HYDROFORMING ADVANCED HIGH-STRENGTH STEEL

KLAUS HERTELL, VICTOR ZAMUDIO, JON BALL, ANDREW DEVITO
PRESENTATION OVERVIEW

1. Standardization for a global implementation
2. Hydroforming DP 1000 material
   Springback, Compensation, Experience
3. Hydroforming Heavy Duty Rollover Protection
STANDARDIZATION FOR A GLOBAL IMPLEMENTATION
EXAMPLE FOR A GLOBAL HYDROFORM IMPLEMENTATION

HYDROFORMED ROOFRAIL IN THE NEW FORD EDGE

Ford Edge (USA):
2015 Model Year
with hydroformed roofrail
HYDROFORMING FOR GLOBAL PLATFORMS

STANDARDIZATION IS THE KEY FOR A GLOBAL PART DEVELOPMENT

“The Need”  Efficient development of parts and tools for global platforms

   “Same parts – same process – different Tier 1 supplier”

“The Method”  Standardization of tools and process

“The Benefits”  Reduced costs for development

   Hydroforming becomes a commodity

   Reduced risk at implementation

   Utilization of a larger Tier 1 supplier base
BASIC SETUP TO DEVELOP PARTS AND DIES FOR A GLOBAL PLATFORM
“GLOBAL HYDROFORM FOOTPRINT”

Product development -> Prototyping -> Production tool -> Piece Production

OEM

Global Tier 1 supplier
- Supplier A (North America)
- Supplier B (Europe)
- Supplier C (China)
- Supplier E

Standardized tool and process

Schuler
THE CONCEPT OF AN UP-GRADEABLE PRODUCTION TOOL

PROTOTYPING INSERTS ARE USED FOR PART DEVELOPMENT AND RE-CUTTING

Prototyping inserts for re-cutting
Upgradeable production Tool
There is no separate prototyping tool used!
TYPICAL ROOFRAIL PRODUCTION TOOL BUILD BY SCHULER

PROTOTYPING INSERTS ARE USED FOR PART DEVELOPMENT AND RE-CUTTING

Global hydroform tool standard
Schuler has build:
16 roofrail dies for 9 suppliers on 3 continents
“Same process”
EXAMPLE FOR GLOBAL PLATFORM: FORD CD4.2

ALL HYDROFORM ROOF RAILS DEVELOPED BY SCHULER

Ford Edge North America (top right) – Supplier A
Ford Edge Asia (top left) – Supplier B
Ford Smax (lower left) – Supplier C
Not shown: Galaxy Europe and Lincoln MKX

Images courtesy of Ford, Carmagazine, Paultan
VARIOUS ROOFRAIL PROJECT WITH ADVANCED HIGH-STRENGTH STEEL

Prototyping parts at Schuler

Selection of various DP 1000 roofrails
HYDROFORMING DP1000 MATERIAL EXPERIENCE, SPRINGBACK, LESSONS LEARNED
PROCESS STEPS: BENDING – PREFORM – HYDROFORM
PROCESS STEPS TO CREATE A HYDROFORMED ROOFRAIL

CNC bending  Preform  Hydroform
SPRINGBACK OF DP1000 MATERIAL AFTER EACH FORMING OPERATION

Each forming step creates springback - which needs to be carefully considered and compensated.
BENDING OPERATION ROOFRAIL (PROTOTYPING)
PREFORM OPERATION ROOFRAIL (PROTOTYPING)
HYDROFORM OPERATION ROOFRAIL (PROTOTYPING)
EXAMPLE FOR SPRINGBACK AFTER HYDROFORMING

DP1000 TUBES AFTER HYDROFORMING SHOW SIGNIFICANT SPRINGBACK

20 mm springback after hydroforming
(Measured on one leg only)
### MECHANICAL PROPERTIES OF ADVANCED HIGH STRENGTH STEEL

#### COMPARISON OF MILD STEEL VS ADVANCED HIGH STRENGTH STEEL

<table>
<thead>
<tr>
<th></th>
<th>Advanced High-Strength Steel: DP 1000</th>
<th>Mild Steel:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield</strong></td>
<td>800 N/mm²</td>
<td>280 N/mm²</td>
</tr>
<tr>
<td><strong>Tensile</strong></td>
<td>1000 N/mm²</td>
<td>330 N/mm²</td>
</tr>
<tr>
<td><strong>Total Elongation</strong></td>
<td>10%</td>
<td>25%</td>
</tr>
</tbody>
</table>

**Reason for springback**

“The reason for springback is the high yield and tensile strength in the raw material”
## Usage of Advanced High-Strength Steel in Hydroforming

Springback compensation is fairly new to hydroforming.

