COMPARISON OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF HARD-FACING WELDS GENERATED BY GTAW AND OAW WELDING PROCESSES

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ABSTRACT

There are many welding processes can be used to perform hard-facing welds. The objective of this research is to compare the microstructure and mechanical properties of the welds that performed by two welding processes: oxyacetylene and gas tungsten arc welding. Base metal is low carbon steel and fused tungsten carbide is used as a filler metal. Various experiments are carried out by that processes. For GTAW, the current are varied from 90 to 120 ampere at constant welding speed. Carburizing flame is used in oxyacetylene welding process. The result is exhibited that at the current of 110 ampere the distribution of tungsten carbide in weld metal is even. The hardness of the welds using OAW is higher than that of GTAW process which is 868.86 HV and 664.5 HV in respectively. For the welds microstructure of both processes are consisted of ferrite and pearlite with fine grain structure. In addition, the welding speed has an effect on the microstructure and mechanical properties of the welds.

1. INTRODUCTION

Nowaday, welding processs has been developed for convenience for further use and greater efficiency. Different welding methods cause different welding efficiency, dilution ration, and welding cost. Therefore, consideration must be given to welding process selection in order to fulfil requirement of work (W.Wo & L.T.Wu,1996). Effect of heat input is another factor influencing bead quality such as penetration, width, height, and heat affected zone (HAZ) of metal (Cited Dec 21 2015).

Hard-facing welding process is a popular method for repairing surface of worn parts. Several factors affecting result of welding include type of electrode, material type and so on (Sukangkana Lee, 2012). Operating hard-facing welding process must consider the appropriateness of material and welding process since these factors can increase service life of parts (Yongyuth Dunyakul, 2012).

Oxy Acetylene Gas Welding is one of the processes used in hard-facing welding process since it is convenient and provides high temperature. It can penetrate high hardness materials such as tungsten carbide. However, the use of acetylene must consider operation safety and law (N. Parkin & C.R. Flood 1979). Different welding method results in mechanical properties and microstructure of metal.

The objective of this research is to compare microstructure and mechanical properties of hard-facing welding process using Tungsten Inert Gas Welding Method and Oxy Acetylene Welding Method. Materials used in hard-facing welding is Fused Tungsten Carbide: Fused WC.

2. EXPERIMENT

2.1 Experimental Apparatus

Materials used in this study is SS400 grade carbon steel with dimension of 100x150x12 mm. Electrodes used are Fused WC with 3.5 mm diameter. Hard-facing welded work pieces are then cut and only the middle of work pieces are used to test microstructure and mechanical properties (Figure 1).

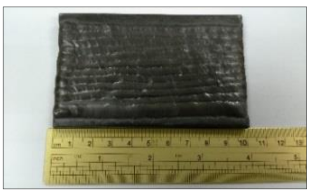


Figure 1. Work piece for microstructure and mechanical properties testing.

2.2 Technique

2.2.1 Experiment Design

For the method of Tungsten Inert Gas Welding, the welding parameters are current, voltage, tip angle, and welding speed (Table 1). Welding current is set at four levels (90, 100, 110, and 120 Amp). Welding current is important for mechanical properties (Noppakorn and Isaratat,2008) Voltage is 14.3 V. and tip angle is 15º. Welding speeds used are 9.2, 11.2, and 15.3 cm/s. For the Oxy Acetylene Welding Method, the welding condition are shown in Table 2.

Table 1. Parameters of Tungsten Inert Gas Welding.

Welding parameters	Value
Welding current (Amp.)	90, 100, 110, 120
Welding voltage (V.)	14.3
Tip angle (degree)	15
Travel speed (cm/min)	9.2, 11.2, 15.3

Table 2. Parameters of Oxy Acetylene Welding.

Welding parameters	Value
Flame	Carburizing
Oxygen pressure (lb./in2)	3-5
Acetylene pressure (lb./in2)	3-5
Tip angle (degree)	15
Travel speed (cm/min)	4.3

2.2.2 Hardness Test

Result of hardness test can be used to analyze property of materials such as wear resistance (Somnuk Watanasriyakul,2006) For the hardness test in this study, the indentation is made on the work piece horizontally and vertically as shown in Figures 2 and 3.The welding current that provides the greatest hardness is selected to determine the travel speed with the greatest hardness.

