GREAT DESIGNS IN STEEL

HOT STAMPING DIE DEVELOPMENT AND PROCESS SIMULATION
PHS 1500 AS

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INTRODUCTION AND OBJECTIVE

• Project objective is to study stamping conditions, and process windows for a challenging part: B - pillar.
  • Design a tool for 1.6 mm PHS 1500 AS (ATC is the industrial press tool technology partner)
  • Tool to accommodate Grades: PHS 1500 AS, PHS 2000 AS, PHS 1000 AS, PHS 500 AS, Monolithic and same-gauge LWB combinations
  • Study stamping conditions required for robust production under industrial conditions.

• Scope of this presentation – Tooling development, commissioning activities for 1.6 mm PHS 1500 AS and FEA support.
• 12,000 kN open loop hydraulic press
  • Proportional controlled hydraulic pumps to provide press force
  • Proportional controlled valves to control velocity, force, and other variables in the press process.

• Water cooling, ≈ 20°C water temp. at exit hose.
Cross Section 85 mm to home

Upper die 85 mm from home

Gap pad, total gap = t + 2.5 mm, controlling wrinkle height to 2.5 mm as upper die travels to home

• Initial simulations:
  • Pads are set 85 mm from home
  • Slide velocity 94 mm/s 85 mm from home
  • Slide velocity 50 mm/s from 2.5 mm to home
  • Constant tool temperature

AutoForm (R10)

PAM-STAMP
TOOLING / PROCESS DEVELOPMENT AIDED BY FEA
CONCEPT CAD VS. PRODUCTION CAD

- Interpretations from FEA based on concept CAD can be a risk
- FEA should be used to check production tools
GAP PAD OPERATION FAILURE DIAGNOSED WITH FEA

AutoForm - Gap = 2.5 mm:
No embossments formed, Wrinkle height of 2.5 mm

AutoForm - Gap = 0.2 mm:
Some embossments formed,
• Tooling misalignment
• Simulations could illustrate this problem
PRESS RECIPE SET UP – SLIDE VELOCITY

Press Trace: 1302 mm set point

1302 mm, set point

Higher Forming velocity
Slide Velocity = 85.6 mm/s, Slide Position = 2.5 mm from home

Instantaneous slide velocity \( \approx 65 \) mm/s

Temperature Profile

0.0 mm from home

Resulting thinning

Press Trace: 1300 mm set point

1300 mm, set point

Low Forming velocity
Slide Velocity = 67.5 mm/s, Slide Position = 2.5 mm from home

Instantaneous slide velocity \( \approx 90 \) mm/s
FEA TOOLING TEMPERATURE / STEADY STATE

• Cooling channel evaluation
• Number of cycles until steady state
• No development of hot spots

FEA Upper Die – with cooling channels

FEA lower Die – with cooling channels

FLIR image tools after ≈ 20 parts
42 PIECE RUN FOR TOOLING BUY-OFF

- 7 pieces run to “warm up” tools/press
- Additional 42 pieces run

Trial Data
- Part temperatures (spot pyrometers):
  - BT1, BT2 blank temperature just before forming
  - BT3, BT4 part temperature just after quenching
  - Thinning was measured in the walls for locations 12, 13
- Full size tensile tests performed

<table>
<thead>
<tr>
<th></th>
<th>Cycle Time (s)</th>
<th>Oven Temp (°C)</th>
<th>Transfer Time (s)</th>
<th>Part Temp start, on tools (BT1, °C)</th>
<th>Quench time (s)</th>
<th>Part Temp, tool opening (BT4, °C)</th>
<th>Press Tonnage (kN)</th>
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<tbody>
<tr>
<td>Med</td>
<td>48.5</td>
<td>933.0</td>
<td>12.1</td>
<td>753.5</td>
<td>9.98</td>
<td>122.5</td>
<td>3589</td>
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<tr>
<td>Min.</td>
<td>45</td>
<td>931.4</td>
<td>12.1</td>
<td>747.0</td>
<td>9.95</td>
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<td>3558</td>
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<tr>
<td>Max.</td>
<td>56</td>
<td>936.8</td>
<td>12.2</td>
<td>756.0</td>
<td>10.01</td>
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**Mechanical Properties (n=5 parts throughout the run)**

