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MATERIALS AND METHOD

The experimental procedure of this investigation work involves preparation of pipe samples, welding of samples, leak testing and tabulation of the results. Experiments are conducted as per number of runs of the OA and welding parameters are controlled as per factors and levels of the OA. Detailed procedure followed is given in the subsequent sections of the chapter.

3.1 WELDING PROCEDURE

In this investigation, Shielded Metal Arc Welding is performed on mild steel pipes by three phases, oil cooled welding transformer which is shown in Figure 3.1. The current settings possible on this machine are 50, 70, 80, 90, 100, 125, 150, 200, 250 and 300Amps.

Figure 3.1 Arc Welding Transformer
The power supply obtained from this transformer has constant current output characteristic, ensuring that current remains relatively constant even if the arc distance and hence the voltage is changing. The voltage and current characteristics is shown in the Figure 3.2. It is evident from the voltage and current relation of the transformer that the heat input from a specific current setting is always remains constant. Welding is performed on the Apollo steel pipes of Ø48mm with 3mm, 4mm wall thicknesses and Ø60mm with same wall thicknesses of 3mm and 4mm.

![Figure 3.2 Voltages and Current Characteristic Graph](image)

The chemical composition of the pipe material is obtained by Optical Emission Spectrometer BAIRD-DV6 is given in the Table 3.1.

<table>
<thead>
<tr>
<th>Elements</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>0.081</td>
<td>0.018</td>
<td>0.437</td>
<td>0.011</td>
<td>0.009</td>
<td>0.009</td>
<td>0.001</td>
<td>0.012</td>
</tr>
</tbody>
</table>
Specimens for the welding are prepared by parting the length pipe into a suitable length of 110mm by lathe machine. V threads of pitch 2mm are formed on one side of the pipe and other end is faced accurately to flat surface, so that same root gap can be maintained all around the pipes. During Leak testing one threaded end is connected to the hydraulic hand pump and the other end is closed by end cap. The samples for the welding are as shown in the Figure 3.3.

Welding is performed in 1G position with the help of welding spinner as shown in the Figure 3.4. In this position welding electrode is in over head position and stationary, where as pipe rotates about its axis.

![Steel Pipe Samples Ready for Welding](image)

**Figure 3.3 Steel Pipe Samples Ready for Welding**

The welding spinner consists of two pipe holders one is live pipe holder and the other one is dead pipe holder. The live pipe holder is driven by the output shaft of a reduction gear box. Power to the
reduction gear box is given by a variable speed DC motor. The use of the DC motor ensures the uniform rotation of the pipe.

Figure 3.4 Welding Spinner

. The dimmer stat controls the speed of the spinner and digital rpm indicator reads the speed. The tack welding is performed on the tack welding fixture and root gap between pipes is maintained with the help of feeler gauge. The tack welding fixture is as shown the Figure 3.5.

Figure 3.5 Tack Welding Fixture
Figure 3.6 Solid edge Modelling of Welding Fixture

Two types of electrodes namely DONEARC and ESAB electrodes of AWS code E6013 and E7018 are used in this work depending upon OA and its factors. DONEARC is most commonly used electrode for all general purpose welding and ESAB is special purpose electrode.

Table 3.2 Composition of DONEARC E6013 Electrode

<table>
<thead>
<tr>
<th>Elements</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>0.082</td>
<td>0.018</td>
<td>0.546</td>
<td>0.028</td>
<td>0.008</td>
<td>0.026</td>
<td>0.002</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Table 3.3 Composition of ESAB E7018 Electrode

<table>
<thead>
<tr>
<th>Elements</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>0.054</td>
<td>0.001</td>
<td>0.465</td>
<td>0.016</td>
<td>0.013</td>
<td>0.016</td>
<td>0.002</td>
<td>0.008</td>
</tr>
</tbody>
</table>

3.2 DESIGN OF EXPERIMENTS BASED ON TAGUCHI METHOD

In this study, the process parameters affecting SMAW quality have been identified based on the field expert’s suggestions, literature survey and on scientific reasons. In general influence of selected parameters on welding quality are discussed as below
1. Welding current (A)

In shielded metal arc welding (SMAW) welding current is one of the important parameter. Welding current depends on both the thickness of the metal to be welded and diameter of the electrode. High welding current results in higher deposition rates, increased depth and width of penetration. With low welding current, difficulty is experienced in striking and maintaining a stable arc. The electrode tends to stick to the base metal and results in poor fusion followed by poor penetration.

2. Welding speed [Spinner speed (B)]

Welding speed is the rate at which the welding electrode moves in the direction of welding or along the weld joint. At low travel speeds, the electrode deposition is high and at welding arc impinges on the molten pool rather than the work piece. At increased travel speeds, the thermal energy transmitted per unit area of the weld increases and then decreases. At very high speeds there is insufficient deposition of the filler metal which may result in welding discontinuities.

In this investigation welding of pipe is performed with the help of welding spinner also called as welding pipe line spinner, it holds the tack welded pipes between dead and live centres and rotates. Rotation of spinner is controlled by controlling the speed of its motor. From revolutions per minute (rpm) of the motor welding speed in terms of
mm per minute can be calculated. However for easy comparison among various levels and for perceptibleness, welding speed is substituted by spinner speed. It also helps in fixing factor level as integer like 3rpm, instead of 452.16 mm per minute. Welding speed is same for given rpm as long as pipe diameter is not changed. Therefore spinner rpm is considered in place of welding speed and it is quoted as just speed henceforth. Further diameter of pipe is not taken as parameter, analysis and optimization is carried out for a particular pipe diameter.

