DUAL PHASE STEEL APPLICATIONS IN TAILOR-WELDED BLANK TECHNOLOGY

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Overview

- **Introduction**
  - Material Properties
  - Opportunities & Challenges
- **DP Steel (Dual Phase) TWB (Tailor Welded Blanks)**
  - Quality
  - Micrographs
  - Fatigue Performance
- **Dual Phase Steel TWB Rails**
- **DP Steel LW (Laser Welded) Tubular Blanks**
- **Conclusions**
**Introduction**

- **Small heat input in laser welding**
  - Due to small heat input, LW is a favorable joining technology for fabrication of DP steel TWB

- **Industrial applications/advanced trials:**
  - TWBs composed with DP600, DP800, DP1000

  Rails

  A & B-pillars

  Body side inner, etc.

  DP LW hydroformed engine cradles, etc.
Opportunities

• **Range of gauge and grade combinations**
  (DQ, DP600, DP800, DP1000, etc.)

• **Unique opportunities to reduce cost and improve performance:**
  - Optimize strength and mass distribution over the vehicle body
  - Optimize vehicle crash and structural performance
  - Reduce part count and overall assembly cost
Challenges

• Challenges:
  ▪ Need to optimize laser welding processes
  ▪ Need to optimize part geometry and stamping process for springback control
  ▪ Higher press tonnage/pressure requirements
  ▪ Impact on tool’s durability
  ▪ Differences in material strength, work hardening rate, and resulting heat generation in stamping
## Example of Typical Mechanical Properties

<table>
<thead>
<tr>
<th>GRADE</th>
<th>YS (MPa)</th>
<th>UTS (MPa)</th>
<th>El (%)</th>
<th>t (mm)</th>
<th>n-value (10%-UE)</th>
<th>n-value (4-6%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF</td>
<td>163</td>
<td>282</td>
<td>49.0</td>
<td>-</td>
<td>0.240</td>
<td>-</td>
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<tr>
<td>DDQ</td>
<td>183</td>
<td>314</td>
<td>42.9</td>
<td>1.6</td>
<td>0.230</td>
<td>-</td>
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<tr>
<td>DQ</td>
<td>214</td>
<td>323</td>
<td>37.5</td>
<td>2.8</td>
<td>0.192</td>
<td>-</td>
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<tr>
<td>HSLA340</td>
<td>387</td>
<td>438</td>
<td>30.8</td>
<td>1.6</td>
<td>0.170</td>
<td>-</td>
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<tr>
<td>C-Mn440</td>
<td>375</td>
<td>484</td>
<td>16.0</td>
<td>2.8</td>
<td>0.180</td>
<td>-</td>
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<tr>
<td>HSLA480</td>
<td>487</td>
<td>604</td>
<td>28.0</td>
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<td>0.128</td>
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<tr>
<td>HSLA550</td>
<td>641</td>
<td>672</td>
<td>13.5</td>
<td>2.0</td>
<td>0.040*</td>
<td>-</td>
</tr>
<tr>
<td>DP600</td>
<td>386</td>
<td>607</td>
<td>25.5</td>
<td>1.2&amp;1.6</td>
<td>0.168</td>
<td>0.208</td>
</tr>
<tr>
<td>T600</td>
<td>390</td>
<td>618</td>
<td>35.1</td>
<td>1.6</td>
<td>0.230</td>
<td>-</td>
</tr>
<tr>
<td>DP800</td>
<td>459</td>
<td>838</td>
<td>17.2</td>
<td>1.2&amp;1.6</td>
<td>0.115*</td>
<td>0.168</td>
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<tr>
<td>T800</td>
<td>475</td>
<td>822</td>
<td>28.0</td>
<td>1.6</td>
<td>0.240</td>
<td>-</td>
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<tr>
<td>DP1000</td>
<td>726</td>
<td>1003</td>
<td>10.8</td>
<td>1.2</td>
<td>0.060*</td>
<td>0.08</td>
</tr>
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</table>
True Stress – True Strain Curves

Comparison of Yield Strength, Tested As Delivered, L-dir.

