Effects of GMAW conditions on the tensile properties of hot rolled Complex Phase 780 steel

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1. Introduction
2. Material Description
3. Experimental Procedure
4. Results and Conclusions
   • Phase 1
   • Phase 2
Introduction

- There have been several efforts to understand different aspects of AHSS\textsuperscript{(2-7)}. A trend to focus on DP steels is observed, with little work dedicated to other steels, particularly CP.

- CP steels have a comparable higher YS and Hole Expansion Coefficient (HEC), while still offering good formability, better suited for some chassis applications where certain ductility is needed to form a structural part, which once fabricated, will require it to withstand high service loads.

![Number of presentations per steel type, along the different GDIS editions.](chart.png)
Introduction

• An important aspect that deserves to be studied, is the effect of arc welding on the mechanical properties of AHSS. In that regards, several studies have been presented during previous GDIS editions, but none of them has been focused on CP steels (vs 28 on DP steels).

• Notable conclusions that have been obtained from those studies are:
  - Under matching filler material does not affect static performance, as failure was generally observed on HAZ. (4-7)
  - Weld tensile strength generally increases as base metal strength increases, though with a weld efficiency reduction. (4,7,8)

• This research focuses on the effects of gas metal arc welding (GMAW) on the mechanical properties of hot rolled CP with 780 MPa tensile strength.
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Material Description

HR660Y780T-CP supplied by Tata Steel

- **Chemical Composition (Max values wt. %):**

<table>
<thead>
<tr>
<th>Element</th>
<th>0.16</th>
<th>2.10</th>
<th>0.040</th>
<th>0.015</th>
<th>0.5</th>
<th>0.01</th>
<th>0.5</th>
</tr>
</thead>
</table>

- **Thickness:** 3.2mm

- **Microstructure:**
The material is made of fine-grained bainitic matrix with pearlite and martensite islands. This steel is additionally strengthened by the presence of Ti-carbides. The volume fraction of second phase constituents ranges between 5 and 15 vol.%. 

![Image of microstructure with scale bar 20 μm]
Material Description

Mechanical Properties:

<table>
<thead>
<tr>
<th></th>
<th>HR CP780*</th>
<th>CR DP780 *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Strength (MPa)</td>
<td>726</td>
<td>470</td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>833</td>
<td>806</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

* Properties and curves provided by TATA steel.
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Phase 1*:

Objective: Evaluate effect of different transfer modes. Using under-matched filler wire (ER70S-6) and 4 different GMAW transfer modes.

- Pulsed
- Short Circuit
- CMT
- CMT Twin

Phase 2*:

Objective: Evaluate effect when including stronger filler materials. Pulsed GMAW using two additional filler materials:
1. ER90S-D2
2. ER100S-G

* Robotic Welding and Manual Repair for each condition.
Experimental Procedure

1. Cutting Sheets
2. Welding sheets
3. Cut 2” Samples
4. Cross Section
5. Micro-hardness
6. Tensile Test
7. Machining
Experimental Procedure

Welding parameters:

- Robotic Parameters:
  - Power source: Fronius TPS5000 CMT
  - Gas = 80-20 (Ar-CO₂) @ 14 Lpm (30 Lpm for CMT-Twin)
  - CTWD = 15mm
  - Welding position = 2F
  - All manually repaired samples were pulse-welded with:
    - Voltage= 24.5 V
    - Current=244 A
    - WFS = 8 m/min

<table>
<thead>
<tr>
<th>Filler Material</th>
<th>Wire Ø (mm)</th>
<th>Process</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Welding Speed (cm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER70S-6</td>
<td>1.2</td>
<td>Pulsed Spray</td>
<td>23.6</td>
<td>298</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short Circuit</td>
<td>17.5</td>
<td>207</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CMT</td>
<td>18.4</td>
<td>242</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CMT Twin</td>
<td>28 &amp; 16.3</td>
<td>350 &amp; 270</td>
<td>300</td>
</tr>
<tr>
<td>ER90S-D2</td>
<td>1.4</td>
<td>Pulsed Spray</td>
<td>22.1</td>
<td>295</td>
<td>125</td>
</tr>
<tr>
<td>ER100S-G</td>
<td>1.2</td>
<td></td>
<td>27.9</td>
<td>311</td>
<td>125</td>
</tr>
</tbody>
</table>