3. Angle of electrode (C)

In SMAW there are two electrode angles that the welder must control. First angle is one which forms between electrode and the pipe to be welded, called work angle. The second angle is the angle between the electrode and the direction of travel called travel angle. Sometimes travel angle is also measured with the electrode holder. The terminology of the travel angle followed in this work is as shown in the Figure 3.7. The orientation of the welding electrode affects the welding bead shape and penetration to a greater extent than welding speed.

4. Root gap (D)

Root gap is the small distance (separation) between root faces of the pipes to be joined. The method of edge preparation for components to be welded depends on cost and time incurred. The type root gap employed depends on strength requirement of the joint.
In general, methods used for edge preparation are sawing, shearing, machining and flame cutting. The various edge preparations are square, single V, single U, single J, double V and so on. In the present investigation square butt root gap with varying root gap is considered as a factor with the objective of studying the influence of the root gap in obtaining leak proof joint.

5. Number of tack welds (E)

Number of tack welds improves the alignment between the pipes. It is essential that the pipes to be welded should be aligned for quality weld without any defects.

6. Electrode diameter (F)

A larger electrode diameter requires higher current for melting which results in higher deposition rates. A smaller electrode results in lesser deposition rates and low penetration and hence smaller electrode is used in multi pass welding, hard facing and in arc cutting.

Figure 3.7 Electrode Angles
7. Electrode classification (G)

Two different types of electrodes have been used for this work, E6013 and E7018. E6013 is very commonly used for all commercial welding. Features of E6013 are good flowing properties, stable arc even at low arc current. Whereas the features of E7018 are insensitive to the composition of the base metal, suitable for high speeds and deposition of tough crack resistance weld metal. The composition of E6013 and E7018 obtained by spectrum analysis is as given in the Table 3.2 and Table 3.3.

8. Electrode condition (H)

Preheating of electrodes and base metal are carried out to reduce cooling rate, shrinkage stresses, weld distortion and to remove moisture. In welding of pipes concern for the above is not so high but the presence of moisture in the electrode will reduce the quality of weld. Welding by damp electrode acts as a source of hydrogen and that may leads hydrogen cracking. Hence electrode condition is considered as a one of the quality influencing factor. Preheating of electrodes is performed in an induction furnace, electrodes are held at a temperature 80 to 120°C for about 1 hr.

9. Surface cleanliness (I)

Generally pipes are received in a condition not suitable for welding, the uncovered metal surface may corroded, may contain oils, grease and dust. The pipes with protective coating are not amicable
for welding processes. Hence proper cleaning of the surface is necessary to remove surface contaminations. Therefore in the present work, surface cleanliness is taken as a one of the factor influencing the welding quality. Pipe surface is cleaned by emery sheet of grit size 80, pipe is cleaned while it is rotating in the spinner at low rpm as shown in the Figure 3.8.

![Figure 3.8 Cleaning of Rotating Pipe Surface](image)

**Table 3.3 Welding Parameters, Corresponding Notations and Units**

<table>
<thead>
<tr>
<th>SL.NO</th>
<th>Parameters</th>
<th>Notations</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Current</td>
<td>A</td>
<td>Amperes (A)</td>
</tr>
<tr>
<td>2</td>
<td>Spinner speed</td>
<td>B</td>
<td>rpm</td>
</tr>
<tr>
<td>3</td>
<td>Angle of electrode</td>
<td>C</td>
<td>Degree</td>
</tr>
<tr>
<td>4</td>
<td>Root gap</td>
<td>D</td>
<td>mm</td>
</tr>
<tr>
<td>5</td>
<td>Number of tack welds</td>
<td>E</td>
<td>In numbers</td>
</tr>
<tr>
<td>6</td>
<td>Electrode diameter</td>
<td>F</td>
<td>mm</td>
</tr>
<tr>
<td>7</td>
<td>Electrode classification</td>
<td>G</td>
<td>AWS code</td>
</tr>
<tr>
<td>8</td>
<td>Electrode condition</td>
<td>H</td>
<td>As received/preheat</td>
</tr>
<tr>
<td>9</td>
<td>Surface cleanness</td>
<td>I</td>
<td>As received/Emery cleaned</td>
</tr>
</tbody>
</table>
The parameters and corresponding notations and units are shown in the Table 3.3. Experiments are conducted as per OA L₉ for all the four pipes namely Ø48×3mm, Ø48×4mm, Ø60×3mm and Ø60×4mm. To study interactions and some more suspicious factors second phase of investigation is planned. In the second phase welding is performed on the above said four types of pipes as per OA's L₁₂, L₁₆, L₃₁, and L₃₂. The parameters and their levels for various OA are discussed in the respective experimental analysis. Thus in total 127 pipes have been welded and same have been shown in the Figure 3.9.

3.3 LEAK TESTING PROCEDURE

One end of the welded pipe is closed by threaded end cap and other end is connected to the hydraulic hand pump with the help of adaptor and hydraulic hose pipes, the leak test arrangement is as shown in the Figure 3.10.

Pressure is built up slowly by operating hand lever of the hydraulic pump up to 30bars testing pressure. In case of leak, leaking oil is collected in a beaker at 1bar gauge pressure and corresponding time is also noted. Thus leakage is expressed in ml per minute at 1bar gauge pressure. However amount of oil collected depends on given pressure and temperature and at atmospheric temperature it depends on pressure prevailing on the fluid. Therefore, leakage rate often expressed as product of pressure and volume per unit of time [138].
Figure 3.9 Lot Showing 127 Welded Pipes

Figure 3.10 Leak Testing Setup