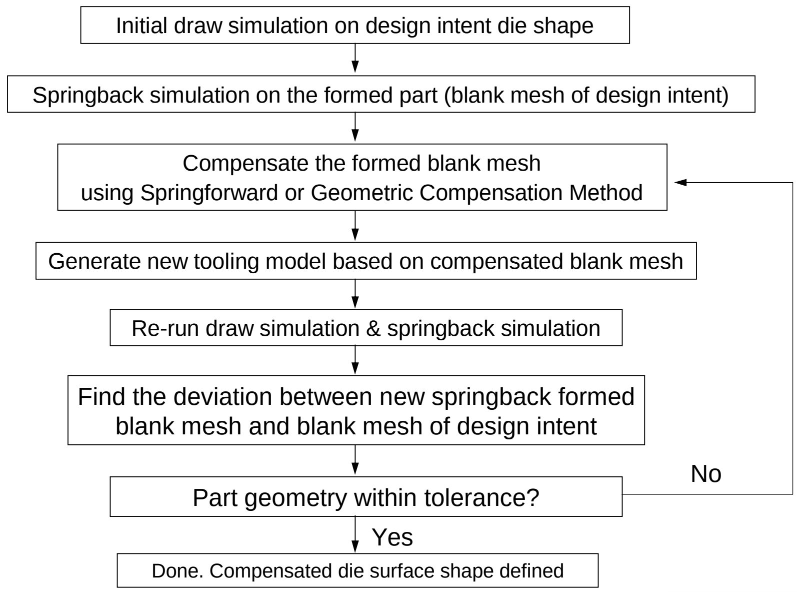
* Enhanced Geometric Method

* Enhanced Springforward Method

* Demonstration Examples

* Conclusions

Overview of Traditional Springback Compensation Methods



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Issues in Traditional Springback Die Compensation Methods

1) "Formed blank mesh" was used as design intent reference during compensation iterations.

When the wrinkles occur on drawn panels, traditional methods include these "geometry defects" into reference during compensation iterations, and thus distort the die face smoothness.

2) A "constant force multiplier" used in traditional springforward method is difficult to uniformly achieve a deviation within a specified tolerance.

Since this difficulty can be overcome by geometric compensation method, a new approach is proposed here to enhance the efficiency of "Springforward" by incorporating the geometric compensation method.

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New Concept on Springback Compensation

Increasing application of AHSS is posing a challenge to the stamping technology to deal with solutions of associated severe springback problems.

To reduce die cost, compensation usually starts from the first die cut, which makes it impossible to use traditional methods for further compensation. Therefore, a new flexible approach, which can start from an already modified die shape, is desired.

Unlike traditional methods, this study proposes a new concept by using the tooling mesh of design intent as reference during compensation iterations.

A mapping technique is used to establish the relationship between the tooling mesh of design intent and tooling or blank mesh at each iteration.

The traditional Springforward and geometric compensation methods are enhanced by incorporation of this concept.

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Advantages of Enhanced Compensation Methods

1) The enhanced geometric method minimizes the "wrinkle" effect caused by traditional methods done on the blank mesh.

2) The enhanced springforward method improves the convergent rate to a specified tolerance.

3) Compensation iterations can start from a die with either design intent surfaces or already modified surfaces.

4) Actual panel scan data can be incorporated into compensation process to achieve high compensation accuracy.

