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The experiment of ambient wind speed and argon flow rate on tig welding process

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The experiment of ambient wind speed and argon flow rate on tig welding process

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Abstract. Tungsten inert gas (TIG) welding is one of the most popular welding which has high quality welds. TIG welding can be used for all kinds of welding positions and high efficient. During the welding process, the welding specimen and the heat affected zone (HAZ) affected by a series of thermal cycles where the area warms up to a maximum temperature then followed by cooling process. The thermal cycle affects the microstructure of the welding specimen and HAZ. By controlling these parameters to reach the right heat cycle, the mechanical property of the weld metal can be improved and maintain the microstructure of the weld metal. This study is conducted an experiment to determine the effect of different wind velocity around the TIG welding material. Moreover, this study also discuss the effect of shielding gas flow rate on TIG type welding on JIS G 3131 SPHC steel material. The welding area and HAZ the higher the wind speed the hardness value tends to decrease. Because there is a difference in cooling speed and heat input on weld metal and HAZ.

1. Introduction

1.1. Tungsten Inert Gas Welding

Tungsten inert gas (TIG) welding which is commonly known as GTAW (Gas Tungsten Arc Welding) is a process of welding without consuming tungsten electrodes. This welding process use inert shielding gas as a protector to avoid environmental air influence. In the TIG welding process metal smelting occurs due to heat generated by an electric arc between the electrode and electrode filler with the base metal. The TIG welding is one of the most popular welding technologies in manufacturing industries which has high quality welds. TIG welding can be used for all kinds of welding positions and high efficient. Low weld penetration is the main problem in TIG welding [1]. TIG welding has limited thickness of material that can be weld in single pass about 2-3 mm thick plate. In thick material this welding type causes poor productivity resulted by many factors such as low energy input, welding speed and high number of passes required to fill the weld join [2]. There are several factors that affected on welding process result such as filler material, inert gas, welding speed, local temperature welding area, welding penetration, and so on.

A low carbon steel material tests to find the effect of the welding current on the tensile strength, hardness and microstructure of the TIG welding with E6013 electrodes. The welding treatment use current variation of 80 Amperes, 100 Amperes and 120 Amperes in AISI 1045 steel. The strength testing of the welding material showed that higher current resulted in decrement of material strength in tensile strength. Moreover micro-photo testing shows that the greater the current used in welding the lower the porosity will occur[3]. Previous research shows for low carbon steel material using V temper and ER 70S-6 filler that using 100 A current gives 522.2 HVN and 120 A current gives 623.2 HVN. It means that higher current will give higher hardness number [4]. Also, other research states a 28% hardness change of the weld metal, the HAZ showing a 30% hardness difference increase, and no significant change in the base metal when the current [5].

The current and speed of welding process combine as improvement step to maintenance the microstructure of welding material. In an experiment study, the higher current and welding speed resulted better improvement on material microstructure in mild steel (low carbon steel). It results high yield strength and ultimate strength on material compared with base material especially on 75 A with 1.75 rpm welding speed[6]. The optimum value of current and welding speed parameter is adjusted with the welding material used. In Incoloy 800HT plates which tested on TIG welding process in various current and welding speed. The welding process is using various electric current in 90, 110 and 130 A. The welding speed which used in the process is various among 1.2, 1.5 and 1.8 mm/s. The optimum welding parameter which suitable for Incoloy 800HT is using 110 A current and 1.5 mm/s[7]. The welding current has significant influence around 58% and followed by the influence of welding speed 30% and voltage 12%.

Welding process causes temperature raising in local area which causes thermal expansion and shrinkage during cooling time. The thermal stress in local welding area is able to change the when it has short duration of cooling time, the welding material become harder and brittle. This condition results weld cracks and can be endanger the welded construction[8]. Arc welding process is applied to produce hard-faced weld metals on high strength surfaces such as low alloy, grey cast iron, carbon steel, or alloy steel by control some parameter such as welding process, welding parameter, and electrode. By controlling these parameters to reach the right heat cycle, the mechanical property of the weld metal can be improved and maintain the microstructure of the weld metal. The suitable heat cycle of the welding process is required to produce high quality welding joint. Furthermore, the control of heat cycle during the welding process such as input heat, pre-heat, inter-pass, and post-heat temperature is able produce a reinforce particle which resulted increment of the hardness and strength of the weld metal[9], [10], [11].

