THE EFFECT OF COMBINATION BEADS ON SPRINGBACK: EXPERIMENTAL STUDY & VIRTUAL STUDY

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OBJECTIVE

To Investigate the Effects of the Combination of Draw Bead and Stake Bead in Springback Management on 3rd Gen AHSS

An Auto/Steel Partnership Stamping Team Project
STRESS EQUALIZATION VS. SPRINGBACK

Stress distribution across wall thickness is closely related to springback. Equalized stress distribution achieves better springback control. Optimized bead combinations promotes to approach stress equalization.
The contour shows the level of absolute major stress.

The progressive bead forming is shown with 1mm interval, synchronized with the evolution of stress difference.

Three stages are divided by dash lines, the bead forming progressions are shown at bottom.
COMBINATION BEAD FORMING PROCESS

- Drawn blank is drawn over and passed draw bead
- Binder Wrap
- Stake bead engaged
- Post stretching

(Animation)
COMBINATION BEAD FORMING PROCESS

Binder Wrap

Forming

(Video)
## EXPERIMENTAL TEST

<table>
<thead>
<tr>
<th>Stake Bead</th>
<th>Draw Bead</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 mm</td>
<td>0.0 mm</td>
</tr>
<tr>
<td>4.6 mm</td>
<td>1.0 mm</td>
</tr>
<tr>
<td>5.6 mm</td>
<td>2.0 mm</td>
</tr>
<tr>
<td>6.6 mm</td>
<td>3.0 mm</td>
</tr>
<tr>
<td>7.6 mm</td>
<td>4.0 mm</td>
</tr>
</tbody>
</table>

- **Sprung Geometries Export**
- **Geometry Analysis of Argus**
- **Geometries Layout**
- **Springback Evaluation**
INDEXES FOR SPRINGBACK EVALUATION

**Index 1: relaxed space of panel top**

Index of relaxed space of panel top to define part tightness

**Index 2: sprung ratio of punch radius**

to define springback of side wall and top surface:

\[
\frac{(R_{\text{sprung}} - R_{\text{target}})}{R_{\text{target}}}
\]

**Index 3: sprung ratio of die radius**

to define springback between side wall and lower flange:

\[
\frac{(R_{\text{sprung}} - R_{\text{target}})}{R_{\text{target}}}
\]

**Index 4: side wall curvature**

to characterize side wall curl degree:

\[
\frac{1}{R_{\text{sprung}}}
\]
EXPERIMENTAL TEST RESULTS

Indexes with bead combinations

Stake Bead Height: 0.0 mm
Stake Bead Height: 4.6 mm
Stake Bead Height: 5.6 mm
Stake Bead Height: 6.6 mm
Stake Bead Height: 7.6 mm
EXPERIMENTAL TEST RESULTS

Draw Bead Impact to Springback

Without stake bead, draw bead reduces indexes of relax space of part top, sprung ratio of punch radius and sprung ratio of die radius, but makes side wall curl worse.

When the stake bead is engaged for post stretch, draw bead impacts less on springback control.
EXPERIMENTAL TEST RESULTS

Stake Bead Impact to Springback

Stake bead improves springback significantly on sprung ratio of punch radius and side wall curl, but not as much on relaxed space of part top and makes sprung ratio of die radius worse.
SUMMARY OF EXPERIMENTAL STUDY

- Combined influence of draw and stake beads towards springback management was explored.

- A novel approach, based on radius / curvature change, is proposed to quantify panel springback; each of the four indices is focused on a specific geometry feature of the panel.

- Stress distribution across sheet thickness is closely related to springback; combination-bead can be used effectively to achieve stress equalization for springback control.

- Because of the complexity of combination bead impacts, optimized bead combinations should be considered for springback control.

- Scale-up laboratory-scale study and develop springback control guidelines for effective control of springback in stamping production.
VIRTUAL STUDY

• Baseline Virtual to Physical outcomes

• Mechanical rationale for tryout observations
  • Panel shape response to bead changes?