Tested Materials, Cont’d
Dual Phase Steel
Tailor Welded Blanks
# TWB Welding Process Parameters

<table>
<thead>
<tr>
<th>Batch</th>
<th>Laser Welding</th>
<th>Mash Seam Welding</th>
</tr>
</thead>
</table>
| 1     | Laser: YAG  
      | Power: 4kW, 2 beams  
      | Speed: 6.1 – 7.1 m/min  
      | Focus: Part surface | Current: 18kA  
      | Force: 12kN DP600  
      | Overlap: 2.5 mm  
      | Speed: 4m/min |
| 2     | Laser: YAG  
      | Power: 3kW  
      | Speed: 5.25m/min  
      | Focus: 0.5mm from bottom of part | - |
Weld Seam Quality and Hardness

Performed test:
- Tension test
- Olsen test
- Geometry evaluation
- Microhardness

High quality laser weld seam geometry for dissimilar gages of TWB is not an issue. Acceptance criterion: Minimum 85% of theoretical cross-section.

<table>
<thead>
<tr>
<th></th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2mm DP600</td>
<td>427</td>
<td>638</td>
</tr>
<tr>
<td>Welded</td>
<td>429</td>
<td>646</td>
</tr>
<tr>
<td>1.5mm DP600</td>
<td>432</td>
<td>683</td>
</tr>
<tr>
<td>Quality</td>
<td>93.6%</td>
<td></td>
</tr>
</tbody>
</table>
Weld Seam Quality and Hardness, Cont’d

DP600 1.2mm + DP800 1.6mm

<table>
<thead>
<tr>
<th>Weld Quality</th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2mm DP600</td>
<td>408</td>
<td>647</td>
</tr>
<tr>
<td>Welded</td>
<td>433</td>
<td>648</td>
</tr>
<tr>
<td>1.6mm DP800</td>
<td>407</td>
<td>786</td>
</tr>
<tr>
<td>Weld Quality</td>
<td>93.0%</td>
<td></td>
</tr>
</tbody>
</table>

DP600 1.2mm + DQ 1.6mm

<table>
<thead>
<tr>
<th>Weld Quality</th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2mm DP600</td>
<td>404</td>
<td>639</td>
</tr>
<tr>
<td>Welded</td>
<td>170</td>
<td>307</td>
</tr>
<tr>
<td>1.6mm DQ</td>
<td>168</td>
<td>298</td>
</tr>
<tr>
<td>Weld Quality</td>
<td>95.5%</td>
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</tr>
</tbody>
</table>

Microhardness Traverses

**DP600 1.2mm + DP800 1.6mm Microhardness Traverses**

**DP600 1.2mm + DQ 1.6mm Microhardness Weld Traverse**
Weld Seam Quality and Hardness, Cont’d

<table>
<thead>
<tr>
<th>Material</th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2mm DP800</td>
<td>492</td>
<td>866</td>
</tr>
<tr>
<td>Welded</td>
<td>502</td>
<td>870</td>
</tr>
<tr>
<td>1.6mm DP800</td>
<td>418</td>
<td>795</td>
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<tr>
<td>Weld Quality</td>
<td>92.4%</td>
<td></td>
</tr>
<tr>
<td>1.2mm DP800</td>
<td>470</td>
<td>851</td>
</tr>
<tr>
<td>Welded</td>
<td>168</td>
<td>306</td>
</tr>
<tr>
<td>1.6mm DQ</td>
<td>160</td>
<td>300</td>
</tr>
<tr>
<td>Weld Quality</td>
<td>97.4%</td>
<td></td>
</tr>
</tbody>
</table>

**DP800 1.2mm + DP800 1.6mm**

**DP800 1.2mm + DQ 1.6mm**

**Microhardness Traverse**

![Microhardness Traverse Graph](image)
Weld Seam Quality and Hardness, Cont’d

DP600 1.2mm + DP600 1.2mm

<table>
<thead>
<tr>
<th></th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Bar</td>
<td>407</td>
<td>640</td>
</tr>
<tr>
<td>Welded</td>
<td>408</td>
<td>635</td>
</tr>
<tr>
<td>Right Bar</td>
<td>401</td>
<td>632</td>
</tr>
<tr>
<td>Weld Quality</td>
<td></td>
<td>91.8%</td>
</tr>
</tbody>
</table>

