The Penetration Depth of Weld Metal in Underwater Welding with Variations in Water Depth and Water Flow Velocity

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Abstract

Underwater wet welding (UWW) is widely used in the repair of offshore construction and underwater pipelines using the Shielded Metal Arc Welding (SMAW) method. This research was conducted to see the effect of flow (0 m/s, 1 m/s, and 2 m/s) and water depth (2.5 m and 5 m) on the depth weld metal penetration of the SS400 steel underwater welded joints. The control variables used were welding speed of 1.5 mm/s, current of 90 A, electrode E6013 (RB26) with a diameter of 4 mm, type of negative electrode polarity (DC), spraying distance of 10 cm, the direction of spraying in the opposite direction of welding, and fresh water. The results showed that the deeper and fast the flow velocity would decrease the depth of penetration and increases porosity. This is due to the decreased transferability of the molten metal during the welding process.

Keywords: *SMAW, underwater welding, macrostructure*

INTRODUCTION

Welding is a process of combining two metals of the same type or another type where the strength of the metal is expected to be the same as the strength of the parent metal [1]. One application of the current welding method is underwater welding or commonly called underwater welding which is a development of the welding process that is commonly used [2]. Underwater welding methods are divided into two main types, wet and dry methods [3][4]. The wet underwater welding process or commonly called underwater wet welding (UWW) is carried out in an environment that is directly exposed to water without a physical barrier between the water and the welding arc [5]. Meanwhile, dry underwater welding is carried out in a watertight enclosed space around the structure to be welded which is filled with a mixture of helium and oxygen gas [6].

UWW is widely used in offshore industries such as marine construction, pipeline repair, and nuclear power plants [7][8][9]. This is done because it is easy to perform, flexible, and has a lower cost compared to other underwater welding methods. One of the disadvantages of UWW is that the arc flame is not stable, so it can affect the results of the penetration of the liquid metal [10].

UWW parameters such as water flow rate, temperature, and water pressure have a significant impact on the welding arc [11]. The welding quality will change according to different water environmental conditions such as different water flows. Increasing water flow velocity causes a decrease in instability which will affect the weld yield. The arc weld protective bubble affects the arc. The arc weld guard bubble is a key factor that can keep the arc burning. A larger expansion size is obtained from a more stable weld. The maximum frequency of protective boasting decreases gradually with water pressure [7].

Most of the previous studies only focused on the microstructural characteristics and mechanical properties of wet underwater welding carried out in still water, whereas welding inflowing water conditions focused only on arch stability [12][13]. In conditions in the field, UWW is mostly carried out on the water with flowing conditions at a certain depth and speed. This condition is commonly found in wet underwater welding in seas, ports, and rivers. Limited research has been found on the effect of water flow and depth in wet underwater welding on the penetration depth of weld metal. So, it is necessary to carry out further research for the storage of weld metal depth which is carried out in underwater welding with variations in water depth and water flow velocity.

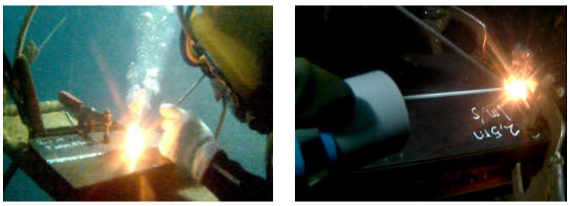
METODOLOGY

The material used in this research is low carbon steel SS400 with dimensions of 400 mm x 100 mm x 4 mm. SS400 is low carbon steel, which has a purity level of 96.4% [14]. Table 1 shows the results of the low carbon steel composition test based on the composition test that has been carried out.

Table 1. Chemical composition.

Element	Fe	C	Si	Mn	Cr
%	96,4	0,0337	0,193	0,288	0,0273

Welding is carried out in the water with a spray pump that is made in such a way as to get a specified water flow rate. The pump used is a 1.5 HP Yamamax with a discharge of 450 liters/minute. Input and output channels of 2 inches with a nozzle tip size of 1 ¼” inch. The controlled variables in this study were welding speed at 1.5 mm/s, current of 90 A, electrode E6013 (RB26) with a diameter of 4 mm, type of negative electrode polarity, 10 cm spraying distance, the direction of water flow was opposite to the welding direction and using freshwater. The underwater wet welding process is carried out at a depth of 2.5 m and 5 m with a variation of the flow velocity of 0 m/s, 1 m/s, and 2 m/s. Figure 1 shows the underwater welding process with variations without water flow and using water flow.



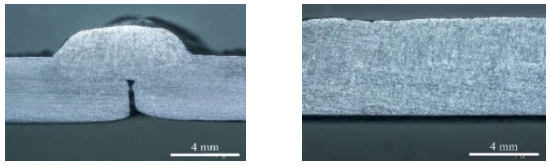
(a). Without water flow (b). With water flow

Figure 1. Welding process

After the welding process, the macro photo testing process is carried out using the Olympus macro test tool. This test aims to determine the defects that occur in the welding area and the depth of penetration of the weld metal.

