Defect Analysis of Linke Hofmann Busch Bogie Frames

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ABSTRACT

Welding defects occurring in manufacture of Linke Hofmann Busch (LHB) coaches leads to wasted effort, time and cost for the Integral Coach Factory, Chennai. The defects were inspected by Visual inspection and Dye Penetrant Testing. By Pareto analysis, some vital defects leading to maximum failure of welds were identified. Most of the major defects was found to be influenced by the shielding gas. Experiment was conducted by variation of shielding gas composition. It was found that the optimum weld quality was obtained when the mixture 25% CO2, 65% Argon and 10 % Helium was used, and that superior mechanical properties were obtained. Implementation of this gas ratio will increase the service life of the coaches, reduce weld defects, and ensure safe and world class passenger coaches that are cost effective.

Keywords: Gas Metal Arc Welding (GMAW), Defects, Shielding gas composition, Weld strength

1. Introduction

Bogie is the load carrying structure of a coach. The LHB coaches use FIAT bogie, which is an adoption of the Eurofirma design. It carries the primary and secondary suspensions, axle mounted disc brake system and hydraulic shock absorbers. A bogie has two main sub assemblies which are depicted in the Fig. 1.

Figure 1: Bogie Frame Assembly
1- Sidewall frame assembly
2-Brake beam assembly

Bogies serve a number of purposes,
1. Support of the rail vehicle body
2. Stability on both straight and curved track
3. Improve ride quality by absorbing vibration and minimizing the impact of centrifugal forces when the train runs on curves at high speed
4. Minimizing generation of track irregularities and rail abrasion

Based on our study conducted using Dye Penetrant tests and visual inspection on a sample set of 50 Brake beam assemblies and 50 Side-wall assemblies, the following welding defects were found to be predominant.

1. Lack of side wall fusion
2. Porosity
3. Crater cracks
4. Undercut
5. Excessive penetration

This work aims to analyze the weld bead characteristics through different shielding gas composition and study its effect on the defect occurrences.

1.1 Impact of Defects

1. The production time increases.
2. Rejection of components and rework has to be done.
3. Cost of production increases.
4. Passenger safety is affected due to risk of weld failure.

1.2 Literature Review

XIAOYU CAI et al. (2017) investigated the effect of varying the shielding gas composition on arc behaviors and weld formation. The result show that the arc behaviors in different shielding gas are different. When the CO2 or helium content is increased, the arc expands and the arc length decreases. When the shielding gas is of the composition 80%Ar 10%CO2 10%He, the widest arc is obtained. When the CO2 content is increased, at first the weld width increases but then it decreases with further increase in CO2 content.

VISHAL A. SAPATE et al. (May 2017) evaluated the effects of using Argon-Carbon Dioxide in the ratio 80:20 as the shielding gas in GMAW and compared the results with welding done by 100% CO2 shielding gas. hey found the following. Spatter defect was 48% more when 100% CO2 gas was used compared to Ar:CO2 (80:20) gas. Travel speed was 11% slower when 100% CO2 gas was used than the Ar:CO2 (80:20) mixture. Gas consumption was 13% higher in 100% CO2 than Ar:CO2 (80:20). It is therefore concluded that CO2 alone as a shielding gas is inefficient and that Ar:CO2 in the proportion 80:20 is a more viable alternative.

NORFADHLINA KHALID et al. (2017) determined the effects of changing the shielding gas mixture and the flow parameters.
in GMAW on the arc transfer characteristics and the resultant weld quality. They have experimented with carbon dioxide and argon as shielding gas and analyzed the weldment using Visual inspection, dye penetrant Inspection and also Ultrasonic Testing. The measurement standard used was according to ISO 5817 and ASTM E164/E165. It was found that weld defects were substantially reduced in the weldments that used Carbon Dioxide as the shielding gas when compared to weldments done with Argon as the shielding gas. It was also identified that the weldments had higher strength when performed under CO2.

2. Experimental Setup

![Figure 2: GMAW Setup](image)

Gas Metal Arc Welding (GMAW) is a metal joining process in which an arc is formed between a consumable metal electrode and the work piece, and the arc and the molten weld puddle are protected from atmospheric contamination (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of either an inert gas such as argon or some active gas such as carbon dioxide, argon-carbon dioxide mixture, which is chemically active or not inert. Initially GMAW was called as MIG Welding because only inert gases were used to protect the molten weld puddle. The CO2 gas helps supplying the argon gas at high pressure. A copper coated mild steel consumable electrode is currently being utilized for this process at ICF.