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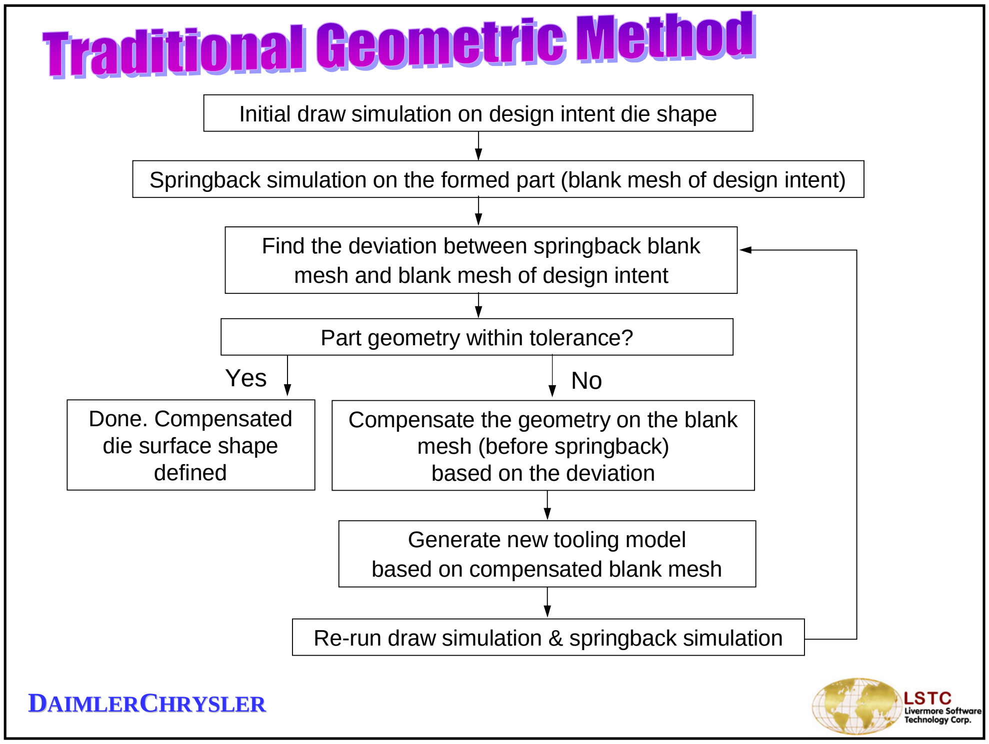
Traditional Geometric Method
Initial draw simulation on design intent die shape
Springback simulation on the formed part (blank mesh of design intent)
Find the deviation between springback blank mesh and blank mesh of design intent
Part geometry within tolerance?
Yes
No
Done. Compensated die surface shape defined
Compensate the geometry on the blank mesh (before springback) based on the deviation
Generate new tooling model based on compensated blank mesh
Re-run draw simulation & springback simulation
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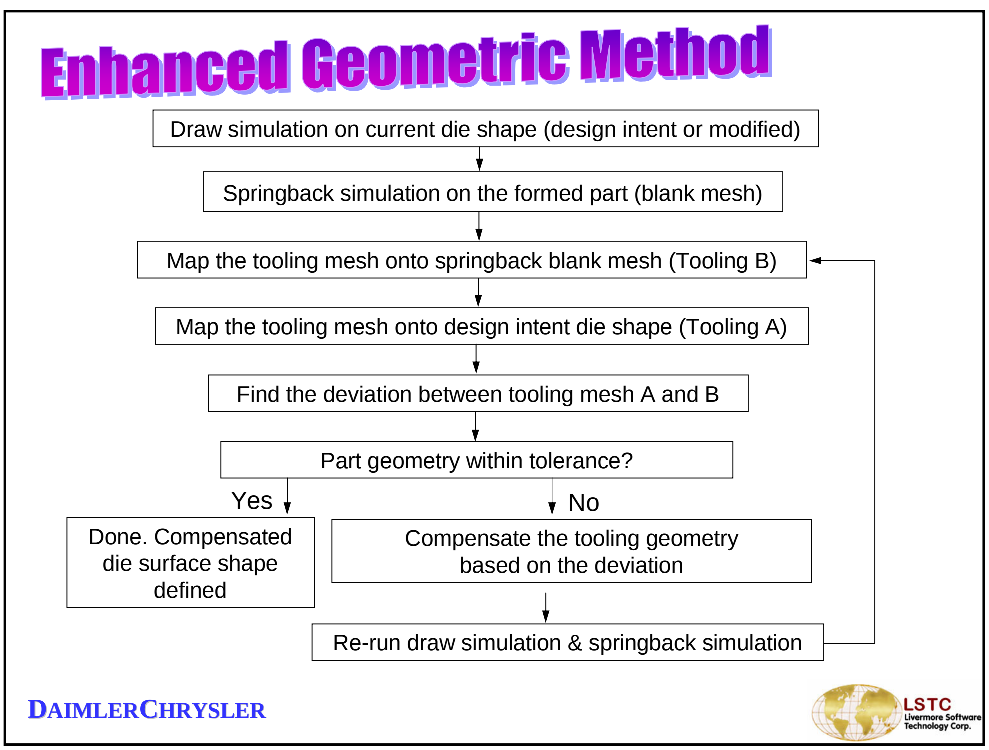
Enhanced Geometric Method
Draw simulation on current die shape (design intent or modified)
Springback simulation on the formed part (blank mesh)
Map the tooling mesh onto springback blank mesh (Tooling B)
Map the tooling mesh onto design intent die shape (Tooling A)
Find the deviation between tooling mesh A and B
Part geometry within tolerance?
Yes
No
Done. Compensated die surface shape defined
Compensate the tooling geometry based on the deviation
Re-run draw simulation & springback simulation
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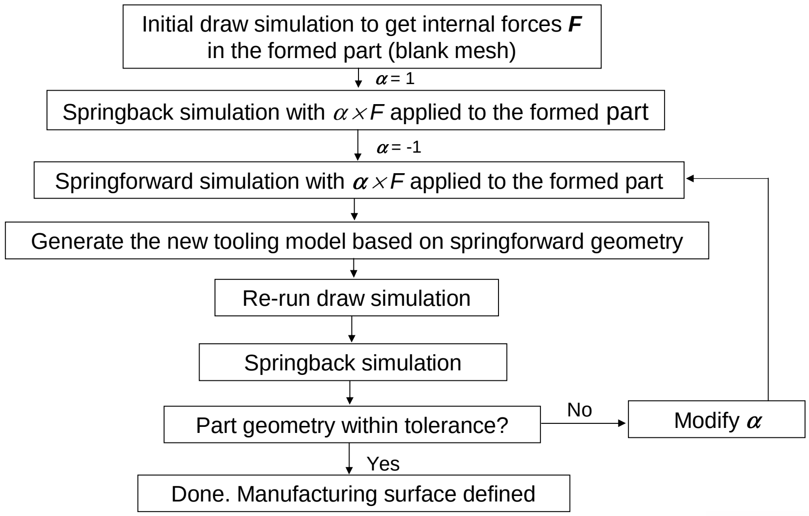
Traditional Springforward Method