RESULTS AND DISCUSSION

Figure 2 and Table 2 are the results of macro photographs of welding specimens cut Transverse and longitudinal. The macro photo test in Table 2 shows that there is a difference in weld penetration depth and porosity due to differences in welding depth and water flow velocity. Based on the results of the macro photo test shown in Table 2, it is clear that the increase in water flow velocity causes porosity. Underwater wet welding at a water flow rate of 2 m/s as in Table 2 (c and f), it is clear that there is a large porosity of the weld metal. Gas inclusions will increase with increasing cooling rate. Inclusions are oxides and other non-metallic objects that are trapped in the weld metal [9]. Welding that is subjected to water causes forced convection heat transfer. The higher the water flow rate is directly proportional to heat loss. This results in very rapid cooling compared to welding on land or in still water. This speedy cooling causes the fast solidification of the weld metal so that the gas in the liquid metal does not have time to escape [15][16]. Increasing the welding current and reducing the welding speed can increase the heat input. The higher heat input will reduce the cooling rate and the longer solidification time of the weld liquid metal so that the gas in the liquid metal can escape.



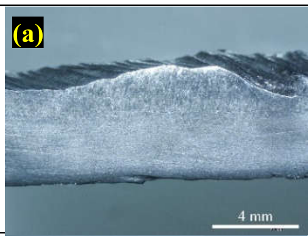
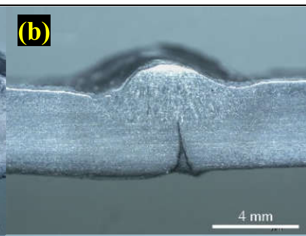
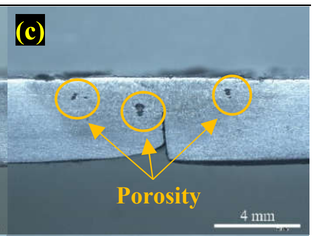
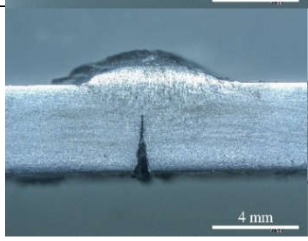
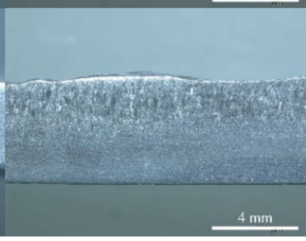
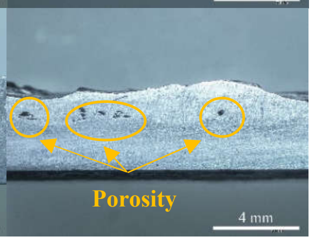
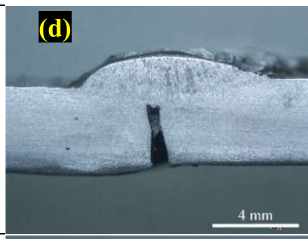
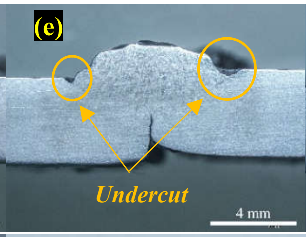
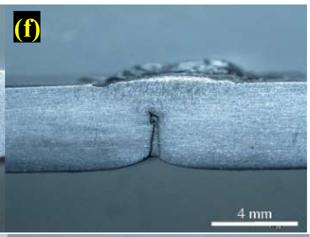
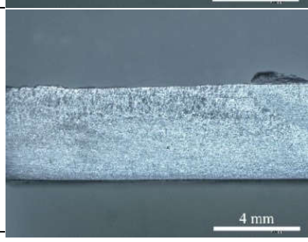
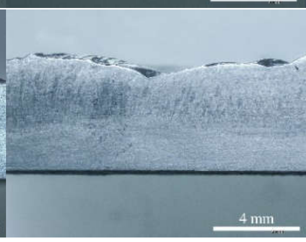
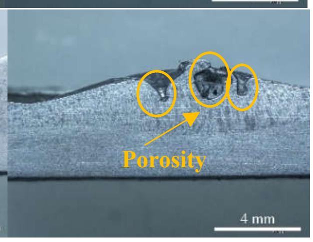
(a). Transverse (b). Longitudinal

Figure 2. Macro photo of ground weld

The results of welding at a depth of 2.5 m and 5 m with a flow rate of 2 m/s in table 2 (c and f) when compared, it can be seen that welding with a depth of 5 m produces a higher porosity than welding at a depth of 2.5 m. Fydrych and Rogalski (2014) stated that water is one of the primary sources of hydrogen. The increase in welding current and salinity causes a decrease in the hydrogen content.

