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Corrosion Behavior Evaluation of TIG Welding Joint of Low Carbon Steel

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ABSTRACT

The current research studies the corrosion behavior of Low Carbon Steel 1020 AISI welded joint by means of TIG welding method using mutable DC current and constant voltage. Before the welding process, shot peening by steel balls for certain welded joints is applied to the sheet metal, and then welding under the same welding conditions without shot peening. A number of corrosion inspection samples have been prepared with the measurements of (15 * 15 * 3 mm), according to ASTM (G71-31). Microstructure, residual stress has been tested and the corrosion test has been conducted electrochemically in 3.5 per cent NaCl solution for all samples. Corrosion rate was computed by means of the Tafel equation. The results show a rise in corrosion rate in some welded joints compared with other welded joints and base metal due to the variation in heat input from the input current for each weld passes. Shot peening process contributed to lower corrosion rate compared to welded joints without shot peening, due to the residual compression stresses produced by shot peening process. The best results obtained when number of welds passes and welding current are decreased to get suitable heat input.

1. Introduction

(TIG) welding is an arc welding procedure that applied using the tungsten electrode generated the arc which supplies the temperature 5000° C for a welding process [1,2,3]. The weld area is protected by inert gas (usually argon or helium) from atmospheric pollution and then a filler metal is applied to complete the welding process[4,5,6]. Heat input is the most important factor that effects for cooling rate which has the greatest effect in defining the final metallurgical structure of the weld and Heat Affected Zone (HAZ). Moreover, heat input determines HAZ grain size and width [4]. Corrosion is an electrochemical behavior that happens when an electrolyte film generates on the external surface of the metal. The amounts of the corrosion basically rely on the period that the external surface is exposed. Number of factors effect on the corrosion behavior of low carbon steel welded joints and the most effective factors are the chemical composition of the metal and the type of welding process used. This is because the welded metal go through different metallurgical changes through the weld pool [7,8]. Many researchers studied the subject as:-

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Syahida et al, [9] have mentioned that the heat input is significant to recognize the actual properties of the steel microstructure which has the aim of this study. Two types of carbon steels have been updated using gas metal arc welding method to show the effect of low, medium and high heat inputs on steel microstructures. The results has exposed that heat input factor influences on carbon steel at heat affected zone by making extent and rough grain in the area of heat affected zone and length of fusion line.

Gharibshahiyan et al, [10] studied the effect of using inert gas for welded joints of low carbon steel on hardness and toughness to improvements of the microstructure. Results showed that the particle extent figure decreased from 12.4 to 9.8 by the voltage from 20 to 30 V. And that high heat input and quick cooling speeds in welded metal formed fine grained polygonal ferrites at a temperature that was increasing. High heat input made coarse grain that was more visible in the HAZ, and decreased impact strength and durability as well. The increase in heat input decreased the hardness in the HAZ, for instance increasing the heat input from 5 to 8 kJ / cm decreases the hardness from 160 to 148 HBN.

Rana A.Majed [11] studied of welded joints of low carbon steel by Arc, MIG and TIG and characteristics of microhardness, tensile strength, corrosion behaviour, and mechanical properties. The characteristics obtained showed that the micro-hardness of the TIG, MIG welding joint was higher than that of the arc welding, but the tensile strength was higher in arc welding compared to the TIG and MIG. Potentiostat implemented the corrosion behavior of all specimens in 3.5 per cent NaCl to demonstrate polarization counteraction and the Tafel extrapolatio inferred. The corrosion rate was inferred from linear polarization data by the Tafel extrapolation method. The results indicated that the TIG welding increases the strength of the corrosion current and the anodic Tafel slop, thus reducing the counteraction of polarization with unwelded steel. Cyclic polarization has been tested to show sample counteraction to corrosion pitting and to define potential for forward and reveres. of welded samples in comparison to base metal, the characteristic showed a change of potential forward, opposite and pitting in active direction.