• Develop guidance for springback management
VIRTUAL STUDY

Die / Process Conditions

Material Type / Properties

Stamping Simulations

Tryout / Production Conditions

Friction / Tribology

\( \mu \)
VIRTUAL STUDY

Baseline Virtual to Physical outcomes

- Friction / Lube Conditions unknown
- Virtual Reverse-engineering using highlighted tryout outcomes
- 0.34
VIRTUAL STUDY

Baseline Virtual to Physical outcomes

Combinations of large Draw Bead Height and Stake Bead Entry observed to split panel at Stake Bead
VIRTUAL STUDY

Baseline Virtual to Physical outcomes

Sprung Panel Scans overlaid on Virtual Outcomes
VIRTUAL STUDY
Panel shape response to bead changes

Draw Bead 0 mm, Stake Bead 0 mm:
lack of bead restraint leads to
minimal panel stretch, and
therefore to large panel
distortion upon springback

Draw Bead 4 mm, Stake Bead 7.6 mm:
bead restraint leads to strong
panel stretch, and therefore to
reduced panel distortion upon
springback

Increased panel stretch reduces stress difference between top and bottom surfaces;
this reduces panel distortion – curvature change – upon springback
Guidance for Springback Management

• Optimal combination of Draw Bead and Stake Bead?
• Considerations from practical experience:
  • Stake Beads improve stretch => reduce springback
  • Draw Beads ensure stable process
• Metric for characterizing springback / panel distortion?
VIRTUAL STUDY

Guidance for Springback Management

• Metric for characterizing springback / panel distortion?

“Curvature Change” upon springback relaxation is an appropriate measure of panel distortion.
Systematic Process Exploration
Explore full range of tooling / process
- Draw Bead 0-6 mm
- Stake Bead 0-7.6 mm

Define Quality Targets
- Minimize Curvature Changes
- Avoid Splits at Stake Bead

Identify process / tool settings for achieving Quality Targets
- Automatic
- Balanced, to accommodate conflicting Quality Targets
- Establish “process window” with acceptable results
VIRTUAL STUDY - OUTCOMES

Identify Dominant Tooling Parameter Influence on Curvature Change
As Stake Bead and / or Draw Bead height increases, panel Curvature Change is seen to approach 0, the target line:

- Stake Bead observed to be more effective than Draw Bead in achieving this target
- Effectiveness varies over Bead height ranges
VIRTUAL STUDY - OUTCOMES

Identify Solution Range => “Process Window”
- Reduced Springback
- Intact panel (no splits)

Green zones represent permissible range of Draw Bead and Stake Bead heights capable of producing “acceptable panels”: reduced springback, no splits

“Process Window” provides ranges of Draw and Stake Bead heights capable of producing acceptable panels; opportunity for trade off between these parameters
.Validate a Solution within “Process Window”

- Draw Bead 2.5 mm, Stake Bead 6.5 mm
- Reduced Springback
- Intact panel (no splits)

Combination of Draw Bead Height 2.5 mm, and Stake Bead Height 6.5 mm reduces Curvature Change, and therefore minimizes panel distortion; this combination also avoids splits on the panel.
SUMMARY OF VIRTUAL STUDY

▪ Material, Process, and Tooling conditions were diligently represented
  ▪ Unknown Friction conditions were reverse-engineered
▪ Virtual outcomes were reliably baselined to physical panel observations
▪ Mechanical rationale provided for panel shape / distortion response to changes in tooling – draw bead and stake bead height
▪ Systematic Virtual Study carried out:
  ▪ Desired outcomes – quality targets – were defined upfront
  ▪ Full range of controllable tooling parameters was explored
  ▪ Outcomes:
    ▪ Range of Draw Bead and Stake Bead heights over which springback can be mitigated: “Process Window”
    ▪ Draw Bead 2.5 mm and Stake Bead 6.5 mm represents a viable solution within this Process Window, and was virtually validated
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THANK YOU!

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