The following tests are used to test the weld strength.

1. Ultimate tensile stress test using Univesal Testing Machine
2. Impact strength test using Charpy Impact Testing

The process parameters which have to be monitored are,

1. Polarity
2. Electrode angle
3. Travel Speed
4. Welding Current
5. Welding Voltage
2.1 Experimental Details

<table>
<thead>
<tr>
<th><strong>Welding process</strong></th>
<th>Gas Metal Arc Welding (GMAW 135)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Polarity</strong></td>
<td>Direct Current Electrode Positive (DCEP) (Reverse Polarity)</td>
</tr>
<tr>
<td><strong>Filler Wire</strong></td>
<td>Diameter 1.2mm, IRS M46 Class I/ER7056 to AWS A5.18</td>
</tr>
<tr>
<td><strong>Gas Used</strong></td>
<td>ACM- Argon CO2 mixture (80:20), Ar-CO2-He mixture</td>
</tr>
<tr>
<td><strong>Gas Flow rate</strong></td>
<td>10-15 LPA</td>
</tr>
<tr>
<td><strong>Parent Material</strong></td>
<td>RM plate- EN10025-S355J2W+N; Brake support &amp; Pin bracket- Cast steel (DIN 17182-Gs20Mn5V); Break beam &amp; Spring Pot- Seamless tube (DIN 1630-Si524); Other sub-assemblies-EN10025-S355J2W+N</td>
</tr>
<tr>
<td><strong>Weaving technique</strong></td>
<td>Root run- Stringer bead (straight) Sealing run- Weave bead</td>
</tr>
<tr>
<td><strong>Stick out</strong></td>
<td>15-18mm</td>
</tr>
<tr>
<td><strong>Torch angle</strong></td>
<td>15° from vertical axis</td>
</tr>
<tr>
<td><strong>Welding position</strong></td>
<td>PA (Flat) PB (Horizontal)</td>
</tr>
<tr>
<td><strong>Welding Speed</strong></td>
<td>8m/min</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Welding Current</strong></th>
<th>247A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Welding Voltage</strong></td>
<td>28.3V</td>
</tr>
<tr>
<td><strong>Weld Pool Temperature</strong></td>
<td>6000°C</td>
</tr>
</tbody>
</table>

Table 1: Experimental parameters

2.3 Problem Solving Method

The shielding gas composition in the welding of the bogie frames is varied and the ultimate tensile strength, Young’s modulus and hardness are evaluated. Initially, all defects occurring in the welding of bogie frames are investigated and by using Pareto analysis, the vital few defects which cause the maximum failure are determined. Cause and effect analysis is used to determine the causes of the vital defects. Experiment is conducted by varying the carbon dioxide and Argon composition, and the occurrences of defects are analysed. Moreover, Helium is used to regulate the pressure of the gas flow. At first, CO2:Ar is used at 15:85 ratio. Then the CO2 percentage is kept at 17%, 20% and 25%, and Argon is varied accordingly. Helium is also introduced to the shielding gas mixture and its effect is studied.

3. Analysis

With shielding gas composition of Ar:CO2 in the ratio 80:20, an experiment was
conducted on a sample set of 50 Brake Beam Assemblies and the defects were estimated.

Table 2: Defect occurrences in Brake Beam

<table>
<thead>
<tr>
<th>DEFECT</th>
<th>Upper Stop Plate</th>
<th>Tracti on Lever bracket</th>
<th>Brake Support</th>
<th>Lift Plate</th>
<th>Crossing Brace</th>
<th>Brake Support Lift Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>LACK OF SIDE WALL FUSION</td>
<td>16</td>
<td>8</td>
<td>-</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>POROSITY</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>EXCESSIVE PENETRATION</td>
<td>5</td>
<td>-</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>CRATER CRACKS</td>
<td>5</td>
<td>3</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>BLOW HOLES</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Pareto chart for defects in Brake Beam

Figure 4: Pareto chart for defects in Side Frame Assembly
4. Results and Discussion

The weld quality at various gas composition were investigated and the results are as follows.

