Effect of Welding Current and Welding Speed on Weld Geometry and Distortion in TIG Welding of A36 Mild Steel Pipe with V-Groove Joint

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Abstract. In this study, the effect of welding current and welding speed on the weld geometry and distortion in TIG welding process was investigated. The material used in this experiment is A36 mild steel pipe. The dimensions of specimen were 114.3 mm of outer diameter and 6 mm of thickness. The wire feeder used was ER70-S 6 with a V-groove joint as a type welding joint. The welding parameters varied were the welding current and welding speed. Welding results will be tested for weld geometry (outer bead width) and distortion after the welding process. The weld geometry was measured using Digital Microscope and the distortion was measured using outside micrometers before and after the welding process. The results show that increasing the welding current can widen the weld bead and increase distortion. While increasing the speed has little effect on the weld bead and distortion. Welding parameters with a welding current of 170 A and a welding speed of 0.9 mm / s produces the widest outer bead and the biggest tapers and distortion.

1. Introduction
Welding has an important role in an industry, one of which is pipe welding. The gas, nuclear, oil, water and chemical industries are examples of an industry that applies pipe welding. In the industry, pipes are an effective means of transportation to flow from one place to another place. One of the problems in pipe welding is the depth of penetration and distortion that occurs after the welding process. If the welding penetration is too deep then the flow in the pipe will be interrupted. Distortion in welding pipes is interpreted as a change in the shape of the diameter of the pipe such as being oval, tapers, smaller or irregular, as shown in Figure 1. This will certainly interfere if the pipe will be installed in pipeline construction.

Many studies have been done by previous researchers about distortion. Sattari-Far [1] reported the results of his research that the welding sequence has an influence on the distortion that occurs. This type of joint uses a V-groove joint and the results of the experiment are compared with the FE model. In addition to verification the results are compared with FE modelling. Many studies use models such as finite element, ANSYS and ABAQUS to predict distortion and residual stress results from welding [2-5]. Kalyankar [6] made a review of distortion and methods to reduce the distortion that occurs. Distortion can be reduced before the welding process, during the welding process and after the welding process by several methods.
The objective of this study to determine the effect of welding current and welding speed on weld geometry and distortion on A36 mild steel pipe. The base metal has a diameter of 114.3 mm with a thickness of 6 mm and joined using a V-groove joint. ER 70S-6 is used as an added material to joint pipes [7]. Weld geometry measurements include the width of weld bead. While distortion is measured by changes in pipe diameter before and after the welding process.

![Figure 1. Distortion in pipe [1]](image1)

2. Experiment Method
In this experiment use A36 mild steel pipe with outer diameter 114.3 mm and thickness of 6 mm. The specimen was joint using wire feeder ER 70S-6 of 1.6 mm diameter. V-groove joint method was chosen with no gap between pipes. Figure 2 shows the schematic of V-groove joint of pipes. The chemical composition of base metal and wire feeder were listed in Table 1 and Table 2, respectively.

![Figure 2. Dimension of V-groove joint of pipe](image2)

| Table 1. Chemical composition (wt %) of A36 pipe |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                | C                | Si               | Mn               | P               | S               | Cr              | Mo              | Ni              |
| A36            | 0.183            | 0.233            | 0.392            | 0.013           | 0.007           | 0.017           | <0.005          | <0.005          |
|                | 0.003            | 0.007            | <0.002           | <0.002          | <0.002          | bal.            |                 |                 |
Table 2. Chemical composition (wt %) of ER-70S 6

|        | C  | Si | P  | S  | Cu |
|--------|----|----|----|----|----|
| ER-70S 6 | 0.06 | 0.8 | 0.025 | 0.03 | 0.5 |

All of the specimens were cut with a size of 55 mm and cleaned with sandpaper from grits 200-1000. Acetone solution was used to clean the remaining impurities. In this study, the type of welding used was Tungsten Inert Gas (TIG) welding using Dynasty 210 DX welding machine. Argon gas was used to protect the weld surface from oxidation with a flow rate of 11 L/min. A tungsten electrode was used EWTh-2 with a red code AWS with a diameter of 2.4 mm and a sharpening angle of 25°. TIG welding parameter variations used were welding current and welding speed. Welding position was 5G where the pipe was idle while the welding torch rotates automatically and welding starts at an angle of 330 degrees. The welding parameters were performed in Table 3.

Table 3. Welding parameters GTAW process

| No | Code | Welding current (A) | Welding speed (mm/s) | Arc efficiency (%) | Voltage (V) | Heat input (kJ/mm) |
|----|------|---------------------|----------------------|--------------------|-------------|-------------------|
| 1  | P-1511 | 150                | 1.1                  | 60                | 11.3        | 924.55            |
| 2  | P-1510 | 150                | 1                    | 60                | 11.3        | 1017.00           |
| 3  | P-1509 | 150                | 0.9                  | 60                | 11.3        | 1130.00           |
| 4  | P-1611 | 160                | 1.1                  | 60                | 12.45       | 1086.55           |
| 5  | P-1610 | 160                | 1                    | 60                | 12.45       | 1195.20           |
| 6  | P-1609 | 160                | 0.9                  | 60                | 12.45       | 1328.00           |
| 7  | P-1711 | 170                | 1.1                  | 60                | 13.4        | 1242.55           |
| 8  | P-1710 | 170                | 1                    | 60                | 13.4        | 1366.80           |
| 9  | P-1709 | 170                | 0.9                  | 60                | 13.4        | 1518.67           |

Weld geometry can be determined from width of weld bead (WoWB). The WoWB being measured was the outside of the pipe. The WoWB measurements start from 0 to 285 degrees with an increase of 15 degrees. This measurement uses a digital microscope (Dino-Lite).