The amount of hydrogen diffusion depends on water pressure or the depth of welding. Increasing the water depth causes higher hydrostatic pressure. The hydrostatic pressure causes weld protection bubbles to rise faster to the surface. Increasing the speed of the protective welding bubble to the surface and the smaller the bubble size causes less protection in the welding arc. Lack of protection of the arc weld from bubbles leads to increased porosity [18]. The gas that causes porosity that appears in the liquid metal will be difficult to escape due to the high hydrostatic pressure, as seen in the schematic of figure 3 (b). Figure 3 (c) describes the porosity scheme that occurs in the welding results in table 2 (g) where when the porosity gas bubbles start to come out of the liquid metal, freezing occurs very quickly so that porosity is formed which looks like gas bubbles rising to the surface.

Table 2. Macrostructure

Variation		Water flow		
		0 m/s	1 m/s	2 m/s
2,5 m	Longitudinal			
	Transverse			
5 m	Longitudinal			
	Transverse			

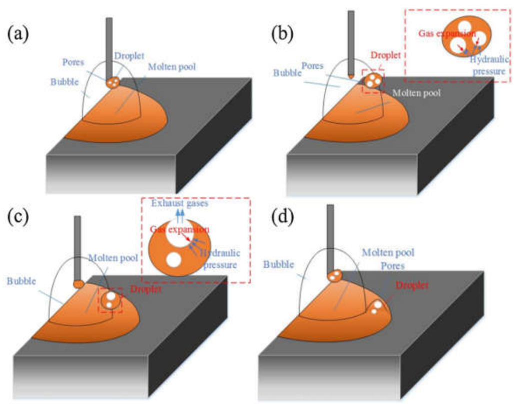


Figure 3. Schematic analysis of porosity during the droplet transition [19]

The results of direct metal penetration measurements shown in Figure 4 prove that the depth of welding and the velocity of water flow affects the penetration of the weld metal. Figure 4 shows the flow less welding with the welding depth below. Wet underwater welding without water flow produces the lowest penetration depth with a penetration depth of 0.9 mm at a depth of 2.5 m and 0.8 mm at a depth of 5 m. The results of wet underwater welding at a speed of 1 m/s show the highest penetration depth reaches 1.7 mm at a depth of 2.5 m or 5 m. The depth of penetration in the water flow with a speed of 2 m/s with a penetration depth of 1.4 mm at a depth of 2.5 m and a depth of 5 m.

The high pressure raises the boiling point of the water point and the compressed arc welding. Increasing the boiling point results in more weld heat being lost during process welding, which causes the dilution rate of the weld to decrease as depth increases [20]. The reduction in weld heat will decrease the weld penetration depth. Welding with water flow at a water flow rate of 1 m/s produces the deepest penetration depth caused by droplets which during the metal transfer process are pushed by water flow with a scheme as shown in Figure 4.

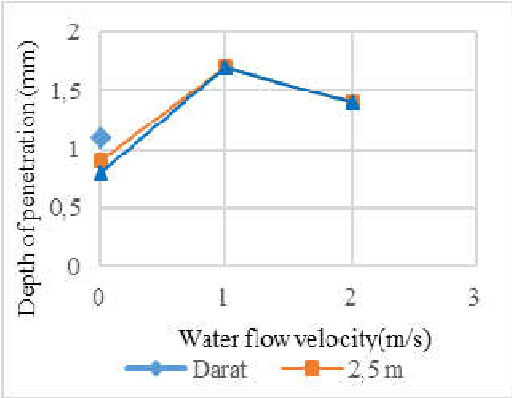


Figure 4. Graph of penetration of the weld

The weld liquid metal is pushed by water towards the back of the welding electrode and collects. which causes the heat energy received by the base metal to be more. The impulse of the water flow which dominates over the increase in cooling speed causes a deeper penetration of the weld metal[21][22]. Increasing water flow velocity up to 2 m/s causes high heat loss. The presence of high heat loss due to forced convection causes a reduced heat input so that the volume of the liquid metal decreases which results in a reduced penetration depth [19].

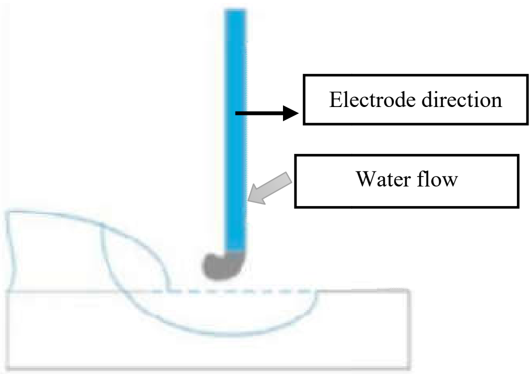


Figure 5. Schematic of droplet transfer

CONCLUSIONS

Based on the research results that have shown that the deeper the welding process and the higher the water flow velocity, the more porosity increases and the lower the penetration depth. This becomes the deeper the welding process, the higher the hydrostatic pressure so that the displacement of the molten metal during the welding process is imperfect.

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