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Effect of Shielding Gas Mixture on Gas Metal Arc Welding (GMAW) of Low Carbon Steel (LR Grade A)

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Abstract. The aimed of this research is to determine the feasibility and effect of the mixture of the shielding gas in the physical and mechanical properties. Low carbon steel LR grade A in a thickness 12 mm were joined in butt joint types using GMAW (Gas Metal Arc Welding) with groove's gap 5 mm and groove angle's 40^0 with variation of shielding gas composition. The composition of shielding gas that used were 100% Ar, 100 % CO_2 and 50% Ar + 50 % CO_2. The measured of mechanical properties with regard to strength, hardness and toughness using, tensile test, bending test, Vickers hardness Test, and Charpy impact test respectively. The physical properties examined with optical microscope. Results show that tensile strength of welding metals are higher than raw materials. Welds metal with mixing Ar + CO shielding gas has the highest tensile strength. Hardness of weld metals with the shielding gas 100% Ar, 100 % CO_2 and 50% Ar + 50 % CO_2 are 244.9; 209.4; and 209.4 VHN respectively. The temperature of Charpy test was varied to find the transition temperature of the materials. The temperature that used were –60°C, -40°C, -20°C, 0°C, 20°C, and room temperature. Weld metals with various shielding gas have similar trends of toughness flux that was corellated with the microstructure of weld .

Introduction

The Study for The Maritime Traffic Safety System Development Plan reports that in the year 2007-2011 the percentage of the factors causing the sea accident caused by technical factors is 59%. These data indicate the weld joint is the most critical part of including a structure so that researchers and practitioners should pay greater attention on the part of the weld joint.
There are four mechanisms that lead to the failure of the ship's structure, that yield due to tensile or pressure, buckling due to shear instability, fatigue cracking and brittle fracture. According to German Standard DIN 8528 (1975) weldability properties are composed of three elements, that welding suitability of materials, welding reliability of design, and welding in manufacturing feasibility.

The shielding gas used for GMAW process has to protect the weld pool and molten droplet transferred across the arc. Carbon dioxide (CO_2) generally used as a shielding gas due to its cheapness, but it use has been limited because of the problem of poor all position performance, spatter and oxidation losses [1].On the other hand Argon (Ar) cannot obtained the desired bead characteristic and arc stability [2]. Therefore, argon mixed with CO2 is being preferred as a shielding gas for weld bead characteristics, inclusions distribution arc stability, and mode of metal transfer. The use of different shielding gas produces corrosion resistance and hardness values are different [3]. The composition of shielding gas and filler wire in GMAW of HSLA steels determines inclusion characteristic, microstructures, and mechanical properties [4].

Material and Welding Experimentals

Materials

The steel sheet used was LR Grade A steel plate with a thickness of 12 mm. The steel sheet that has been provided measuring 600 mm x 300 mm, can be seen in Figure 1. The chemical compositions of test materials are shown in Table 1.

Fig. 1 Steel Sheet Grade A

Table 1. Chemical Composition of LR Steel (BKI, 2013)

Grade	C max	Mn min	Si Max	P Max	S Max	Al Min
A	0.21	2.5 x C	0.50	0.035	0.035	-
B	0.21	0.80	0.35	0.035	0.035	-
C	0.21	0.60	0.35	0.035	0.035	0.015
D	0.20	0.70	0.35	0.035	0.035	0.015

Welding Processes

The welding process was multilayer one side welding, the parameters of weld are shown in Table 2. Welding processes used Butt joint types using GMAW (Gas Metal Arc Welding) with groove's gap 5 mm and groove angle's 40^0 with variation of shielding gas mixture. The composition of shielding gas that used were 100% Ar, 100 % CO_2 and 50% Ar + 50 % CO_2.

Table 2. Parameters of Welding

No	Wire Rate (mm/s)	Welding Rate (mm/s)	Voltage (Volt)	Gas Rate (liter/menit)
1	100,43	6,25	22	15
2	100,43	6,25	23	15
3	100,43	6,25	24	15
4	100,43	6,25	25	15
5	100,43	6,25	26	15
6	100,43	6,25	23	15
7	100,43	6,25	24	15
8	100,43	5,56	23	15
9	100,43	3,16	23	15
10	100,43	3,16	24	15
11	135,58	5,56	23	15
12	172,41	5,56	23	15

Joints Characterizations

Mechanical strength of weld metals were performed by tensile testing ,impact toughness testing and bend testing. Charphy Impact testing is used to determine the value of the toughness of welds. Temperature impact testing is used at -60ºC, -40ºC, -20ºC, 0ºC, 20ºC, and 30ºC. Liquid nitrogen is used to get the temperature < 0°C.

The impact speciments refered to ASTM E23-96 as seen in fig.2. The Vickers hardness measurements across the base metal, HAZ (heat affected zone), and the weld metal.

Standard metallographic procedure ASTM E3-01 used to prepared metallography speciments. The microstructure of mild steel was revealed by using HNO_3 2.5%

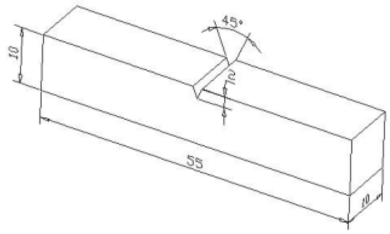
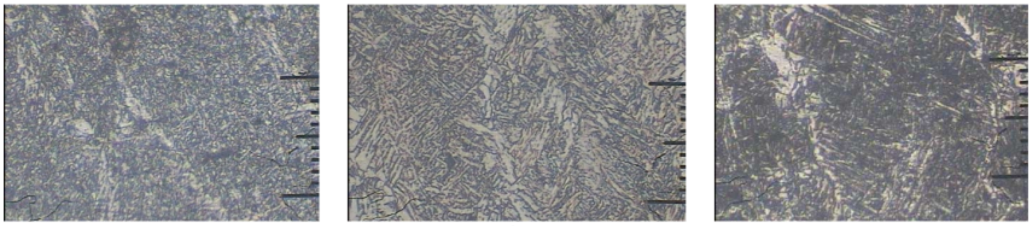


Fig. 2 Impact Test Speciment (ASTM E23-96) [5]

Results and Discussions

As we can see from Fig. 3 the shielding gas influence on microstructure of material of welding joint. The most homogeneous structure is received, using shielding gas Argon (Fig. 3 a). It is evident that an increase in CO_2 content in the shielding gas increases the grain size. This microstructure was formed due to the high welding heat during welding process.