See: Li Zhang, Fang-Loong Cheng, et al. "*Springback Compensation in Die Surface Geometry Using Simulation Methodology*". IBEC'95 *Body Assembly & Manufacturing, pp.98-103.*



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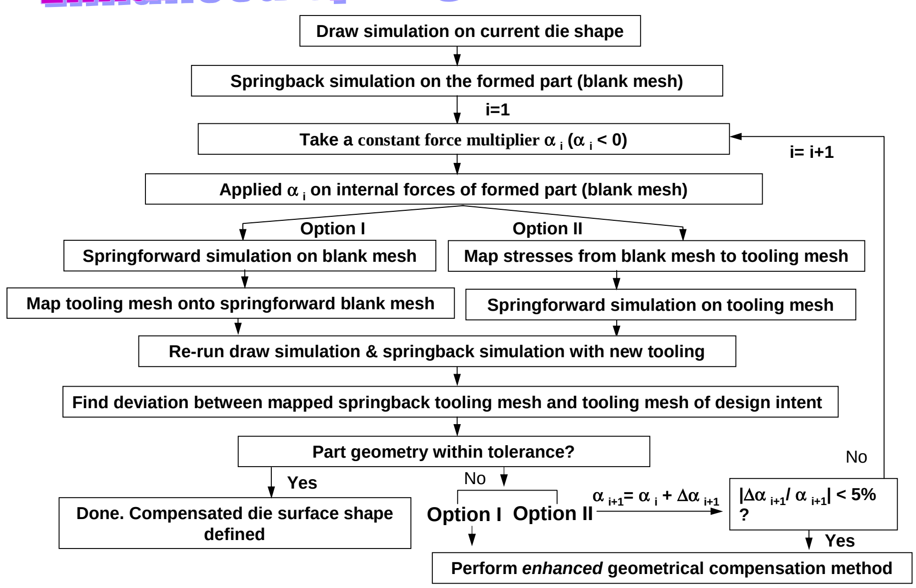
Enhanced Springforward Method



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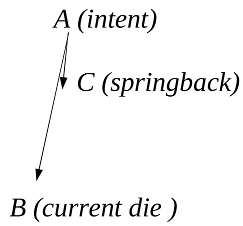
Iterations for the force multiplier α_i ($\alpha_i < 0$)



