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IMPACT TOUGHNESS OF ASTM A36 LOW CARBON STEEL BY METAL ACTIVE GAS (MAG) WELDING PROCESS USING DIFFERENT COOLING MEDIA

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This study was conducted to examine the immersion effect of cooling media used after the MAG welding process on impact toughness behavior of A36 steel plate. The media used in the experiment include air, water, and ice while CO_2 shielding gas and ER70S-6 filler metal were used in the MAG process. It is also important to note that the speed of the weld material cooling process has the ability to affect the hardness and toughness of the post-welding product. The experimental results showed that the use of cooling media affected the impact properties of the welding joint. The highest toughness value was recorded in the ice cooling media with 4,38 J/mm².

Keywords: ASTM A36 steel, MAG welding, cooling media, impact toughness, microstructure

INTRODUCTION

The technological developments in the increasingly advanced manufacturing sec-tor are related to the welding process. This is indicated by the recent construction activities using carbon steel which involves a lot of welding elements. Moreover, industries producing machinery and structures such as shipbuilding, piping, offshore building, and other engineering construction industries generally join metals through welding processes. This has, therefore, led to the continuous development of different studies on welding A36 carbon steel.

The measurement of the residual stress on welded ASTM A36 steel plates through the MAG method has been studied using non-destructive techniques including Magnetic Barkhausen Noise and X-ray Diffraction [1-2]. Moreover, process parameters such as welding current, welding speed, arc voltage, blur distance, the laser-to-arc distance at penetration depth, bead shape, arc stability, spark, and plasma formation have also been investigated in carbon steel [3]. The MAG process was also compared with Metal Inert Gas (MIG) and Tungsten Inert Gas (TIG) welding with the focus on the porosity formed by carbon steel welds based on the consideration of current, speed, and heat input during the welding process, and the results showed an increase in the heat input affected the distribution and size of the porosity, thereby, having further effects on the weld bead depth [4-5]. Meanwhile, an-other research focused on the MAG welding process on a thin steel plate or low carbon steel through Cold Metal Transfer (CMT) [6]. Therefore, the purpose of this current experiment was to determine the effect of air, water, and ice cooling media on the hard-ness and toughness of ASTM A36 steel due to MAG welding.

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EXPERIMENTAL PROCEDURES

The material used in this experiment was ASTM A36 low carbon steel plate with its chemical composition presented in Table 1. The weld samples were prepared in the form of steel plates with dimensions of 100 x 200 x 8 mm (width, length, and thickness respectively) and a Single V-groove with a slope angle of 70 ^{o}, as shown in Figure 1.

The welding was conducted through a metal inert gas/metal active gas (MIG/MAG) process. The inert gas welding was generally argon-based while the active gas was CO_2-based gas and they were used as the plasma for electric arc initiation and as the shielding gas for metals at high temperatures. This process was required to avoid contaminating the welded product with oxygen

Table 1 **Chemical composition A36 steel /wt.%**

C	0,25
Mn	0,90
P	0,04
S	0,05
Si	0,04
Cu	0,02
Fe	Bal.

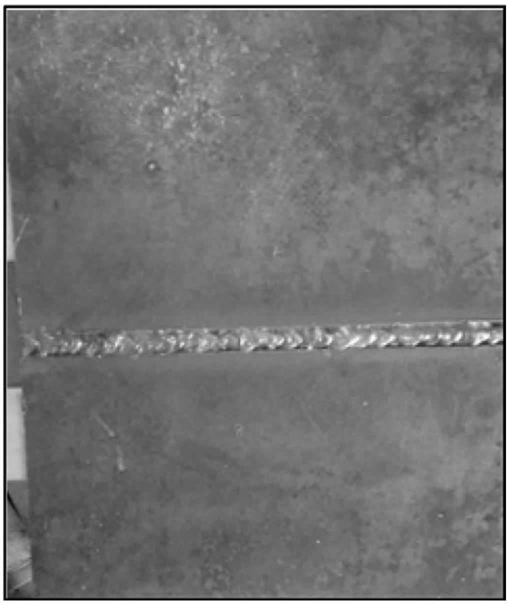

Figure 1 Welding samples of A36 steel plate produced.

and nitrogen. It is, however, important to note that the arc welding process involves feeding the added material with a coil of electrode wire after which it is melted by the Joule effect and an electric arc.