Oladele et al, [12] Mechanical characteristics such as tensile, hardness, bending and corrosion were studied. Microstructure shift Austenitic Stainless Steel304L welded with Mild Steel using Gas Tungsten Arc Welding (GTAW) technique and ER308L as filler metal on a prepared single V butt joint and 5 mm in thickness . The comportement of corrosion was inspected at 3.5 wt. NaCl percentage by electrochemical potentiodynamic polarisation The effects of the tensile and stiffness characteristic of the weld truth between the austenitic stainless steel and the soft steel base metals while the bending power of the metal joint tends to be the strongest. Austenitic Stainless Steel (ASS) obtainable large thermodynamic stability in 3.5wt% NaCl solution in analogy to the DMWJ which had a large counteraction to corrosion than the mild steel in same medium.

Talabi S I et al, [13] The effect of welding parameters (arc current, arc voltage, welding speed and electrode diameter) on the mechanical characteristics of the 10 mm thick low carbon steel plate welded by the Shield-ed Metal Arc Welding (SMAW) technique was studied. The welded samples were cut and machined to specific requirements for standard tensile, impact toughness and hardness testing. Results showed increased arc voltage and welding speed, resulting in increased hardness and decreased yield strength, tensile strength and effect toughness. Increasing the welding speed from 40- 66, 67 mm / min resulted in an increase in the toughness of the welded samples. As the welding velocity increased, early decrease in tensile and yield strength was observed. As compared to the samples collected, an electrode diameter of 2.5 mm provided the best combination of mechanical properties.

Zakaria Boumerzoug et al, [14] The effect of arc welding on microstructures and mechanical properties of industrial low carbon steel (0.19 wt. % C) was studied. This steel is used to render cylinder for gas storage. Optical microscopy, EBSD, X-ray diffraction and hardness checking were used to realize the objective. Diverse areas are established, and certain stages. Use of EBSD to detect new microstructural phenomenons.

The electro chemical corrosions behavior of low carbon steel AISI 1020 weld joint Implemented by tungsten inert gas process was studied in this paper and the correct welding parameter was described which improves corrosion resistance.

2. Experimental work

2.1. Selected metal

The metal used for this study was low carbon steel AISI (1020) which is widely used for shipbuilding and self-propelled manufacturing. The chemical analysis of the used metal is listed in Table (1), which was done by ARL Spectrometer in the General Company for Heavy Engineering Equipment.

Table 1 The chemical composition of AISI low carbon steel 1020

Elements wt.%	C	Si	Mn	Ni	Mo	Cu	Co	Al	Ti	S	P
Real value	0.2	0.009	0.65	0.012	0.005	0.041	0.0009	0.009	0.009	0.05	0.09
Standard value	0.18-0.23	0.01	0.3-0.6	-	-	-	-	-	-	-	0.04

2.2 Preparation of the weld joint

Weld specimens were cut with dimensions of (100* 50* 6 mm), and then oxidation was extracted from the surface by grinding operation. A single angle of type V was formed at 45 °. Shot peening is a cold working technique and is widely used to create film with compressive residual stress on the outside of the work approximately 5µm that depends on several factors such as shot diameter, ball material and shot time, Some specimens were treated with the shot peening system type STB-OB in order to study the effect of pre-shot peening on corrosion behavior. The rotational speed was 40 rev / min for 20 minutes and the shot angle was 10^o and the distance from the system nozzle to the metal surface is 120 mm using a 2.25 mm diameter steel ball and a 59 HRC hardness. Shot peening developed comparative residual stresses calculated using a computerized Lab XRD-6000 shiatsu X-RAY diffraction meter. The stress values were calculated and then replaced by Brag law to calculate the compressive residual stress (-273MP) from the system.

2.3 Welding process

The prepared specimens were divided into five groups. TIG welding process was used at different current values and fixed voltage according to welding conditions shown in Table (2). The specimens with symbol (C, E) were exposed to pre-shot. The filler metal ER70S-3, table (3) show chemical composition was used, and the volume of inert argon gas was 10 L / min.

