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Study The Effect of Filer Material on Microstructure of Welding the Carbon Steel in Shielded Metal Arc Welding

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ABSTRACT: The purpose of this work is to study the mechanical and metaullurigical properteris of carbon steel plates welded by two types of fillers using a shielded metal arc welding (SMAW). The carbon steel plate matreial was of type ASTM A283-C with a thickness of 6mm. The electrodes were of type E7018 and E309-16 with a diameter of 3.2mm. A butt welding configuration was used with a gap of 2mm with a process parameters of welding current = 100A, voltage = 26V. The welded palates were tested by a tensile test, microstructure test, scanning electron microscope (SEM) and X-ray diffraction (XRD) test. The results refer that the tensile strength of similar filler metal achieved better results than dissimilar filler metal, the microstructure test of welding by E7018 gives the welding zone similar to the base metal, the SEM test showing the microstructure of weld metal when welding by E7018 & E309-16 consist of a mixture of the filler metal and the base metal is about 90% and 20% respectively, The XRD examination showed the base metal of carbon steel having the ratio of the Fe element is high, when welding by E7018 having the ratio of the Fe and Cr are high, and when welding by E309-16 having the ratio of the Ni was high.

KEYWORDS: *Shielded metal arc welding (SMAW), Carbon steel, E7018, E309-16, SEM.*

INTRODUCTION

Shielded metal arc welding (SMAW) or simply stick welding is a manual arc welding process that uses an arc between a consumable electrode and a weld pool to accomplish the weld, the electrode is covered with a flux to lay the electric current of welding, in the form of either alternating current or direct current from a welding power supply , is used to form an electric arc between the electrode and the metals to be joined . The workpiece and the electrode metals forming a pool of molten metal (weld pool) that cools to form a joint. Shielded metal arc welding can be used to join most of the common metals and alloys , including low alloy steels, carbon steels, cast iron and stainless steels as well as copper, aluminum, and nickel, and some alloys of these metals due to its less expensive, easily controllable and a pretty good portable nature [1,2,3]. The process is also used to weld many chemically dissimilar metals. The SMAW process is adaptable to any material thickness within certain practical and economical limitations . For thinner materials less than about 1.6 mm (1/16 in.), most of the applications of the SMAW process are in thicknesses between 3 mm and 38mm (1/8 and 1-1/2 in.) [4]. According to American Welding Society (AWS) classification, there are several welding and cutting processes used in industries, each one of them uses different way to join or cut pieces [5].

The welding is a process in which two or more pieces of metal are joined to make them act as a single piece. It is used to join most metals types and alloys, and to join metals in different types. Welding is the most economical and efficient way to permanently join metals [6,7]. For welding of the milled carbon steel is recommended by use low hydrogen procedure. Preheating and control of the inter pass temperature also may be required, particularly when the joint thickness is greater than 25 mm (1 in.) or when extrinsic joint restraint is high . If hydrogen cracking still is a problem with these procedures, hydrogen may be diffused from the joint either by maintaining the preheat temperature or by post heating after welding is complete . A temperature of at least 150°C usually is effective for dissipating hydrogen in mild steel weldments . The hold time will increment in proportion to the thickness of the weld, in general 2 to 3 hours per 25 mm (1 in.). Some mild steels are supplied in the normalized or quenched and tempered condition to provide good toughness or high strength properties [8,9,10,11]. Tensile strengths may range from 450 MPa to 690 MPa, depending on the heat treatment and the content of carbon and manganese [12]. Carbon steels are alloys of iron and carbon in which carbon usually does not exceed 1.0%, manganese does not exceed 1.65%, and copper and silicon each do not exceed 0.60%. The properties and weld ability of these steels depend mainly on carbon content; other elements have only a limited effect. The mild carbon steels containing from about 0.15% to 0.30% carbon are commonly called mild steels . These steels can be welded without preheat, post heat, or special welding procedures when the joint thickness is less than 25 mm (1 in.) [13,14,15].

