Oil and gas construction in offshore
IT'S ALL ABOUT POSITION: GMAW DOWNWARD AND UPWARD WELDING

1. INTRODUCTION

Gas Turbine Generator Cooling Equipment as shown in Figure 1. Large fillet weld size made of stainless steel materials is highly sensitive to welding induced distortion where it can lead to expensive fit-up and re-work efforts throughout the build process if not controlled. In addition to distortion issue in out of position welding, there are some other requirements such as adequate penetration at the root weld, having good tie-in at the toes of fillet weld without any undercut, good sidewall fusion on a groove weld, and producing a weld bead face that conforms to given code and specification not being excessive concave or convex.

At different welding positions, the metal transfer is important because of the gravity and can result in varied qualities. Also, the frequency and the diameter of the droplet are affected by the mode of metal transfer.

To address these issues, this paper studies the effect of the metal transfer and welding parameters in vertical up and vertical down positions during GMAW on weld quality and bead shape.
2. EXPERIMENT PROCEDURE

The controlled dip transfer welding processes was tested on the couple of T-joints. This process provides low heat input welds with minimum spatter and relatively good weld shape. ESAB GMAW power sources with a series of new metal transfer mode including pulse/pulse (super pulse), pulse/short, and spray/pulse as shown in Figures 2 to 4 was used for this project. Figure 5 shows the relationship between mode of metal transfer, material thicknesses, and heat input. This type of power sources combines a high frequency inverter technology with advanced waveform control provide a better welding features than traditional short circuiting GMAW.

A series of plate thicknesses and welding variables examined to develop a parameter envelope for each of this metal transfer mode for fillet welding. The parameter envelope was designed to avoid lack of fusion and provide low distortion with acceptable weld profile. Each of the parameters was monitored and recorded with data acquisition and controlled during welding. A controller was used to modify the waveforms to optimize them for the specific applications in this project. As initial trial point, the welding parameters that are predefined in the systems provided a good start point.

2.1 Test Set-Up

Vertical welding, either up or down, is challenging. This makes pre-weld set up very important for making high quality welds. Some production plate samples made from stainless steel (ASTM A240 Grade 316L) were chosen. These plates for welding were fit-up in T joint with a square edge preparation (mach into cut edge) and zero root gaps. Tack welds were performed at a minimum 4 inches using GTAW process to maintain joint alignment during welding.

2.2 Performing Benchmark Welding

Productivity benchmark procedures were provided by ESAB for GMAW process on a series of plate thicknesses. In out of position, welding operators must rely on their skill to deposit filler material and use the force of the arc direct the weld puddle into the joint. The operator can control weld puddle and weld bead profile by manipulating the following variables:

- Pulse setting (mode of metal transfer)
- Wire speed
- Voltage
- Electrode diameter
- Electrode work angle
- Direction of travel
- Electrode manipulation
- Travel speed
- Electrode stick out
- Shielding gas flow

Table 1 summarizes some key differences between downward and upward welding directions.

Photographs of the samples are shown in Figures 6 and 7.

For a weld bead on type 316L stainless steel plate, the experimental semi-automatic welding conditions set up in vertical position are given in Table 2.

<table>
<thead>
<tr>
<th>Welding Direction</th>
<th>Application</th>
<th>Productivity</th>
<th>Penetration</th>
<th>Heat Input (Distortion)</th>
<th>Weld Profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downward</td>
<td>Light gauge metal</td>
<td>Faster</td>
<td>Shallow</td>
<td>Low</td>
<td>Concave</td>
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<tr>
<td>Upward</td>
<td>Heavy gauge metal</td>
<td>Slower</td>
<td>Deep</td>
<td>High</td>
<td>Convex</td>
</tr>
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</table>
FIGURES

01 Hebron Offshore Turbine Generators Cooling Equipment
02 Pulse/Pulse Waveform
03 Pulse/Short Wave form
04 Spray/Pulse Wave form
05 Heat Input and Mode of Metal Transfer
FIGURES

06 ESAB Welding Equipment – Boucherville, QC
07 Fillet Weld Samples – Vertical down Position
08 Fillet Weld Visual Inspection
09 Fillet Weld Cross Sections Inspection (P denotes pulse mode and SP denotes super pulse mode)
### Table 2 GMAW Parameters in Vertical down Position

<table>
<thead>
<tr>
<th>Sample NO.</th>
<th>Member THK. (IN)</th>
<th>Wire (IN)</th>
<th>Gas</th>
<th>Position</th>
<th>Pulse Setting</th>
<th>Voltage</th>
<th>Wire Speed (IN/MIN)</th>
<th>Heat Input (K)</th>
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<tr>
<td></td>
<td>Type</td>
<td>Size</td>
<td>Type</td>
<td>Flow</td>
<td>Super Pulse</td>
<td>Pulse</td>
<td>Upper</td>
<td>Lower</td>
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<td>1</td>
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<td>ER316LSi</td>
<td>0.045</td>
<td>AR+CO₂+N₂</td>
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<td>↓</td>
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<td>19.2</td>
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<td>2</td>
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<td>↓</td>
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<td>AR+CO₂+N₂</td>
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<td>↓</td>
<td>X</td>
<td>19</td>
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<td>4</td>
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<td>ER316LSi</td>
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<td>AR+CO₂+N₂</td>
<td>25</td>
<td>↓</td>
<td>X</td>
<td>19</td>
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<tr>
<td>5</td>
<td>3/8-3/8</td>
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<td>AR+CO₂+N₂</td>
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<td>↓</td>
<td>X</td>
<td>21</td>
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<tr>
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<td>↓</td>
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<tr>
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<td>X</td>
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<tr>
<td>11</td>
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<td>ER316LSi</td>
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<td>AR+CO₂+N₂</td>
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<td>↓</td>
<td>X</td>
<td>19</td>
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</table>

### 2.3 Inspection Results

Each of the final weld procedures were inspected visually first to size the weld profile. Liquid penetrant testing was performed on all samples to test for surface weld flaws. In addition, several welds’ cross section were extracted, polished, and etched to examine for subsurface defects and assess the weld penetration profiles as shown in Figures 8 and 9. The amount of distortion achieved with these processes were compared against the benchmarks in the as welded and those that were welded with the regular short circuit transfer mode to show the distortions is reduced.

Among the two metal transfer modes, it can be seen that super pulse weld penetration and weld profile is better than the pulse transfer mode. Comparing distortion, pulse heat input generates more distortion than the super pulse heat input in term of bending type distortion.

### 3. SUMMARY & CONCLUSION

The GMAW in out of position has been limited due to the low productivity, penetration, and high repair weld rate. Through a series of experiments in the gas turbine generators cooling equipment production we have shown proof of principle for a range of acceptable fillet weld procedures with a tuned weld set up. These procedures include mode of metal transfer, welding variables, productivity, welding techniques, welding distortion control, and producing an acceptable fillet weld profile.

According to the results in the present work, the conclusions are summarized as following:

- The controlled dip metal transfer mode can be used in out of position GMAW to increase penetration and productivity.
- The Super pulse metal transfer parameters for fillet weld production in out of position are introduced in order to make an acceptable fillet weld profile being neither excessive concave nor convex.
- Advanced power sources are tested to improve efficiency and quality of GMAW process in out of position.
- Keeping all welding parameters unchanged, the bending distortion in fillet welds were found to be strongly affected by different setting of pulse metal transfer. ☀
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References