CHARACTERIZATION OF 3RD GEN AHSS TOWARDS RELIABLE FORMING AND SPRINGBACK

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Extension of above project towards following objectives:
• Representation of Material and Forming Process – Best Practices
• Comparing Simulation Outcomes to Physical Panels
MATERIAL PERFORMANCE

Quasi-static tensile test
Test direction: TD

Engineering stress (MPa)

Engineering strain

590R 1.4 mm
3rd Gen 1180 V1, 1.4 mm
3rd Gen 1180 V2, 1.4 mm
3rd Gen 980, 1.4 mm

Accumulated Equivalent Strain

V-Bend tests (plane strain tension)
Gap: 2*th + 0.5 mm

<table>
<thead>
<tr>
<th>Steel Grade</th>
<th>Accumulated Equivalent Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>590R</td>
<td>0.88</td>
</tr>
<tr>
<td>DP980</td>
<td>0.54</td>
</tr>
<tr>
<td>3rd Gen 980 V1</td>
<td>0.47</td>
</tr>
<tr>
<td>3rd Gen 1180 V1</td>
<td>0.38</td>
</tr>
<tr>
<td>3rd Gen 1180 V2</td>
<td>0.32</td>
</tr>
<tr>
<td>3rd Gen 1180 V2</td>
<td>0.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade</th>
<th>Nominal sheet thickness (mm)</th>
<th>Yield strength (MPa)</th>
<th>Ultimate Tensile Strength (MPa)</th>
<th>Yield-to-UTS ratio</th>
<th>Uniform Elongation UE (%)</th>
<th>Total Elongation TE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>590R</td>
<td>1.4</td>
<td>490 (±2)</td>
<td>671 (±1)</td>
<td>0.73</td>
<td>19.9 (±0.3)</td>
<td>23.7 (±0.4)</td>
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<tr>
<td>DP980</td>
<td>1.2</td>
<td>735 (±2)</td>
<td>1065 (±3)</td>
<td>0.69</td>
<td>7.8 (±0.2)</td>
<td>13.7 (±0.5)</td>
</tr>
<tr>
<td>3rd Gen 980 V1</td>
<td>1.4</td>
<td>681 (±8)</td>
<td>1034 (±10)</td>
<td>0.66</td>
<td>18 (±0.5)</td>
<td>24.9 (±0.6)</td>
</tr>
<tr>
<td>DP1180</td>
<td>1.0</td>
<td>843 (±0)</td>
<td>1216 (±8)</td>
<td>0.69</td>
<td>6.5 (±0.4)</td>
<td>11.5 (±0.2)</td>
</tr>
<tr>
<td>3rd Gen 1180 V1</td>
<td>1.4</td>
<td>950 (±12)</td>
<td>1251 (±8)</td>
<td>0.76</td>
<td>8.4 (±0.2)</td>
<td>14.1 (±0.6)</td>
</tr>
<tr>
<td>3rd Gen 1180 V2</td>
<td>1.4</td>
<td>1043 (±4)</td>
<td>1225 (±8)</td>
<td>0.85</td>
<td>10.7 (±0.4)</td>
<td>16.4 (±0.3)</td>
</tr>
</tbody>
</table>
HARDENING CHARACTERIZATION

Isotropic hardening to large strains obtained using tensile and shear test data

Accurate predictions in CAE of tensile test without inverse modelling
CHORD MODULUS CHARACTERIZATION

Chord modulus can be critical for springback: Perform loading-unloading tests.

Saturation chord modulus of tested 3rd Gen steels similar to DP literature data.
KINEMATIC HARDENING CHARACTERIZATION

Side force applied to the gauge area to prevent buckling in compression.

Magnitude of side force depends on material.
FORMABILITY CHARACTERIZATION

In-Plane FLC obtained using Marciniak tests → Linear strain path, no tool contact or bending effects

- Marciniak Undeformed specimen
- Carrier blank
- Cylindrical punch

![Graph showing In-plane Marciniak FLC ISO12004-2 with 3rd Gen 980 results and ISO 12004-2 limit strains]
ACCURATE DIGITAL MODEL

Material

Tribology

Material Modelling - Mechanical Properties

Tribology System

Result Evaluation

Simulation Parameters

Fundamental Understanding

Geometries

Tool Kinematics

Process Parameters

Robustness

Process Understanding

Forming Process
FORMING PROCESS

Draw – Laser Trim (Springback)

FORMING TRIALS AT BOWMAN

Tooling design, fabrication, stamping and part scanning by Bowman precision tooling
• Simpac 1500-ton Tryout press (2.5 m x 6 m)
• 5-axis CNC machining of B-pillar tooling
• Autoform used to design B-pillar tooling and springback compensation

• Binder Stroke 100mm
• Binder tonnage: 275 tonf - 400 tonf over stroke

• 590R, 3rd Gen 980, and 3rd Gen 1180 blanks were stamped, trimmed and scanned

MATERIALS

- 590R, 3rd Gen 980, 3rd Gen 1180
- 1.4mm thick
- Essential components of sheet material behavior
  - Elastic Properties
  - Tensile and Kinematic Hardening Representations
  - Plastic Anisotropy (R-values)
  - Yield Surface Model
MATERIALS

• Essential representation of sheet material behavior

R-Values:
Rolling 0.675
Diagonal 1.076
Transverse 0.903
Steady state friction coefficients were determined using the Twist-Compression-Test (TCT) for the following forming system:

- Sheet metal (590R, 3rd Gen 980, 3rd Gen 1180 V1)
- Lubricant / drawing oil CommDrawTM200 (Commonwealth Oil Corp., Harrow ON, Canada)
- Tool steel Cr-Mo-Va, hardened to 53 HRC
- Contact Pressure 25 MPa

Steady-state / dynamic Coulomb Friction Coefficients determined were:

- 590R: 0.11
- 3rd Gen 980: 0.13
- 3rd Gen 1180: 0.19
SIMULATION OUTCOMES

Predicted splitting of the 3rd Gen 1180 V1 in multiple locations
Forming trials split at only one location (in-plane stretching)

B-Pillar sidewall (in-plane stretching)


Predicted splits in plane strain tension are false positives
→ Located along part radii with appreciable bending and tool contact

• Material?
• Forming Process?
• Tribology?
Friction influence is strongly evident in study using AutoForm-Sigma

What is the correct Friction Coefficient?

