Use of Servo Press with a CNC Hydraulic Cushion in Forming AHSS

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Outline

Introduction

Challenges in forming AHSS

Servo presses and CNC cushions
Introduction

• DP 980 – DP 1200 steels are used by various OEM’s and suppliers
• UHSS – DP 1200 (by Nippon Steel/Sumitomo Metals/Kobe Steel) is used for B-Pillar in selected Nissan models
• R&D is being conducted for forming 1400 MPa steels to produce structural parts
• Main challenges are: flow stress data, formability, flanging and edge fracture, springback, temperature and lubrication, and press and tool deflection
Material properties

- E-modulus (tensile test, loading unloading test, tension compression test)
- Strain rate dependency at room and elevated temperature

**Tensile test (uniaxial):**
- Engineering stress vs. strain
  - Uniaxial
  - Relatively small strains
  - Yield stress
  - Tensile stress
  - Uniform elongation
  - Total elongation
  - E-modulus

**Bulge test (biaxial):**
- Effective stress vs. strain (flow stress data)
  - Biaxial
  - Large strains
  - Not accurate for small strains
Material properties:
Tensile Test + Bulge Test

True stress (GPa) vs. True strain for 1.2mm DP980.

- Yield point from tensile test
- Flow curve from bulge test
- Calculation of K and n values and extrapolation

Equation: \( \sigma = 1.563\epsilon^{0.10} \)
Formability:
Uniform Elongation, Total Elongation, Bulge Height, and FLD

*For some materials the FLD data is not for the same thickness of tensile data.
FLC data are obtained from POSCO
Flanging and Edge Fracture

- Complex microstructure of AHSS materials can lead to significantly different hole expansion ratio (HER).
- In DP steels, the difference in hardness between the hard and soft phases (martensite and ferrite) is large and this facilitates the formation of micro-cracks.
- Tests with the current ISO standard (ISO 16630) for hole flanging (10 mm hole diameter) show large scatter. Larger hole diameter (20 mm to 75 mm) are used in recent studies.

\[
(\text{HER}) \quad \lambda = \frac{D_f - D_0}{D_0} \times 100
\]
Springback
Tensile Strength, E-modulus

**DP**
Yield: 350 MPa
UTS: 600 MPa

**HSLA**
Yield: 350 MPa
UTS: 450 MPa

*Courtesy of WorldAutoSteel—AHSS Application Guidelines ver. 4.0.*

E-modulus changes with strains. Variation of E-modulus as a function of strain can be obtained through loading-unloading tensile test. However, determination of E-modulus through a tensile test is not accurate and can cause error in springback prediction.

[Kardes 2011]
Temperature and Lubrication

Lubrication tests:
1) Draw Bead Test
2) Strip Drawing Test
3) Twist Compression Test (TCT)
4) Cup Drawing Test (CDT)

The test conditions in cup drawing test (CDT) are closer to the real stamping conditions than TCT. In stamping there is heat generation due to friction and also due to plastic deformation of the material.
Servo Press and Servo Cushion

Crank or Link press
Fixed Motion

Cycle time of mechanical press

Free motion press

Slide Position

Minimum stroke length

Forming length

Standstill at BDC

Time

(1) Variable stroke length

(2) Best speed for materials

(3) Improve accuracy by dwelling at BDC

(4) Other Process at BDC (Multi Process)

(5) Prevention of noise and shock at contact or breakaway of tools

(6) Synchronize with feeder

(a) Holding

(b) Bottoming

(c) Re-striking
Servo Press and Servo Cushion

Schematic of a hydraulic servo cushion system
Forming AHSS Using 300 Ton AIDA Servo Press

Materials used in the study:

- DP980 1.2mm
- DP590 1.4mm
- CP800 1.4mm
- TRIP1180 1.2mm
- TWIP980 1.3mm
- TWIP900 1.1mm

Die made by Shiloh
AIDA Servo Press Tests and PAM-STAMP Simulations

The thinning value around the corner of the panel is measured and compared with simulation results.
Temperature and Lubrication

Temperature predicted in panels formed up to 48 mm depth with 250 kN blankholder force and 75 mm/sec ram speed.

