FutureSteelVehicle – 3B Forming Optimization (Expanding the Forming Window of AHSS)

Jody Shaw
Chair – WorldAutoSteel

Director – Technical Marketing & Product Research
United States Steel
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- Acknowledgment
Automotive Group of the World Steel Association

MEMBER COMPANIES:

- Ansteel
- ArcelorMittal
- Baosteel
- China Steel
- Tata Steel
- JFE
- Hyundai-Steel
- Kobe
- Nippon Steel
- NUCOR
- POSCO
- Severstal
- Sumitomo
- ThyssenKrupp
- USIMINAS
- U. S. Steel
- voestalpine
• State-of-the-future development process
• 188 kg body structure mass - 35% mass reduction
• 97% use of HSS and AHSS
• Nearly 50% GigaPascal steels
• Enables 5-star safety ratings
• Nearly 70% Total Lifetime Emissions Reduction
• Mass savings at no cost penalty
FSV Design Optimization Methodology

FutureSteelVehicle (FSV) Program final designs released May 2011

- **T1**: Topology Optimization
- **T2**: Low-Fidelity 3G Design Optimization
- **T3**: Body Structure Sub-System 3G Optimization
- **T4**: Design Confirmation FEA
- **T5**: Detail Design
- **T6**: Gauge Optimization
- **Phase 1**: Technology Assessment
- **Powertrain Layout**
- **Phase 2**: Report & Decision for Phase 3
- **Final Design Confirmation FEA**
Optimization resulted in very mass efficient but complex geometries.

TRIP 980 front rails
Optimization resulted in very mass efficient but complex geometries.

Upper rail die

Lower rail die
Complex geometries with significant formability challenges
Complex Geometries with significant formability challenges

Part 40

Part 39

Part 38

Part 37

Part 40 1.8mm

Part 39 1.8mm

Part 38 1.8mm

Part 37 1.8mm
The automotive and steel industries have several initiatives to expand the forming window of high-strength steels:

- Gen 3 AHSS
- A/SP Nonlinear Strain Path Project
- A/SP AHSS Stamping Team Projects

which will allow AHSS to be incorporated into more vehicle components with fewer geometry design concessions and enable additional mass reduction.

The optimization methodology process that was applied to the FSV program is now applied to formability.

This proposed approach may provide a new tool in the effort to expand AHSS’s forming envelope.
## Desirability of Forming Countermeasures

<table>
<thead>
<tr>
<th>Desirability</th>
<th>DESIGN VARIABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Die parameter- <strong>Binder Pressure</strong></td>
</tr>
<tr>
<td></td>
<td>Die parameter- <strong>Draw Beads</strong></td>
</tr>
<tr>
<td></td>
<td>Die parameter- <strong>Size &amp; Shape of Blank</strong></td>
</tr>
<tr>
<td>Mid</td>
<td><strong>Product parameter</strong> - <strong>Geometry</strong></td>
</tr>
<tr>
<td>Low</td>
<td><strong>Product parameter</strong> - <strong>Gauge</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Product parameter</strong> - <strong>Grade</strong></td>
</tr>
</tbody>
</table>
Design Optimization 3B Forming Process (ACP)

1. Forming Solution (Beads, Binder)  DYNAFORM®
2.  
3. Performance LS-DYNA ®
4. Optimization HEEDS ®
The following targets were set for forming results:

- **No material folding**
  (material folding is not acceptable, since it can act as initiators under any type of loading. It can initiate high stress concentration under severe static loads and undesired buckling mode under crash/impact loads)

- **No Cracks**

Feasible designs in zone between wrinkling & cracking
Binder pressure controls material flow into the draw uniformly.
Draw Bead Parameterization

- Line beads are added to control material flow.
- Line beads are non-geometric representations of draw bead geometry & forces.
- Each line bead (color) is unique, allows localized tuning of the beads.
- Total of 57 line beads in upper frame & 35 in lower.
Configured Blank Parameterization
Configured Blank Parameterization
Configured Blank Parameterization
3B Optimization-Balancing Cracks and Wrinkles

