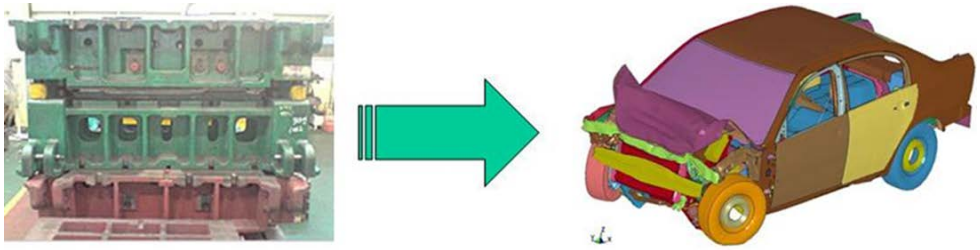
Mapping Forming Effects to Structural Models
ASP-390



Raj Sohmshetty

Ford Motor Company

May 18, 2012

Project ID # LM065

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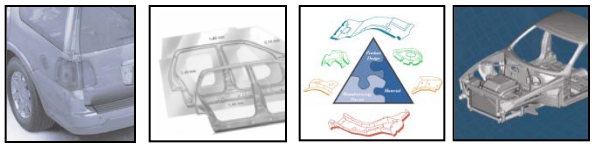


OVERVIEW

Timeline

- - January 2011
- - December 2011
- - 100%

Budget

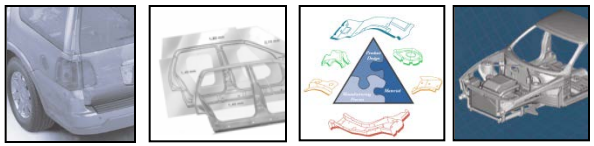
- Total project funding
  - DOE share: $85,000
  - Contractor share: $85,000
- Funding received in FY11: $40,000
- Funding for FY12: $112,000

Barriers

- Alternate forming simulation approaches
- Product development compatible mapping methodology
- Benefits of mapping

Partners

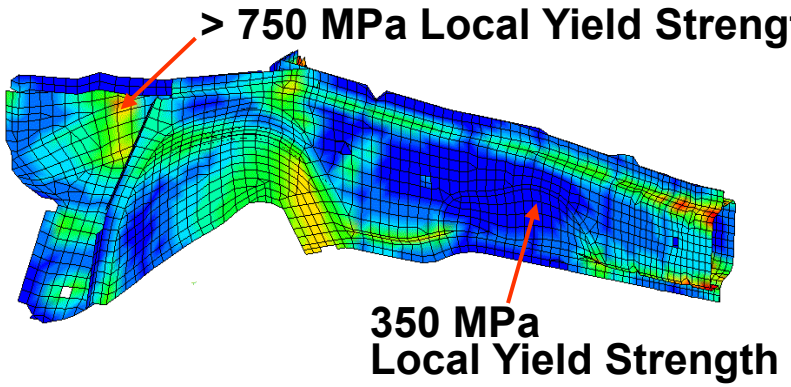
- Ford, GM, Chrysler
- ArcelorMittal, US Steel, Severstal, Nucor, AK Steel
- Altair, ETA, and Generalety
- Raj Sohmshetty, Ford Motor Co.



