1 August 2013

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Dear Clive White

Study of the Effectiveness of the TIG Brush® Process at Cleaning and Passivating an Autogeneous TIG Weld on 316L
TWI Report 23027/1/13-2

Please find attached the above report. If there is anything you would like to discuss please do not hesitate to contact me.

Yours sincerely

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cc: Commercial Group, Master Files - TWI
1 Introduction

Stainless steel products are adversely affected by the welding process. The intense heat generated during welding causes oxidisation and chromium depletion in the alloy's surface layer, as well as unsightly heat tint around the weld area. These surface contaminants have a negative effect on the ability of the steel to resist corrosion, leading to a reduced surface life and potentially a reduction in strength.

In order to improve the corrosion resistance of the steel, the surface can be passivated. In this process, the surface is cleaned, iron compounds are removed from the surface and a chemically inactive layer forms on the steel piece. This inactive surface forms spontaneously in contact with air or other oxygen-containing environments, but its formation can be enhanced by the application of an oxidant.

The Ensitech TIG Brush® TBE-700 is a device designed for the easy electrochemical cleaning and passivation of stainless steel surfaces, which makes use of proprietary cleaning and polishing fluids to treat steel in various ways.

This report describes a study involving the production of test welds on 316L plates, which were then cleaned or treated, using both traditional methods and the TIG Brush®. The corrosion resistance of these plates was to be tested by uniform immersion in a chemically active environment and the weight loss of the plates was recorded.

2 Objective

Quantify the influence of the TIG Brush® process for cleaning and passivating welds on type 316L stainless steel.

3 Materials

Five test pieces were cut from an austenitic stainless steel 316L bar, which was hot rolled and annealed, with the mill scale removed (1D finish). The test pieces were cut to dimensions of 120 x 75 x 5mm and cleaned and degreased with acetone.

4 Approach

4.1 Welding

An autogeneous bead on plate weld was manually applied using the DCEN Tungsten Inert Gas (TIG) process. Welding was performed in the PA position using a Polysoude AUTOTIG 600PC. A 2mm diameter tungsten electrode was used, and commercial grade argon was used as a shielding gas. The welding parameters applied are given in Table 1. The shielding gas flow was reduced below the normal level that would be applied in a standard weld procedure, to promote the formation of a surface tint on the test pieces. Four of the test pieces were welded, with one test piece being used as a control.

4.2 Post-weld cleaning of test pieces

The five test pieces were given various post weld cleaning treatments as described in Table 2. Two (welded and un-welded) samples were left untreated to generate baseline data for the effect of a welding on corrosion resistance against which the cleaning and passivating effects of the TIG Brush® treatments could be quantified.

Welded samples were allowed to cool to ambient temperature before any post-weld cleaning was applied. The TIG Brush® treatments were then applied as per manufacturer's instructions, with the carbon brush dipped into the cleaning fluid before being applied to the surface of the weld. The welds were brushed until no further reduction in heat tint was
observed, and then neutralised with the relevant neutraliser. The carbon brush was repeatedly rinsed between the different chemical solutions used.

4.3 Corrosion Resistance Testing

Three corrosion resistance samples of dimensions 25 x 75 x 5mm were cut from the post-weld specimens with a rotary carbide wheel. The cut edges and faces were dry ground with silicon carbide polishing wheels to eliminate inter-sample variation.

The corrosion resistance of the samples was tested to the ongoing standardization ISO CD 18069. This was an immersion test. Samples were placed in a heated solution of 3% sulphuric acid, and maintained at 80°C for a total of one week. The mass of the samples was measured using a high accuracy balance after 24hrs, 96hrs, after which the samples were placed back in solution. A final mass reading was made at the end of the week long test. A corrosion rate of mm/year was calculated for each period according to ASTM G1 – 03, using the equation given in the Appendix.

5 Results

5.1 Welding

The welds produced are shown in Figure 1. Each weld showed a significant degree of heat tint.

5.2 Post weld cleaning

Figure 2 shows the test pieces following post weld cleaning. Each of the TIG Brush® treatments was able to remove all of the heat tint/surface oxidation observed on the test pieces.

5.3 Corrosion testing

The changes in mass of the samples after each corrosion testing period are given in Table 3 and summarised in Table 2.