Table (2) The conditions of the (TIG) Welding procedure.

Table 2 The welding conditions of (TIG) procedure

Specimens Symbol	Pass.-No	Current (A).				Voltage (V)	Heat In. J
		1	2	3	4		
B.	4.	270	200.	175	150	20	1815
C.	4.	270	200.	175	150	=	1815.
D.	3.	250.	200	190	-	=	1650
E.	3.	250.	200	190	-	=	1650.
F.	3.	280.	240	230	-	=	1848

Table 3 The chemical composition of filler Wire

Element. wt%	**C.**	**Si.**	**Mn.**	**S.**	**Ni.**	**Cr.**	**Cu.**	**P.**
Stander.	0.060 - 0.150.	0 .450 - 0 .750.	0.9.- 1.4	0 .02	0.15	0.025	0. 5	0.025max.
Real value	0,07	0.52	1.19	0.022	-	-	0.4	0.012

Heat input is calculating by the following equation - (1) [15]: -

Heat Input=543*I*V* 60/S (1)

where, I = Current (A), V=Voltage (V), S= Weld speed (m/min).

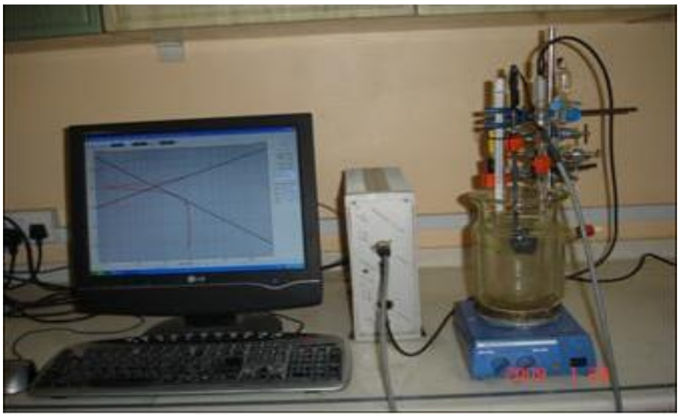
Welded joints were examined by X-ray radiography; the joints that were out of order were left out. joints without defect were used for prepared corrosion inspection samples. Microstructure test for the specimens was made by grinding using the SiC emery paper at grain size of (240,320,600,800 &1000) in inch square and then polished with diamond of size (0.5μm) And special polishing towel. Use of Nital solutiCon (98 percent cohol + 2 percent HNO3) was used to etch process. Optical inspection of the specimens was carried out using a camera-equipped optical microscope which was connected to a monitor.

2.4 Corrosion test

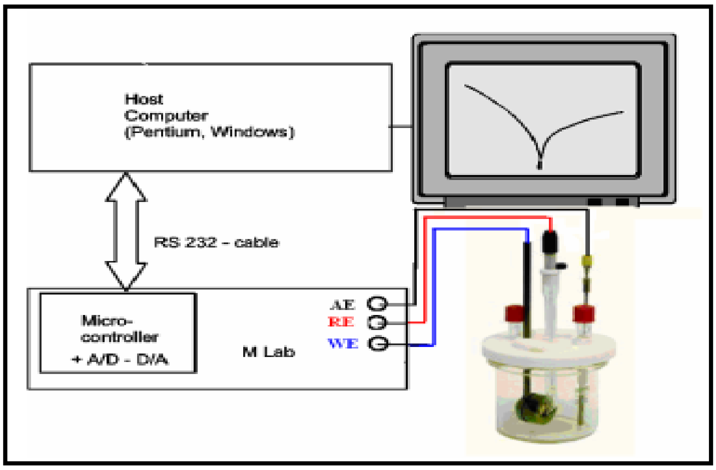
Corrosion test was done to the weld joint and base metal based on the ASTM standard (G71-31) for specimens with dimensions of (15*15*3 mm) in sea water which was prepared from 3.5% NaCl solution at PH of 6.7 to total, at each point, corrosion factors such as corrosion potential (E_{corr}) and corrosion current (I_{corr}). Cell current readings were being used through a tardy short sweep of potential. The sweep was taken from relative (-250 to + 250) mV relative to open cycle polarization (OCP). Scan rate defines the velocity of the potential sweep in mV / sec and is fast (10) mv. The tests were completed using potentiostate multi-channel WENKING Mlab and corrosion measurement device SCI-Mlab from Bank Electronics-Intelligent Control GmbH, Germany 2007, as shown in Figure (1). The rate of corrosion agreed to in Tafel equation as shown in equation (1)[12].