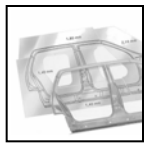
BACKGROUND

Incoming Material:
350 MPa Yield Strength

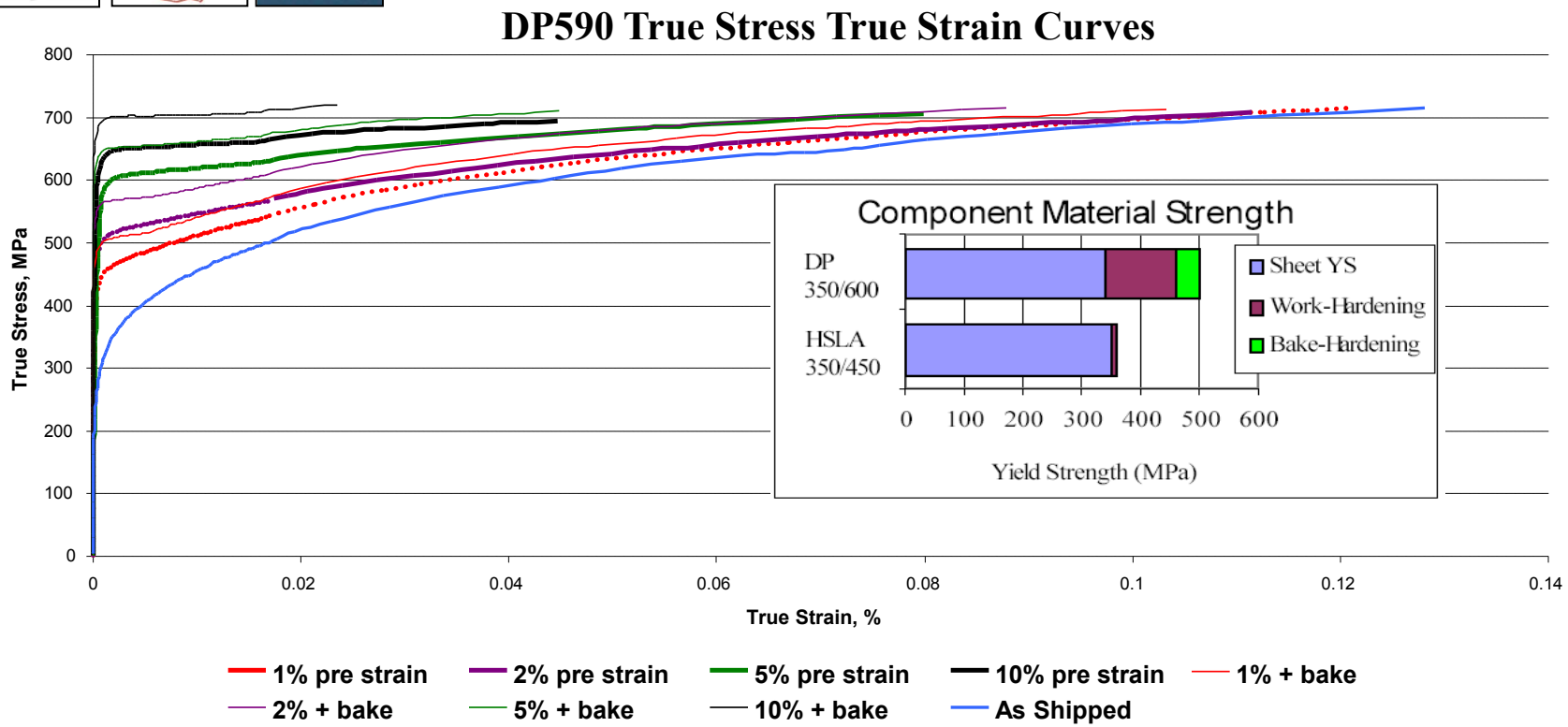
Stamping



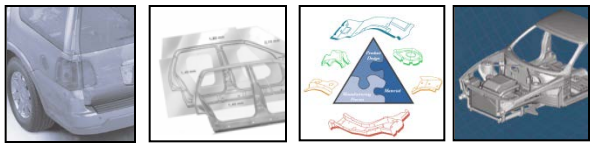
- Stamping process changes the material properties of the incoming material.
- Product CAE models traditionally used incoming material properties resulting in modeling inaccuracies and sub-optimal designs.

Example – DP590 (AHSS grade) Properties



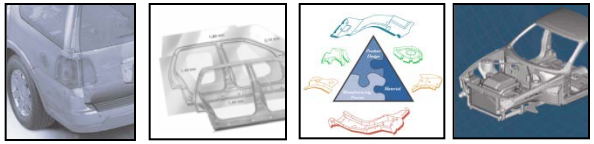
- Advanced High Strength Steels such as DP590 work harden and bake harden more than conventional high strength steels.
- As vehicle structures are using more AHSS grades, consideration of forming effects in product attribute CAE models is becoming more important.



TECHNOLOGY GAPS

- The OEM structural design and analysis community requires a robust and simple software tool to rapidly perform forming analyses and map the strains and thickness distribution to product attribute models.

- Some forming effects mapping software tools are available, but are too cumbersome to be practical in routine design and structural analysis activities.
  - Generating forming simulation data takes too much time and expertise.
  - Often detailed manufacturing process data is not available during the early design phase.



Project Objectives & Relevance

1. Compare alternative forming simulation and mapping methodologies and select a method that can be practically applied in early product development phase.
2. Provide recommendations on software tools and processes to incorporate forming effects into structural crash models.
3. Demonstrate weight reduction potential when forming effects are incorporated in structural models at vehicle design stage.

Forming Effects Mapping Project

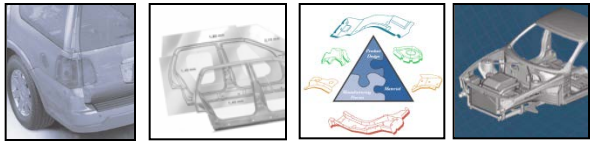
Improved Structural Optimization

- Reduce material use
- Lighter weight vehicles

DOE Vehicle Technologies Program

Transportation technologies that are:

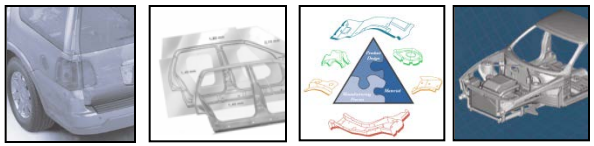
- Environmentally friendly
- Energy efficient