1.2. Thermal Affected Welding Area

In an experiment hard-faced weld metal was produced on JIS-S50C carbon steel using the welding process parameter was 100 A welding current, 50-450°C of pre-heat and inter pass temperature. The increase of the inter pass temperature resulted the increment of the grain size, but decrease the hardness and the wear resistance of the hard-face weld metal. Low inter pass temperature increase residual stress and lead cracking on the interface between the first weld metal layer and the base metal[12]. Annealing process also could be a heat treatment to increase material hardness after welding process. Experimental research shows annealing process on material ST 42 low carbon steel has significant effect in material hardness increment. The material which is ready welded compared with basic material specimens in impact test. The material is welding in TIG using ASTM E6011 specifically low carbon steel and current used 78-125 A. The annealing heat treatment is various at 600°C, 650°C and 700° C at 30 mins. The welding material with 700°C annealing process, shows slight difference result compare with basic material. The higher the temperature used in annealing process generate higher toughness value which can take after the toughness of the basic material[13].

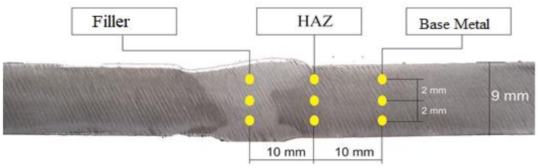

Figure 1. The classification area of temperature cycle effect on TIG welding process.

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During the welding process, the welding specimen and the heat affected zone (HAZ) affected by a series of thermal cycles where the area warms up to a maximum temperature then followed by cooling process. The thermal cycle affects the microstructure of the welding specimen and HAZ which shown in figure 1. In the HAZ area, grounding without annealing changes in the micro structure. This change is marked by the growth of crystal grains. In this area the structure is martensitic because the structure is small and elongated. The increase in the value of violence in the HAZ area is the highest. This high increase in hardness value occurs because in this area there is a rapid thermal heating and cooling cycle[14]. The welding specimen undergoes a series of phase transformations during the cooling process where the molten welding metal turns into Ferrite-δ then γ (Austenite) and eventually becomes α (Ferrite). In general, cooling time between 800^{o}C – 500^o C. is used as a reference for carbon steel welding, because at this temperature interval a phase transformation from Austenite (γ) to Ferrite or Bainite depends on the cooling speed. The duration of cooling in a certain temperature region of a thermal cycle of a weld greatly influences the welding quality. Some researches have been done to extend the duration of cooling time. The microstructure and mechanical properties of the HAZ region largely depend on the cooling time from temperatures of 800^{o}C to 500^{o}C, while cold cracks in which hydrogen plays an important role are highly dependent on the cooling duration from temperatures of 800^{o}C to 300^{o}C or 100^{o}C.

Beside the parameters mentioned earlier, other parameters derived from the environment can also have an influence on welding results such as temperature and pressure on the environment. Ambient temperature around the weld material has a material influence on the cooling process. The cooling process affects the microstructure of the material and establishes the material strength. The cooling temperature is determine the hardness level of the material, whether the material becomes hard or brittle. The cooling temperature can be determined by ambient temperature, wind velocity or even the weather. This study is conducted an experiment to determine the effect of different wind velocity around the TIG welding material. Moreover, this study also discuss the effect of shielding gas flow rate on TIG type welding on JIS G 3131 SPHC steel material.

2. Experimental set up

This experiment study conducted in JIS G 3131 SPHC steel with 9 mm thickness in single V TIG welding. The material welds on horizontal position or down hand welding. The metal fillers used are ER 70 S-6 with a diameter of 2.4 mm. The argon gas which used in this experiment flows at 9 L/min, 11 L/min and 13 L/min. This welding processes conducted in various in wind speed used are 3 mph, 5 mph, 7 mph. After welding process the material tests on hardness, macro structure and microstructure test.

2.1. Welding Step

- The material cut into 60 mm x 30 mm and clean the surface from the dirt. The less neat remaining pieces polish on oxide with brush wheel hand grinding. The dimension of the material is shown in figure 2. The brush wheel is used to clean the surfaces from oxide contamination and corrosion.
- The V tempers welding made by a hand grinding with 60^o. Then grinding the material in the same direction so that the surface of the tempers is flat. After the steel is tempered, the steel is connected with a 2 mm root pass with an angle of 60^o. A tack weld is implemented at the ends of the steel to avoid the deformation and clean the dirt with a steel brush so it does not affect the welding results during the root pass, filler pass and capping process.

