NEW DEVELOPMENTS IN SHEET METAL FORMING

Ongoing Activities of the Center for Precision Forming - CPF
The Ohio State University

https://ercnsm.osu.edu / https://cpf.osu.edu

May 1, 2018
Columbus, Ohio
CPF – Objectives and Strategies

OBJECTIVES

• Conduct R&D in stamping and apply results in cooperation with CPF members

• Support students and offer education/training courses for industry in stamping science, technology and applications

STRATEGY

• Cooperate closely with CPF members and others interested in stamping technology

• Conduct application–oriented R&D

• Keep up with world-wide advances in stamping technology and related training/education activities
Outline

- **Material Characterization** – How to Obtain True Stress/True Strain (Flow Stress) Curve from Uniaxial Tensile and Biaxial Bulge Tests
- **Friction / Lubrication** – Cup Draw Test (CDT) / effect of interface temperature and forming speed
- **Deep Drawing** with and without spacers / design of draw beads in forming AHSS (can they be eliminated?)
- **Forming of AHSS, Stainless Steel and Al Alloys in a Servo Press with Hydraulic Servo Cushion** – Effect of Ram Motion / Attach-Detach / Variation of BHF during Press Stroke
Outline (cont)

- **Blanking in a Servo Press, Hole Extrusion and Hole Flanging** – Effect of Blanking Speed in Punch / Die Clearance / Effect of Strain Hardening

- **Springback in Forming AHSS** – Theory and Practice / Springback Models / Inverse Analysis / bending Test to obtain E-value

- **Conclusions / Future Trends**
MATERIAL CHARACTERIZATION

In cooperation with HONDA R&D, SHILOH Industries, EWI, NUCOR, POSCO, NOVELIS, ARCELOR, FCA

It is necessary to have reasonably accurate true stress/true strain (flow stress curve) for FE Simulation

A. **Uniaxial Tensile Test Data**
   a) Engineering stress/stress curve, given by the testing machine (can be provided by material supplier)
   b) YS, UTS, E-modulus (usually provided)
   c) YS, UTS, Uniform Elongation (may be provided)

B. **Biaxial Bulge Test Data**

Bulge test also provides biaxial formability information
Flow Stress Curve Obtained From the Tensile Test
Al 6205/1.0 mm (HONDA EGA)

Al 6205/1.0 mm
(tensile test conducted at CPF)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young’s Modulus (E)</td>
<td>31.25 GPa</td>
</tr>
<tr>
<td>Yield Strength (YS)</td>
<td>85 MPa</td>
</tr>
<tr>
<td>Ultimate Tensile Strength (UTS)</td>
<td>186 MPa</td>
</tr>
<tr>
<td>Uniform elongation</td>
<td>22.6%</td>
</tr>
</tbody>
</table>

True stress, \( \sigma = K \varepsilon^n \)

**True stress strain curve**

Extrapolation

From UTS, YS and E

\[ K = 341.94, n = 0.259 \]

From UTS and Uniform Elongation

\[ K = 315.34, n = 0.204 \]

From Eng. Stress-Strain Curve

\[ K = 330.92, n = 0.24 \]
Flow Stress Curve Obtained From the Tensile Test  DP 980/1.2mm (NUCOR)

DP980/1.2mm (tensile test conducted at HONDA R&D, see CPF-2.1/14/02)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus (E)</td>
<td>187 GPa</td>
</tr>
<tr>
<td>Yield Strength (YS)</td>
<td>707 MPa</td>
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<tr>
<td>Ultimate Tensile Strength (UTS)</td>
<td>989 MPa</td>
</tr>
<tr>
<td>Uniform elongation</td>
<td>8.6%</td>
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</tbody>
</table>

True stress,  
\[\sigma = K \varepsilon^n\]

True stress strain curve
In cooperation with AFTON Chemical, HOUGHTON International, QUAKER Chemical, SHILOH Industries, IRMCO, HYSON Solutions

• The Cup Draw Test is well accepted for the evaluation of lubricants.

• Tests are conducted (a) at EWI (160 ton Hydraulic Press and CDT Tooling, and (b) at HYSON (300 ton Servo Press and CDT-IRMCO Tooling)

• For the lubricants and materials (AL and AHSS) tested, friction seems to decrease with increasing drawing speed. However, the effect of Blank Holder Force (BHF) variation at various ram speeds may be a factor.
Friction – Cup Draw Test

Cup Draw Test

Lubrication performance:

Successfully Formed Cup
Fractured Cup

Higher BHF before fracture
Friction / Tribology

Temperatures in Cup Draw Test – DP 600 (simulation DEFORM)

Challenges:
1) Higher contact pressure and higher temperature affect the performance of lubricants,
2) Temperature and pressure additives are needed
In cooperation with AIDA, SHILOH, HONDA-EGA, BATESVILLE, ESI, HYSON