$$C.R\ (m.p.y) = 0.13 * I_{corr} * eq.wt / \rho \quad (2)$$

where C.R (m.p.y) corrosion rate in mille-inches per year, (Icorr) current density ($\mu A/cm^2$) ,(eq.wt) equivalent weight, ρ = density (g/cm^3).



(a)



(b) **Fig. 1.** The unit used for electrochemical corrosion cell

2. Result and discussions

Figure (2) show the photograph of the weld joint and the effect of pre shot peeningon the shape of weld joint line was clear. The results of microstructure of all samples are presented in Figure (3).

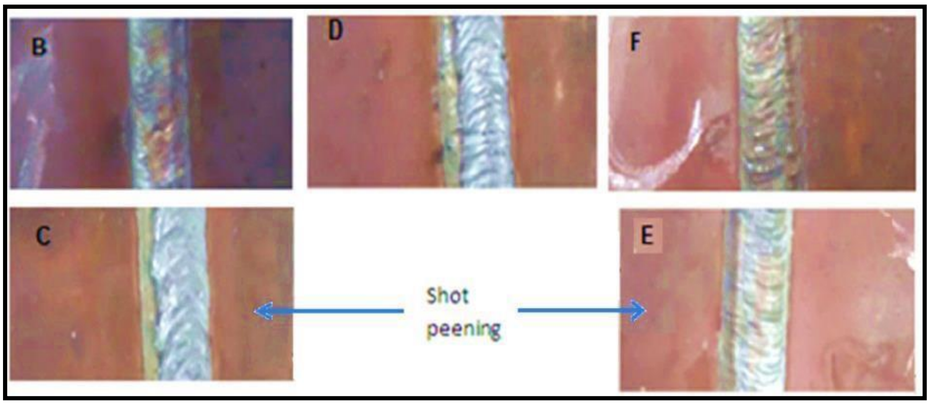
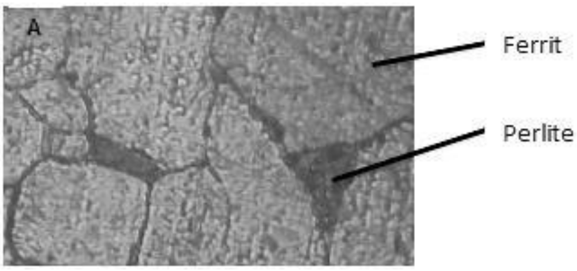


Fig. 2. Photograph of the weld joints the specimens with symbol (C, E) were exposed to pre-shot



Sample (A)