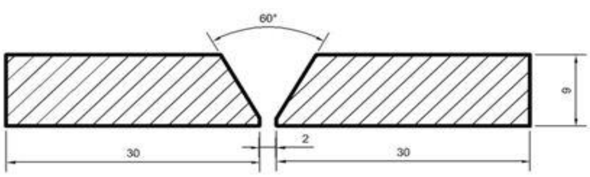

Figure 2. The dimension of TIG Specimen test.

- Set up the welding material in the TIG welding machine. Set the welding on 100 A current and open the Argon gas flow rate of 9 l / m, 11 l / m, and 13 l / m. The filler used is ER 70 S-6 2.4 mm in diameter.
- Set up the fan to reach the wind speed parameters in 3 mph, 5 mph, and 7 mph and measure the speed with anemometer.
- Weld the root pass and does the welding process stable welding speed. Cleaning impurities with a steel brush is an important part and make sure to fill the tempers neatly. This process is completed by capping step.

2.2. Metallography Test

- The hardness test on the specimen is carried out up to three points on one specimen. This test is carried out on the specimen before the welding process and on the specimen after the welding process. The method used in this hardness test is the Rockwell method. Rockwell used in this test is Rockwell C with HRC units and carried out using a 150 kg (981 N) load using a 120^o diamond cone indenter for 30 seconds. The material is cut into cross section direction of the welding line after the welding process complete.
- Macro test is carried out after the specimen is cut transversely at both ends so that the base metal, HAZ area and weld metal appear to have no welding defects. After that sandpaper with rubbing paper grade 100, 500, 1000, 1200 and 1500. Sanding is done in the same direction. After sanding process, polishing is done using wool and auto sol paper. Then the etching process is done using NHO_3 liquid. The macro pictures using the camera.
- Microstructure tests conducted in few steps. First the mounting process is carried out by giving a mixture of resin and catalyst in a ratio of 10: 1 which is poured into the cast. When mounting has hardened then the grinding process is done by first adjusting the grinding rotation and water flow rate. The polishing process is done by installing a polishing cloth smeared with alumina paste and adjusting the rotation speed and water flow until the specimen becomes smooth and shiny. The surface of the material is smeared with nitric acid: alcohol = 5%: 95%. Then the specimen is washed, dried and observed using an optical microscope.

2.3. Microstructure point count (ASTM E562)

Point count ASTM E562 is a method to determine the percentage of phases in a metal. By using a formula:

$$\%\,point\ phase = \frac{total\ phase}{total\ point} \times 100\% \quad (1)$$

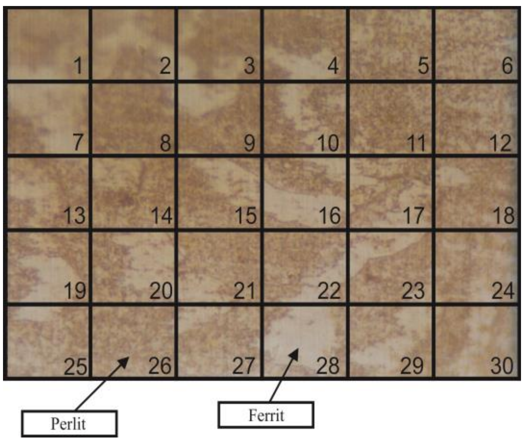

Figure 3. The calculation of ferrite and pearlite at 3 mph wind speed with a discharge rate of 9 L/min on HAZ

Using this method, observation is focused on weld metal and HAZ area. Then, the percentage of ferrite and percentage of pearlite will be obtained. With the data obtained and then made in the form of graphs and then analysed. The microstructure of the weld metal with a discharge rate of 9 L/min is shown in Figure 3. A grid contains a number of points with a certain number that is placed on the microstructure images. The number of points associated with the phase compared to the total points on the grid result the volume fraction of the phase. In order to get more accurate, more points on the grid can be used. The exact point on a particular phase is counted 1 (one), while those who stick to the edge of the phase are counted ½ (half).

