N. Springback Compensation in Advanced Sheet Forming Materials

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Objective

- Eliminate die re-cuts and thereby realize significant reductions in the lead time and cost involved in die construction and production tryout.
- Develop a robust, integrated software package, which is capable of accurately and reliably generating optimized die surfaces that compensate for part springback while maintaining formability.
- Have ZERO die re-cuts when forming panels with advanced sheet metals, such as high-strength steel (HSS) and aluminum.
- Demonstrate concept feasibility with
  - a graphical user interface (GUI) tool that can modify the die mesh locally or globally based on predicted springback results and user-specified morphing criteria; and

— numerical simulation modeling results showing minimized deviation from nominal for a part using a newly developed compensation strategy.

Accomplishments

- Implemented new finite-element method (FEM) (manual compensation) code and collaboratively performed iterations to test mesh-based, iterative-based analytic (manual) die compensation techniques and prototype software released by LSTC for porting to common workstations.
- Trained vendor staff and trouble-shooted with the SCP team users to implement and run the new SCP code on a wide variety of materials and geometries for evaluation within the automotive part design/analysis environment.
- Developed geometric compensation method and a software module delivered by ETA to the project team, with GUI pre-/post-processors implemented in DYNAFORM. The software was developed exclusively for use by the U.S. Automotive Materials Partnership (AMP) team.
- Tested manually the robustness of the developed compensation strategies and compared against production part die faces with numerical data developed by the project team (see attached selected examples—each original equipment manufacturer (OEM) tested the code on at least two component geometries):
  - GM: Springback compensation of a DP600 steel rail
  - Ford: Springback compensation of a 6111-T4 aluminum decklid
  - DCX/DCAG: Springback compensation of a HSS load beam outer
  - In addition, T. K. Budd studied a fender outer for an EDDS steel sheet part which has a 0.75-mm thickness and predicted springback of 1.25 mm during draw (before trim); they also developed benchmark information for performing tool re-cuts.
- For all parts, the predicted springback at critical measurement locations on the compensated virtual production dies was within specified tolerance of ±2 mm.

Future Direction

- Submit a proposal to USAMP AMD for research into the Technical Feasibility Phase 2 of the SCP project.
- Demonstrate and validate the new compensation code technology by performing die re-cuts to the numerically compensated shape, with panel tryouts and measurement comparisons.

Introduction

Current manual die compensation is costly and time-consuming, largely trial-and-error. A major gap exists between a "proposed die mesh" and "machinable die face," resulting in countless hours of mesh-to-computer-aided design (CAD) surface smoothing using repetitive human intervention and checking. An average-size stamping die for steel panels requires up to 2 re-cuts; a die for aluminum panels takes up to 4 re-cuts. A typical die re-cut operation (NC Program, machining, checking, benching, spotting) is very costly, requiring several weeks. OEM costs are far higher when die handling, labor, tryout, and panel measurement costs and time are factored, not to mention the overall loss of productivity.

Thus, when working with the newer HSSs and aluminum alloys, the computer-aided engineering (CAE) analysts need a robust technique for generating the new binder and knowledge-based modeling techniques to avoid back draft and perform selective local compensation. The AMD 311 SCP project offers a significant opportunity to compress lead time and productivity in stamping tool development and tryout.

Progress

The technical approach consisted of collaboratively customizing and evaluating commercial FEM software, that would automatically (a) analytically predict, and (b) recommend optimized tool geometry (FEA mesh and CAD surface) and the stamping process, capable of producing panels with the desired final shape after springback. The project utilized the results and deliverables of the completed Springback Predictability Project (SPP, funded by NIST-ATP in 1995–2000), which are incorporated in LS-DYNA, a commercial FEA package available from Livermore Software Technology Corporation (LSTC), a leading software vendor.

Each OEM team member and industrial supplier company collaboratively exercised the FEM code (with the assistance of the software vendors) on at least two (per company) selected automotive sheet panels of HSS and aluminum, and numerically simulated the predicted panel geometry after springback, comparing it with the compensated virtual die.