Let's use ***A, B & C*** to denote the position of a tooling mesh node ***j*** on the design intent, current die shape (at iteration ***i***)and springback location respectively. Assuming the effect of α_i on springback behavior is linear, we have the compensated ratio (e_i^j) for α_i at the next iteration as

$$\left|e_i^j\right| = \left|\frac{\Delta\alpha_{i+1}^j}{\alpha_i^j}\right| = \left|\frac{\alpha_{i+1}^j - \alpha_i^j}{\alpha_i^j}\right| = \frac{\left\|\vec{AC}\right\|}{\left\|\vec{AB}\right\|} \quad \text{That is,} \quad e_i^j = -\frac{\cos(\vec{AC},\vec{AB})}{\left|\cos(\vec{AC},\vec{AB})\right|}\frac{\left\|\vec{AC}\right\|}{\left\|\vec{AB}\right\|}$$

For a panel with n nodes, take

$$e_i = \frac{\sum_{j=1}^{n} e_i^j \left\|\vec{AC}\right\|}{\sum_{j=1}^{n}\left\|\vec{AC}\right\|} \quad \text{and} \quad \alpha_{i+1} = \alpha_i\,(1+e_i\,)$$

Please note that these iterations are only designed to get a "best fit" springback panel by adjusting the constant force multiplier α, and may not uniformly achieve a deviation within a required tolerance.

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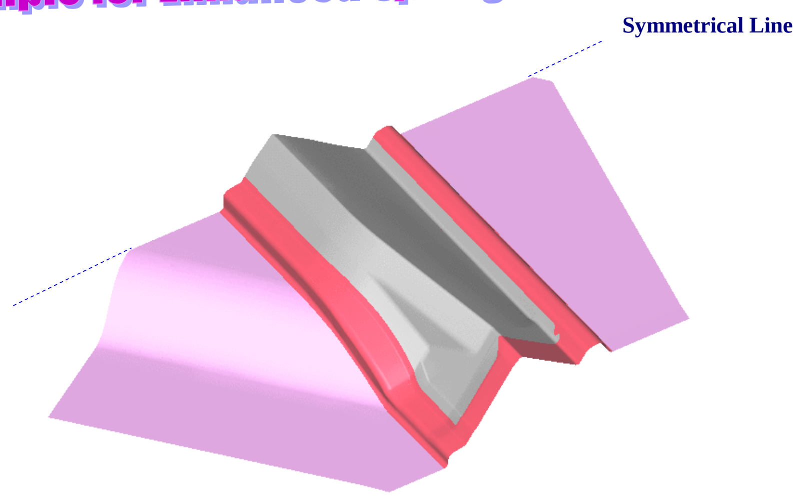
Example for Enhanced Springforward Method



Material: AHSS, YS 664MPa, TS 953MPa
Thickness: 1.4 mm

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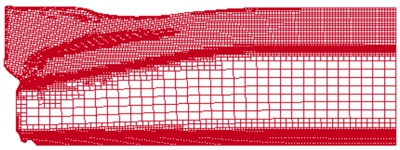
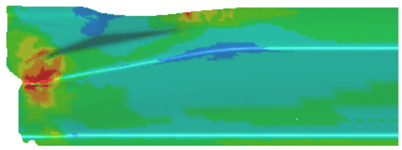
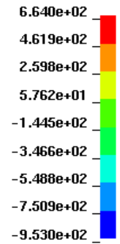
Mapping stresses from blank mesh onto tooling mesh

Blank mesh



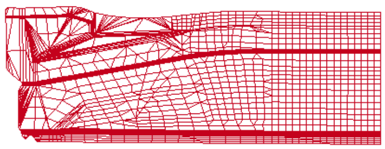
Mean stress (middle surface, MPa)

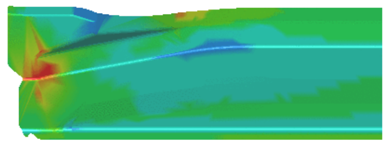




Stress mapping

Tooling mesh





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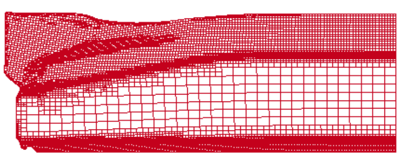
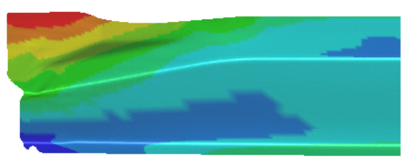
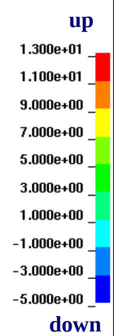
Springback comparison between two meshes