The electrode used as filler metal was ER70S-6 and its chemical composition is presented in Table 2. The welding was conducted manually with direct current reverse polarity (DCRP), the welding position was flat (PA/1G), and the speed was assumed to be constant by the short circuit droplet metal transfer method.

Table 2 **Chemical composition ER70S-6 /wt.%**

C	0,100
Mn	1,560
Cr	0,020
Si	0,860
Mo	<0,010
Ni	0,010
Cu	0,240
S	0,012
P	0,012

The cooling media used include air, water, and ice and they were all used due to the difference in the ability of each type to cool the weld sample. This media determines the cooling speed of the materials that received heat during the welding process. The experiment conducted, therefore, focused on analyzing the response of the material's properties such as the hardness and toughness to the temperature difference of the cooling media. Meanwhile, the temperature of the cooling media was measured through a K-type thermocouple and found to be 30, 26, and 3 °C for air, water, and ice respectively.

The impact test was conducted to simulate the operating conditions of the material against shock loads which are often encountered in constructions and practically difficult to avoid. The test was based on the principle of potential energy absorption from the pendulum of a load swinging from a certain height and made to strike the test object to ensure it is deformed. This experiment, therefore, applied the Charpy method for this test with the samples prepared through a machining process in line with the ASTM E 23 standard [7]. The dimensions of the cross-sectional area were 55, 10, and 8 mm for the length, width, and thickness respectively while a V-45° notch angle with a base radius of 0,25 mm and a notch depth of 2 mm was also applied as indicated in Figure 2.

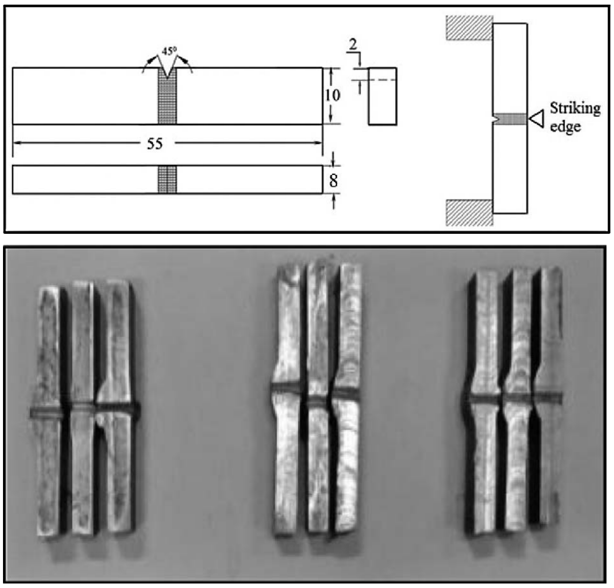

Figure 2 Dimensions and the sample of the Charpy V impact test [7].

RESULTS AND DISCUSSION

The results obtained from the impact test are presented in Figure 3. The results showed the impact strength due to the use of air media for cooling was 3,18 J/mm^2, water media produced 1,31 J/mm^2, and ice media was 4,38 J/mm^2. Moreover, the Charpy impact energy was used to directly or indirectly estimate the KIC value which was applied to determine the fracture impact toughness of the metal [8].