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<th>YS(MPa)</th>
<th>TS(MPa)</th>
<th>TE(%)</th>
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<tr>
<td></td>
<td>Walls</td>
<td>Flat areas</td>
<td>Walls</td>
</tr>
<tr>
<td>med</td>
<td>1045</td>
<td>1030</td>
<td>1510</td>
</tr>
<tr>
<td>min</td>
<td>1010</td>
<td>960</td>
<td>1460</td>
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<tr>
<td>max</td>
<td>1110</td>
<td>1090</td>
<td>1560</td>
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**Thinning**

<table>
<thead>
<tr>
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<th>Thinning (loc 12)</th>
<th>Thinning (loc 13)</th>
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<tbody>
<tr>
<td>med</td>
<td>-0.085</td>
<td>-0.106</td>
</tr>
<tr>
<td>Min</td>
<td>-0.109</td>
<td>-0.137</td>
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<tr>
<td>Max</td>
<td>-0.055</td>
<td>-0.08</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Positive (above CAD) (mm)</th>
<th>Negative (below CAD) (mm)</th>
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<tbody>
<tr>
<td>med</td>
<td>2.24</td>
<td>-0.58</td>
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<tr>
<td>min</td>
<td>1.72</td>
<td>-0.6</td>
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<tr>
<td>max</td>
<td>3.34</td>
<td>-0.48</td>
</tr>
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</table>

Formability is safe. Good mechanical properties, dimensional performance.
Part Temperature vs. Stroke

- Part Temp. (deg C)
- Press Stroke or Part# (0 to 135)

Thinning in Loc 13 vs. Stroke

- Thinning
- Press Stroke or Part# (0 to 35)

Surface matching, Upper Die at Home

- Upper die tooling compared to lower die tooling offset by 1.58 mm

Calculated average velocity profile

- V mm/s
- time (s)
PAM-STAMP FEA USING CONSTANT VELOCITY ASSUMPTION AND TOOLING CAD

- FEA predicts different location of maximum thinning vs. the buy-off trial
PAM-STAMP FEA USING STL, ACTUAL PRESS SLIDE VELOCITY CURVES - BETTER THINNING PREDICTIONS

- FEA using actual velocity curves (Part#4, Part#40):
  - Matches the location of maximum thinning from the trial (mid wall)
  - The thinning trend from the trial is reproduced in the FEA
  - In the trial at Loc 13, thinning increases from -0.087 (Part#4) to -0.137 (Part#40)
Good agreement with location, and trial values
PAM-STAMP DISTORTION USING STL, CALCULATED AVERAGE OF PRESS SLIDE VELOCITY CURVES

- Min/Max predicted distortion magnitudes are less than that seen in the trial
- Also, the pattern of distortion is similar to that in the trial

STL scan top surface stamped part – best fit to Punch tool, corrected for thickness
(Part from middle of trial run)
PAM-STAMP FEA USING STL, MEASURED PRESS SLIDE VELOCITY CURVES: QUENCHED AFTER 10 S, 3600 KN

- The effect of tooling gap in the walls in the scanned (STL) tools is reflected in the simulation quenched results
- The part is > 97% martensite, in alignment with the good mechanical properties from the trial
SUMMARY, FUTURE WORK AND NEXT STEPS
SUMMARY

- Benefits of FEA simulation of tooling commissioning demonstrated in:
  - Assessing production intent tooling CAD vs. concept CAD
  - Diagnosing gap pad failure
  - Assessing the effect of misalignment
  - Aid to making decisions for the press “recipe”
  - 3D thermal simulations show promise to determine hot spots on tools

- Tooling Buy Off:
  - Good parts made using 1.6 mm PHS 1500 AS
  - Able to measure press stroke variations (slide velocity, quench force, timing)
  - Good agreement between simulation and trials,
  - FEA predictions for thinning were more in agreement with the trial results when actual velocity curves from the trial were used in the simulation instead of assumed constant velocity.
  - Predicted martensite fraction in-line with good mechanical properties measured in parts from the trial
  - Predicting part distortion (with FEA) is a challenge, magnitudes were underpredicted, but trend is somewhat correctly predicted
NEXT STEPS

• Model stamping process noise effects on stamped product consistency
  • Development of FEA robustness (Monte Carlo) simulations of the hot stamping process incorporating process variation
  • Net shape hot stamping modeling, stability of the part edge with respect to holding part tolerances.
• Ongoing process window for new grades, new coatings etc.
• FEA modeling ongoing improvement:
  • Development and validation of material cards, and prediction of mechanical properties
  • Improve understanding of heat transfer and part distortion
FOR MORE INFORMATION

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