Blank mesh

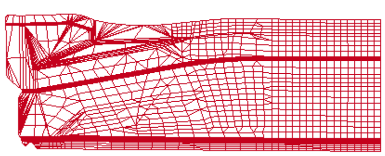


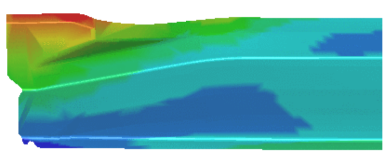
Z-displacement, mm





Tooling mesh





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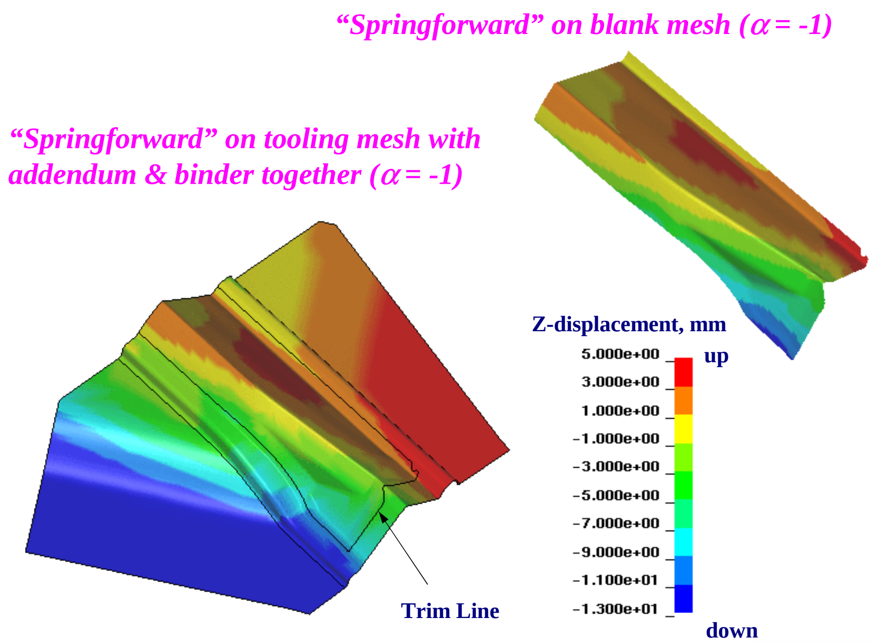

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Convergence study on the force multiplier α_i

Iterations	α_i trial-I	α_i trial-II
1	1.0 (initial)	0.7 (initial)
2	1.13	1.235
3	1.20	1.21
4	1.18	
Converged α_i	1.20	1.235

The study indicated that the force multiplier converged at around 1.2. Because it didn't uniformly achieve a deviation within the tolerance, the enhanced geometric compensation method was adopted here for further compensation. The compensation was performed on trial-II.

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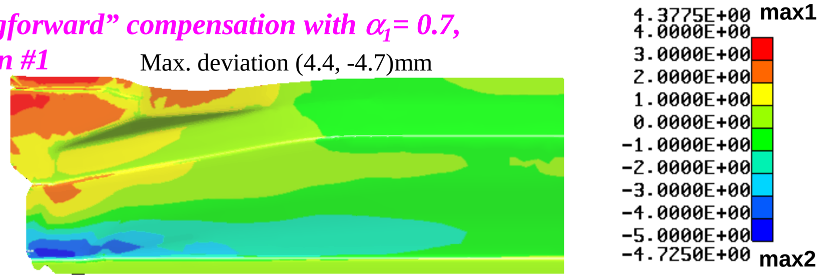
Deviation to design intent during compensation iterations