Pipe distortion measurement can be measured by calculating the change in diameter before welding and after welding. Measurements were made with a variation of 4 sections from the welding point of 10, 15, 30 and 50 mm and measured from the axial and transverse direction of the pipe position, as shown in Figure 3. Each measurement location was measured using an outside micrometer with an accuracy of 0.01 mm. This measurement was carried out before and after welding at the same pipe position on both pipes to be welded. The difference from this measurement was used as the value of the distortion that occurs after the welding process. There are several types of deformation in the pipe after welded such as the oval, irregular and tapers in the direction of the axial and transverse pipe.

The value of transverse distortion (TD) and axial distortion (AD) can be found by using Equation 1:

\[
TD = D_{a1} - D_{b1}
\]

\[
AD = D_{a2} - D_{b2}
\]

(1)
where $D_{a1}$, $D_{a2}$ were pipe diameter after welded while $D_{b1}$, $D_{b2}$ were pipe diameter before welded in the transverse and axial direction. In addition to seeing the change in diameter of the pipe into an oval can be calculated using Equation 2 in each section of the pipe. If the calculation results for each section of the pipe were not the same then the diameter of the pipe has become oval. Tapers were the diameter of the pipe at one end with the other end of the pipe not the same in the direction of the axial or transverse pipe. It can be calculated using Equation 3:

$$\text{Oval} = AD - TD$$  \hspace{1cm} (2)

$$\text{Tapers} = AD_{\text{max}} - AD_{\text{min}}/TD_{\text{max}} - TD_{\text{min}}$$  \hspace{1cm} (3)

![Figure 3. Schematic measurement of distortion in the pipe](image)

3. Results and Discussion

3.1. Weld Geometry

One of the welding geometries can be determined from the width of weld bead (WoWB). Figures 4a and 4b show the weld surface profile of pipe welding in parameter code P-1611 and the average of outer bead width. Increasing the welding current can raise the average of outer bead width while increasing the welding speed can decrease the average of outer bead width. The widest of outer bead width at welding current of 170 A and welding speed of 0.9 mm/s and the smallest of outer bead width at welding current of 150 A and welding speed of 1.1 mm/s.

Increasing the welding current will indirectly increase the temperature, while the welding speed will affect the rate of temperature received by the material. If the welding speed slows down the temperature will also slow down which will widen the weld bead [8, 9].
Figure 4. (a) Photograph of the welding surface profile and (b) The average of outer bead width

Figure 5. Result of distortion test (a) axial distortion, (b) transverse distortion and (c) ovality in each section of pipes
3.2. Distortion

The calculation result of axial distortion, transverse distortion and ovality in millimeter (Equation 1-3) as shown in Figures 5a, 5b and 5c, respectively. The left pipe and the right pipe were measured in diameter in each section (see Figure 3) in the axial and transverse direction. The results show that axial distortion and transverse distortion decrease in each section. Ovality in the pipe can be determined from the difference between AD and AT in each section. The results show that after welding the pipe was ovality (see Figure 5c).

The closer from the welding point, the heat input and temperature will increase so that the distortion that occurs is greater while the farther from the welding point, the heat input and temperature will decrease so that the distortion that occurs is smaller [6, 10].

Figure 6 shows the comparison between heat input, tapers and maximum distortion in pipe welding. Heat input has a significant effect on tapers and the distortion that occurs. Raising the heat input can increase tapers and distortion. Axial tapers and axial distortion were greater than transverse tapers and transverse distortion. This was due to the welding point starts at 330 degrees or approaches transverse direction so that the heat received is not large enough but in the axial direction the heat received will be even greater. As a result, the tapers and distortion in the axial direction were getting bigger.

4. Conclusions

Generally increasing the welding current (hence, increasing heat input) can widen the weld bead and increase distortion whereas increasing the welding speed (hence, decreasing heat input) can reduce the weld bead and reduce distortion. The results show that welding current of 170 A and welding speed of 0.9 mm/s produces the widest outer weld bead. Based on the calculation of distortion, axial distortion and transverse distortion will decrease if getting further from the welding point. After the welding process, the pipe will also ovality. In addition, the results of tapers and distortion in the axial direction were greater than the transverse direction of the pipe. The highest tapers and distortion occur at 170 A welding current, welding speed 0.9 mm/s and the axial direction of the pipe.

Acknowledgments

This research is supported by the Master Program to Doctorate for Scholar Excellent (PMDSU) program of the Ministry of Research & Technology and High Education (RISTEK DIKTI) 2019 with contract number NKB-1855/UN2.R3.1/HKP.05.00/2019.
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