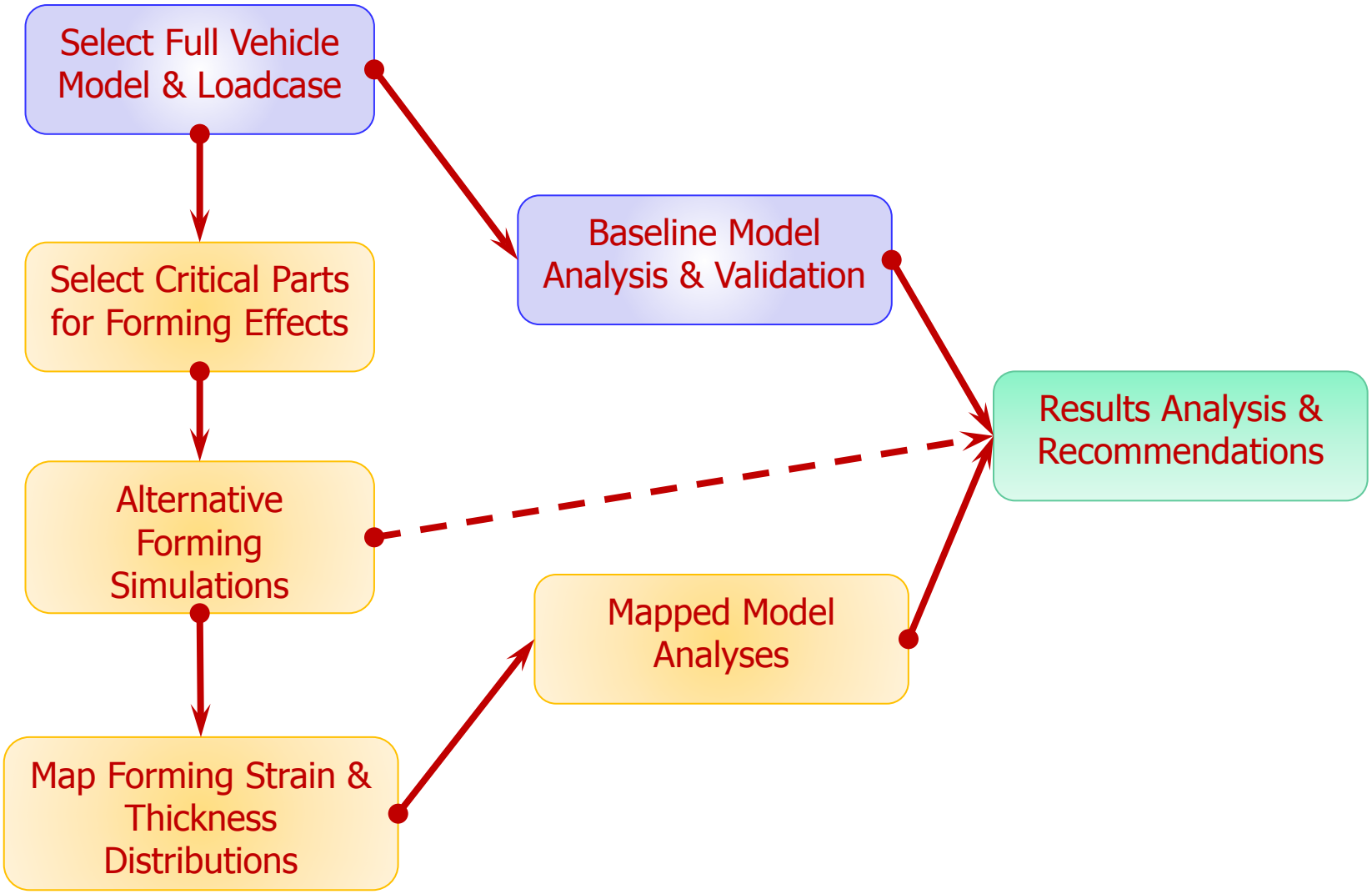
Relationship to USDRIVE

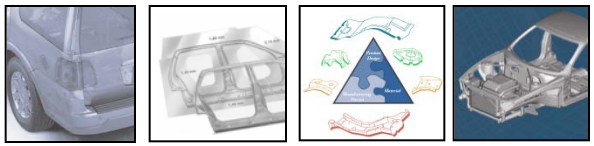
"Improve the efficiency of all vehicle types by using lightweight materials to reduce vehicle mass."

- Improved design optimization with 5-10% weight saving opportunity on affected parts
- The process is applicable to steel as well as other materials that show work-hardening behavior
- Improved simulation accuracy to further reduced reliance on physical testing



Technical Approach





Technical Approach

Alternative Forming Effects Simulation Approaches:

- Quick one-step forming simulation (using crash CAE model)
- Full incremental forming simulation (see Figure)
- Uniform pre-strains based on estimates or historical data

Step 1: Die Preparation

- Refine the given mesh as required
- Introduce fillets
- Die preparation:
- Filling holes and smoothening outer edges
- Generating binder and addendum

Step 2: Draw Surface Development

- Define blank geometry
- Use the curve from the crash model and R-values provided.
- Define stamping parameters

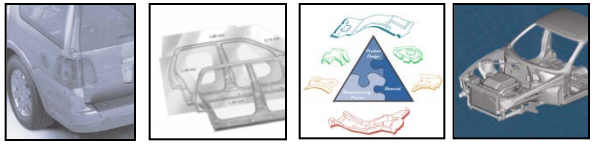
Step 3: Analysis

- Run the stamping simulation

Step 4: Results

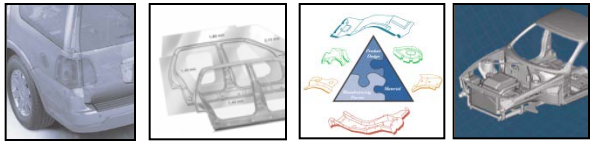
- Analyze the results using Forming Limit Diagram, Thinning curve and Plastic strains
- Based on results re-run the analysis, if required, by fine tuning die geometry, bead forces and blank shape
- Generate the results for the symmetrical parts