The fracture of the ASTM A36 steel due to the MAG welding and cooling through the air, water, and ice is presented in Figure 4 and Figure 5 with the Charpy impact indicating a slightly ductile material and a fibrous structure like fibers. This fracture is usually initiated by the presence of shear along the plane that receives the maximum shear stress and its main characteristic is the dark and fibrous surface observed in the form of shear at a macro level. It is important to note that a ductile metal usually experiences a change in shape or gets deformed both on the outside and in the air cavities when it receives a load [9]. In addition, it can be seen that there are inclusion defects on the fracture surface of the impact toughness. These inclusion defects can reduce impact resistance. Therefore, the microstructure constructed between the cavities in an area during plastic

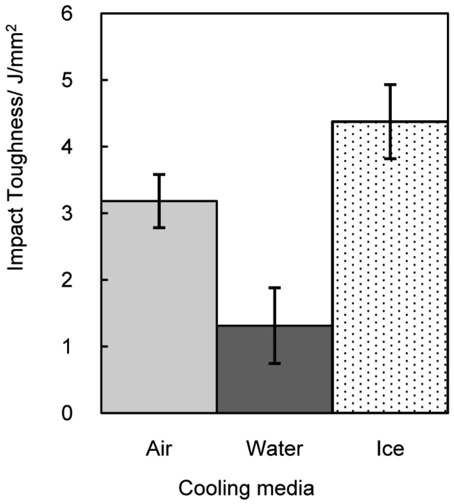

Figure 3 Impact toughness value of A36 welding plate at different cooling media.

Figure 4 Microscopic photo of the fractured surface cooled through (a) air, (b) water, and (c) ice.

and elastic deformation usually becomes the basis for the fractured surface [10].

From Tables 3 and 4, it can be seen that the probability of the significance value (Sig.) is 0,003, which means < 0,05, so H_0 is rejected. So, it can be concluded that the effect of cooling media (air, plain water and water-ice) can increase the impact toughness significantly in ASTM A36 steel welding.

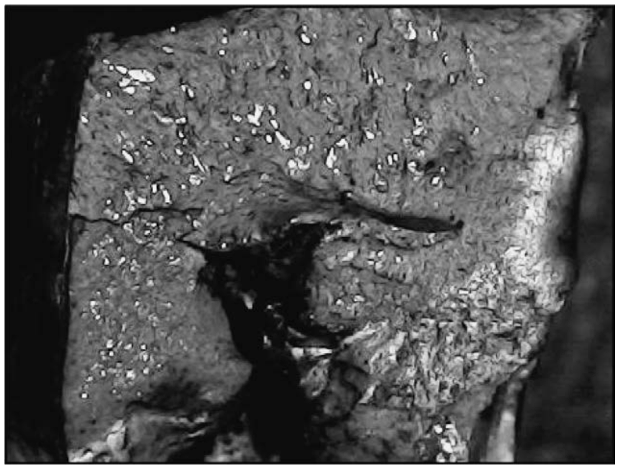

Figure 5 Fracture surface of the water-cooling media.

Table 3 **Description impact**

Groups	N	Mean	Std. Dev.	Std. Error	Lower Bound	Upper Bound
Air	3	3,1833	0,48911	0,28239	1,9683	4,3984
Water	3	1,3133	0,69695	0,40238	0,4180	3,0446
Ice	3	4,3767	0,68157	0,39350	2,6836	6,0698
Total	9	2,9578	1,44412	0,48137	1,8477	4,0678

Table 4 **ANOVA impact**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14,305	2	7,152	18,039	0,003
Within Groups	2,379	6	0,397		
Total	16,684	8			

CONCLUSIONS

The research was conducted using the MAG welding process with ER70S6 as the filler metal, CO_2 as the shielding gas, and the product was cooled using air, water, and ice media. The results from the analysis, therefore, leads to the following conclusion: the cooling media type used in the MAG welding process was found to have an influence on the welding joint strength in terms of impact toughness of the material under load. The impact toughness analysis showed the use of ice cooling media produced the highest toughness value of 4,38 J/mm² followed by air with 3,18 J/mm² while the lowest was found with the use of plain water to be 1,31 J/ mm². The fractured surface was observed to be ductile as indicated by the presence of large plastic deformation.

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