Design Optimization

3B Forming Process (ACP)

Performance LS-DYNA®

Parametric Blank Geometry SFE®

Optimization HEEDS®

Forming Solution (Beads, Binder) DYNAFORM®

Wrinkles

splits
3B Optimization-Balancing Cracks and Wrinkles

Wrinkles vs. Cracks - Cycle 58

Wrinkles

Cracks

100 200 300 400 500 600

80 100 120 140 160 180
Design 1959
- Cracks 88
- Wrinkles 117
Configured Blank Optimization - (Design 1959)
### Upper Rail 3B Forming Results

<table>
<thead>
<tr>
<th>Upper Rail Results</th>
<th>Num of Crack Points</th>
<th>Num of Wrinkle Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>3017</td>
<td>3253</td>
</tr>
<tr>
<td>Design 1959</td>
<td>88</td>
<td>117</td>
</tr>
</tbody>
</table>
Lower Rail 3B Forming Results

<table>
<thead>
<tr>
<th>Upper Rail Results</th>
<th>Num of Crack Points</th>
<th>Num of Wrinkle Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1413</td>
<td>1568</td>
</tr>
<tr>
<td>Design 1265</td>
<td>284</td>
<td>366</td>
</tr>
</tbody>
</table>

Baseline

Design 1664

Legend:
- CRACK
- RISK OF CRACK
- SAFE
- WRINKLE TENDENCY
- WRINKLE
- SEVERE WRINKLE
- INSUFFICIENT STRETCH
## Desirability of Forming Enablers - Geometry

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<td>Mld</td>
<td>Product parameter - Geometry</td>
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Product Geometry Modification
• Opened draw angles and increased the radius at flange
• Increased radius on the top face
Geometry Modification

Design
Optimization
3B Forming Process (ACP)

1. Optimization
   HEEDS®

2. Forming Solution
   (Beads, Binder)
   DYNAFORM®

3. Parametric Blank Geometry
   SFE®

4. Performance
   LS-DYNA®

www.autosteel.org
Forming Process Results

Design 1959

Modified Geometry
Forming Process Results

Design 1664

Modified Geometry

- CRACK
- RISK OF CRACK
- SAFE
- WRINKLE TENDENCY
- WRINKLE
- SEVERE WRINKLE
- INSUFFICIENT STRETCH
NCAP and 40% ODB Front Crash Performance

FSV NCAP Pulse

- Baseline Geom
- Mod Frt Rails DP1000
- Mod Frt Rails Trip980

FSV T6 Forming ODB Intrusions

- Original Geom Baseline
- Mod Geom DP1000
- Mod Geom Trip980

1: Footwell  2: Left Toe  3: Center Toe  4: Right Toe  5: Brake Pedal  6: Left IP  7: Right IP  8: Door
## Desirability of Forming Enablers - Gauge

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Front Crash Gauge Optimization

- Total number of design evaluations = 90
- Best design picked based on performance and mass
- Design 87 is best design, 0.5 Kg mass reduction
- 38g front crash pulse and good for front ODB

Baseline
Mass = 17.6 kg

Opt Design 87
Mod Geometry
Mass = 17.1 kg
Front Crash Gauge Optimization

FSV NCAP Pulse

38g

FSV ODB Intrusions

1: Footwell 2: Left Toe 3: Center Toe 4: Right Toe 5: Brake Pedal 6: Left IP 7: Right IP 8: Door
– Using a multidisciplinary optimization tool to balance Draw Beads, Binder Pressure, and Blank Geometry can be used to address the formability of complex parts.

– Optimization has been proven an effective tool to find solutions to complex forming issues which maintain crash and other key performance criteria.
Acknowledgements

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  www.worldautosteel.org

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  www.eta.com
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