Incremental Forming Simulation Methodology



Project Milestones

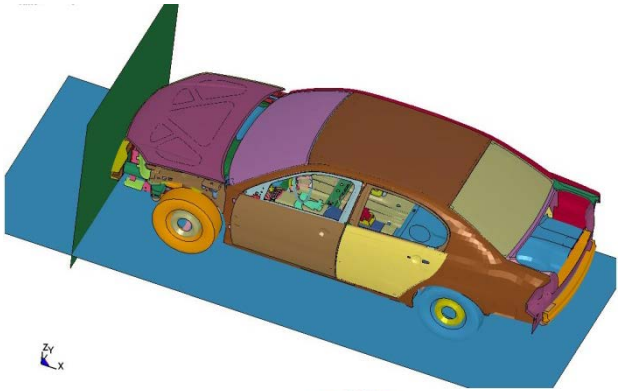
Tasks	Fiscal Year 2011			
	Q1	Q2	Q3	Q4
1. Select baseline model & load case; perform validation analyses	■	■		
2. Select critical parts for forming effects mapping		■		
3. Perform forming simulation on selected parts using alternative approaches		■	■	
Gate 1: Do quick forming simulation results compare well with the incremental forming simulation results?			◆	
4. Map forming simulation results to crash model			■	■
5. Analyze mapped crash models & interpret results			■	■
6. Documentation & technology transfer				■

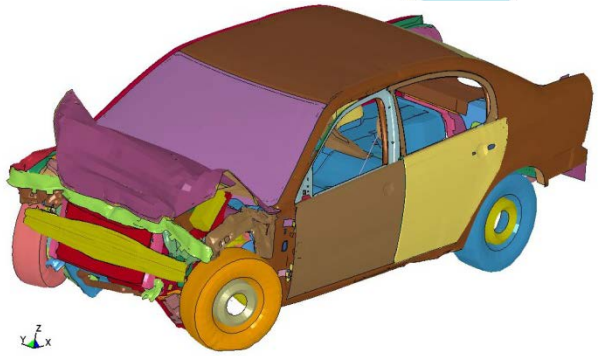


Project Results

Baseline Model:

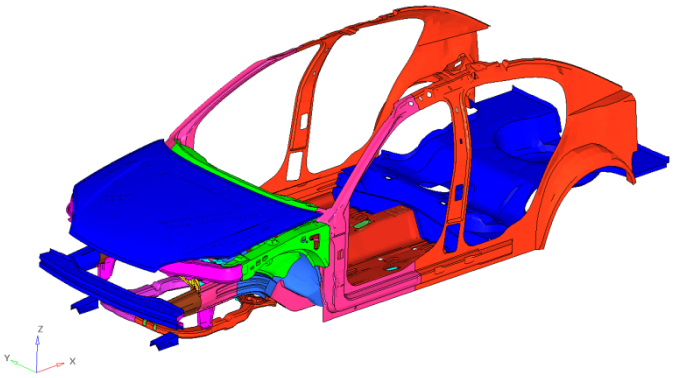
- Light Weight Front End (LWFE) project model
  (5-passenger mid-size vehicle)
- 35 MPH Front Impact Loadcase

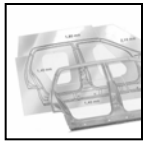




Parts selected for forming simulation:

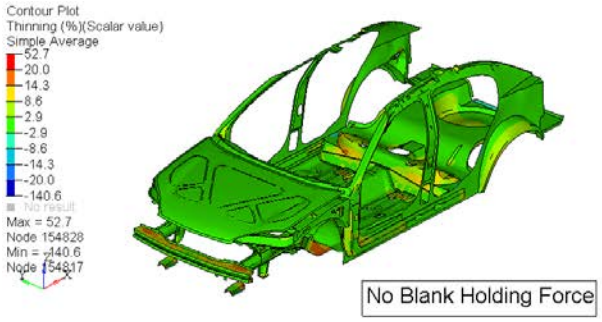
- Based on the amount of energy absorption, energy density, amount of forming strains and materials type (i.e. AHSS).
- A total of 36 components, including 10 symmetric parts, were selected.



