EFFECT OF WELDING HEAT INPUT ON CORROSION RATE OF SPRINKLER IRRIGATION PIPING JOINTS BY TIG WELDING USED IN SOUTH OF IRAQ

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ABSTRACT

The aim of this experiment was to study effect of welding heat-input on microstructure and corrosion resistance of butt weld joint pipes in irrigation pipe used in South of Iraq. For this purpose, a single V-butt joint was carried out on low carbon steel pipes type (AISI 1005) welded in different parameters; welding current, welding voltage and heat input. The results are found, an increase of weld heat input lead to increase Widmanstatten ferrite (WF), acicular ferrite (AF) and polygonal ferrite (PF) phases in fusion zone (FZ) region. Also it is noted the Icorr of weld joint increases with increase of welding heat input, and subsequent increasing in corrosion rate, corrosion rate increased up to (0.0757µm/yr.) with increasing of heat input up to (5.151 KJ/mm).

Keywords: welding current, TIG welding, corrosion, microstructure, carbon steel.

تاثير الحرارة الداخلة للحام على معدل التاكل لملحومات انابيب الري بالرش المستعملة جنوب العراق

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المستخلص

يهدف البحث الى دراسة تأثير حرارة اللحام على البنية المجهرية ومقاومة التآكل لمناطق اللحام في أنابيب الري المستخدمة في جنوب العراق. تم تنفيذ العمل على أنابيب فولاذية منخفضة الكربون (AISI 1005) ذات تشكيل نوع V–but من جهة واحدة. تم اجراء اللحام باستعمال معاملات تتضمن تيار اللحام ، فولتية اللحام، و الحرارة الداخلة. اظهرت النتائج ان زيادة المدخلات الحرارية للحام تؤدي إلى زيادة كل من طور الفرايت Widmanstatten (WF) ، الفرايت acicular ferrite (AF) و الفرايت polygonal ferrite (PF) في منطقة الانصهار. كما لوحظ زيادة Icorr لمنطقة اللحام بزيادة مدخلات الحرارة ، وبالتالي زيادة في معدل التآكل، اذ ارتفع معدل التآكل الى (yr0.0757 / µm.) مع زيادة المدخلات الحرارية حتى (KJ / mm 5.151).

كلمات مفتاحية: تيار اللحام، لحام التنكستن، التأكل، البنية المجهرية، الصلب الكاربوني.

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INTRODUCTION

Tungsten inert gas welding (TIG) or gas tungsten arc welding (GTAW) is one of the widely used techniques for joining ferrous and non-ferrous metal. TIG process; consist of non-consumable tungsten electrode which is used to provide the arc for welding. The weld area is protected from atmosphere with a shielding gas generally Argon or Helium. The process of TIG welding is so good that it is widely used in the high-tech industry applications such as, aircraft, nuclear industry, maintenance, food industry and repair work and some other manufacturing areas. Four major components make up a TIG welding station. They are the welding power supply, welding torch, work clamp and the shielding gas cylinder. The parameters that affect the quality and outcome of the TIG welding process are Welding Current, Welding Voltage, Inert Gases and Welding speed (6, 7). TIG welding offers several advantages i.e: Able to weld ferrous and non-ferrous metals, low heat affected zone, Narrow concentrated arc, purer and cleaner high volume weldments. In TIG welding operation, weld quality mainly depends on welding parameters such as voltage, current and gas flow rate. To consistently produce high quality of welds, welding technique needs personnel have experienced welding to properly select parameters of welding (2,8,14, 19). Steel is an important engineering material. It's found applications in several fields. It is capable of presenting economically a very wide range of mechanical and other properties. Variety of steels, most especially low carbon steel (<0.25% carbon content), are significant in the local manufacturing industries, such as in production of machine parts, pipe and other engineering components applications. These devices / machines parts are used in different working environment, which are often hostile (corrosive) in nature (4, 10,17,20). Carbon steel pipes and vessels are often required to transport water or submerged in water to some extent during service. This exposure can be conditions flow rate, varying temperature, pH, and other factors, all of those alter the corrosion rate. For these reasons, most of the corrosion research groups around the world devoted themselves to effectively control steel corrosion in various aggressive media employing different methods (10, 13). Pipelines are the most common and feasible medium in transporting because of the volume that can be transported. The pipeline is normally constructed using metal which is related to problems such as corrosion. Chloride ion plays a big role in the corrosion process of structural steel. The rust layer itself would then become porous and introduce chloride ions from outside easily, which promoted corrosion (5, 11,20,21). The corrosion behavior of carbon steel weldments is dependent on a number of factors such as compositional of low carbon steel and the different welding processes used, because carbon steels undergo metallurgical transformations across the weld and heat-affected zone (HAZ), microstructures and morphologies become important. A wide range of microstructures can be developed based on cooling rates, and these microstructures are dependent on energy input, preheat, metal thickness, weld bead size, and reheating effects due to multiphase welding. As a result of their different chemical compositions and weld inclusions (oxides and sulfides), weld metal microstructures are usually significantly different from those of the HAZ and base metal. Similarly, corrosion behavior can also vary (15). The heat transfer of the welding process has the potential to change the microstructure of the piping materials. The corrosion process occurs when metal is exposed to a flowing corrosive environment which combines the processes of electrochemical corrosion and mechanical wear, otherwise known as erosion-corrosion. (18). The aim of the current study is to investigate the effect of TIG welding heat input generated on the microstructure and corrosion resistance of Sprinkler Irrigation pipes joint used in south of Iraq (irrigation water which accesses to 3 - 5 % NaCl).

