Repairability of Advanced High Strength Steel (AHSS) Structural Components

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Background

Common Collision Repair Processes:

• Bolt off, bolt on
• Cold straightening
• Cut-off, weld on
• Flame (hot) straightening

The latter two require application of heat, which could affect steels that gain their strength by thermal processing
Thermal histories of welds, flame straightening were determined previously by GM using thermocoupled coupons*

Simulated Flame Straightening Thermal Cycle

*Stevenson, et. al, SAE Technical Paper No. 910292
### AHSS Repairability

#### Materials

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<th>GM Grade</th>
<th>Description</th>
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<td>IF Grade 4</td>
<td>GMW2M-ST-S</td>
<td>HDGI IF mild steel</td>
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<td>Grade 4</td>
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<td>Grade 4</td>
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<tr>
<td>HSLA 340</td>
<td>GMW3032M-ST-S</td>
<td>HDGI 340 MPa YS CR340</td>
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<td>HSLA steel</td>
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<td>DP 600</td>
<td>GMW3032M-ST-S</td>
<td>HDGI 340 MPa YS, 600 MPa UTS DP steel</td>
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<td>Mart 1300</td>
<td>GMW3399M-ST-S</td>
<td>Uncoated (bare) 1300 MPa UTS martensitic steel</td>
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<td>1300T/1030Y M</td>
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Experimental Procedure

• Test as-produced mechanical properties
• Strain 8% uniaxial tension, bake 170 °C/20 sec
• Test as-fabricated mechanical properties
• Apply simulated flame straightening thermal cycles
• Test as-repaired mechanical properties
Notes on Experimental Procedure

- 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 steels before thermal treatment
- 750 °C condition included 3x30sec interrupted heating
- AC₁, AC₃ temperatures provided by steel suppliers

For all steels tested:

- 650 °C was high in α phase field
- 750 °C was low in α + γ phase field
- 850 °C was high in α + γ phase field
- 1000 °C was in γ phase field
AHSS Repairability

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

0 100 200 300 400

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

AC1
AC3

UTS, MPa

0 100 200 300 400

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

AC1
AC3

TEL, %

0 10 20 30 40

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

AC1
AC3

n-value

0 0.05 0.1 0.15 0.2 0.25

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

AC1
AC3
AHSS Repairability

Results - HDGI HSLA 340 Steel

- **Hold Temperature, C**
- **YS, MPa**
- **UTS, MPa**
- **TEL, %**
- **n-value**

- **8% Strain + Bake**
- **As Received**
- **As Received + 650C/90s**
- **5sec**
- **10sec**
- **30sec**
- **60sec**
- **90sec**
- **30x3sec**

- **AC1**
- **AC3**
Results - Mart 1300 Steel

1300 MPa UTS Martensitic Steel

1300 MPA UTS Martensitic Steel

Hold Temperature, C

YS, MPa

UTS, MPa

TEL, %

n-value

Hold Temperature, C

AC1

AC3

As Received

5sec

10sec

30sec

60sec

90sec

30x3sec

Bake
Interpretation - Mart 1300 Steel

- Heating martensitic steel to lowest practical flame straightening temperature (650 °C) for even short time caused tempering of martensite phase and reduction in strength
AHSS Repairability

Results - HDGI DP 600 Steel

DP 600 Steel

YS, MPa

8% Strain + Bake

As Received + 650C/90s

As Received

AC1

AC3

Hold Temperature, C

0 200 400 600 800 1000 1200

5sec

10sec

30sec

60sec

90sec

30x3sec

DP 600 Steel

UTS, MPa

8% Strain + Bake

As Received

As Received + 650C/90s

AC1

AC3

Hold Temperature, C

0 200 400 600 800 1000 1200

5sec

10sec

30sec

60sec

90sec

30x3sec

DP 600 Steel

TEL, %

8% Strain + Bake

As Received

As Received + 650C/90s

AC1

AC3

Hold Temperature, C

0 200 400 600 800 1000 1200

5sec

10sec

30sec

60sec

90sec

30x3sec

DP 600 Steel

n-value

As Received

As Received + 650C/90s

AC1

AC3

Hold Temperature, C

0 200 400 600 800 1000 1200

5sec

10sec

30sec

60sec

90sec

30x3sec

DP 600 Steel
Metallography - HDGI DP 600 Steel

As-received

8% strain + bake
650 °C/60 sec

8% strain + bake
750 °C/90 sec

Un-tempered martensite

All specimens etched in LePera’s reagent
Interpretation - HDGI DP 600 Steel

• Heating the HDGI DP 600 steel to the lowest practical flame straightening temperature (650 °C) reduced strength by:
  1.) Tempering the hard martensite phase, and
  2.) Promoting recovery of cold work in the softer ferrite phase.

• Heating to the higher 750 °C temperature transformed the martensite to austenite which, upon cooling, formed fresh, untempered martensite and restored DP properties.
Conclusions

1.) IF Grade 4 mild steel and HSLA 340 can be repaired by flame straightening. Temperature should be limited to no more than 650 °C (1200 °F, or dull cherry red color) for short duration.

2.) DP 600 and Mart 1300 steels should not be repaired by flame straightening.
Recommendations

1.) The nature and suitability of repair procedures for AHSS components will depend highly on the nature and location of damage.

2.) AHSS response to repair thermal cycles should be used in developing procedures tailored to specific AHSS components.
Future Work - Phase 2 Underway (3/2003 completion)

1.) Four additional AHSS grades:
   • TRIP 590
   • TRIP 780
   • DP 500/780
   • DP 700/980

2.) MIG welds on both Phase 1 and Phase 2 materials
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