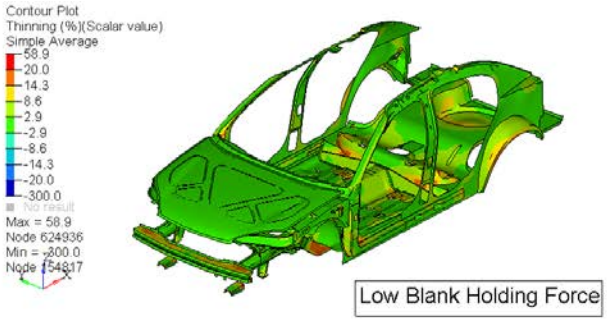



One Step Forming Analysis Results

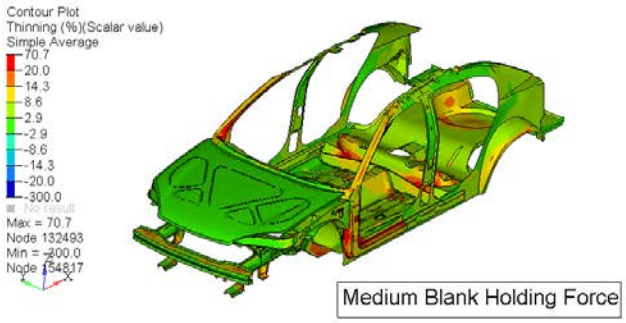
- Done on crash CAE model without mesh refinements
- Sensitivity study on “blank holding force”
- Medium blank holding force or part specific optimal blank holding force gives best results
- Documented parameters used, procedures, and lessons learned



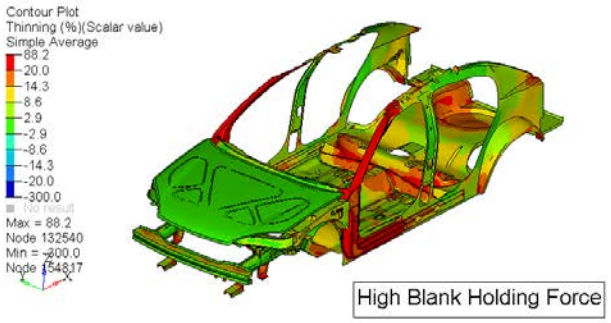
No Blank Holding Force



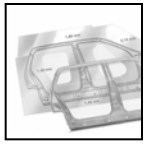
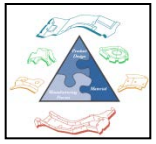
Low Blank Holding Force



Medium Blank Holding Force

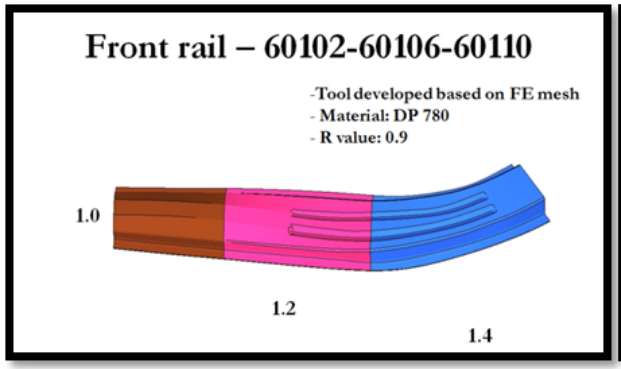


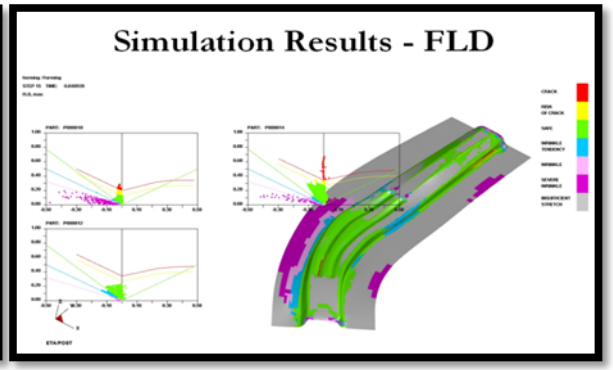
High Blank Holding Force

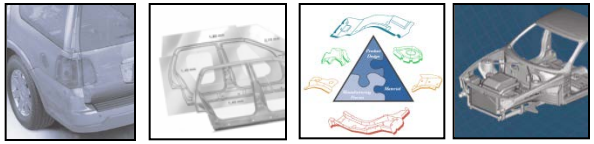





Incremental Forming Simulation Results

- Draw die surfaces developed based on the mesh of the components in the baseline vehicle model.
- Part models were refined as needed (e.g., refined mesh size, added fillet radii, etc.)
- Secondary processes, such as flanging, piercing, re-striking and cam forming were not included as the goal is to get strain and thinning due to primary forming process
- Iterated the process till part formed satisfactorily.
- Documented process parameters used, procedures, and lessons learned.