MATERIALS AND METHOD

A- **Materials**

Low carbon steel (AISI-1005) was used in fabrication and installation Sprinkler Irrigation pipes joint used in South of Iraq. The chemical composition and the typical mechanical properties are shows in tables 1and 2 respectively.

Table 1. Chemical composition of low carbon steel (AISI 1005)

Element	C%	Mn%	P%	S%
Actual value	0.058	0.33	0.04	0.04
Standard value	0.06 Max.	0.35 Max.	0.04 Max.	0.05 Max.

Table 2. Typical mechanical properties of weld alloy (16)

Yield stress (Mpa)	Tensile strength (Mpa)	Elongation (%)	Impact Charpy (J)
450	645	36	170

B- Wire selective

TIG wire type Ok Tigrod 13.22 electrode with diameter (1.6mm) was selective because a good suitable for welding high strength steel (16). Wire composition as shows in table 3.

Table 3. Chemical composition of wire (ER90S-G) (16)

Element	C%	Mn%	Si%	Cr%	Mo%
Value	0.08	1.0	0.7	2.6	1.0

C- Welding procedure

The pipes of low carbon steel with dimensions of (20 cm long, 12 cm diameter and 0.6 cm thickness) were prepared by milling hand machine from V-single butt joint is designed from mainline pipes metal around angle (60^o) as shows in Figure 1, the welding process was implemented using direct current straight polarity (DCSP). Figure 2, which reveal the sprinkler Irrigation system and mainline pipes were used in this study. Six samples of weldments at different welding parameters (welding current,
welding voltage and heat input) with 200 mm/min welding speed were prepared as shows in table 4. The heat input calculated by the following equation (3):

$$Q= \eta \times VI/ S \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where: I: is the welding current, V: is the welding voltage, S: is the welding speed (mm/s) and weld heat transfer efficiency η=0.30 the range of Efficiency is equal (0.22-0.48) in TIG welding (3).

TIG process is executed using consumables electrodes in accordance of AWS specifications and welding machine used in this work was type (ESAB), Ideal arc DC-600-Lincoln Company- Sweden. A stop watch was used to record the welding time.

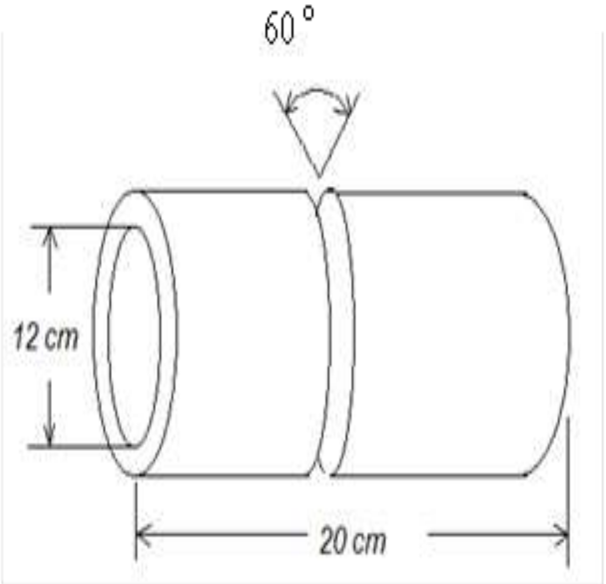


Figure 1. Single V- joint design of work pieces joints in mainline pipes

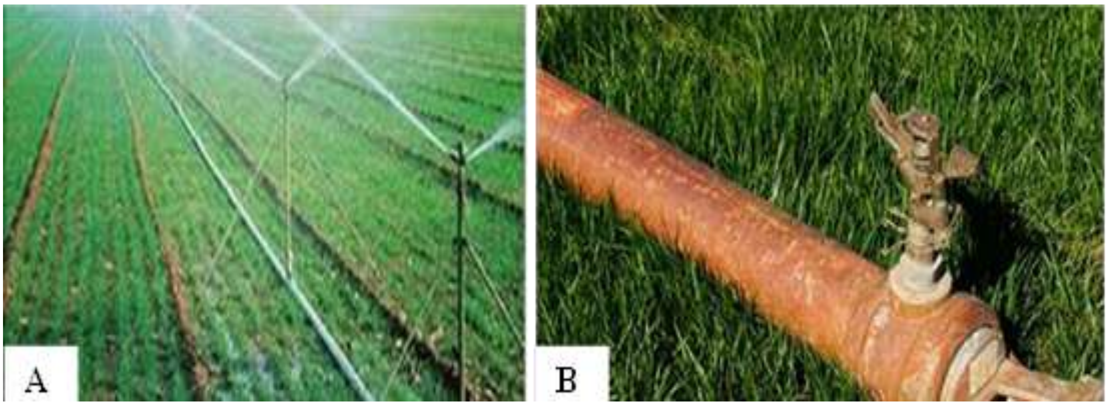


Figure 2. Sprinkler Irrigation system (A) and Mainline pipes(B).