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</thead>
<tbody>
<tr>
<td>Material grade</td>
<td>HSLA</td>
<td>DP600</td>
<td>DP800</td>
<td>DP1000</td>
<td>???</td>
</tr>
<tr>
<td>Springback</td>
<td>None</td>
<td>Small</td>
<td>Medium</td>
<td>Major</td>
<td></td>
</tr>
<tr>
<td>Example</td>
<td>DP1000 rooftop, 10 mm springback per leg after hydroforming</td>
<td></td>
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</tr>
</tbody>
</table>
IMPROVING OF PART QUALITY THROUGH RE-CUTS

COMPENSATION SEQUENCE FOR RE-CUTS

Step 1:
- Springback prediction with FEA
- Initial morphing in CAD
- First prototyping

Step 2:
- Laser-scanning / reverse engineering
- Update morphing in CAD
- 1st recut and tryout

Step 3:
- 2nd recut
SCANNING AND REVERSE ENGINEERING OF ACTUAL PARTS

SCANNING IS THE ESSENTIAL TOOL FOR SPRINGBACK COMPENSATION

Actual parts are measured on a CMM fixture
3D laser-scanning and reverse engineering
Loading actual part surfaces back into CATIA
IMPROVING OF PART ACCURACY THROUGH RECUTS
WITH EACH RECUT THE PART IS GETTING CLOSER TO PRINT

Part accuracy at original prototyping

Part accuracy after 2\textsuperscript{nd} recut
SPRINGBACK EFFECTS IN HYDROFORMING

3 DIFFERENT TYPES OF SPRINGBACK: GLOBAL – CROWNING - TWISTING

Green: Target cross section
Red: Actual cross-section after forming

Global Springback  
Crowning  
Twisting
TYPICAL EFFECTS OFF SPRINGBACK ON AN ACTUAL CROSS SECTION

- Corner radius not filled (acceptable)

- Critical surface for laser welding (needs to be accurate and flat)

- Critical surface for packaging (cannot exceed certain envelope)

- None-critical area (relaxed surface tolerance)
SPRINGBACK PART ACCURACY ON A 3-DIMENSIONAL PART

GLOBAL SPRINGBACK – CROWNING – TWISTING – ALL IN ONE PART
COMPENSATION OF SPRINGBACK THROUGH TOOL DESIGN
SPRINGBACK GETS COMPENSATED IN THE HYDROFORM TOOL

Morphing means:
Compensation for springback

“The entire part needs to be re-designed to create tool surfaces”
CROWN COMPENSATION IN THE TOOL DESIGN

THE DIFFICULTY TO GET FLAT SURFACES WITH DP1000

Too much compensation
(Concave part surface)

Too little compensation
(Convex part surface)

Correct compensation
(Straight surface)
**SPRINGBACK PREDICTION IN THE FEA SIMULATION**

**RESULTS FROM AUTOFORM SIMULATION AT SCHULER**

<table>
<thead>
<tr>
<th>Project</th>
<th>Material</th>
<th>Diamter</th>
<th>Wall thickness</th>
<th>Part length</th>
<th>Max predicted FEA</th>
<th>Max observed actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project 1</td>
<td>DP 1000</td>
<td>60</td>
<td>1.8</td>
<td>2450</td>
<td>11.3</td>
<td>10.0</td>
</tr>
<tr>
<td>Project 2</td>
<td>DP 1000</td>
<td>60</td>
<td>1.8</td>
<td>2325</td>
<td>11.7</td>
<td>10.3</td>
</tr>
<tr>
<td>Project 3</td>
<td>DP 1000</td>
<td>63</td>
<td>1.4</td>
<td>2200</td>
<td>8.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Project 4</td>
<td>DP 1000</td>
<td>60</td>
<td>2</td>
<td>1850</td>
<td>2.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Project 5</td>
<td>Alu 6082</td>
<td>51</td>
<td>2.8</td>
<td>2615</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Project 6</td>
<td>Alu 6161</td>
<td>101</td>
<td>3.1</td>
<td>1525</td>
<td>1.7</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Predicted vs. actual springback on 6 different projects. Using Autoform for the FEA simulation.
### VARIABLES CAUSING VARIATION IN SPRINGBACK

**SELECTION OF FACTORS CAUSING SPRINGBACK ARE SHOWN BELOW**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect on Springback</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length of part</strong></td>
<td>The longer the part – the more springback</td>
</tr>
<tr>
<td><strong>Thickness of the tube</strong></td>
<td>A thicker tube is stiffer and has less springback</td>
</tr>
<tr>
<td><strong>Diameter / Thickness</strong></td>
<td>Tube diameter / wall thickness ratio plays a role in springback</td>
</tr>
<tr>
<td><strong>Bending radius</strong></td>
<td>The larger the bending radius - the smaller is the springback</td>
</tr>
<tr>
<td><strong>Cross section / Geometry</strong></td>
<td>The shape of the cross section</td>
</tr>
<tr>
<td><strong>Forming process</strong></td>
<td>Bending, preforming method, hydroform parameters etc.</td>
</tr>
</tbody>
</table>

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[30] **Steel Matters**

[Great Design in Steel Seminar]

[www.autosteel.org]
HYDROFORMING HEAVY DUTY ROLL-OVER PROTECTION
HYDROFORMED ROLL OVER PROTECTION

Hydroformed roofrail

Hydroformed Roll-Over Protection:
“Not just in Automotive”
HYDROFORMED ROLL OVER PROTECTION

Example for a heavy duty part application in hydroforming

Tube thickness: 8 mm
Tube diameter: 150 mm
Part weight: 270 lbs
Material tensile: 500 N/mm²
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