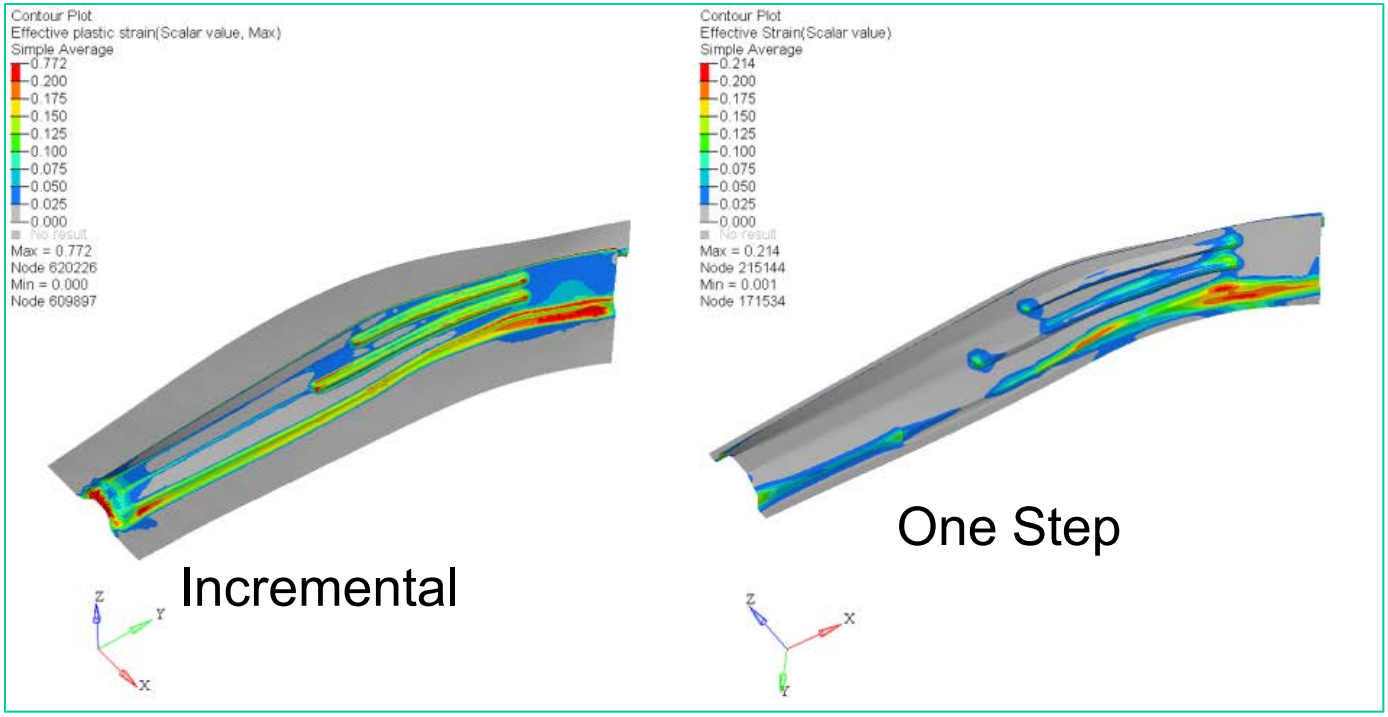


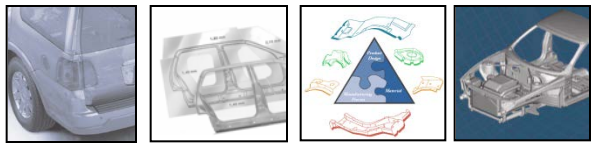




One-step vs. Incremental Forming

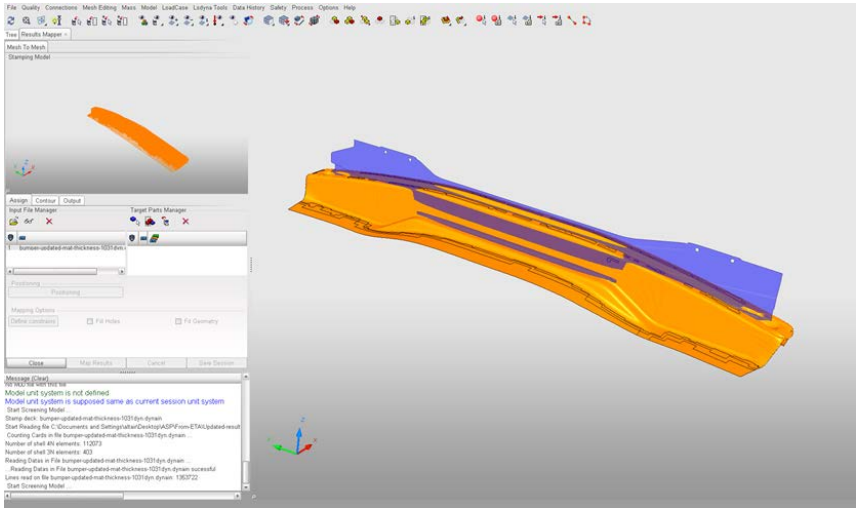
- Comparisons between the incremental and the one step forming analysis results indicate that the one step forming analysis captures the forming effects reasonably well for the project's purpose
- Incremental forming analysis requires accurate models, process expertise, and considerably more time (40 to 60 hours per part)