3. Result and Discussion

3.1. Rockwell test

Rockwell experiment data were taken at one point in the weld metal area, HAZ and base metal. This comparison aims to determine the strength of the material from each point affected by the thermal cycle effect on the welding process. Based on table 1 the highest hardness value (HRC) is found in the weld metal followed by HAZ and base metal. From the data in table, it can be seen that the highest hardness value (HRC) is found in the weld metal area with a value of 33.25 HRC. Meanwhile the lowest hardness value is found in the base metal area with a value of 25.875 HRC.

The average value of hardness in the weld metal area is relatively decreased with increasing wind speed. The lowest hardness is at 7 mph wind speed with a shielding gas flow rate of 11 L/min with a hardness value of 29 HRC. The highest hardness in the weld metal area is at 3 mph wind speed with a p shielding gas discharge rate of 9 L/min with a hardness of 33.25 HRC. However, at 3 mph wind speeds with a flow rate of 13 L/min the hardness value rises according to the various in flow rate gas.

Table 1. The result of hardness test using Rockwell method

Argon Flow rate (L/min)	Ambient wind Velocity (mph)	Rockwell test (HRC)		
		Weld metal	HAZ	Base Material
9	3	33,25	29	27
	5	30,875	28,5	27,75
	7	30,25	28	27,25
11	3	30,875	30,25	27,375
	5	29,875	28,375	27,7
	7	29	28,25	27,12
13	3	31,875	29,5	27,125
	5	31,5	28,625	27
	7	30,125	28,25	27,12

In the HAZ area the greatest hardness value is 30.25 HRC at 3 mph wind speed with a shielding gas flow rate of 11 L/min and the lowest hardness value is 28 HRC at 7 mph wind speed with a shielding gas flow rate of 9 L/min. From the graph it can be concluded that the welding metal and HAZ the higher the wind speed the hardness value tends to decrease. Because there is a difference in cooling speed and heat input on weld metal and HAZ. The presence of wind speed that directly leads to the weld metal affects the mechanical properties of the steel. Conversely, the greater the flow rate used the average value of violence tends to rise.

Whereas in the main metal area the greatest hardness value is 27.375 HRC at 3 mph wind speed with shielding gas flow rate of 11 L/min and the lowest hardness value is 27 HRC at 3 mph and 5 mph wind speed with shielding gas flow rates of 9 and 13 L/min. In general, the average value of the base metal is relatively the same. On the base metal the average value of hardness tends to be the same and there is a slight difference according to the time of testing the suppressor indenter is not always right on the pearlite or ferrite phase. Sometimes the indenter presses on the pearlite phase so that the hardness rises, and sometimes the indenter presses on the ferrite phase so that the average value of hardness decreases. However, the values of the hardness of the base metal are relatively the same.

3.2. Microstructure test

In this study macro test shows the HAZ area, weld metal, and base metal, in JIS G3131 SPHC material using single V tempers with an angle of 60^o currents 100 A. Table 2 shows the point phase of welding material which process on 9, 11 and 13 L/min of argon gas in variation of wind speed 3, 5 and 7 MPH. From this table an increase in the argon gas flow rate in the welding process can cause a decrease in the percentage of phase ferrites in the welding area and the HAZ. The decrease in the percentage of ferrite in the weld specimen is followed by an increase in the percentage of the pearlite structure. Moreover the decrement of the ferrite structure is also influenced by an increase in wind speed around the weld specimen.

Table 2. The result of phase percentage on the microstructure

Wind Speed	Argon Gas Flow rate (L/min)	Welding Area		HAZ	
		% Ferrite	% Perlite	% Ferrite	% Perlite
3 mph	9	56,6	43,4	50	50
	11	43,4	56,6	40	60
	13	43,34	56,66	33,34	66,66
5 mph	9	40	60	46,67	53,33
	11	53,33	46,67	60	40
	13	53,33	46,67	56,67	43,33
7 mph	9	36,66	63,34	36,66	63,34
	11	33,34	66,66	63,34	36,66
	13	40	60	56,66	43,34