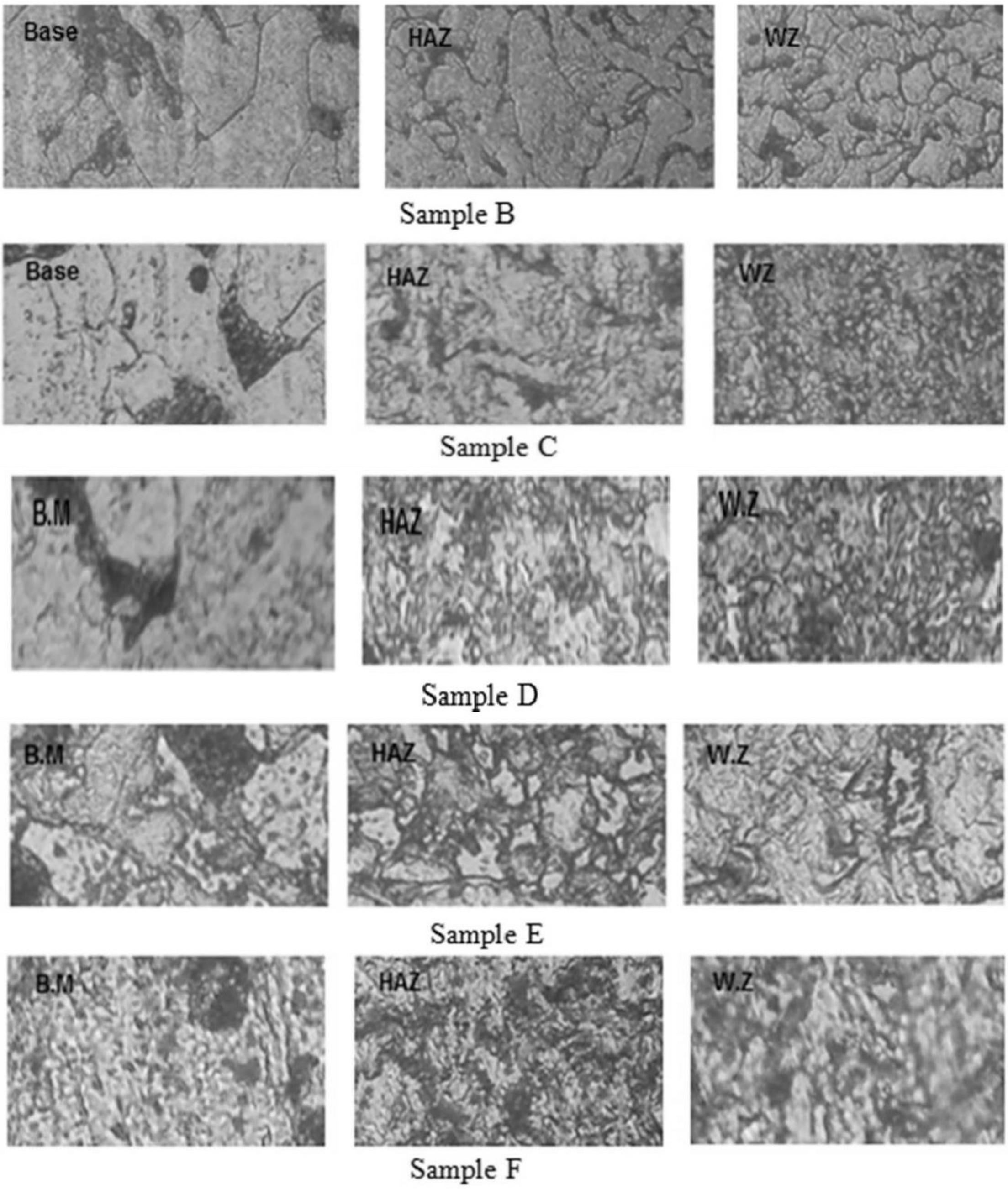


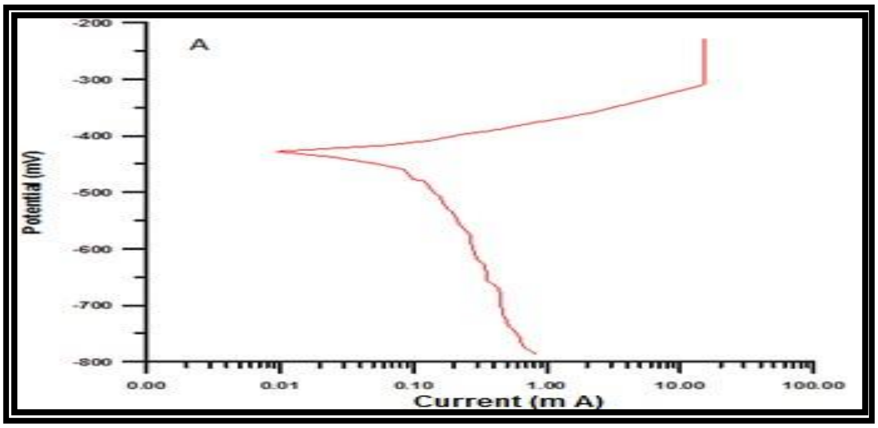
Fig. 3. The microstructure of all Sample at (40x)