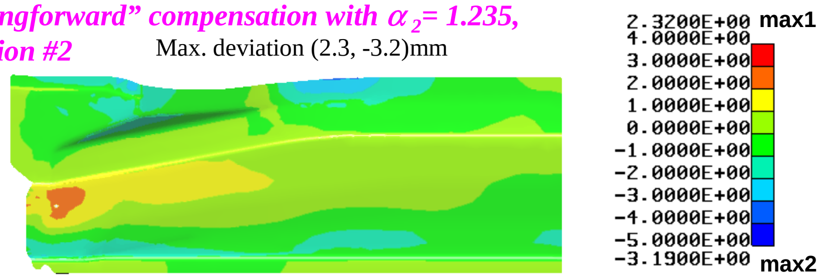
"Springforward" compensation with α_1= 0.7, iteration #1

Max. deviation (4.4, -4.7)mm



"Springforward" compensation with α_2= 1.235, iteration #2

Max. deviation (2.3, -3.2)mm



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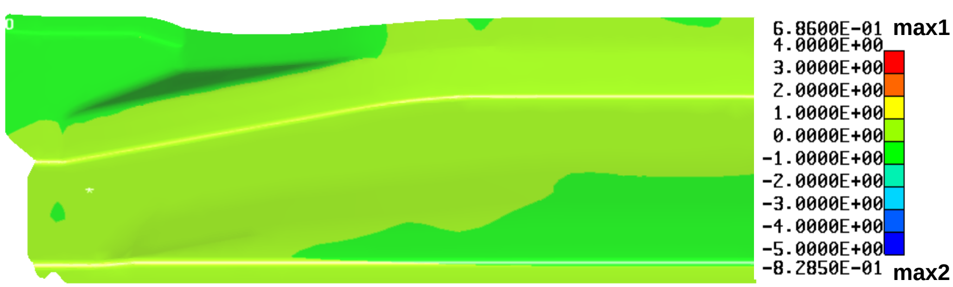
Deviation to design intent during compensation iterations

Enhanced geometric compensation - iteration #3

Max. deviation (0.7, -0.8)mm



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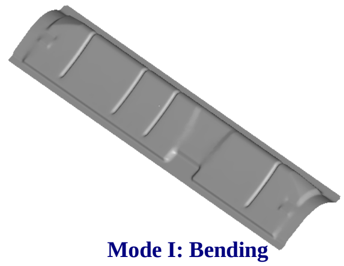
Example for Enhanced Geometric Method

Cab Back Reinf.

Material: 80ksi HSS
Thickness: 1.3 mm

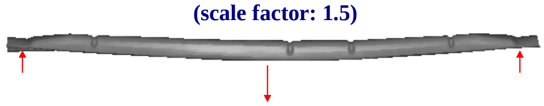


Springback Modes:

* Global uneven bending
* Wall angle open
* Local distortion
* Small twist

Mode I: Bending

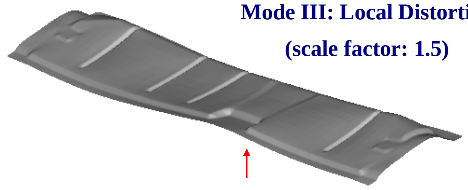
(scale factor: 1.5)



Mode II: Opening

Mode III: Local Distortion

(scale factor: 1.5)



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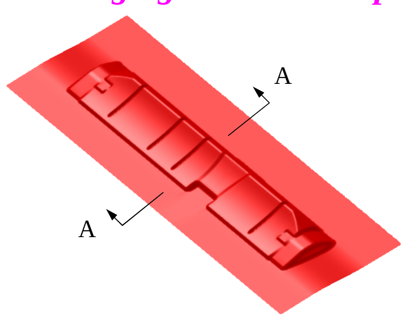
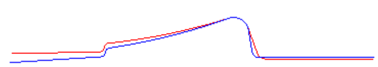
Challenging issues in compensation



Section A-A



Red: CAD development for design intent surfaces

Blue: CAD development with modified die surfaces

1) No actual panel springback information available from the design intent die. Die compensation has to start from modified die surfaces.
Solution: Map the tooling mesh and blank mesh onto design intent shape.

2) Simulation prediction underestimates springback.
Solution: Scan data must be incorporated into compensation. Map the tooling mesh & blank mesh onto actual panel, and find the deviation to design intent.