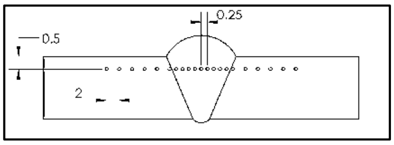


Figure 2. The horizontal indentation of the work piece.

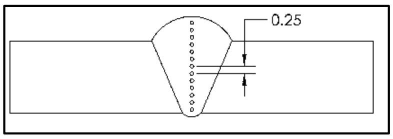


Figure 3. The vertical indentation of the work piece.

3. ANALYSIS

3.1 Hardness Test

The result of hardness test shows that Tungsten Inert Gas Welding with welding current of 110 Amp. provides the greatest hardness (664.5 HV). Then, the work pieces with current condition of 110 Amp. with different travel speeds are then compared. It is found that the travel speed of 11.2 cm/min yields the greatest hardness (Figure 4).

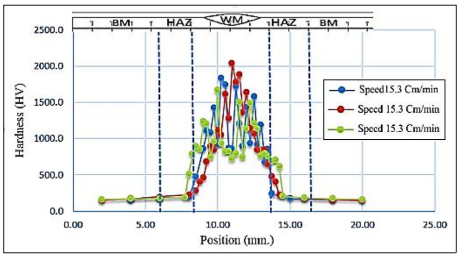


Figure 4. The relationship between travel speed and hardness

3.2 Macrostructure

After investigating the macrostructure of Tungsten Inert Gas Welding, it is found that different welding current influence welding bead (Figure 5). Welding current of 90 Amp. results in small bead and low penetration. This is because lower current causes rapid cooling. Therefore, tungsten carbide is spread all over the bead. Welding current of 100 Amp. makes it easier to control the melting of electrode and also results in perfect bead. By greater heat at the bead and the work piece, tungsten carbide is mostly placed at the bottom of the bead. For the 110 Amp. current, the electrode is well melted. The bead is perfect. The spread of tungsten carbide when using the 110 Amp. current is better than when using the 100 Amp. current. For the 120 Amp. current, the bead is wide and flat. Tungsten carbide is well spread. However, the penetration is too high. This can affect dilution of materials and change the mechanical properties (Noppakorn and Isaratat,2008).

Oxy Acetylene Welding with carburizing flame requires low oxygen flow rate. This can prevent the work piece from cracking of bead during welding and damage. Figure 6 shows that the bead is wider than the bead of Tungsten Inert Gas Welding and low penetration. Tungsten carbide is spread all over the bead. This helps controlling the flame of Acetylene feather (3x) to be twice longer than the flame of the inner cone (x) (Cited Dec 21 2015) as shown in Figure 7.

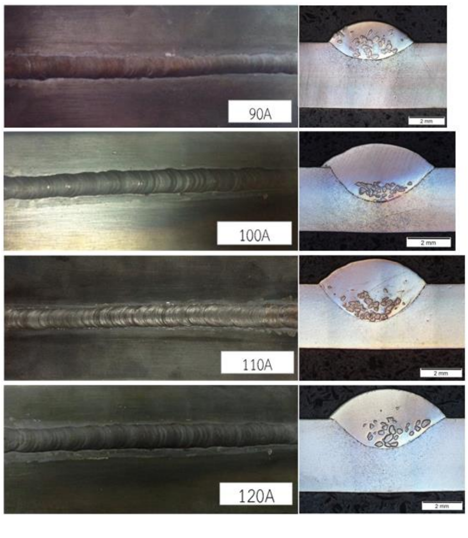


Figure 5. (a) TIG bead.

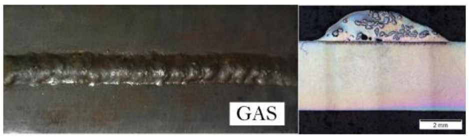


Figure 6. OAW bead.

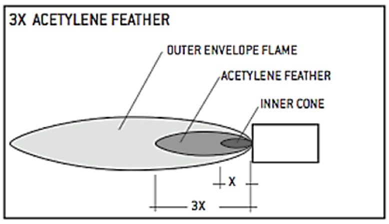


Figure 7. Oxy Acetylene flame (Cited Dec 21 2015).

