Numerical Analysis of High Speed Roller Hemming Processes

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Outline

- Introduction
- Motivation
- Target
- Approach
- Results
- Conclusion and Outlook
Introduction
Roller hemming process

Principle of roller hemming

- Flange is bent in a continuous process using a robot-manipulated roller
- Incremental forming process

2-step 90°-roller hemming process

![Diagram of 2-step 90°-roller hemming process]

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Introduction
Roller hemming technology implementation

<table>
<thead>
<tr>
<th>Model</th>
<th>Components to be roller hemmed</th>
<th>Plant</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tigra</td>
<td>Doors, hood, roof, tailgate</td>
<td>Heuliez</td>
<td>Medium</td>
</tr>
<tr>
<td>Zafira</td>
<td>Hood</td>
<td>Bochum</td>
<td>High</td>
</tr>
<tr>
<td>Combo</td>
<td>Tailgate</td>
<td>Azambuja</td>
<td>Low</td>
</tr>
<tr>
<td>Saab Cadillac</td>
<td>Doors, hood, tailgate</td>
<td>Trollhättan</td>
<td>Low</td>
</tr>
<tr>
<td>Astra RHT</td>
<td>Doors, a-pillar</td>
<td>Antwerp</td>
<td>Low</td>
</tr>
<tr>
<td>Saab 606</td>
<td>Hood, tailgate</td>
<td>Trollhättan</td>
<td>Medium</td>
</tr>
<tr>
<td>Next Generation</td>
<td>All closures</td>
<td>Rüsselsheim</td>
<td>High</td>
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<tr>
<td>Vectra</td>
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</table>

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GME’s Vision
Introduction
High speed roller hemming technology

“Dynamic High Speed Roller Hemming” tool with driven rollers (patent pending)

Facilitates hemming speeds of up to 1400 mm/s

Experimental straight-edge / straight-surface process for fundamental investigations

Modeled in this study

Motivation
Pre-hem wrinkling
- Wrinkles can occasionally be not fully flattened out during final-hemming
- Impairs the final part’s quality in terms of surface and flushness conditions

One of the most significant problems associated with roller hemming

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Target

Provide tangible recommendations for optimized process design to minimize pre-hem wrinkling

Understand underlying physical processes

Systematically identify influence of major process parameters

Current situation:
• Literature/suppliers yield very limited data
• In-depth theoretical analysis still to be performed

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Approach

Sensitivity analysis by means of FEA

Investigated major process parameters

• Pre-hem roller diameter d:
  \( d = 20\text{mm}; 40\text{mm}; 60\text{mm} \)

• Pre-hem roller taper angle \( \alpha \):
  \( \alpha > 0^\circ; \alpha = 0^\circ; \alpha < 0^\circ \)
  \( (\alpha_4 = -60^\circ; \alpha_5 = -75^\circ) \)

• Pre-hem roller lead angle \( \beta \):
  \( \beta < 0^\circ; \beta = 0^\circ; \beta > 0^\circ \)

• ...

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**Approach**

**Model**

- Workpiece:
  - Length of „inner“ and „outer“ = 300mm
  - Sheet thickness „outer“ = 0.75mm
  - Sheet thickness „inner“ = 1.7mm
  - Material: mild steel

*Geometries of pre- and final-hem roller vary in the course of the sensitivity study*

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**Approach**

**FEA details**

**Numerical parameters**
- LS-DYNA (Version 970, MPP, single precision)
- Shell elements (type 16, full integration, 7 thru-thickness integration points)
- Material model 24: piecewise linear plasticity

**Meshing guidelines for hem radius**
- 4 elements on 90° hem radius
- Element size = 0.2mm
- Aspect ratio = 1.0

**Computing resources**
- p550 (IBM) with 4 Power5 CPUs, 4x4=16Gb Memory
- Expense: approx. 6.4 hours

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Results
Pre-hem wrinkling

Evolution of stresses [MPa] in z-direction (tangential stresses) in hem flange during pre-hemming simulation (roller diameter = 20mm; taper angle = 0°; lead angle = 0°)

Wrinkling phenomena can be reproduced using explicit FEA

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Results
Pre-hem wrinkling

Local elongation of flange causes tangential compressive stresses

Tangential compressive stresses likely to be cause of wrinkling

Tangential tensile stresses of up to 440 MPa

Tangential compressive stresses of up to 320 MPa

Stresses [MPa] in z-direction (tangential stresses) in hem flange during pre-hemming simulation (roller diameter = 20mm; taper angle = 0°; lead angle = 0°)

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### Results

**Pre-hem Elongation of hem flange edge**

- Local elongations sum up to substantial values of up to 5%
- Large roller radii of curvature lead to low elongation values

<table>
<thead>
<tr>
<th>Process parameters</th>
<th>d [mm]</th>
<th>β [°]</th>
<th>α [°]</th>
<th>d [mm]</th>
<th>β [°]</th>
<th>α [°]</th>
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<tbody>
<tr>
<td></td>
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<td>0</td>
<td>40</td>
<td>0</td>
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<tr>
<td></td>
<td>60</td>
<td>0</td>
<td>0</td>
<td>80</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Pre-hemming stage of roller hemming**

$\Delta l$ and $l$

### Results

**Pre-hem wrinkle depth**

- Minimum wrinkle depth = 0.15mm
- Maximum wrinkle depth = 1.71mm

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Results
Pre-hem wrinkle depth

- Occurrence of large wrinkle depths coincides with large elongations of hem flange edge
- Elongation of flange causes tangential compressive stresses = cause of wrinkling
- Measures fit to reduce flange elongation lead to lower tendency towards wrinkling

<table>
<thead>
<tr>
<th>Process parameters</th>
<th>(d) [mm]</th>
<th>(\alpha) [°]</th>
<th>(\beta) [°]</th>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>r5</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>r8</td>
<td>60</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

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Results
Validation

- Simulation accuracy calls for improvement
- Good qualitative agreement
- Simulation accuracy calls for improvement
- Process parameters investigated do not affect wrinkle width

<table>
<thead>
<tr>
<th>Process parameters</th>
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<th>(\alpha) [°]</th>
<th>(\beta) [°]</th>
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</thead>
<tbody>
<tr>
<td>r5</td>
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</tr>
<tr>
<td>r14</td>
<td>40</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>r23</td>
<td>60</td>
<td>0</td>
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</tbody>
</table>

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Conclusion and outlook

Conclusion
• Straight-edge/straight-surface high speed roller hemming process modeled using LS-DYNA
• Pre-hem wrinkling phenomena reproduced
• Good qualitative agreement simulation/experiment
• Recommendations for an optimized process design developed and validated

Outlook
• Model curved-edge/curved-surface processes
• Improve simulation accuracy
• Model production process

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