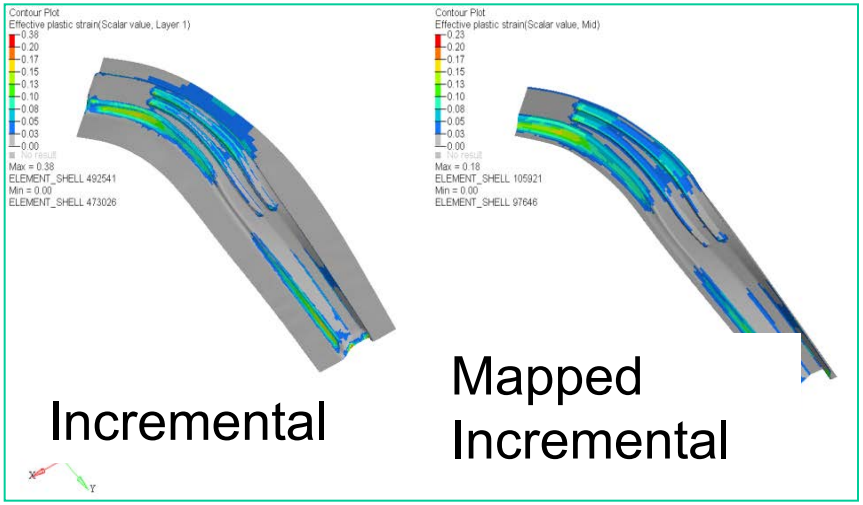


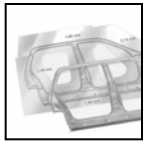


Mapping Forming Results to Crash Model

- For incremental forming, manual re-orientation of forming model to match crash model may be required
- The mapping tool used considers thickness and plastic strains
- Comparisons between the incremental and the mapped incremental forming results indicate the mapping algorithm from the forming model to the structural model works with high accuracy.

