Weldability of AHSS

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Overview

- AHS Steels & Weld Joint
- Spot welding
  - Spot Welding Window
  - Effect of Coating
  - AC vs. Mid-Frequency DC
  - Weldmetal Hardness
  - Mechanical Properties
  - Fracture Mode
  - Effect of Paint Baking
  - Impact Testing at -20 °C and 20 °C
- Arc welding
- Laser welding
- Induction welding
- Summary
• The optimum resistance welding parameters of AHSS are different from the mild steel parameters.

• AHSS can be welded using Resistance, Arc, Laser, Induction welding processes.
Effect of cooling rate in a steel

![Graph showing the effect of cooling rate in a steel with different phases and temperature over time.](image-url)
Weld Microstructure

- All weld joints including AHSS, will have similar microstructures.
- The hardness of each region depends on the alloying elements.

HSLA350 Arc weld

Ferrite Ferrite + Martensite Martensite
# Chemical composition of steels

<table>
<thead>
<tr>
<th>Steel Type</th>
<th>C (wt%)</th>
<th>Mn (wt%)</th>
<th>Si (wt%)</th>
<th>S (wt%)</th>
<th>P (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DQSK CR</td>
<td>0.04</td>
<td>0.19</td>
<td>0.012</td>
<td>0.015</td>
<td>0.011</td>
</tr>
<tr>
<td>HSLA350 CR</td>
<td>0.08</td>
<td>0.73</td>
<td>0.022</td>
<td>0.005</td>
<td>0.01</td>
</tr>
<tr>
<td>DP500 CR</td>
<td>0.07</td>
<td>1.71</td>
<td>0.025</td>
<td>0.006</td>
<td>0.011</td>
</tr>
<tr>
<td>DP600 CR</td>
<td>0.09</td>
<td>0.95</td>
<td>0.300</td>
<td>0.008</td>
<td>0.01</td>
</tr>
<tr>
<td>DiForm140T CR (DP965)</td>
<td>0.14</td>
<td>1.45</td>
<td>0.300</td>
<td>0.007</td>
<td>0.015</td>
</tr>
<tr>
<td>M220 CR (M1500)</td>
<td>0.25</td>
<td>0.45</td>
<td>0.026</td>
<td>0.015</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**TRIP Steels**: High C, Mn, Al/Si, etc.
SPOT WELDING
## Influencing parameters on weldability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild Steel</th>
<th>AHSS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alloying Elements</strong></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Microstructure</strong></td>
<td>Simple</td>
<td>Ferrite/DP/Martensite</td>
</tr>
<tr>
<td><strong>Resistivity</strong></td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td><strong>Current Range</strong></td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td><strong>Electrode Life</strong></td>
<td>Longer</td>
<td>Shorter</td>
</tr>
<tr>
<td><strong>Fracture Location</strong></td>
<td>in HAZ</td>
<td>in HAZ/ Nugget / Interface</td>
</tr>
<tr>
<td><strong>Electrode Force</strong></td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td><strong>Current</strong></td>
<td>Higher</td>
<td>Lower</td>
</tr>
</tbody>
</table>

