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

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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
Outline

- Light Weighting in Automotive Industry – Drivers/Considerations
- **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 / effect of draw beads in forming AHSS
- **Forming of AHSS and Al Alloys in a Servo Press with Hydraulic Servo Cushion** – Effect of Ram Motion / Attach-Detach / Variation of BHF during Press Stroke
• Blanking in a Servo Press and Hole Flanging – Effect of Blanking Speed in Punch / Die Clearance

• Springback in Forming AHSS – Theory and Practice /Springback Models / Inverse Analysis

• Summary / Future Trends
Drivers for Light-Weighting--Automotive

Safety Regulations

Profit

COST

Design Materials
Processes
Lubricants
Presses

Miles per gallon

Pollution/CO₂ Emission per mile

Perception by Customer and Society
Material Properties

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, from the testing machine (can be provided by material supplier)
   b) YS, UTS, E-modulus, total elongation (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 Combined Method (Tensile + Bulge Test - Al 6014/1.2 mm (NOVELIS))

- Extrapolation I - From Yield Strength point to the first point of the experimental data
- Extrapolation II - From the fracture of the sample (last point of the experimental data) to the required strain

\[ K = 429.88 \text{MPa} \]
\[ n = 0.2035 \]

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

- Experimental curve
- Fitted curve
- Extrapolation I
- Extrapolation II

\( YS = 136 \text{MPa} \) (Provided by NOVELIS)
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>70 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

\[ K = 341.94, n = 0.259 \]

\[ K = 315.34, n = 0.204 \]

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

True stress strain curve

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>
</tr>
<tr>
<td>Ultimate Tensile Strength (UTS)</td>
<td>989 MPa</td>
</tr>
<tr>
<td>Uniform elongation</td>
<td>8.6%</td>
</tr>
</tbody>
</table>

True stress,  
\[ \sigma = K \varepsilon^n \]
In cooperation with AFTON Chemical, EWI, HOUGHTON International, QUAKER Chemical, SHILOH Industries, IRMCO, HYSON Solutions

• The Cup Draw Test is well accepted for the evaluation of lubricants/ forming speed and temperatures are important.

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

• 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

Shorter Perimeter
Better Lubrication

Highest BHF without fracture in the cup
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
Deep Drawing in a 300t Servo Press with Servo Hydraulic Cushion

In cooperation with AIDA, SHILOH, HONDA-EGA, BATESVILLE, ESI, HYSON

• With or without spacers/advances
• Elimination or modification of draw beads
• Use of servo hydraulic cushion (BHF variable with stroke, vibrating BHF, change of BHF between stroke)
• Use of servo press capabilities (slow down before deformation, attach/detach, coining)
“Intelligent Tool” for stamping (w/spacers) (courtesy Audi)

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)
Forming of Al, SS and AHSS in a Servo Press with Servo Hydraulic Cushion

In cooperation with AIDA, SHILOH, HYSON, HONDA EGA, BATESVILLE TOOL & DIE, ARCELOR, NOVELIS, NUCOR, ESI

• Forming of Al 5182-0-1.2mm and Al 6014-1.2mm using Shiloh Die (4 mm Punch Radius)
• Forming of AHSS (DP1180-1.2mm, DP980-1.2mm, CP800, 1.4mm) Using Shiloh Die at AIDA
• Forming of round and square parts form DP980 (1.2mm), using Batesville dies
• Forming of Al 6205-1mm and SS 304-1mm at Hyson
Shiloh die (4mm punch corner radius / blank sizes / example formed part)

- 445 mm used in experiment
- 520 mm modified for buckling reduction
- Punch
- Punch/Die clearance 1.6mm
- 1.2 mm Al5182-O
- Draw depth 65 mm
- BHF=100 kN

660 mm
Experiments – at Hyson
*Die / blanks used and part geometry*

Blank size (Material Al 6205-1mm)

Original blank geometry (A) (cracks)

New blank geometry (modified but not optimized) (B) (no cracks)

- Diameter: 190 mm
- Width: 170 mm
- Length: 160 mm

**Photo of Hyson Part**
Length of the part= 139.32mm
Width of the part= 133.55mm
Experiments – BHF (cushion force) variations -variable and pulsating cushion force (VBHF)-

Example: VBHF-Input VS Output in a 300 ton Servo Press (Effect of Press Speed)

Pulsating BHF
Experiments
- Ram speed variations used -

Punch stroke [mm]

“Attach-Detach”

“Stop at touch”
Conclusions / Observations

- 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, appears to improve drawability slightly (lubrication/BHF)
- As expected, cushion force (BHF) output is affected by press speed (SPM)
- Work is in progress to (a) optimize blank size, ram motion and BHF (cushion force) during stroke, for selected parts and (b) develop guidelines
Work is in progress to develop two courses for forming various materials, for industry
- Principles and Applications of mechanical Servo Drive Presses
- Principles and Applications of Servo Hydraulic Cushions
These courses will 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.
• 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 590 – 1.4mm, Al 5182-O – 1.2mm, Al 6014, 1.2mm) and Z-bending (DP 980 – 1.14mm)

Objective: 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
Schematic of Tooling for U-Bending

Initial position of tools for U-bending

Final position of tools for U-bending
U-bending-Improvement of springback prediction using inverse analysis
Al 5182-O (1.2mm)

Al 5182-O (1.2 mm)

Simulation results

Experiment

Determined through inverse analysis

Inverse analysis Al 5182-O (1.2 mm) Case U1

E-modulus (Gpa)

Springback (°)

Yoshida Model  E=70 Gpa  E=106 GPa  U1 (5 SPM)

Al 5182-O (1.2 mm)
Objective: For a given material/thickness and final part dimensions (a) determine the optimum punch geometry and (b) develop guidelines for future use.

- Initial state
- First bending
- Second bending
- Final bending
As expected, the springback angle increases with decreasing E-modulus.
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 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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