Basic of SMAW low-hydrogen electrodes are used for welding the carbon steel plate. Low hydrogen electrodes should be used when higher strength metal or low-hydrogen welding conditions, or both, are required. The low-hydrogen types (E7015, E7016, E7018, E7028, and E7048) must be handled and stored under conditions that prevent moisture pickup in the coating . The E7018 has a large amount of iron powder in the covering and performs best when applied with DCEP, although AC is possible. The iron powder quiets the metal transfer and increases the deposition rate. The E7018 class is a popular choice for many applications because it can be used in all positions with high deposition rates, has excellent welder appeal [16,17,18,19]. This paper displays the study of the effect of using the similar and dissimilar filler metal with the base metal in terms the structure of microstructure, mechanical behavior (tensile strength) and a ratio of mixing between the welding metal and the base metal. By using the SMAW manufacturing processes. Two type different of electrode were studied: E7018 & E309-16

EXPERIMENTAL WORK

Metals Properties

The metal selection was chosen the carbon steel alloy ASTM A283-C according to ASME classifications at 6 mm thickness which have the analysis of chemical composition as shown in Table (1a) below and the electrodes (E7018 & E309-16) which have the chemical composition as shown in Table 1b & 1c respectively.

Table 1a. chemical composition of carbon steel alloy ASTM A283-C

Elements	C%	Mn%	P%	S%	Si%	Cu%
Actual %	0.26	0.98	0.035	0.04	0.24	0.3

Table 1b. chemical composition of the electrodes E7018

Elements	C %	Cr %	Mn %	Mo %	Ni %	P%	Si %	S%	V %
Standard [20]	0.15	0.20	1.60	0.30	0.30	0.035	0.75	0.035	0.08
Actual	0.07	0.03	0.87	0.01	0.2	0.015	0.61	0.011	0.01

Table 1c. chemical composition of the electrodes E309-16

Elements	C%	Cr%	Mn%	Mo%	Ni%	P%	Si%	S%	Cu%
Standard [20]	0.15	22-25	0.5-2.5	0.75	12-14	0.04	1	0.03	0.75
Actual	0.08	23.50	1.70	0.1	12.30	0.024	0.52	0.024	0.1

The analysis of mechanical properties of each the carbon steel alloy ASTM A283-C and the electrodes (E7018 & E309-16) is shown below in Tables (2).

Table 2. Mechanical Properties of ASTM A283-C and electrodes (E7018 & E309-16).

Material		Mechanical Properties	
		Yield Strength YS, (MPa)	Tensile Strength UTS, (MPa)
ASTM A283-C	Actual	205	515
E7018	Actual	480	570
E309-16	Actual	410	604

Welding Procedures

Selective electrodes E7018 and E309-16 by the welding process of SMAW was performed to weld the base metal of carbon steel which having the dimensions 100mm X 150mm X 6mm, as shown Figure (1).

Figure 1. Shown the base metal and electrodes E7018 & E309-16

The procedures of this work used in this investigation are:

1- Preheat for E7018 at 250C for 1.5h to reduce hydrogen content to avoid hydrogen-induced cracking
2- Welding : The welding was performed by welding parameters are
a- Gap = 2mm
b- Current = 100A
c- Voltage = 26v
d- Electrode diameter = 3.2mm

Figure 2 shown the photographic picture of welding specimens which have been prepared.

Figure 2. Shown base metal of carbon steel welded by E7018 & E309-16

Tensile Test Procedures

Prepares the specimens of tensile test according to ASTM specification E 8M - 04 that having dimensions of tensile test specimens as shown in figure (3), applying the load gradually until the specimen fractured with recording the specimen extension [21]. After the test has been completed, it is often required that the cross-sectional dimensions again be measured to obtain measures of ductility.