The results and team progress were tracked and reported via monthly team meetings held at USCAR, augmented by video/teleconferencing and electronic collaboration tools. OEM team members contributed their knowledge of advanced die engineering and massive parallel processing.

The SCP Concept Feasibility Phase 1 project has demonstrated potential to create technology for leadership of the USAMP team that will enable them to

- reduce lead time and cost for hard tools up to 50% in comparison to traditional (manual) approaches;
- accelerate application of advanced metals for weight reduction, such as HSS, advanced aluminum;
- extended project findings in future to magnesium and titanium sheet forming; and
- promote rapid development and implementation of innovative product designs in new vehicles.

Conclusion

The SCP project has demonstrated proof-of-concept with new die compensation software that will help accelerate applications of advanced metals for weight reduction by reducing tool modification costs and lead-time in comparison to traditional approaches. It will also demonstrate new collaboration paradigms in the industry by integrating the product, process and tool design functions.

Future Plans (to be addressed in Phase 2)

In the proposed Technical Feasibility Phase, the technical emphasis of software developments will be on the following areas (as identified from Phase 1 code trials):

- development and evaluation of several additional promising analytic compensation strategies, with down-selection to one method for full-scale code implementation and automation, and its demonstration for a broader variety of parts;
- localized wrinkling must be identified to user criteria and removed before die compensation; and
- the new method and software need to be validated by die recuts to compensated shape and panel forming trials.

Example Automotive Panels Studied in AMD 311 Phase 1

DCX/DCAG HSS Load Beam Outer:

- This is a 1.4-mm gauge HSS 50-ksi galvanneal steel alloy sheet part in production at DaimlerChrysler (Figure 1).
- The initial process FEM simulations indicated that significant local wrinkles and waviness would occur in several locations.
- Application of the new LS-DYNA SCP code indicated that with the first iteration compensation, it was possible to bring the part within the specified ±2-mm tolerance specification.
- OEM conducted simulation and compensated 90% of die geometry to within 0.5 mm.
- It was discovered that local springback deviations greater than 0.5 mm are caused by part wrinkling during draw forming.
- DCX learned that one must minimize wrinkling in the draw die before next iterations are performed.

GM Steel Rail

- Material used was 1.8-mm gauge DP600 dual-phase steel (Figure 2).
- GM used two strategies and performed numerous iterations in each trial to identify issues and gaps for the manual compensation methods.
- All sections were successfully compensated to within 0.5 mm.

Ford Aluminum Decklid

- Material used was 0.9-mm gauge 6111-T4 aluminum sheet (Figure 3).
- The emphasis of the compensation strategy was to evaluate ten different smoothing techniques to generate the compensated die.

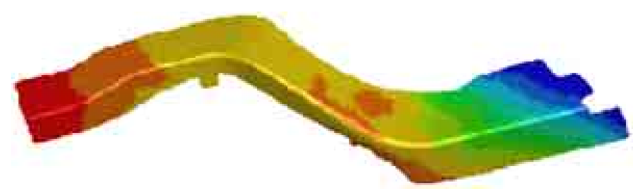

Figure 2. GM steel rail.