<table>
<thead>
<tr>
<th>Shielding gas composition</th>
<th>Tensile Strength (MPa)</th>
<th>Young’s modulus (GPa)</th>
<th>Impact Energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15% CO2 &amp; 85% Ar</td>
<td>593.843</td>
<td>204.63</td>
<td>27.5</td>
</tr>
<tr>
<td>17% CO2 &amp; 83% Ar</td>
<td>601.12</td>
<td>212.19</td>
<td>29.4</td>
</tr>
<tr>
<td>20% CO2 &amp; 80% Ar</td>
<td>623.392</td>
<td>239.24</td>
<td>32.9</td>
</tr>
<tr>
<td>25% CO2 &amp; 75% Ar</td>
<td>654.43</td>
<td>299.22</td>
<td>36.4</td>
</tr>
<tr>
<td>25% CO2, 70% Ar &amp; 5% He</td>
<td>690.785</td>
<td>302.31</td>
<td>43.1</td>
</tr>
<tr>
<td>25% CO2, 65% Ar &amp; 10% He</td>
<td>702.12</td>
<td>312.55</td>
<td>45.7</td>
</tr>
</tbody>
</table>

Table 3: Weld Strength measurement

4.1 Calculation of weld strength

The main failure mechanism of welded joint is tensile failure. Therefore the tensile strength of a welded butt joint is

\[ S = \frac{P}{(l \times t)} \]

For all welds, P= tensile load on the weld material

\[ t = \text{thickness of the weld} = 12\text{mm} \]

\[ l = \text{length of the weld} = 100\text{mm} \]

For the gas mixture 15% CO2 & 85% Ar,

\[ \text{Tensile Stress} = \frac{712.61 \times 10^3}{1200} = 593.8 \text{ MPa} \]

For the gas mixture 17% CO2 & 83% Ar,

\[ \text{Tensile Stress} = \frac{721.34 \times 10^3}{1200} = 601.12 \text{ MPa} \]

For the gas mixture 20% CO2 & 80% Ar,

\[ \text{Tensile Stress} = \frac{748.07 \times 10^3}{1200} = 623.392 \text{ MPa} \]

For the gas mixture 25% CO2 & 75% Ar,

\[ \text{Tensile Stress} = \frac{785.32 \times 10^3}{1200} = 654.43 \text{ MPa} \]

For the gas mixture 25% CO2, 70% Ar & 5% He,

\[ \text{Tensile Stress} = \frac{828.94 \times 10^3}{1200} = 690.785 \text{ MPa} \]

For the gas mixture 25% CO2, 65% Ar & 10% He,

\[ \text{Tensile Stress} = \frac{842.5 \times 10^3}{1200} = 702.12 \text{ MPa} \]

Comparing the tensile strength and the impact strength of the weldments produced with different shielding gas compositions, the optimal gas mixture was found to be Argon-Helium-CO2 in the ratio 65:10:25.

To further confirm the findings, a test run was conducted on 50 bogie frame
assemblies with the shielding gas composition Ar-He-CO2 in the ratio 65:10:25. The reduced defect occurrence has further strengthened the findings that addition of Helium to the gas mixture leads to reduction of the major defects in GMAW.

<table>
<thead>
<tr>
<th>Defect</th>
<th>Lower &amp; Control</th>
<th>Inner/Outer</th>
<th>Sup port</th>
<th>Spring</th>
<th>Pot</th>
<th>Head &amp; Brack et</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of side wall fusion</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Porosity</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Undercut</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Crater cracks</td>
<td>-</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blow holes</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Excessiv e penetrati on</td>
<td>1</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4: Defect occurrences in bogie manufacture when Argon-Helium-CO2 shielding gas at 65:10:25 is used

The table shows that the defects have been remarkably reduced with the new composition.

Conclusion

The process parameters in the welding of the bogie frames were varied as per the findings of the experiment and it was found that the occurrences of welding defects have been significantly reduced. Incidentally, the best tensile strength and impact energy of the weld was obtained when the shielding gas of 25% CO2, 65% Ar and 10% He was used at a gas flow rate of 15 lpm. It was found that, with decrease in CO2 in the gas mixture, the strength of the weld also reduced. This is due to the decrease in weld penetration. Usage of the shielding gas mixture Ar-He-CO2 in the ratio 65:10:25 will lead to an increased service life of the coaches and ultimately the safety of the passengers would be enhanced. Furthermore, the cost of the coach is also reduced due to less time spent in reworking the welding defects.

References