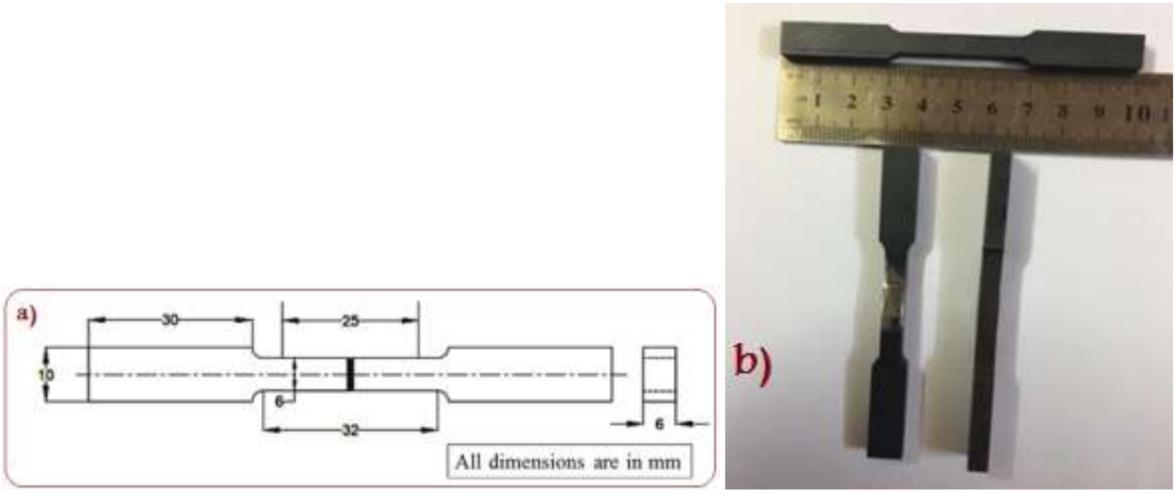

Figure 3. Shown tensile specimen: a) The standard dimensions of tensile testing specimen, b) Tensile specimen

Microstructure, SEM and XRD Tests

Preparation of specimens for metallographic examination were select the specimens from carbon steel welded by E7018 & E309-16 which having dimensions (25mm X 12mm). The specimens to be polished form metallographic examination are generally not more than about 12 to 25 mm square. The height of the specimen should be no greater than necessary for convenient handling during polishing.

The other steps of prepared the specimens for microstructure

- CUTTING: Cutting specimens by wire cut machine
- MOUNTING: Larger samples are not to be mounted
- GRINDING : (180,400,800,1200,1500,2000)
- POLISHING: Is the process of creating a smooth and shiny surface by rubbing it or using a chemical action. Aluminum oxide (0.5, 0.1 , 0.05 μ) .
- ETCHING: The surface of the sample is flattened in an etching solution (98% alcohol – 2% nitric acid) for 20 to 30 sec.

The dimension of SEM and XRD specimens for 6mm thick is (5X15X6)mm and (10X20X6)mm respectively, depended on the machine test.

RESULTS ANALYSIS

Tensile Test

The tensile tests were performed on the base metal of the carbon steel without apply welding by any electrode, also perform on the base metal with using two types of electrode. The welding is a two-piece of carbon steel by using electrode E7018 that is similar to the base metal and electrode E309-16 which is dissimilar to the base metal. The result can be classified in table 3 as shown in Figure 4. It has been observed that the welded carbon steel by E7018 is more tolerant to the strength than welding two pieces of carbon steel by E309-16.

Table 3. Tensile test result

Mechanical Properties / Material	Yield Strength YS, (MPa)	Tensile Strength UTS, (MPa)	Elongation %	Fracture Zone
The base metal	297.222	388.889	56	In center of base metal
With E7018	222.944	455	68	In base metal
With E309-16	333.3	397.2	40	In HAZ

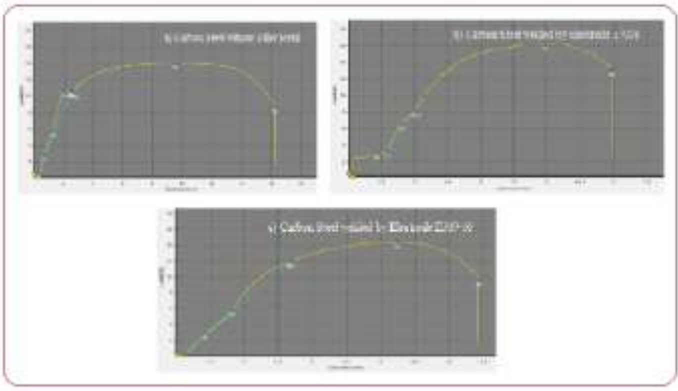

Figure 4. Tensile test

Microstructure Test

After obtained the microstructure test, the examination shown when is welding the base metal by E7018, the welding metal was similar to the base metal that become the welding zone having longitudinal grains because of the dispersion of high temperature, the heat affected zone (HAZ) which is a zone nearby the welding zone characterized by a large grain relative to the base metal grain because of its effect in the heat and form irregular, but when welding the base metal by E309-16 which is shown the welding metal dissimilar from of the base metal, These results are appear in figure (5).

