FORMABILITY CHARACTERIZATION OF ADVANCED HIGH-STRENGTH STEELS

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OUTLINE

- **Introduction**

- **Results**
  - Sheared edge stretching limits
  - Bending under tension limits
  - Springback and Curl

- **Conclusions**

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INTRODUCTION

Part/Die geometry

Friction

Formability

Material

Process

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INTRODUCTION
PROJECT SCOPE

Mechanical behavior

Formability Characterization of AHSS

Splitting limits

Simulative tests
**PROJECT SCOPE**

**Mechanical behavior**
- ASTM tensile testing
- Instantaneous work hardening
- Medium strain rate mechanical behavior
- Bauschinger effect

**Splitting limits**
- Forming limit curves
- Sheared edge stretching limits
- Bending under tension limits

**Simulative tests**
- Stretch Formability
- Stretch Drawability
- Springback & Curl
STEELS EVALUATED

- **Baseline Steels**
  - DQSK, DDQ+

- **Exposed Panel Steels**
  - BH210, BH280, IF-Rephos, GA340BH, DP500

- **Structural Steels**
  - BH300, HSLA350, HS440W, DP600, TRIP600, DP800, DP980, RA830, M190

Multiple lots for each steel grade
RESULTS

- Sheared Edge Stretching limits
  - Hole extrusion test

- Bending Under Tension limits
  - Angular stretch bend test

- Springback & Curl
  - U Channel Draw test
Application

- Finishing operations
  - Curved flanging

Test Method

- Hole extrusion test
- %HE ($\lambda$) before thickness crack
SHEARED EDGE STRETCHING LIMITS

% HE vs Ultimate Tensile Strength (MPa)

- BH
- IF
- DP
- DQSK
- HS440W
- HSLA350
- IF-Rephos
- M190
- RA830
- TRIP600
- TRIP
- DP980
- HSS
- GA340BH

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STRETCH FLANGING

\[ HE = \frac{R_0 - (R_0 - L)}{(R_0 - L)} \]

\[ \frac{L}{R_0} = \frac{HE}{1 + HE} \]
• Need to reduce stretch flange length for AHSS
BENDING UNDER TENSION LIMITS

- **Application**
  - Tight tool radius + stretching
  - Relationship between max. stretching and tool radius

- **Test Method**
  - Angular Stretch Bend test
ASB TEST: STRETCH BENDABILITY

Maximum true sidewall thinning strain vs. UTS (MPa) for different R/t ratios.

- R/t = 5
- R/t = 3
- R/t = 1

Max. thinning strain in sidewall.

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ASB TEST: STRETCH BENDABILITY

Maximum true safe sidewall thinning strain

- R/t = 5
- R/t = 3
- R/t = 1

Fixed geometry lines

max. thinning strain in sidewall

UTS (MPa)

0.00 0.05 0.10 0.15 0.20 0.25 0.30

0 200 400 600 800 1000 1200
SPRINGBACK

Curl

IF

Springback

HSLA350

DP600
Process Variables (factors)

- Tooling radii
- Tool gap
- Drawbead penetration

Two levels for each Process Variable

<table>
<thead>
<tr>
<th></th>
<th>Tooling Radii</th>
<th>Tool Gap</th>
<th>Bead Penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>3.0 or 6.0 mm (R/t &lt;5)</td>
<td>1t+0.05mm</td>
<td>Quarter</td>
</tr>
<tr>
<td>Large</td>
<td>10.0 mm (R/t&gt;5)</td>
<td>1.5t</td>
<td>Maximum</td>
</tr>
</tbody>
</table>
Tooling radii, tool gap, and drawbead penetration are the most influential factors.

Interactions of these factors are not significant.

Drawbead penetration and tooling radii are more important than tool gap.
- Penetration > Tool Radius > Tool Gap
SPRINGBACK: EFFECT OF DRAWBEAD PENETRATION

Graph showing the relationship between springback angle and yield strength for different steel types and bead penetrations.
SPRINGBACK - DP600 VS. HSLA350

### Drawbead penetration

- **DP600**: 9, 8, 7, 6, 5, 4 degrees
- **HSLA350**: 9, 8, 7, 6, 5, 4 degrees

- **Quarter**, **Half**, **Full**

### Tool gap

- **DP600**: 9, 8, 7, 6, 5, 4 degrees
- **HSLA350**: 9, 8, 7, 6, 5, 4 degrees

- **t+0.05mm**, **1.1t**, **1.5t**

### Tool Radii

- **DP600**: 9, 8, 7, 6, 5, 4 degrees
- **HSLA350**: 9, 8, 7, 6, 5, 4 degrees

- **3.0mm**, **6.0mm**, **10.0mm**

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**CONCLUSIONS**

- **Stretch Flanging**
  - Guidelines
    - Reduce flange length for AHSS
    - Gainers in addendum

- **Bending Under Tension**
  - Guideline
    - Reduce sidewall stretching strain for tight bending radii

- **Springback of DP600 > HSLA350**
  - Guideline
    - 1~2° difference