Laser welding is more difficult for similar gages

Fatigue testing results for this case are presented later

DP600 1.2mm to DP600 1.2mm Microhardness Traverse
Weld Seam Quality and Hardness, Cont’d

Mash Welding results in “added material”

Fatigue testing results for this case are presented later

<table>
<thead>
<tr>
<th></th>
<th>YS, MPa</th>
<th>TS, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Bar</td>
<td>398</td>
<td>632</td>
</tr>
<tr>
<td>Welded</td>
<td>412</td>
<td>634</td>
</tr>
<tr>
<td>Right Bar</td>
<td>398</td>
<td>633</td>
</tr>
<tr>
<td>Weld Quality</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

DP600 1.2mm + DP600 1.2mm

Mash Weld  DP600 1.2mm to DP600 1.2mm
Microhardness Traverse
Specimen as a cantilever beam with constant controlled stress

\[ \delta = \frac{Fl^3}{2EI} \]

\[ I = \frac{bt^3}{12} \]

\[ l = \frac{Sbt^2}{6F} \]
Experimental setup for constant stress bending fatigue test
Fatigue test performed in fully reversed bending mode; \( R = -1 \) at frequency of \( f = 7 - 15 \) Hz using constant stress specimens. Variable speed, LFE-550 fatigue testing machine was used. Tests performed in lab environment; \( T = 23 \) °C, RH = 30%.
Hybrid Laser/MAG Welding

Hybrid Laser Welding for TWB production: Tolerates gaps up to 1.00mm
Dual Phase Steel
Tailor Welded Blank Rails
Stamping of DP TWB Rails

Example of DP600 TWB Front Rail

Heavy gauge side

Laser Weld Seam Location

Heavy gauge side
Stamping of DP TWB Rails, Cont’d

Springback for DP600 and HSLA280 TWB rails

HSLA280, 2mm
Original Design

DP600, 2mm
Direct Substitution
AHSS – TWB: Part geometry designed for springback control

- Various grades combinations: from DQ to DP800, and gages from 1.2mm to 1.6mm
- 5% stretch across weld seam
- All combinations stamped without failure in industrial conditions
- No springback related issues even though UTS varied by 500MPa within the part
Stamping of DP TWB Rails, Cont’d

Dimensional Accuracy/Springback Control Solution for DP TWB

View from the end of DP800, 1.2mm

View from the end of DQ, 1.6mm

500 MPa difference in UTS
Dual Phase Steel
Laser Welded Tubular Blanks
Microhardness & Micrograph

DP600 ERW (Electric Resistance Welded) Tube

DP600 LW (Laser Welded) Tube

Microhardness, H

Location, mm

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0

0 50 100 150 200 250 300 350 400 450

ERW LW
Tubular Laser Welded DP600 Blanks

Die for hydroforming expansion

- Free expanded LW DP 600 tubes
- Various end feed rate
- No failure up to 65% expansion
Conclusions

- **DP Steels are excellent candidates for TWB component applications**
- **As demonstrated, springback in stamping of DP TWB can be controlled even though UTS varies up to 500MPa**
- **DP TWB display good fatigue performance**
- **Similar to other welded joints, fatigue performance for LW joints is geometry driven.** Note: Weld seam area in TWB components are located by the designer in the “protected zones”
- **DP600 LW tubular blanks are suitable for hydroforming applications with expansion up to 65%**
Conclusions, Cont’d

- Laser welding is the only recommended process for manufacture of DP 800 and DP1000 TWB (after M. Uchihara & K. Fukui)

- Industrial laser welding processes allow for good quality production DP TWBs

- Adding material in welding process (e.g. mash welding) results in improved fatigue performance of TWB (almost as good as of substrate material)

- In case of welding similar or heavy gauges of DP steels, other blank welding technologies could be applied, e.g. hybrid laser welding

- Further study is needed to optimize TWB technologies for AHSS
Presented in cooperation with:
Tailor Welded Blank Technologies
Committee of Auto-Steel Partnership
References

• M. Uchihara, K. Kiyoyuki, Tailored Blanks of High Strength Steels – Comparison of Welding Processes, SAE 2003-01

DUAL PHASE STEEL APPLICATIONS IN TAILOR-WELDED BLANK TECHNOLOGY

Q & A

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