The microstructure in the weld and HAZ area is dominated by ferrite and pearlite. The grain size in the HAZ area is bigger than the weld area as a result of the influence of heat on welding. Figure 4, 5 and 6 shows the argon gas discharge of 9 L/min, the structure of pearlite tends to decrease along with the increase in the amount of ferrite. But the pearlite grain boundaries still has big structure size, this is due to the greater wind speed that is 5 mph. At a wind speed of 5 mph the amount of ferrite is finer compared to the speed of 3 mph. The average value of ferrite is 40% and pearlite is 60%. There was a decrease from the previous speed of 3 mph. At a speed of 7 mph according to the calculation, the amount of ferrite was 36.66% and the number of pearlite was 63.34%. The decrease in the amount of ferrite and pearlite is caused by the presence of wind speeds of 7 mph which directly enter the welding area. Thus causing reduced heat input to the metal. The greater the heat input applied to the steel, the greater the amount of pearlite produced. So, the average value of hardness has also increased. At 7 mph the number of pearlite and ferrite decreased significantly.

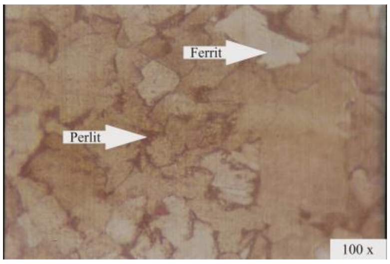

Figure 4. Microstructure of weld metal at gas discharge 9 L/min with wind speed of 3 mph.

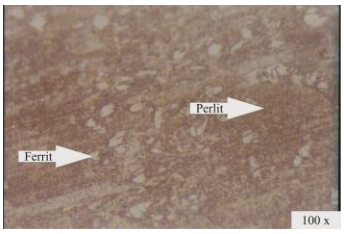

Figure 5. Microstructure of weld metal at gas discharge 9 L/min with wind speed of 5 mph.

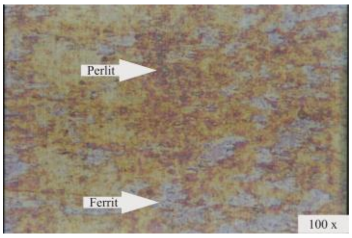

Figure 6. Microstructure of weld metal at gas discharge 9 L/min with wind speed of 7 mph.

3.3. Macro structure test

In this study macro test shows the HAZ area, weld metal, and base metal, in JIS G3131 SPHC material using single V tempers with an angle of 60º currents 100 A. Figure 7, 8 and 9 shows welding material which process on 9 L/min of argon gas in variation of wind speed 3, 5 and 7 mph. It has a wide weld pool but the penetration is not deep enough so that more welding inter pass layers are needed. Root pass in 3 mph variation is difficult to do so at the discharge of 9 L/min using back weld to prevent welding defects. In macro photos of HAZ areas can be seen in darker areas around the weld area. The thermal cycle change microstructure of the welding material. From the figure 7, 8 and 9 it can be seen that the length of the HAZ change along with increasing wind speed. Table 2 shows the change in the length of the HAZ area in the variation of wind speed around the welding material. Based on table 3 the material which is cooling with 5 mph air speed has the longest HAZ length in welding with argon gas discharge 9 L/min. The shortest HAZ length is found in welding material cooled by 7 mph wind speed. This high increase in hardness value occurs because in this area there is a rapid thermal heating and cooling cycle. In the HAZ area of grounding without annealing there has been a change in the microstructure characterized by the growth of pearlite crystal grains. In this area the structure is martensitic because the structure is small and elongated. In the HAZ region the welding with annealed critical temperature has begun to change. In this area the ferrite structure is larger than the pearlite.

Figure 7. Macro structure of weld metal at gas discharge 9 L/min with wind speed of 3 mph.

Figure 8. Macro structure of weld metal at gas discharge 9 L/min with wind speed of 5 mph.

Figure 9. Macro structure of weld metal at gas discharge 9 L/min with wind speed of 7 mph.

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Table 3. The result of HAZ length at gas discharge 9L/min with various wind speed.

Wind Speed (mph)	HAZ length (mm)
3	3,05
5	3,42
7	2,82

4. Conclusions

In the TIG welding process the HAZ area gives a slight enhancement of hardness with increase in argon flow rate. This is because during the welding process the HAZ area is affected by the welding heat cycle. Then the HAZ area will experience a rapid decrease in temperature due to the cooling process. During the heat cycle of the weld, the HAZ region changes the microstructure phase by decreasing the amount of ferrite and increasing the structure of the pearlite with increase in wind speed. The macrostructure results reveal the HAZ length getting smaller with the escalation of wind speed.

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