ON THE ADVANTAGES OF FORTIFORM®
980 GI - A 3RD GENERATION AHSS
GRADE WITH SUPERIOR WELDABILITY

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ArcelorMittal Global R&D, East Chicago, IN, USA
Engineered product - Excellent mechanical properties with improved LME resistance

<table>
<thead>
<tr>
<th>Targeted Mechanical Properties</th>
<th>Bendability</th>
</tr>
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<tbody>
<tr>
<td>YP (MPa)</td>
<td>TS (MPa)</td>
</tr>
<tr>
<td>FORTIFORM® 980 GI</td>
<td>670</td>
</tr>
</tbody>
</table>

Engineering Stress-Strain Curve

Microstructure

- Tempered Martensite/Bainite
- Retained Austenite
- Ferrite
- Fresh Martensite
WELDABILITY
SPOT WELDING

Stackup: 1.6mm GI980HF / 1.5 mm GI EDDS / 1.5mm GI EDDS
Welding Condition: SEP1220-2

Max. Welding Current (Imax):
Just Below Expulsion

10% Above Imax
(Above Expulsion)

No surface cracking in high thickness heterogenous stackups with mild steel; even at Expulsion

Stackup: 1.6mm GI980HF / 1.6 mm DP980GI
Welding Condition: SEP1220-2

10% Above Imax
(Above Expulsion)
WELDABILITY
GAS METAL ARC WELDING (GMAW)

Cross-section Images at Maximum Penetration

Microhardness plots

Continuous Lap Welds - \( V_{\text{MAX}} \)

- \( V_{\text{MAX}} - S1 \)
- \( V_{\text{MAX}} - S4 \)

Distance (mm)

Microhardness (HV 1000g)

0 2 4 6 8 10 12 14 16 18 20 22 24 26

No Surface Cracks for all the different welded geometries studied
V-groove, VDMAX

Continuous brazed seam, VDMAX

Stitch brazed cross tension, VD_{MIN}

MIG Brazing

Load-Displ.; continuous, stich seam and CT

Laser Welding

Load-Displ.; continuous, stich seam and CT

WELDABILITY
MIG BRAZING AND LASER WELDING
To assess the Resistance Spot Weld (RSW) performance in a dynamic event:

- A double hat section was used to ensure spot welds are subjected to peel loading mode.
- 3 gauges tested - 1.4mm, 1.6mm and 1.2mm.
- Parts baked at 180°C for 27 mins.
- Weld pitch - 25 mm & 20 mm.
- Test Speed of 9.0 mph & a target energy of 15kJ.

**Welding Schedule**

<table>
<thead>
<tr>
<th>Welding Schedule</th>
<th>Welding - RE#452</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding Mode: MFDC</td>
<td>Weld force: 5.5 KN</td>
</tr>
<tr>
<td>Tip Face Diameter: 7 mm</td>
<td>Welding Schedule(cycles): W/T-12, SQZ-70, H/T-10, Cool-2, Pulse-2</td>
</tr>
<tr>
<td>Nugget Size: 6.2 mm</td>
<td>Welding Current: 7.85 K.A.</td>
</tr>
<tr>
<td>Weld pitch: 25 mm</td>
<td>Test Setup</td>
</tr>
</tbody>
</table>

**Test Setup**

- Fixture
- Impactor
- Displacement Measurement by Laser Sensor
- Part
- Load Measured by load cells
- Barrier
AXIAL CRUSH TEST
GEOMETRY SELECTION

Geometry 1 selected to ensure repeatability
<table>
<thead>
<tr>
<th>Sample Thickness</th>
<th>Sample Configuration</th>
<th>Weld Nugget Size</th>
<th>Weld Pitch</th>
<th>Observations</th>
</tr>
</thead>
</table>
| 1.4mm Unbaked    |                      | 6.2mm           | 25mm      | • Exhibited mainly HAZ & base metal failure  
• Effect of baking is not significant |
| 1.4mm Baked      |                      | 5.0mm           | 20mm      | • Crush performance of 20mm weld pitch with 5mm weld nugget size is GREATER THAN 25mm weld pitch, 6.2mm weld nugget size |
| 1.6mm Unbaked    |                      | 6.7mm           | 25mm      | • Exhibited mainly HAZ failure on the welds  
• Effect of baking is not very significant |
| 1.2mm Unbaked    |                      | 5.3mm           | 25mm      | • Effect of baking on lower gage (1.2mm thickness) is more pronounced on weld toughness  
• Unbaked samples showed failures - interfacial & HAZ |
| 1.2mm Baked      |                      | 6.7mm           | 25mm      | • Exhibited mainly HAZ failure on the welds  
• Effect of baking is not very significant |
FORTIFORM® 980 GI
1.4MM SAMPLES

Un-Baked Sample
25mm Weld Pitch, 6.2mm Nugget Size

Baked Sample
25mm Weld Pitch, 6.2mm Nugget Size

Sample 1

Sample 2

Test provided repeatable crush pattern. Effect of Baking is not significant at 1.4mm thickness
Effect of weld pitch is higher than the weld nugget size
Samples with 20mm pitch, even at a lower nugget size, maintain consistent average force
FORTIFORM® 980 GI
1.6MM SAMPLES

Sample 1

Un-Baked Sample
25mm Weld Pitch, 6.7mm Nugget Size

Baked Sample
25mm Weld Pitch, 6.7mm Nugget Size

Sample 2

Repeatable crush pattern is observed. Effect of baking is not significant at 1.6mm thickness
FORTIFORM® 980 GI
WELD TOUGHNESS IMPROVEMENT – BAKING EFFECT

Cross Tension Strength (kN)

<table>
<thead>
<tr>
<th></th>
<th>UnBaked</th>
<th>Baked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force (kN)</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Displacement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Weld Toughness

- Toughness (Area under the curve up to Max Load)
- Full Toughness (Area under the full curve)

<table>
<thead>
<tr>
<th></th>
<th>UnBaked</th>
<th>Baked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toughness (kJ)</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Force (kN)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Displacement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1.2mm Coupon
FORTIFORM® 980 GI
1.2MM SAMPLES

Un-Baked Sample
25mm Weld Pitch, 5.3mm Nugget Size

Baked Sample
25mm Weld Pitch, 5.3mm Nugget Size

Repeatable crush pattern is observed. Effect of baking is significant at 1.2mm thickness
• Over all Fortiform® 980 GI 3rd GEN product,
  • Combines excellent strength & formability and offers light weighting opportunities
  • Product can absorb energy during crash events and deform in a controlled manner similar to currently used steel grades
  • Exhibits superior weldability
  • Effect of baking on weld performance during crash is more pronounced at lower thickness
    o Gen3 samples should always be baked when testing samples
• Four different welding types of Resistance Spot-Welding (RSW), Laser Welding, MIG Brazing and Gas Metal Arc Welding (GMAW) have been examined with no signs of surface cracks in critical zones
• Important to note that Fortiform® 980 GI 3rd GEN is compatible with the current welding technology used in the industry
For More Information about ArcelorMittal Fortiform® grades:

https://automotive.arcelormittal.com/fortiform