- With or without spacers/advances
- Elimination of modification of draw beads
- Possibility of using servo hydraulic cushion
- Use of servo press capabilities (slow down before deformation, attach/detach, coining)
The laser sensor detects the flow of the material / a servo motor activates the wedge as spacer between die and blank holder (between 2 consecutive strokes)
In cooperation with AIDA, SHILOH, HYSON, HONDA EGA, BATESVILLE TOOL & DIE, ESI

- Forming of Al 5182-0 (1.1mm) and Al 6014 (?) using Shiloh Die (4 mm Punch Radius)
- Forming of AHSS Using Shiloh Die
- Forming of round and square parts form DP980 (1.2mm)
- Forming of Al 5182-0 (1.1mm) and SS 304 (1.0 mm) using Hyson Die
Shiloh Die (4 mm punch corner radius) pad force

- 445 mm used in experiment
- 520 mm modified for buckling reduction
- 1.2 mm Al5182-O
- Drawing depth 65 mm
- BHF=100 kN
Experiments – Hyson Die
Blanks used and part geometry

- Initially original blank geometry (A) was used to form the part but as we experienced cracks the blank geometry was changed to (B)
- Blank geometry (B) is not optimum but was selected to continue the experiments

Photo of Hyson Part
Length of the part= 139.32mm
Width of the part= 133.55mm
Experiments

BHF variations used (1/2)

BHF Variations:
- Constant and Variable BHF
- Pulsating BHF

Ram Speed Variations:
- “Attach-Detach” Method
- “Stop at touch” Method

![Graphs showing Blank holder force vs. Stroke (mm) and Blank holder force vs. Time (sec).]
Experiments

Ram Stroke variations used (2/2)

“Attach-Detach” Method

“Stop at touch” Method
Two courses on forming various materials, have been developed, for industry

- **Principles and Applications of Mechanical Servo Drive Presses**
- **Principles and Applications of Servo Hydraulic Cushions**

These courses also cover the effects of (a) materials, (b) lubrication, (c) blank shape, size and thicknesses, (d) machine characteristics (productivity-SPM, force vs. stroke, energy vs. stroke and speed), (e) various ram speed motions and (f) various cushion force (BHF) applications.
• Part size/geometry needs to be optimized (using simulation) to reduce BHF and increase draw depth

• Increasing draw speed and attach/detach motion of the press ram, and appears to improve drawability slightly (lubrication/BHF)

• As expected, BHF output is affected by press speed (SPM)

• Work is in progress to optimize blank size, ram speed and BHF (cushion force) during stroke
In cooperation with AIDA, KTH and EWI

- Blanking with KTH tool in the AIDA 300 ton press using different blanking speeds and strategies
- Hole flanging with EWI tool and press to determine edge fracture

CONCLUSIONS

- Low speed blanking (75 mm hole) and double blanking increase Hole Expansion Ratio (HER) slightly (23 to 26.5%)
- Most fractures occurs near a specific location on the blanked sample. Thus, punch/die clearance and centering is very important
- The widely used ISO standard (10 mm punch) does not give reproducible results (US and Europe studies)
Locations of Crack Initiation in Hole Flanging (left) and example micro edges obtained from single blanking at 2 SPM
• Depending upon material and geometry, 4 to 6 die cuts may be necessary during tryout. Can we reduce these?

• Various theoretical models (Yoshida and others) have been developed. However,
  (a) In some cases, the models cannot predict springback accurately, and
  (b) The models require large number of parameters that are expensive to determine experimentally

• E-modulus is the most important parameter that affects springback, it varies with strain and is difficult to measure accurately

• A new simple “inverse analysis” method is being developed at CPF
Examples: U-bending (DP 5890 – 1.4mm, Al 5182-0 – 1.2mm, Al 6014, 1.2mm) an Z-bending (DP980 – 1.14mm)

Objectives: Develop guidelines to predict springback using FE simulation and experiment

Inverse Analysis: A constant apparent E value, for a given material and bending process, is determined by measuring springback in experiments and comparing it with simulations. This method is essentially similar to the method used in industry for die try-out.
Materials:
• Need for reliable true stress vs. true strain curve, if possible for biaxial deformation
• Information on forming of new materials (DP980, DP1180, TWIP, TRIP, steels, etc.) including cost and availability

Friction/Lubrication:
• CDT (Cup Draw Test) and other tests/effect of temperature and forming speed

Deep Drawing:
• Spacers? / Drawbeads? / use of servo hydraulic cushions/ variable BHF / multiple point cushions

Servo Press:
• Productivity/Attach-Detach/Ram speed before and during forming/dwell/pendulum motion
Summary / Future Trends

Springback in Forming AHSS:
• Theoretical methods vs inverse analysis / applications

Training/Education:
• Training for effective use of new technologies (FE simulations, servo presses, servo hydraulic cushions, new materials and lubrications, hot stamping, warm/hot forming of heat treatable Al alloys, etc.)
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Non-proprietary information can be found at web site:

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