Repairability of Advanced High-Strength Steel

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General Motors Corporation
Range of Modern Automotive Sheet Steel Products

- Low Strength Steels (<270MPa)
- Ultra High Strength Steels (>700MPa)
- High Strength Steels
  - IF
  - IF-HS
  - Mild
  - ISO
  - BH
  - TRIP
  - CMn
  - HSLA
  - DP, CP
  - AHSS
  - MART
  - Conventional HSS

Elongation (%)

Tensile Strength (MPa)

www.autosteel.org
AHSS Repairability Concerns

- AHSS are strengthened by a combination of soft and hard phases
- The hard phases are metastable, and want to revert to soft equilibrium phases when heated
- Conventional repair procedures involve application of heat
To address these concerns, AISI and General Motors performed a study to determine the mechanical property response of AHSS to conventional collision repair practices.
Thermal histories of welds, flame straightening were determined previously by GM using thermocoupled coupons.*

*Stevenson, et. al, SAE Technical Paper No. 910292
<table>
<thead>
<tr>
<th>Steel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IF Grade 4</td>
<td>HDGI IF mild steel</td>
</tr>
<tr>
<td>HSLA 340</td>
<td>HDGI 340 MPa YS HSLA steel</td>
</tr>
<tr>
<td>DP 600</td>
<td>HDGI 340 MPa YS, 600 MPa UTS DP steel</td>
</tr>
<tr>
<td>DP 780</td>
<td>HDGI 420 MPa YS, 780 MPa UTS DP steel</td>
</tr>
<tr>
<td>TRIP 580</td>
<td>HDGA 380 MPa YS, 590 MPa UTS TRIP steel</td>
</tr>
<tr>
<td>TRIP 780</td>
<td>Uncoated 440 MPa YS, 780 MPa UTS TRIP steel</td>
</tr>
<tr>
<td>Mart 1300</td>
<td>Uncoated 1300 MPa UTS martensitic steel</td>
</tr>
</tbody>
</table>

(note: all steels ~1.5 mm gauge)
• Test as-produced mechanical properties

• Test as-fabricated mechanical properties
  • Strain 8% uniaxial tension, bake 170 °C/20 sec

• Test as-repaired mechanical properties
  • Apply simulated flame straightening thermal cycles
Experimental Procedure - MIG Welding

Welder: Miller 190 MIG, 220V, Single Phase

Welder Settings: Gas = 20 PSI, 75% Ar/25% CO2
Wire Speed Setting = 53
Voltage Setting = 3 to 4

Filler Wire: 0.023" Harris-Welco Welco-Matic ER70S-6
Martensitic steel was baked only, not pre-strained
All tensile tests ASTM longitudinal
n-values calculated in 10%-UE range (YS-UE for mart.)
Zinc stripped from GI, GA steels before thermal treatment
750 °C condition included 3x30sec interrupted heating
AC\textsubscript{1}, AC\textsubscript{3} temperatures provided by steel suppliers

For all steels tested:
650 C was high in ferrite phase field
750 C was low in ferrite + austenite phase field
850 C was high in ferrite + austenite phase field
1000 C was in austenite phase field
Results - HDGI IF Grade 4 Steel

IF Grade 4 Mild Steel

8% Strain + Bake

As Received

As Received + 650C/90s

Hold Temperature, C

YS, MPa

UTS, MPa

5sec
10sec
30sec
60sec
90sec
30x3sec

5sec
10sec
30sec
60sec
90sec
30x3sec

0 200 400 600 800 1000 1200

0 100 200 300 400

0 10 20 30 40

0 0.05 0.1 0.15 0.2 0.25

AC1
AC3

AC1
AC3
Results - HDGI HSLA 340 Steel
Results - HDGI DP 600 Steel
Results - HDGI DP 780 Steel

DP 780

YS, MPa

Hold Temperature, C

UTS, MPa

TEL, %

n-value

Hold Temperature, C
Results - Uncoated TRIP 780 Steel

TRIP 780

YS, MPa

U, UT, MPa

TEL, %
n-value

Hold Temperature, C

5sec 10sec 30sec 60sec 90sec 30x3sec

8% Strain + Bake

As Received + 650C/90s

As Received

As Received + 650C/90s

AC1 AC3

5sec 10sec 30sec 60sec 90sec 30x3sec

As Received

As Received + 650C/90s

AC1 AC3

5sec 10sec 30sec 60sec 90sec 30x3sec

As Received

As Received + 650C/90s

AC1 AC3

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As Received

As Received + 650C/90s

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Results - MIG Welding Tensile Tests

MIG welds on 8% strain + bake samples.

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<td>455</td>
<td>29.8</td>
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<tr>
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<td>404</td>
<td>642</td>
<td>26.1</td>
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<tr>
<td>DP 780</td>
<td>521</td>
<td>857</td>
<td>18.3</td>
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<td>TRIP 600</td>
<td>402</td>
<td>651</td>
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# Results - MIG Welding Tensile Tests

MIG welds on 8% strain + bake + 650°C/9sec. samples

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<th>8% + Bake + Heat + MIG Welded</th>
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The mechanical properties of the tested AHSS materials were substantially degraded by exposure to 650°C (1200°F). However, the exposure did not significantly embrittled any of the tested steels.

Temperature was the most significant factor affecting mechanical properties; time at temperature was not a significant factor.
Conclusions

• Structural components made from DP, TRIP or Martensitic steels of any tensile strength level should not be repaired by application of heat

• MIG welding results were encouraging, but HAZ failures are a concern. Further work is required to validate use of MIG welding in repair. This work is under way at the Auto/Steel Partnership