(a) (b) (c)

Fig. 3 Microstructure of Welding Metals
(a) Argon (b) Argon + CO_2 (c) CO_2

The tensile strength of the GMAW joints are shows in Figure 4. During tensile test, all welded specimens exhibited fracture at base metals (Fig 5). The tensile strength of welding materials are higher than raw material.

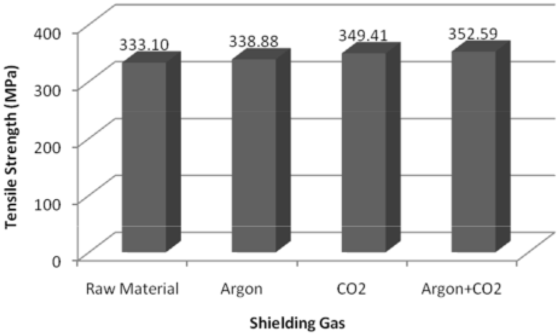


Fig. 4 Effect of Shielding Gas on Tensile Strength

Bending tests using the face transverse bending. The use of this method aims to look at the strength of the weld surface tensile and compressive stress. Another objects of bending test is to see the cracks that appear in the welding structure.

Criteria for bending test according to ASME IX 2010 is as follows:

1. Cracks size in the area of weld metal and HAZ does not exceed 1/8 inch (± 3.0 mm) were measured from all directions surface.
2. Maximum crack size in the welding area is 1.6 mm.
3. Cracs in the corner are ignored except as a result of SI (Slag Inclusion) and IF (Incomplate Fusion).

The results of bending test shown at figure 5 and the bending speciments shown at figure 6. Test results shows that the value of the bending strength of the raw material has the highest value is 632.33 Mpa. The lowest value of bending strength is welding metals with shielding gas argon gas which has a value 17.5% lower than the base metal.

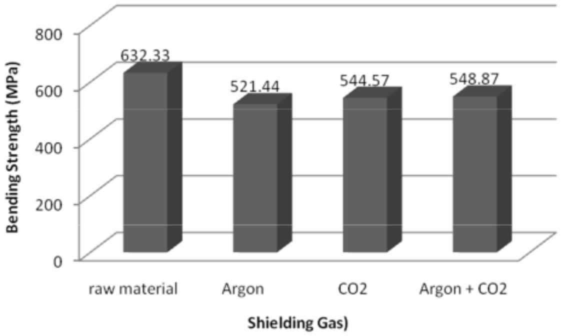


Fig. 5 Effect of Shielding Gas on Bending Strength

In Figure 6 is shown that all the specimens are eligible to qualify in the bending test, because there is no defects in welding and welding quality can be said to be good.

Fig. 6 Speciments of Bending Test

Transition temperature is the temperature at which the material properties change from brittle to ductile. At temperatures below the transition temperature, the weld metal has a brittle properties while at temperatures above the transition temperature of the metal having ductile properties. The lower the transition temperature, the better the toughness of metals.

Figure 7 shows that the transition temperatures are at temperatures between -20°C to 0°C. Welding joints can be used for construction if the value of the absorbed energy at a temperature -50°C is 30 J and at the temperature 0°C is 100 J [6].

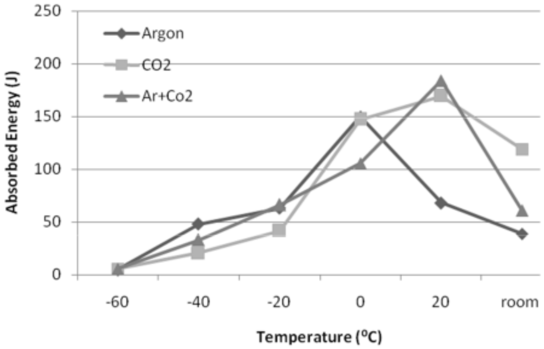


Fig. 7 Absorbed energy of welding metals

The hardness of weld metal given in Fig 8. The highest hardness numbers found on the weld metals with shielding gas Argon.

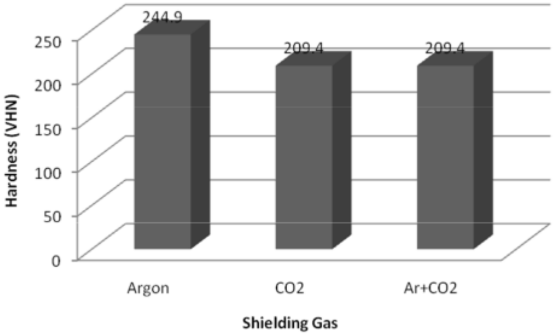


Fig. 8 Effect of Shielding Gas on Hardness

Conclusions

The main results are summarized as follows:

1. An increase in CO_2 content in the shielding gas increases the grain size of microstructure.
2. That tensile strength of welding metals with variation of shielding gas are higher than raw materials.
3. The transition temperatures of weld metals are at temperatures between -20^{o}C to 0^{o}C.
4. Welded joints can be used for construction because eligible absorbed energy value.

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