3.2 Microstructure

Tungsten Inert Gas Welding has dendrite structure which composes of ferrite and pearlite. Different welding current and travel speed causes different percent of ferrite and pearlite as shown in Table 3. Lower welding current leads to bigger grain, whereas greater welding current leads to finer grain. Using 100 Amp. welding current brings about the similar microstructure as using 110 and 120 Amp. welding current. The grain size affects mechanical properties (Figures 7 and 8). Metals with small grain size and large number of grain have greater strength than those with big grain size and small number of grain. For the structure at HAZ area, the grain is long and fine. The grain of 90 Amp. welding current is bigger than that of 100 Amp. welding current. The grain sizes of 110 and 120 Amp. welding current are quite similar (Figures 7 and 8).

The microstructures of the Oxy Acetylene Welding and the Tungsten Inert Gas Welding are almost alike. From Table 3, it is obvious that the areas of weld metal, HAZ, and base metal of the Oxy Acetylene Welding shows high percent of perlite. This is because the Oxy Acetylene Welding produces greater heat and thus greater amount of heat accumulated in the work piece (Figures 9 and 10).

Table 3. Percent of ferrite and pearlite for each welding current and process condition.

No.	Welding process	Current (A)	Position	Microstructure	
				Ferrite (%)	Perlite (%)
1	TIG	90	Weld Metal	75.7	24.3
			HAZ	74.6 – 97.1	9.9 – 25.4
			Base Metal	82.5 - 88	12 – 17.5
2	TIG	100	Weld Metal	71 - 81.4	18.6 - 29
			HAZ	74.6 – 97.1	9.9 – 25.4
			Base Metal	82.5 - 88	12 – 17.5
3	TIG	110	Weld Metal	71 - 81.4	18.6 - 29
			HAZ	74.6 – 97.1	9.9 – 25.4
			Base Metal	82.5 - 88	12 – 17.5
4	TIG	120	Weld Metal	71 - 81.4	18.6 - 29
			HAZ	74.6 – 97.1	9.9 – 25.4
			Base Metal	82.5 - 88	12 – 17.5
5	OAW	Carburizing flame	Weld Metal	70 - 75	25 - 30
			HAZ	82.1	17.9
			Base Metal	82.1	17.9

Table 4. Percent of ferrite and pearlite at the travel speed of 11.2 and 15.3 cm./min.

Position	Microstructure			
	Ferrite (%)		Perlite (%)	
	11.2 Cm/min	15.3 Cm/min	11.2 Cm/min	15.3 Cm/min
Weld Metal	71.0	79.5	20.5	29.0
HAZ	90.1	83	9.9	17
Base Metal	88	85.3	12	14.7

From Table 4, when using higher travelling speed, percents of ferrite and pearlite are greater at weld metal area. This is because speed reduces heat accumulated in the work piece. However, at HAZ and base metal areas, the cooling down is slow. This results in lower percent of pearlite but higher percent of ferrite (Figures 11, 12, and 13).

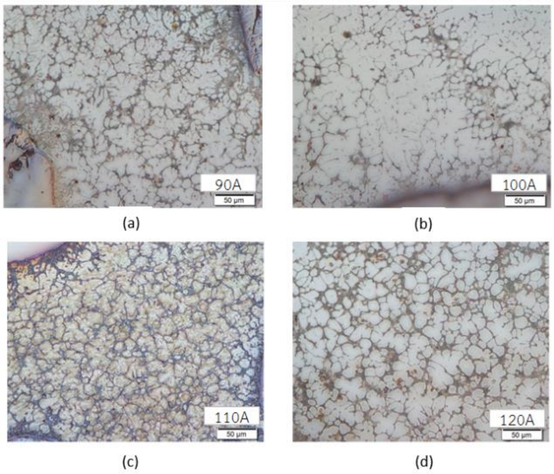


Figure 7. Microstructure at weld metal of Tungsten Inert Gas Welding.

