Bending Process Optimization Study of DP780 Tubing

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OBJECTIVE

- Study the influence of bender variables on the formability of DP780 thin-walled tube.
- Provide comparisons with HSLA350 tube.
- Establish a process window for bending thin-gauge DP780 tube.
1. Accurate measurement techniques for capturing small differences in formability. (what to measure and how to measure)

2. Effect of bender variables on wrinkling, thinning, collapse & springback.

3. Selection of bender variables for successful bends.
Commercially available ERW tube designed for hydroforming (*ArcelorMittal Tubular Products*)

- HSLA350 CR
- DP780 CR

**Tube Mechanical Properties**

<table>
<thead>
<tr>
<th>Grade</th>
<th>HSLA 350</th>
<th>DP780</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2% Y.S.</td>
<td>424 MPa</td>
<td>692 MPa</td>
</tr>
<tr>
<td>UTS</td>
<td>488 MPa</td>
<td>899 MPa</td>
</tr>
<tr>
<td>UEL</td>
<td>14%</td>
<td>8%</td>
</tr>
<tr>
<td>TEL</td>
<td>26%</td>
<td>16%</td>
</tr>
<tr>
<td>N-value (5% - UEL)</td>
<td>0.125</td>
<td>0.084</td>
</tr>
</tbody>
</table>
• Springback
• Collapse
• Length
• Thinning
• Strain

CMM

Ultrasonic Probe & Micrometer

Circle Grid

Ultrasonic probe thickness measurements every 10 mm
## Measurement Efficiency

<table>
<thead>
<tr>
<th>Measurement</th>
<th>R&amp;R (Aim: &lt;10%)</th>
<th>Time/ tube</th>
<th>Minimum Sample Size</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle Grid:</td>
<td>80% 94%</td>
<td>18 min.</td>
<td>n/a</td>
<td>Poor</td>
</tr>
<tr>
<td>- Major Strain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Minor Strain</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness:</td>
<td>14% n/a</td>
<td>1 min.</td>
<td>5 pc³</td>
<td>Good</td>
</tr>
<tr>
<td>- Ultrasonic probe</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- micrometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CMM:</td>
<td>0.09% 0.04% 0.13-1.12%</td>
<td>11 min.²</td>
<td>1 pc</td>
<td>Good</td>
</tr>
<tr>
<td>- Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Collapse</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

1. Destructive test
2. Can be reduced by optimizing set-up
3. 95% confidence in detecting part-to-part thickness differences to 0.01mm
- Steel Grade
- Lubricant
- Bend Radius
- Bend Angle
- Y-Boost Assist
- Pressure Die Assist X-Axis
- Pressure Die Assist Y-Axis
**EFFECT OF GRADE**

**Thinning Profiles of DP780 & HSLA350**

- **DP780**
  - Thinning (%)
  - Distance on outside of bend (mm)
- **HSLA350**
  - Thinning (%)
  - Distance on outside of bend (mm)

- 7” Radius Bend Die
- 90° Bend Angle
- 100% Pressure Die
- Assist X- Axis

**Clamped end**
Thinning Profiles of DP780

Effect of Boost

- 0% Boost
- 4% Boost

- 7" Radius Bend Die
- 70° Bend Angle
- 10% Pressure Die Assist X-Axis

Clamped end

Distance on outside of bend (mm)
Maximum Thinning of DP780 & HSLA350
7" radius Bend Die, 70 degree bend

Y-Boost & Pressure Die Assist Y-axis (%)

Thinning (%)

- DP780
- HSLA350

 wrinkle

www.autosteel.org
EFFECT OF BEND ANGLE

**Thinning Profiles of DP780**

- **15°**: Black line
- **30°**: Blue line
- **45°**: Green line
- **60°**: Red line
- **75°**: Yellow line
- **90°**: Orange line

- **7” Radius Bend Die**
- **0% Y-Boost**
- **100% Pressure Die Assist X- Axis**

**Thinning (%)**

**Distance on outside of bend (mm)**

**0%**  100  200  300  400  500
CONCLUSIONS

- **Thinning**
  - Localized thinning starts early in the bend (insensitive to angle)
  - Dramatically improved by increased bend radius
  - Strongly dependent on grade
  - Slightly improved by Y-Boost

- **Springback**
  - Increased with bend angle
  - Strongly dependent on grade
  - Insensitive to other bender variables

- **Wrinkling**
  - Bender tooling set-up important
  - Y-boost and external lubrication also key
• Set up tooling such that a wide range of Pressure Die Assist X-Axis produces no wrinkles.
• Increase boost to minimize thinning until wrinkling starts.

High boost = Least thinning & no impact on springback
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