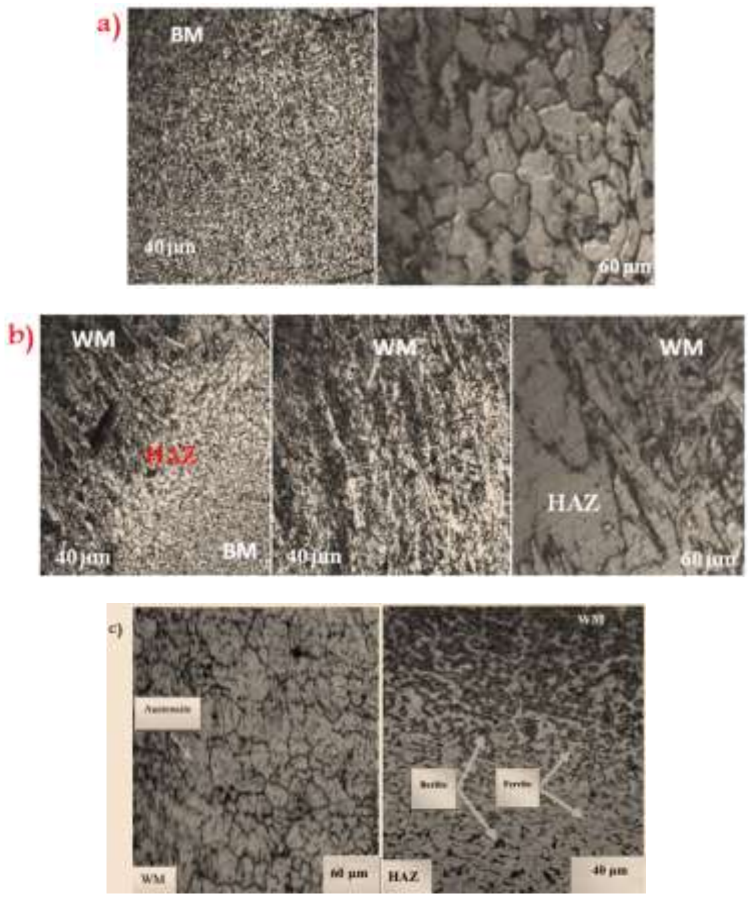

Figure 5. Shown the microstructure test: a) The base metal without welding b) the base metal with welded by E7018& c) welded by E309-16

Scanning Electron Microscope Test (SEM)

The SEM test showing the microstructure of weld metal when welding the base metal of carbon steel by electrode E7018 which consist of a mixture of the filler metal and the base metal is about 90%, but the results showed when welding the base metal by electrode E309-16, the mixing ratio was about 20% this occurs because of the dissimilar base metal with electrode E309-16. And also this test showed the shape of grain, figure (6).

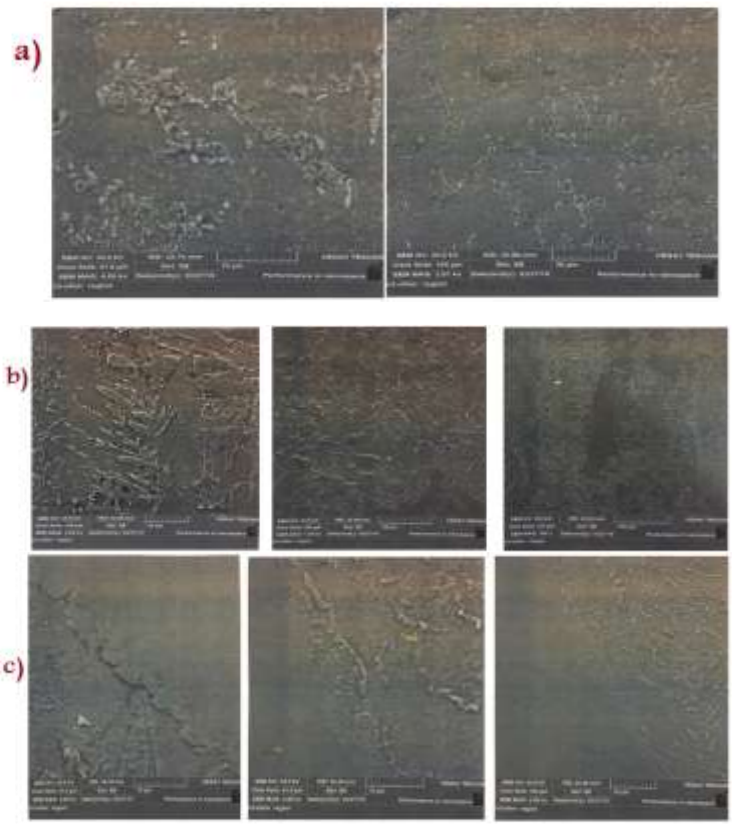

Figure 6. Shown the SEM test: a) The base metal without welding, b) welded by E7018 & c) welded by E309-16

