A New Hybrid Bead with Post-stretching Method to Effectively Control Spring-back for Advanced High-Strength Steel

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Auto/Steel Partnership
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Problem: Spring-back in Manufacturing

- How to Control it? **Stretch** it!
- How to Stretch it? **Clamp** it!
  - Hybrid beads
Solution: Post-stretching

• **Phase 1 Lab-scaled Hybrid Bead Development**
  – U-channel Lab-scaled Hybrid Bead Die Concepts
  – Hybrid Bead Design Based on Finite Element Simulations
  – Test Die, Results and Analysis
  – Advantages and Conclusions

• **Phase 2 (Hat Section Rail Die): Production-Scale Application Study**

• **Phase 3 High Volume Production Robustness Study**
• A U-channel die was designed and manufactured to implement the **Clamp-Stretch concept**.
• A clamp hybrid bead was developed and applied to clamp the blank.
• Multiple conceptual inserts were designed.
Solution: Post-stretching

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- Phase 3 High volume production robustness study
Hybrid Bead Design with FE Simulation

- **A** Ideal Fully-locked
- **B** Hybrid Beads with 3 Cavities
- **C** Hybrid Beads with 5 Cavities
- **D** Waved Hybrid Bead with Cavities
- **E** Conventional Stinger Beads without Cavity

15 mm
Hybrid Bead Design for Effective Stretch

X-axis: Forming Depth (mm) with Bead Engaged
Y-axis: Major Stress (MPa, Abs)

- A: Ideal Fully-lock
- B: 3 Stingers Bead with Cavity
- C: 5 Stingers Bead with Cavity
- D: Waved Bead with Cavity
- E: Conventional Stinger Bead without Cavity

Stress Difference Evolution Contour

Forming with Bead Engagement

Bead Area

0.0 mm

Major Stress Histories, Wall Inner and Outer Surfaces
Hybrid Bead Design with FE Simulation

- Spring-back behavior was simulated and winner is ... Design B: 
  Hybrid Beads with 3 Cavities! with least Springback

**A** Ideal Fully-locked 
**B** Hybrid Beads with 3 Cavities! 
**C** Hybrid Beads with 5 Cavities 
**D** Waved Bead with Cavities 
**E** Conventional Stinger Bead without Cavity 

Before Spring-back
Preferred Hybrid Bead Design

- Synergistic effect of both wave-shaped bead forming and teeth penetration.
- Material Saving: 78%, with reduced risk of fracture in bead forming vs. traditional draw bead.
- Lower risk of fracture at bead

Blank Needed to Form
Hybrid Bead

Blank Needed to Form
Conventional Bead

Hybrid Beads with 3 Cavities

Risk of Fracture

Major Stress (Abs)

-1500.000
-1000.000
-500.000
0.000
500.000
1000.000
1500.000

Totally Bead Length: >35 mm

7.5 mm
Solution: Post-stretching

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• **Phase 2 (Hat Section Rail Die): Production-Scale Application Study**

• **Phase 3** High volume production robustness study
The die was installed in a Servo Press to stamp U-channel parts. The parts were successfully stamped as the FEA predicted.
Test Results: Great Springback Control

Part Geometry without Post-stretching (top) vs. Part Geometry with Post-stretching (bottom)

Top view

Front view
U-channel Die: Test Results
U-channel Die Test Results

- Excellent spring-back control was achieved with successful clamping
- DP980, CP1180, 3rd Gen. 1000 MPa, 1200MPa

Effect of Post-stretching Amount

Hybrid Bead: No Material Sliding
Post Stretch / Clamping Force vs. Springback

- Achieved excellent spring-back control
- Minimal tonnage requirement - significantly reduced the clamping force to 0.1T/mm for DP980 (50%), 0.175T/mm for CP1180 (12.5%)
- Post-stretching amount to 7 mm.
• Significantly reduced the clamping force to $0.13T/mm$ (3rd Gen. 1000 MPa), $0.24T/mm$ (3rd Gen. 1200 MPa).

• Stretching amount 7 mm (3rd Gen. 1000 MPa), 8 mm (3rd Gen. 1200MPa).
Hybrid Bead: Capable and Strong

Strong, Robust Hybrid Bead performance, Excellent performance of resistance to failure.
Solution: Post-stretching

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  - Advantages and Conclusions

- **Phase 2 (Hat Section Rail Die):** Production-Scale Application Study

- **Phase 3** High volume production robustness study
Advantages and Conclusions

- Comprehensive Spring-back Control
  - Excellent Synergistic Clamping Effect in Lab Trials.
- Material savings: 78% flange reduction
  - For Shotgun Panel, 15% less of part blank.
- Lower risk of fracture at bead
  - No bending over tight bead radius and related potential fracture.
Solution: Post-stretching

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- **Phase 2 (Hat Section Rail Die): Production-Scale Application Study**
- **Phase 3 High volume production robustness study**
Phase II: Production Scale Application

- Hybrid Beads are being implemented on a production scale die at AutoDie LLC
Solution: Post-stretching

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• Phase 2 (Hat Section Rail Die): Production-Scale Application Study
• Phase 3 High volume production robustness study
Phase 3  High Volume Production Robustness

• **Bead Profile Optimization**
  - Rounded corners and small ramps were added to reduce the stress concentration
  - New Profile Design: FEA is underway to assess bead designs

• **Surface Treatment**
  - Laser Cladding of hard carbide powder to improve teeth durability
  - Synergy Additive Manufacturing LLC (SAM)
Improvement of Bead Robustness

- Rounded corners and small ramps were added to reduce the stress concentration of the bead.
- Outstanding performance of clamping.
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