Using same welding parameters
## Similar current range

<table>
<thead>
<tr>
<th>Material (Min. Button = 4 x ( \sqrt{t} ))</th>
<th>Gauge (mm)</th>
<th>Current range (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP500 EG</td>
<td>0.65</td>
<td>1.28</td>
</tr>
<tr>
<td>DQSK EG</td>
<td>0.81</td>
<td>1.21</td>
</tr>
<tr>
<td>BH210 EG</td>
<td>0.83</td>
<td>1.79</td>
</tr>
<tr>
<td>DP600 CR</td>
<td>1.40</td>
<td>2.74</td>
</tr>
<tr>
<td>DP600 HDG</td>
<td>1.40</td>
<td>1.90</td>
</tr>
<tr>
<td>HSLA 350 GA</td>
<td>1.50</td>
<td>2.10</td>
</tr>
<tr>
<td>M900 CR</td>
<td>1.50</td>
<td>3.40</td>
</tr>
<tr>
<td>HFT440 GA</td>
<td>1.60</td>
<td>2.75</td>
</tr>
<tr>
<td>TRIP590 CR</td>
<td>1.60</td>
<td>2.63</td>
</tr>
<tr>
<td>DP600 CR</td>
<td>1.80</td>
<td>4.76</td>
</tr>
<tr>
<td>DiForm 140T (DP965) CR</td>
<td>1.87</td>
<td>3.70</td>
</tr>
<tr>
<td>HSLA350 HDG</td>
<td>1.90</td>
<td>2.60</td>
</tr>
</tbody>
</table>

- With optimum welding parameters the AHSS will produce current range similar to mild steel.
Effect of coating on weld time and current

- Similar to mild steel the weld time, current depends on coating

![Graph showing weld time and current for TRIP590 1.6mm, Nugget Size 6.67mm]
- Mid-Frequency DC will increase the current range
Weld metal hardness depends on base material chemical composition, not on weld time.

Base Material
191 HV

Heat Affected Zone
355 HV

436 HV

Weld Metal
469 HV
Weld Time Vs Load

TRIP 590 1.6 mm

TRIP590 CR 1.6 mm, Nugget Size 6.67 mm

TRIP590 GA 1.6 mm, nugget size 6.67 mm

TS - Tension Shear, CT - Cross Tension

- Optimum weld time depends on the type of coating
- Pulsing has little effect of tension shear load.
Fracture mode may not be an indication of weldability.
Paint baking improves the ductility

- Paint baking increases the cross tension load.
- Paint baking improves the weld ductility and energy.
Decreased hardness in baked weld

- Paint baking decreases the coarse grain HAZ hardness and improves the fracture mode.
Impact testing samples

Shear

Impact loading direction

Teflon

Thermocouple

Sample at -20 °C before testing
- AHSS has higher impact load bearing capacity
Spot weld performance under impact load depends on button size.
ARC WELDING
Filler Wire: ER70-S3
AHSS has higher arc weld load

- DP965
- M1300
- DP600
- HSLA350

Weld Strength (MPa) vs. Elongation (mm)
LASER WELDING

Source: M. Gallagher, et. al., "Laser Welding of AHSS", to be presented at the International Automotive Body Congress (IABC), Sep., 2005.
Laser welding of AHSS

- TRUMPF 4.5 kW Nd:YAG laser
- Power used: 3.8 kW
- Focal distance: 200mm
- No Purging Gas
- Shims: 0.004” (0.1mm)
- Location of Shims: 1.5” long with 1.5” spacing between shims
Laser weld: Effect of penetration

- M900 1.5/1.5
- DP600 1.2/1.2
- DP600 1.2/2.0
- DP600 2.0/2.0
- HSLA350 1.9/1.9

Penetration (%) vs. Weld Speed m/min
• Interfacial failure usually occurs when penetration/weld width is small
• When HAZ failure occurs, almost always through bottom sheet.
• Weld rotation occurs
Effect of penetration on load

- DP600 2/2
- DP600 1.2/1.2
- HSLA 1.9/1.9
- M130 1.5/1.5
- M900 1.5/1.5
Laser weld strength increases with base material strength
Summary

- AHSS need higher electrode force and optimized weld schedule.
- AHSS welds have higher load bearing capacity than mild steels.
- Paint baking increases the weld ductility.
- AHSS has higher impact load bearing capacity.
- Weld strength depends on the alloying elements and base material strength.
- The maximum strength in laser lap weld joints can be achieved at ~40% penetration.
• The optimum resistance welding parameters of AHSS are different from the mild steel parameters.

• AHSS can be welded using Resistance, Arc, Laser, Induction welding processes.

Thank you