X-ray Diffraction XRD Test

Through the XRD examination on the base metal of carbon steel showed it was having the ratio of the Fe element is high, so it was obtained the ferrite phase that led to the type of crystal unit cell structures will be (BCC), therefore it was brittle. When it examined the base metal of carbon steel welded by E7018, it has been observed that the ratio of the Fe and Cr are high, so it obtained the ferrite phase because Cr is one of the ferrite promoted, also that result to the type of crystal unit cell structures will be (BCC), as a result it was brittle. But when examining the base metal of carbon steel welded by E309-16 was results refer to the ratio of Ni was high, thus led to the appearance of the austenite phase because Ni is one of the austenite promoted, wherefore the type of crystal unit cell structures will be (FCC),for this reason it became ductility, figure (7).

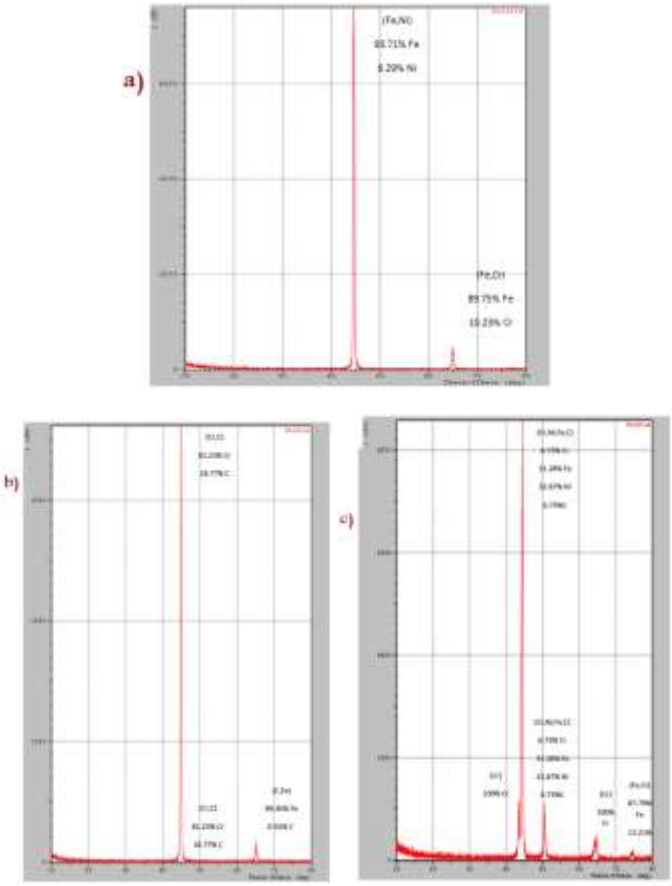

Figure 7. Shown the XRD test: a) The base metal without welding, b) Welded by E7018 & c) welded by E309-16

CONCLUSIONS

The carbon steel alloy ASTM A283-C were welded by SMAW with using the simaler electrode E7018 and dissimaler electrode E309-16. The following conclusions were recorded:

1- The tensile test of carbon steel with welded by similar electrode E7018 has a tensile strength 455 MPa which gives the higher value.
2- The tensile test of carbon steel with welded by dissimilar electrode E309-16 has a tensile strength 397.2 MPa that gives the lower value.
3- The welding by E7018 gives the welding zone similar to the base metal while the welding by E309-16 gives the welding metal dissimilar to the base metal.
4- The SEM test showing the microstructure of weld metal when welding by E7018 consist of a mixture of the filler metal and the base metal is about 90%.
5- The SEM test showing the microstructure of weld metal when welding by E309-16 the mixing ratio of the filler metal and the base metal was about 20%.
6- The XRD examination showed the base metal of carbon steel having the ratio of the Fe element is high, so it was obtained the ferrite phase, therefore it was brittle.
7- The XRD examination showed the base metal of carbon steel welded by E7018 having the ratio of the Fe and Cr are high, so it was obtained the ferrite phase, as a result it was brittle.
8- The XRD examination showed the base metal of carbon steel welded by E309-16 having the ratio of the Ni was high, thus led to the appearance of the austenite phase, so it was becoming ductility.

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