The absolute corrosion rate of each sample is shown in Figure 3. The average corrosion rate of each sample relative to that of base untreated steel for the 168 hour period can be seen in Figure 4.

Several details can be noted:

- Autogeneous welding on 316L with no post-treating leads to an increase in corrosion rate relative to unwelded 316L to 113% over the period tested.
- All of the TIG Brush® chemical variants studied improve the corrosion resistance of a welded sample, such that the corrosion rate is reduced to below that of unwelded steel.
- The least chemically stringent of the treatments, TB-30ND and TB-41, reduces the corrosion rate the least, to 85% that of unwelded steel.
- The chemical treatment TB-25 and TB-40 is the next most effective, reducing the corrosion rate to 82% of that of unwelded steel.
- The pH neutral chemical treatment TB-31ND, which is specifically mentioned as inhibiting corrosion, reduces the corrosion rate relative to that of unwelded steel to 73%.
- The TIG Brush® treatment has its greatest effect in the first 96 hours of the corrosion testing process, accelerating the passivation process.

6 Conclusions

- Post weld cleaning using each of the TIG Brush® treatments: TB-25 and TB-40; TB-30ND and TB-41; and TB-31ND removed all of the surface oxidation for the test samples treated.
- The passivation of the test piece surfaces using the TIG Brush® (TB-31ND solution) process resulted in a corrosion rate of up to 72% of that for un-welded/treated 316L.
7 Bibliography


Table 1 Welding parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current, A</th>
<th>Voltage, V</th>
<th>Travel speed, mm/min</th>
<th>Gas flow, l/min</th>
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<tr>
<td>Value</td>
<td>170</td>
<td>14</td>
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Table 2 Post weld cleaning operations

<table>
<thead>
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<th>Test piece</th>
<th>Processing of test piece</th>
<th>Average mass loss after one week, g</th>
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<tr>
<td></td>
<td>Step 1</td>
<td>Step 2</td>
</tr>
<tr>
<td>1</td>
<td>Wire brush</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Weld</td>
<td>1.10</td>
</tr>
<tr>
<td>3</td>
<td>Weld</td>
<td>TIG Brush® TB25 + TB40</td>
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<tr>
<td>4</td>
<td>Weld</td>
<td>TIG Brush® TB30ND + TB41</td>
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<tr>
<td>5</td>
<td>Weld</td>
<td>TIG Brush® TB31ND</td>
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</table>

Table 3 Mass of sample at each testing period

<table>
<thead>
<tr>
<th>Sample</th>
<th>Testing period, h</th>
<th>Initial mass, g</th>
<th>End mass, g</th>
<th>Mass loss, g</th>
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<td>66.25</td>
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<td>1B</td>
<td>96</td>
<td>69.70</td>
<td>68.86</td>
<td>0.83</td>
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<td>1C</td>
<td>168</td>
<td>68.20</td>
<td>67.09</td>
<td>1.10</td>
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<td>71.36</td>
<td>0.40</td>
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<tr>
<td>2B</td>
<td>96</td>
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<td>68.86</td>
<td>0.91</td>
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<tr>
<td>2C</td>
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<td>72.67</td>
<td>71.40</td>
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Figure 1 316L stainless steel test specimens prior to post weld cleaning treatments outlined in Table 2:

a) Un-welded;
b) Welded with parameters given in Table 1;
c) Welded with parameters given in Table 1;
d) Welded with parameters given in Table 1;
e) Welded with parameters given in Table 1.
Figure 2 Welded samples after post weld cleaning treatments described in Table 2:
a) TB-25 and TB-40;
b) TB-30ND and TB-41;
c) TB-31ND.
Figure 3 Corrosion rates of samples shown in Figures 1 and 2 over the testing period.

![Graph showing corrosion rates over time for different samples.](image)

Figure 4 Corrosion rates of post-weld treated samples relative to base steel.

![Bar chart showing corrosion rates relative to unwelded steel.](image)
Appendix – Calculation of Corrosion Rate of Samples

The corrosion rate is calculated with the following equation (ASTM G1 – 03):

Where:

\[ K = 87600 \] (a constant used to correct units)
\[ W = \text{mass loss in grams} \]
\[ A = \text{area in } \text{cm}^2 \]
\[ T = \text{time of exposure in hours} \]
\[ D = \text{density in } \text{g/cm}^3 \]