Metallurgical Characteristics of Double-Sided Arc Welding in High Strength Structural Steels

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Process Principle
Process Characteristics

- **Direction of Current Flow**
- **Presence of Arc through-the-thickness of the Keyhole**
  - continuous arc compensation through the thickness
- **Deep Narrow Penetration Capability**
- **Symmetric Heat Input and Minimized Distortion**
Energy Compensation Through Thickness
Energy Distribution: Regular Plasma Arc

without keyhole

with keyhole

Plasma arc

Efflux plasma
Arc Concentration in DSAW

without keyhole  with keyhole
Practical System
Double-sided Arc Weld: Flat Position without filler metal
Double-sided Arc Weld: Horizontal Position without filler metal
Double-sided Arc Weld: Vertical-Down Position with filler metal
Test Materials: Low Alloy High Strength Steels

ASTM A514 and SSAB Domex 100XF:
- Widely used in Structural and Pressure Vessel Applications
- Low Alloy High Strength (690 MPa (100 ksi) minimum yield strength)
- Good Ductility, Toughness Formability and Weldability

**ASTM A514**: by US Steel, quenched and tempered (Q&T) steel  
**Domex 100XF**: by SSAB, thermo-mechanically control-processed (TMCP) microalloyed steel, extremely fine grain structure of a mixture of quasi-polygonal ferrite and granular bainite

**Thickness**: 10mm-thick (3/8”)

<table>
<thead>
<tr>
<th>Steel</th>
<th>Yield Strength MPa (ksi)</th>
<th>Tensile Strength MPa (ksi)</th>
<th>Total Elongation %</th>
<th>Reduction of Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM A514</td>
<td>725 (105.0)</td>
<td>787 (114.0)</td>
<td>26.3</td>
<td>47.3</td>
</tr>
<tr>
<td>Domex 100XF</td>
<td>760 (110.1)</td>
<td>826 (119.7)</td>
<td>26.0</td>
<td>-</td>
</tr>
<tr>
<td>DSAW Parameters</td>
<td>“Bead-on-plate” weld Domex100XF</td>
<td>Butt joint, square groove weld</td>
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<tr>
<td>Plasma current</td>
<td>150 A</td>
<td>200 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double-sided arc current</td>
<td>100 A</td>
<td>110 A</td>
<td></td>
<td></td>
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<tr>
<td>Welding speed</td>
<td>90 mm/min</td>
<td>120 mm/min</td>
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<td></td>
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<tr>
<td>Plasma gas flow rate</td>
<td>6.0 cfh</td>
<td>4.5 cfh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma shielding gas flow rate</td>
<td>35 cfh</td>
<td>35 cfh</td>
<td></td>
<td></td>
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<tr>
<td>Plasma orifice diameter</td>
<td>2 mm</td>
<td>2 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double-sided arc shielding gas flow rate</td>
<td>55 cfh</td>
<td>55 cfh</td>
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</tbody>
</table>
Weld Cross-Sections

Bead-on-Plate, Domex 100XF.
2% Nital etch.

Butt Joint, Domex 100XF.
2% Nital etch.
Weld Metal Structures

Weld metal microstructure of butt joint, square groove, double-sided arc weld in 10mm A514 plate. 2% Nital etch.

Weld metal microstructure of butt joint, square groove, double-sided arc weld in 10mm Domex 100XF plate. 2% Nital etch.
Weld Metal Structures: GMAW

Weld metal microstructure of GMAW process in 10mm A514 plate. 2% Nital etch.

Weld metal microstructure of GMAW process in 10mm Domex 100XF plate. 2% Nital etch.
Comparison of Weld Metal and Unaffected Base Metal

Weld metal microstructure of DSAW in 10mm A514 plate. 2% Nital etch.

Microstructure of unaffected base plate of 10mm A514 plate. 2% Nital etch.
Microhardness Traverse in DSAW Joint on A512

Microhardness Traverse in DSAW Joint on Domex 100XF

Double-Sided Weld. 3/8" Domex 100XF Plate. Square Groove.
Plasma Current 180A. Double-Sided Arc Current 110A.
Welding Speed 140 mm/min.

[Graph showing microhardness traverse]
Microhardness Traverse in GMAW Butt Joints

Microhardness Traverse Across Fusion Line in Weld Joints of ASTM A514 and Domex 100XF

--- ASTM A514  --- Domex 100XF

Knoop Hardness, 500g

Relative Distance, inch
Charpy V-notch Specimen
# Charpy V-notch Impact Toughness Test Results

<table>
<thead>
<tr>
<th>Test Weldments</th>
<th>Test Temperature °C (°F)</th>
<th>CVN Impact Toughness of ½-size Specimen Joules (ft-lbs)</th>
<th>Equivalent Toughness of Full-size Specimen* Joules (ft-lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mm A514 Butt Joint Square Groove</td>
<td>24 (75)</td>
<td>19.0 (14.0)</td>
<td>28.0 (20.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19.0 (14.0)</td>
<td>28.0 (20.5)</td>
</tr>
<tr>
<td></td>
<td>-29 (-20)</td>
<td>8.0 (6.0)</td>
<td>12.0 (8.8)</td>
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<tr>
<td></td>
<td></td>
<td>8.0 (6.0)</td>
<td>12.0 (8.8)</td>
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<td></td>
<td></td>
<td>8.0 (6.0)</td>
<td>12.0 (8.8)</td>
</tr>
<tr>
<td>10mm Domex 100XF Butt Joint Square Groove</td>
<td>24 (75)</td>
<td>41.0 (30.0)</td>
<td>60.0 (44.0)</td>
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<tr>
<td></td>
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<td>110.5 (81.5)</td>
<td>161.0 (119.5)</td>
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<td>104.5 (77.0)</td>
<td>153.0 (113.0)</td>
</tr>
<tr>
<td></td>
<td>-29 (-20)</td>
<td>4.0 (3.0)</td>
<td>6.0 (4.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.0 (4.5)</td>
<td>9.0 (5.5)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.5 (4.0)</td>
<td>8.0 (6.0)</td>
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Conclusions

- Symmetrical Weld
- Deep Narrow Penetration
- Fine Equiaxed Grains
- Hardness: acceptable
- Toughness: filler metal use
Acknowledgement

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