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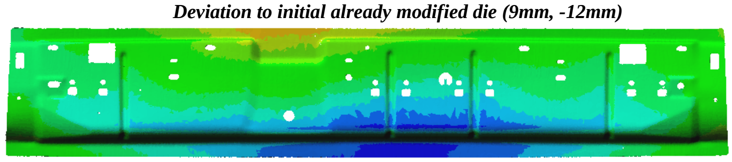
Incorporating scan data into compensation

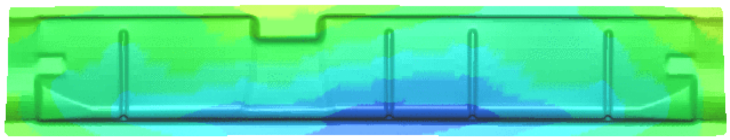
Scan Data (provided by Optimal, inc.)

Deviation to initial already modified die (9mm, -12mm)

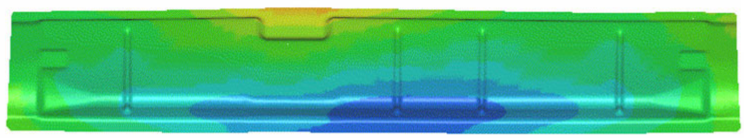


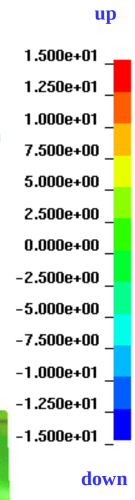
Simulated Springback (under-estimated)

Deviation to initial already modified die (4mm, -11mm)



Springback after incorporating scan data





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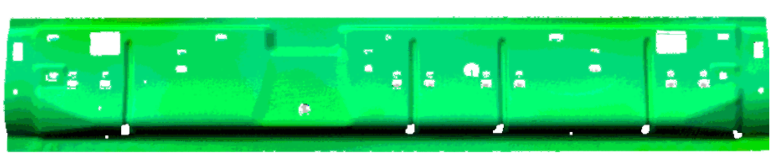
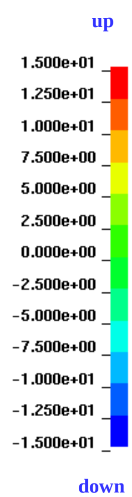
Deviation comparison of actual panels to design intent

Scan Data (provided by Optimal, inc.)

Before compensation

After compensation





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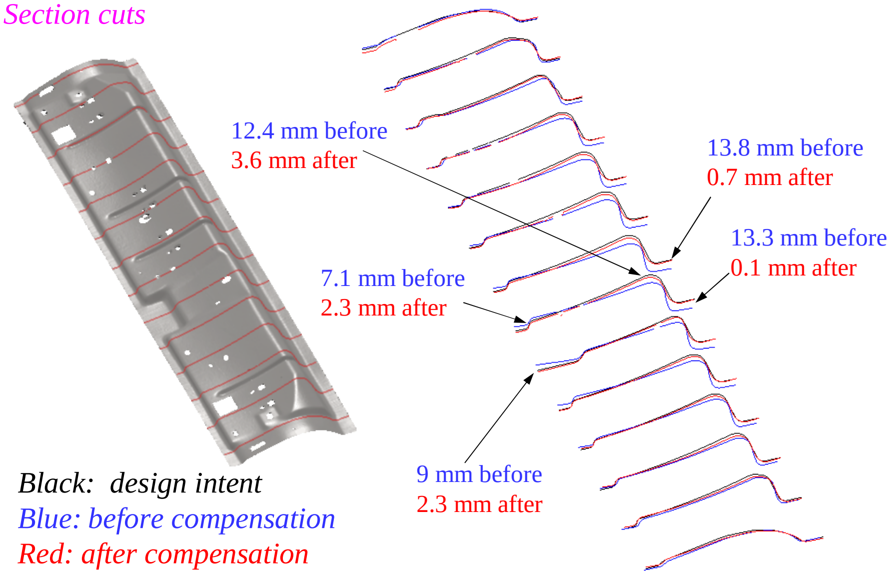
Deviation comparison of actual panels to design intent

Section cuts



Black: design intent
Blue: before compensation
Red: after compensation

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Conclusions

* A new concept is proposed by using the tooling mesh of design intent as reference during compensation iterations.

* The enhanced geometric method minimizes the "wrinkle" effect caused by traditional methods done on the blank mesh.

* The enhanced springforward method improves the convergent rate to a specified tolerance.

* The proposed scheme can start compensations on a die with either design intent surfaces or already modified surfaces.

* It is also capable to incorporate actual panel scan data into compensation process to achieve high compensation accuracy.

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