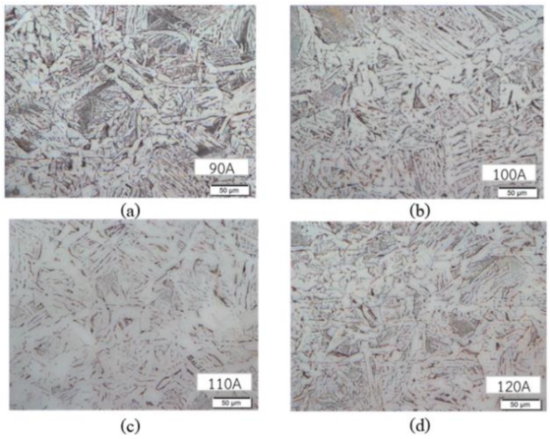


Figure 8. Microstructure at HAZ of Tungsten Inert Gas Welding.

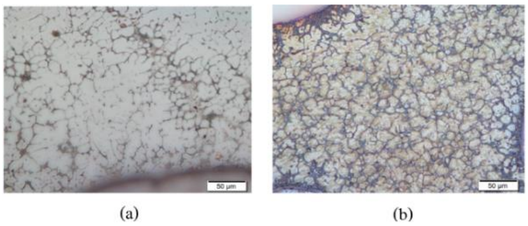
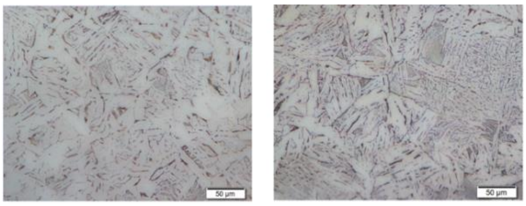
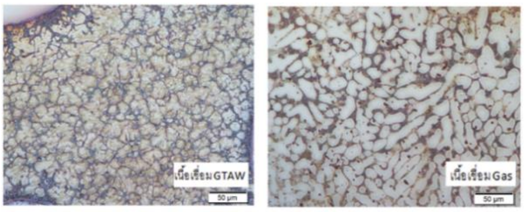


Figure 9. (a) Microstructure at weld metal area of Tungsten Inert Gas Welding. (b) Microstructure at weld metal area of Oxy Acetylene Welding.



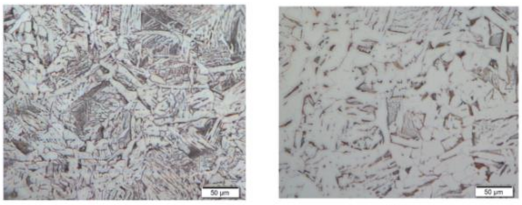
(a) (b)

Figure 10. (a) Microstructure at HAZ area of Tungsten Inert Gas Welding. (b) Microstructure at HAZ area of Oxy Acetylene Welding.



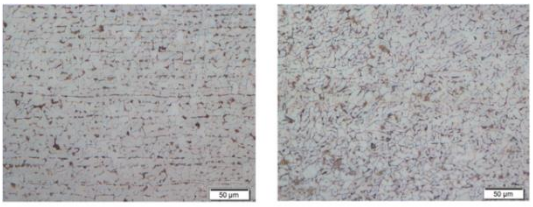
(a) (b)

Figure 11. (a) Microstructure at weld metal area with travel speed of 11.2 cm./min. (b) Microstructure at weld metal area with travel speed of 15.3 cm./min.



(a) (b)

Figure 12. (a) Microstructure at HAZ area with travel speed of 11.2 cm./min. (b) Microstructure at HAZ area with travel speed of 15.3 cm./min.



(a) (b)

Figure 13. (a) Microstructure at base metal area with travel speed of **11.2** cm./min. (b) Microstructure at base metal area with travel speed of **15.3** cm./min.

CONCLUSIONS

1. The process of Tungsten Inert Gas Welding with 110 Amp. welding current produces the most appropriate bead and the hardness of 664.5 HV. It also provides a well spread of tungsten carbide. Using the travel speed of 11.2 cm./min. results in high hardness and perfect bead.

2. For Oxy Acetylene Welding process with carburizing, it shows low penetration. Tungsten carbide is not melted with base metal. Since tungsten carbide is spread all over the bead, the bead has high hardness (868.86 HV).

3. Microstructure of both processes are ferrite and pearlite, but their grains are different. This affects mechanical structure of the materials.

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