- Does this temperature affect material properties? (not for most materials at RT stamping)
- Temperature affects the lubricant performance

Temperature:
- 105 °C for CP800
- 70 °C for DP590

Location of maximum temperature:
- 1.4mm CP800
- 48mm drawing depth
- 250KN blank holder force

1.4mm DP590
- 48mm drawing depth
- 250KN blank holder force
Improving the Drawability Using Servo Characteristic
Effect of Ram Motion

- **Objective:**
  - Determine how the servo ram motion control can influence the drawability
Improving the Drawability Using Servo Characteristic Effect of Ram Motion (In Cooperation with Batesville Tool and Die)

<table>
<thead>
<tr>
<th>Blanking operation mode</th>
<th>Speed (SPM)</th>
<th>status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single forming</td>
<td>15</td>
<td>cracked</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>formed</td>
</tr>
<tr>
<td>Attach / Detach</td>
<td>15</td>
<td>formed</td>
</tr>
</tbody>
</table>

- Forming conditions:
  - 2-in drawing depth
  - 2000-3000 (psi) BH pressure (nitrogen cylinder)
  - No spacer used
  - Three blanks tested for each ram motion condition
  - Using attach / detach mode reduces the cycle time
Improving the Drawability Using Servo Characteristic Effect of Ram Motion – Other Studies

Door inner panel, 6000 Al-Mg-Si alloy

[Hayashi 2009]

Forming speed 41 mm/s

Forming speed 103 mm/s
Improving the Drawability Using Servo Characteristic Effect of Ram Motion – Other Studies

Steel DC04
CRP: cushion ram pulsation

[Landgrebe 2010]

[Nakano 2010]
Improving the Drawability Using Servo Characteristic Effect of Variable BHF (In Cooperation with Hyson)

- **Objective:**
  - Determine how the servo cushion can influence drawability

  The optimum variable blank holder force which avoid both the wrinkle and failure at the part will be determined through FE simulations.
Improving Springback Using Servo Cushion - Effect Of Variable BHF (In Cooperation with Aida and Shiloh)

**Variable BHF**

![Graph showing variable BHF and constant 25 kN](image)

**Simulations**

![Graph showing simulations of springback angles](image)

Springback in $\alpha$ and $\beta$ angles plus curl on the wall

By increasing the BHF at about the final forming stroke, springback can be reduced significantly.
Improving the Edge Fracture Using Servo Characteristic (In Cooperation with Aida and KTH)

- **Objective:**
  - Determine the servo press motion to obtain the “Best” possible blanked / sheared edge quality

<table>
<thead>
<tr>
<th>Case number</th>
<th>Blanking operation mode (75 mm hole)</th>
<th>Speed (SPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case I</td>
<td>Single blanking</td>
<td>20</td>
</tr>
<tr>
<td>Case II</td>
<td>Double blanking</td>
<td>2</td>
</tr>
<tr>
<td>Case III</td>
<td>Double blanking</td>
<td>20</td>
</tr>
<tr>
<td>Case IV</td>
<td>Two step blanking</td>
<td>2</td>
</tr>
<tr>
<td>Case V</td>
<td>Two step blanking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1 mm penetration</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.3 mm penetration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.8 mm penetration</td>
<td></td>
</tr>
</tbody>
</table>

Motion diagram to achieve burr-free edges [Junlapen 2008]
Improving the Edge Fracture Effect of Blanking Speed and Operation Mode

• Blanking with three operation modes and with two different speeds is investigated
• For the evaluation of the edge quality Hole Expansion Test will be run (in cooperation with EWI and KTH)
• The sheared edge is evaluated (under the microscope) and will be correlated with the HER test
Improving Edge Fracture Conditions
Effect of Blanking Operation on Sheared Edge Quality and Flangeability

Example: Single blanking, 20 SPM (50X)
Material = JAC780T

Roll over zone
Shear (Burnishing) zone
Fracture zone(1)
Fracture zone(2)
Burr zone

0.11 mm
0.14 mm
0.58 mm
0.53 mm
|-----------------------------|-------------------------------------------------------------------------------------------------|
Thank you!