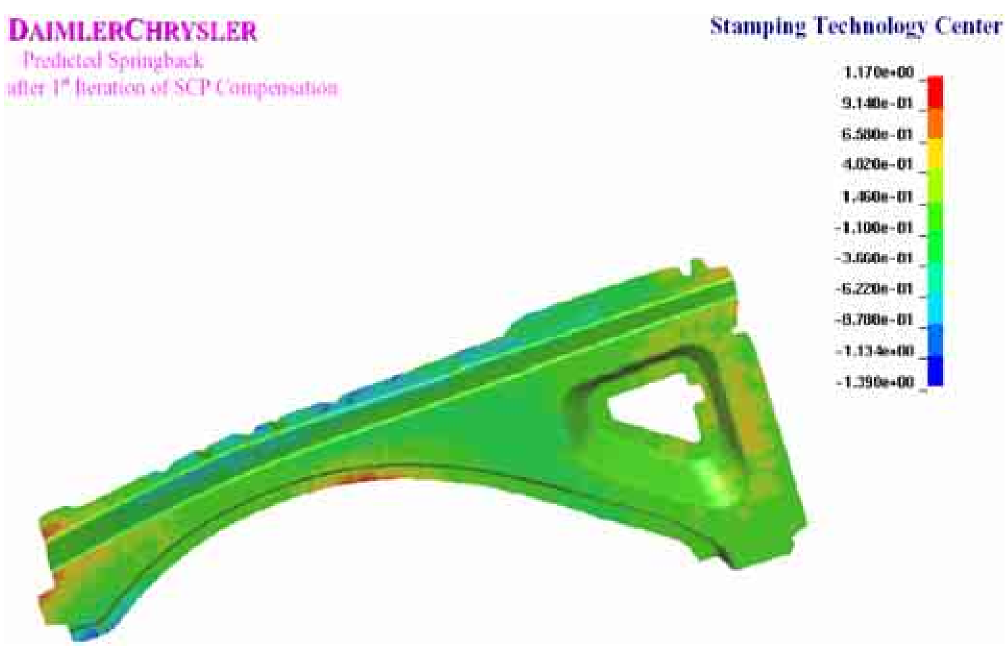

Figure 1. HSS load beam outer.

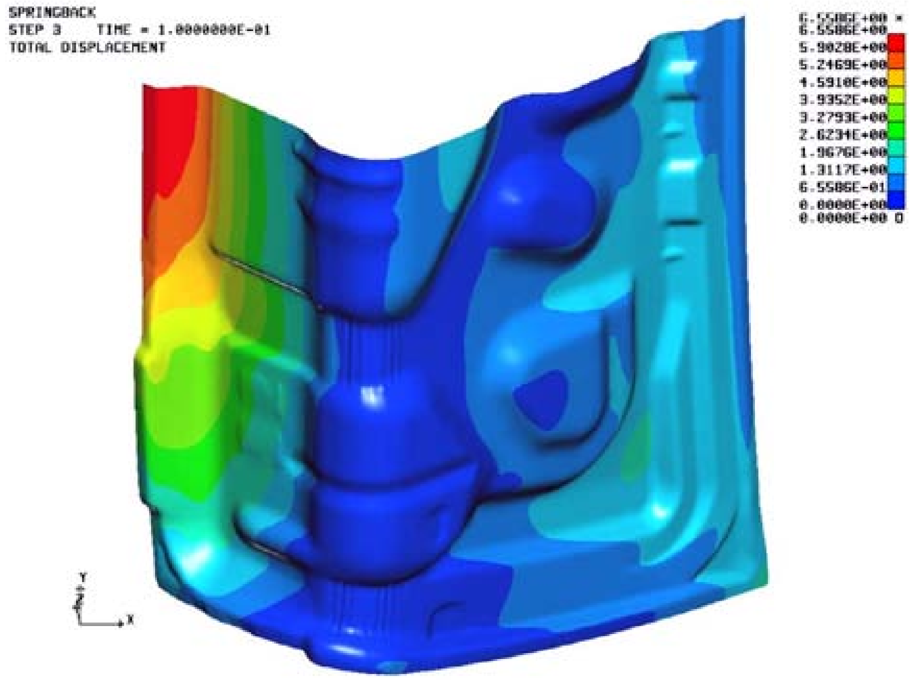

Figure 3. Ford aluminum decklid.

- Good compensated part shape was achieved after one iteration with the right choice of the smoothing method.

Project Team Members

OEM Team: DaimlerChrysler (Auburn Hills and Stuttgart Technical Centers), Ford Motor Company and Volvo Division, General Motors Metal Forming Division (GM-MFD).

Participating Suppliers: (in-kind contributions and project technical guidance): Alcoa, TK Budd, U.S. Steel.

Software Vendors: (under USAMP subcontract for DOE funds): Engineering Technology Associates (ETA), Livermore Software Technology Corporation (LSTC).