Build a Tribology System representative of forming process:
- Sheet metal coating and roughness
- Lubricant
- Tool material and roughness
TRIBOLOGY

Tribology, friction and lubrication in sheet metal forming

Sheet
- Material properties
- Coating and surface finish
- Surface roughness

Lubrication
- Type of lubricant
- Liquid, hotmelt, etc.
- Amount and distribution

Tooling
- Material type
- Surface finish
- Surface roughness

Process
- Pressure
- Velocity / stroke rate
- Temperature
- Sheet deformation
TRIBOLOGY

Data / information available:
- Sheet surface roughness
- Sheet coating
- Lubricant brand name
- Tool Material

Data / information NOT available:
- Tool surface roughness
- Lubricant assumed similar to drawing oil
- Lubricant amount

Tribology system selected from TriboForm Library:

- 590R
  - Sheet: Steel (Default)
  - Surface Finish: EDT
  - Lubricant: Drawing Oil
  - Tool Steel: Polished
  - Tool Steel Surface Finish: Polished
  - Tool Steel ID: Default
  - Tool Steel Roughness: 0.40 - 2.00

- 3rd Gen 980
  - Sheet: HSS (Dual Phase UNC)
  - Surface Finish: EDT
  - Lubricant: Drawing Oil
  - Tool Steel: Polished
  - Tool Steel Surface Finish: Polished
  - Tool Steel ID: Default
  - Tool Steel Roughness: 0.40 - 2.00

- 3rd Gen 1180
  - Sheet: HSS (Bake Hardening +EG)
  - Surface Finish: EDT
  - Lubricant: Drawing Oil
  - Tool Steel: Polished
  - Tool Steel Surface Finish: Polished
  - Tool Steel ID: Default
  - Tool Steel Roughness: 0.40 - 2.00
SIMULATIONS

Simulations run:
- With forming surfaces and process conditions from physical tryout
- With TriboForm friction for the respective tribology system for each blank material
- With and without Kinematic Hardening

Simulation outcomes compared to physical observations:
- Formability of the draw panel
- Forming tonnage for the draw
- Sprung panel after trimming best fit to respective scanned panel for each blank material
SIMULATION OUTCOMES
3RD GEN 1180

Draw Formability

• With TriboForm friction, nearly all false positives, generated with the constant coefficient determined from TCT, are eliminated

• Two locations show splitting / elevated risk

• These likely are due to the assumptions, made to cover unknown information, in the selection of the tribology systems
SIMULATION OUTCOMES
3RD GEN 1180

Draw Tonnage

1180 Gen 3 (1.4 mm).

Predicted tonnage very close to tonnage recorded on the press.
Total Springback: With and without Kinematic Hardening

- Both cases show strong twist and flattening

- Springback magnitudes significantly higher with Kinematic Hardening

- Kinematic Hardening is an important factor in the springback response of panels, particularly AHSS
SIMULATION OUTCOMES
3RD GEN 1180

Best Fit to Scan of Sprung Panel:

• Best Fit shows strong correlation between simulated sheet and scan of sprung panel
SIMULATION OUTCOMES

3RD GEN 980

Draw Formability

- No issues reported in tryout, and none predicted in simulation
Draw Tonnage

- Predicted tonnage is about 8% below recorded
Total Springback:  
With and without Kinematic Hardening  

- Both cases show strong twist and flattening, although reduced relative to 3rd Gen 1180  
- Springback magnitudes significantly higher with Kinematic Hardening  
- Kinematic Hardening is an important factor in the springback response of panels, particularly AHSS
SIMULATION OUTCOMES
3RD GEN 980

Best Fit to Scan of Sprung Panel:

• Best Fit shows strong correlation between simulated sheet and scan of sprung panel
Draw Formability

- No issues reported in tryout, and none predicted in simulation

Draw Tonnage
Total Springback:
With and without Kinematic Hardening

- Reduced twist and flattening, relative to 3rd Gen 980 and 1180
- Kinematic Hardening difference is not as pronounced as with the 3rd Gen grades
SIMULATION OUTCOMES
590R

Best Fit to Scan of Sprung Panel:

- Best Fit shows strong correlation between simulated sheet and scan of sprung panel
SUMMARY

- Available data and information – material, tribology, forming tools and process - afforded a *reasonably accurate* representation of the forming of b-pillar panels from AHSS blanks

- Formability, Tonnage, and Panel Springback outcomes from simulation are shown to correlate very well to physical observations for all the three blank materials formed
CONCLUSIONS

• Material modelling and tribology choices were driven by need, and also by available data

• The influence and therefore the importance of these choices upon all aspects of simulation outcomes is confirmed (again) from this study

• Of particular consequence to the prediction of panel springback for AHSS materials is the characterization of kinematic hardening

• Wide availability of kinematic hardening data, directly from material suppliers, is crucial to engineering and manufacture of products with AHSS, and 3rd Gen (and future) grades
ACKNOWLEDGEMENTS
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