All samples in accordance to AWS D8.8M.
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Phase 1 - Lap Joint Tensile Testing

Different transfer modes with ER70S-6:

<table>
<thead>
<tr>
<th>Mode</th>
<th>Stress (MPa)</th>
<th>Wire Tensile Strength (MPa)</th>
<th>Weld Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulsed</td>
<td>92%</td>
<td></td>
<td>86%</td>
</tr>
<tr>
<td>CMT</td>
<td>86%</td>
<td></td>
<td>79%</td>
</tr>
<tr>
<td>CMT-Twin</td>
<td>79%</td>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>Short Circuit</td>
<td>75%</td>
<td></td>
<td>69%</td>
</tr>
<tr>
<td>Robotic CMT-Twin</td>
<td>69%</td>
<td></td>
<td>68%</td>
</tr>
<tr>
<td>Short Circuit Pulsed</td>
<td>68%</td>
<td></td>
<td>69%</td>
</tr>
<tr>
<td>Short Circuit CMT-Twin</td>
<td>69%</td>
<td></td>
<td>66%</td>
</tr>
</tbody>
</table>

* At least 3 Repetitions of each sample were made.

* Weld Efficiency = tensile strength after welding / tensile strength of the base material. Area assumed for stress calculation was the cross section of base metal.
Phase 1 - Lap Joint Tensile Testing

Robotic

Pulsed

CMT

CMT Twin

Short Circuit

Repaired

* Fracture Location at weld metal = Cross sectional area unknown.
Phase 1 - Microhardness

Remarks:

1. Softening/Hardening did not exceed 9% (HAZ Average / BM Average)
2. In accordance with the failure locations, the welds showed lower average hardness, with respect to HAZ, except for the robotic-pulsed combination.
3. Contrary to the tensile results, robotic pulsed showed the softer HAZ and weld.
Phase 1 – Preliminary Conclusions

• When ER70 filler material was used Pulsed Transfer mode showed the highest weld-efficiency, and failed at the HAZ, while the other methods failed at the weld.

• Contrary to the above observation, Pulsed Transfer mode showed the softest weld and HAZ compared to the other methods.

• Due to uncertain cross sections at weld metal, no full relationship could be determined between tensile and microhardness results.

• Failure location on most of the samples was in the weld metal.

• To understand better the effect of the HAZ softening on the tensile properties, welding trials with stronger filler materials are needed for Phase 2. Test is to be performed using same transfer mode (Pulsed).
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At least 8 Replicates of each condition were tested.

Different filler materials on Pulsed Transfer Mode:

- **Phase 2 - Lap Joint Tensile Testing**

<table>
<thead>
<tr>
<th>Stress (MPa)</th>
<th>70 Ksi</th>
<th>90 Ksi</th>
<th>100 Ksi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotic Pulsed</td>
<td>92%</td>
<td>87%</td>
<td>93%</td>
</tr>
<tr>
<td>Manual Pulsed Repair</td>
<td>69%</td>
<td>88%</td>
<td>90%</td>
</tr>
</tbody>
</table>

- **Weld Efficiency**

* Tensile Strength (MPa)  
* Wire Tensile Strength (MPa)  
* Weld Efficiency
Phase 2 - Lap Joint Tensile Testing

Robotic

ER70

ER90

ER100

Repairs
Phase 2 - Micro-hardness

Remarks:

1. As expected, for robotic welding, the stronger the filler material, the higher the average hardness at the weld.

2. Only the weld metal from the 100 ksi filler material presented higher hardness than HAZ in both conditions.
General Conclusions

- No full correlation between tensile failure and microhardness could be obtained. Further analysis needed.
- Samples welded with ER90 and ER100 failed at the HAZ, while most of ER70 samples failed in the weld.
- Repair has no significant impact when welding with ER90 & ER100 filler material.
- Therefore, it is recommended to utilize a stronger filler material than the more common ER70 when welding CP780.
- Weld efficiency of HR-CP780 is comparable to other 780 steels.
Bibliography


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