Figure (3) sample (A) shows the microstructure of base metal of low carbon steel 1020 AISI having ferrite and pearlite, and Figure (3) samples (B, C, D, E, F) shows the microstructure of weld joints. Ferrite phases are found to be in different grain shape and size, causing corrosion due to oxygen-forming iron oxide reaction this increases due to the use of ER70S-3 filler metal shown in Table (3), which is also made of low carbon steel. The heat quantity calculated and listed in Table (2) during welding depended on heat input factors such as current, voltage, and wire speed. Growing of heat amount donates at growth of granules volume with high ductility due to slow cooling of the metal during welding. Therefore, it is preferred that the welding angle to be 45^o for homogenous heat distribution. From Figure (3) for all samples, the variance of the weld region particles for the different current used in welding can be seen. It is evidenced that the microstructure became finer with the change of current for each pass. Weld ability differs from one metal or alloy to another and the results obtained from the corrosion behavior described in Table (4) and the polarization curves of all welded specimens and base alloys in 3.5 per cent NaCl are shown in Figure (4) and corrosion form in Figure (5).

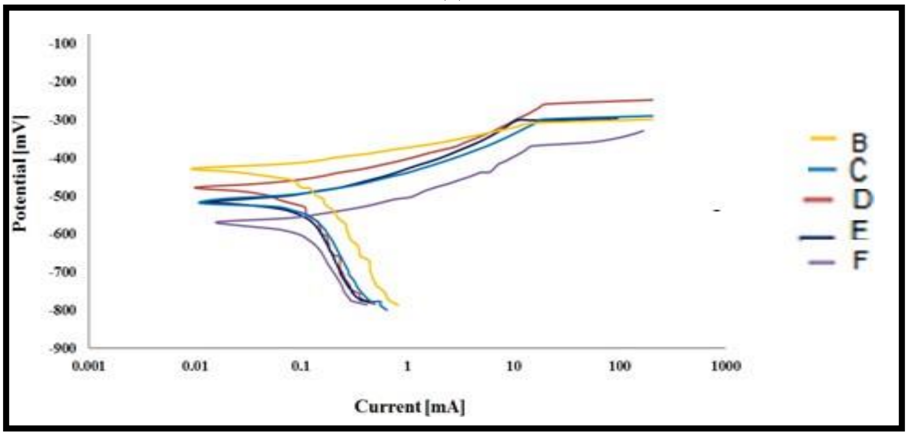
The corrosion rate for A specimens was found to be lower than that for B, C, D and E specimens. This is due to the low carbon steel base metal and filler metal which causes an increase in α ferrite quantity which promotes corrosion. The ferrous ions exit the anodic regions into media. Electrons are then set free from the anode and travel to the cathode where they are joined to make hydroxyl ions with water and oxygen [7,15]. Those react with ferrous anode ions to create hydrated ferrous oxide, which is further oxidized into ferric oxide, called rust.