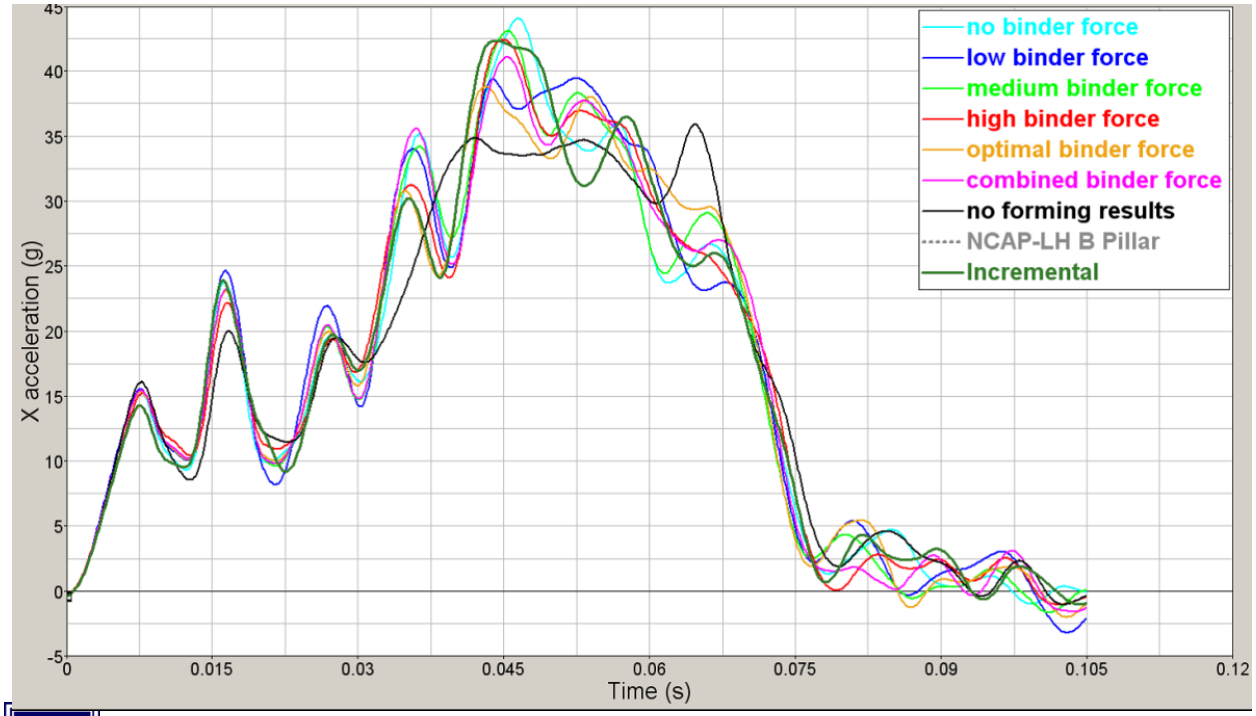


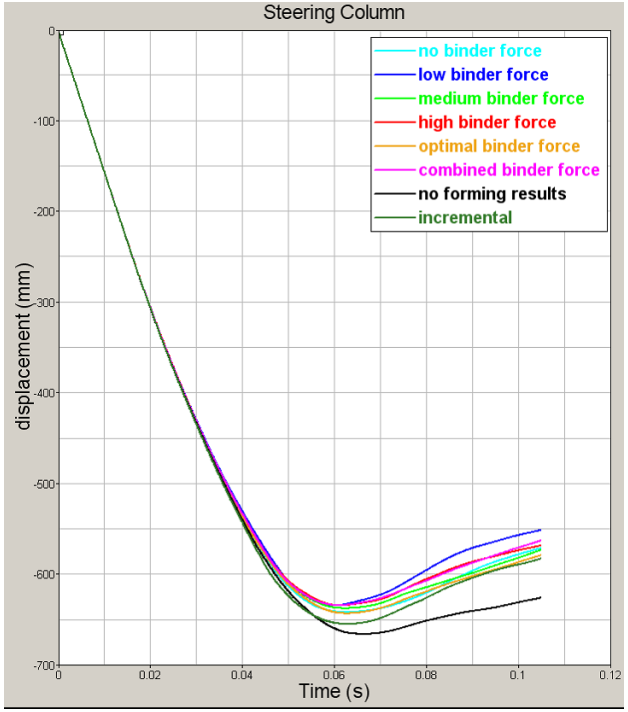


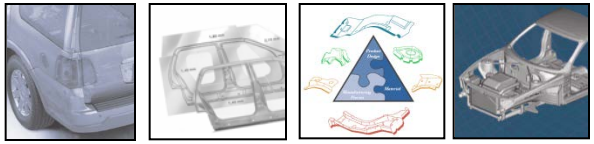



Forming Effects on Crash Results

- Inclusion of the forming effects in front impact model:
  - ✓ increased the B-Pillar accelerations by about 7g (20%).
  - ✓ reduced the steering column intrusion by about 80mm (13%)
- All forming simulation alternatives resulted in stronger structural response
- Results indicate opportunity for weight reduction if the forming effects are considered in crash models

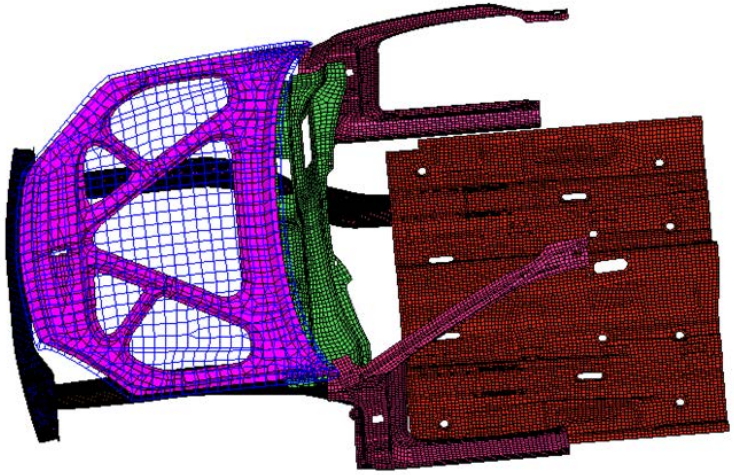






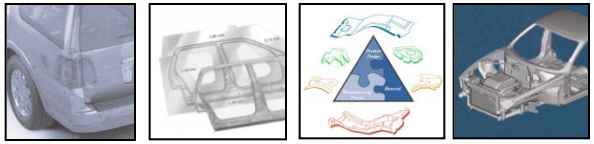
Forming Effects on Crash Results

- Gage Optimization:
  - ✓ Selected sensitive parts
  - ✓ Used baseline B-Pillar acceleration & steering column intrusion as targets
  - ✓ Allowed gage to vary up to 15%
- Optimization resulted in 10% weight reduction in the affected parts



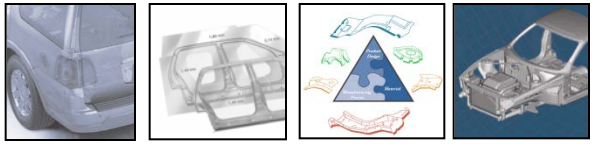
Parts Selected for Optimization

Parts name	Baseline (mm)	Incremental (mm)	Optimized (mm)	Change to Baseline (%)
Rail front (l/r)	1	1	0.95	-5.0
Rail middle (l/r)	1.2	1.2	1.15	-4.2
Rail rear (l/r)	1.4	1.4	1.30	-7.1
Front floor	0.85	0.85	0.75	-11.8
Rail extensio front (l/r)	2	2	1.80	-10.0
Bumper front	1	1	0.90	-10.0
Bumper back	1	1	0.90	-10.0
Body side inner (l/r)	2.1	2.1	1.90	-9.5
Plenum lower	0.75	0.75	0.70	-6.7
Hood inner	0.7	0.7	0.60	-14.3
Hood outer	0.7	0.7	0.60	-14.3
Total mass (kg)	71.7	71.7	64.3	-10.0



Collaborations & Technology Transfer

- This project was a collaboration among:
  - Three OEM members who are the end users of this work
  - Five steel companies who often provide data & simulation support for vehicle part design
  - Three software & services vendors who incorporate the process & lessons from this project into their offerings
- Technology transfer for this project will continue through:
  - Technical report distribution & presentations
  - Continued dialogues with software vendors



Summary

- Automotive crash analysis is typically done without accounting for part stamping effects. With AHSS intensive structures, this results in under-estimation of strength.
- This project compared alternate stamping simulation and results mapping to crash models.
- Based on observations, quick one step forming simulation based approach is recommended.
- Consideration of stamping effects in crash model resulted in 10% weight reduction opportunity.
- Proposed method will be shared with software vendors for process automation.