Table 4 Result of electro comical corrosion test

No	I_{cor}.mA	E_{corr} mv	Corrosion Rate m.p.y
A	51.71	-490.2	22.75
B	77.17	-513.8	33,29
C	66.37	-420	29.2
D	73.77	-567.9	32.45
E	61.17	-562.5	26.9
F	30.21	-575.2	13.30



(a)



(b)

Fig. 4. Polarization curves for all specimens of low carbon steel

Linear polarization of base metal and weldments are shown in Table (4) and Fig. (4). It is observed that the cathode and anodic conduct of all specimens, the cathodic interplay typify the decrease of oxygen agreeing to the next interplay:

$O_2 + 4e + 2H_2O \rightarrow 4OH^-$

Even though the oxidation of iron typifies the anodic Interplay:

$Fe \rightarrow Fe_2 + + 2e$

Also, polarization data are shown in Table (4). These data show that the corrosion potentials (E_{corr}) values for weldments change in the direction of active analogy with unwedded low carbon steel. Corrosion rate from results in Table (4).

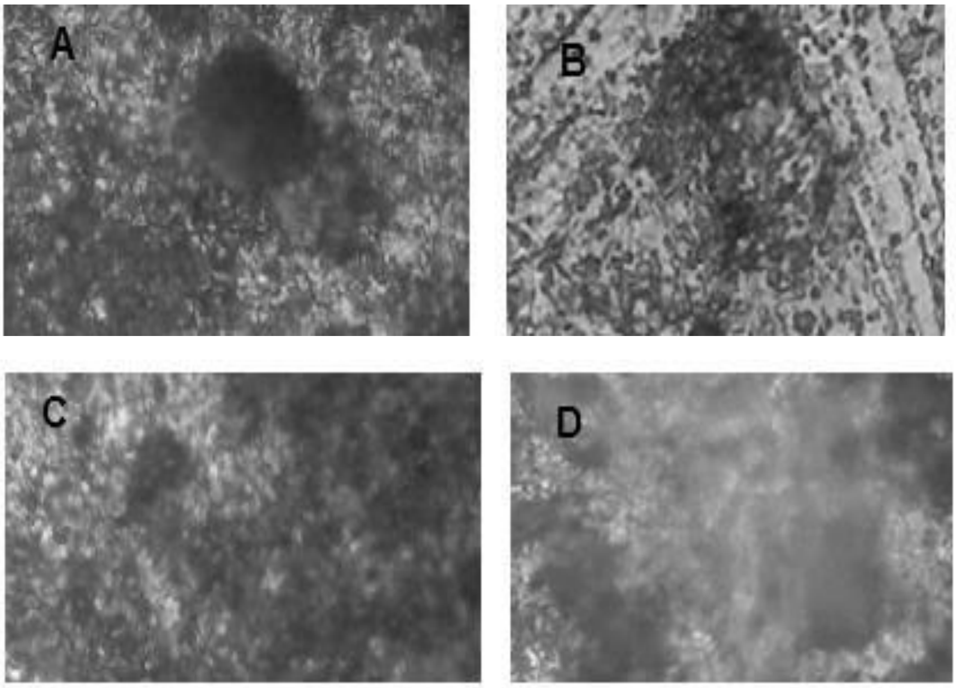


Fig. 5. Corrosion photograph after corrosion test at 40x

Fig. (5) shows the photograph of the shapes of corrosion for all specimens in table (3) which clear an increase in corrosion rate of specimens (B) in compared with un welded metal specimens (A) due to heat input quantity which was unstable when decrease DC current for each welded pass. Specimens (B) also have high corrosion rate for the same reason above, but specimens (F) gave the best corrosion when increase DC current for weld pass and decrease a number of passes. Amount of heat input contributed to homogeneity microstructure Shot peening, expressed in symbol (C, E), and leads to decreases in the rate of corrosion due to shot peeing refinement of the micro stretcher.

4. Conclusions

1. 1-TIG weld joints had a high corrosion rate when decrease DC current for each pass of weld.
2. Improving corrosion behavior in the same type of metal without using a metal filler.
3. TIG welding process is suitable way for welding low carbon steel due the efficiency in protecting weld zone from oxidation.
4. Corrosion resistance for low carbon steel was improved by shot peening and the best choice of welding parameter like current.

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