Table 4. Experimental welding conditions of TIG welding, one pass and welding speed 200mm/min

No.	Welding Current I(Amp)	Welding Voltage V(Volt)	Welding Heat Input H(KJ/mm)
1	170	20.2	5.151
2	180	20.2	5.454
3	185	20.2	5.605
4	190	20.2	5.757
5	200	20.2	6.060
6	210	20.2	6.363

D- Corrosion testing

Six specimens of low carbon steel weldment applied TIG welding process were selected to evaluate the corrosion behavior of low carbon steel weldments. After welding, the specimens were machined by cutting and polished mechanically to a mirror finish, washed in distilled water and stored in desiccators. The electrolyte solution used in south of Iraq with salt concentration (3.5%NaCl) was used in irrigation water (12). Polarization cell experiment was done in “WINKING M Lab 200” Potentiostat from Bank-Elektronik with electrochemical standard cell Figure 3, with provision for working electrode, auxiliary electrode (Pt electrode), and a Lugging capillary for connection with an saturated calomel electrode (SCE) reference electrode. Electrochemical measurements were executed with a potentiostat at a scan rate 3mV.sec^{-1}. At the first step, the potential of the specimen of low carbon steel was measured corresponding to reference electrode and recorded with time. At second step, the polarization scan began rom cathodic to anodic branches. The potential was increased from a value versus SCE reference electrode below the open – circuit potential (OCP) to a value versus SCE above the (OCP). The main objective attained was expressed in terms of the corrosion potentials (Ecorr) and corrosion current density (icorr) along with measure the Tafel slops.

Figure 3. Polarization cell

RESULTS AND DISCUSSION

A- Effect of welding heat input on microstructure

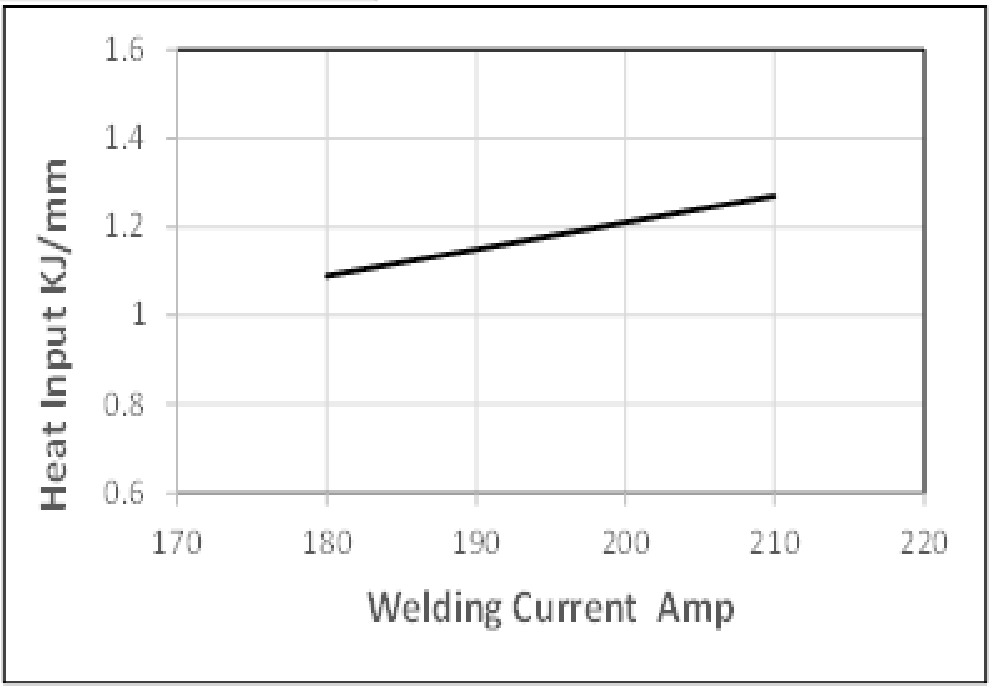


Figure 4. the relationship between Heat Input and Welding Current at welding Speed 200mm/min, and welding voltage 20.2volt

Welding heat input (KJ/mm) is calculated by equation Q= η× VI/s, where increasing of welding current effect to increase heat input as shows in Figure 4. A columnar grain was a coarse is seen in the weld metal (fusion zone) as a large, as increase welding current lead to increase grain size as shows in Figure 5, an increase in welding current effect on the grain size in both FZ and HAZ regions. These variations in grain size due to the effect of cooling rates. Three specimens microstructure were study, in fusion zone the microstructure consists of fine acicular ferrite (AF), Widmanstatten ferrite (WF) and some inclusions as shows in Figures 6, 7 and 8. HAZ region was increase in grain size with increase welding current (increase heat input) that’s mean increased current lead to increasing welding heat generated and causing the grain to recrystallized and grow in size.

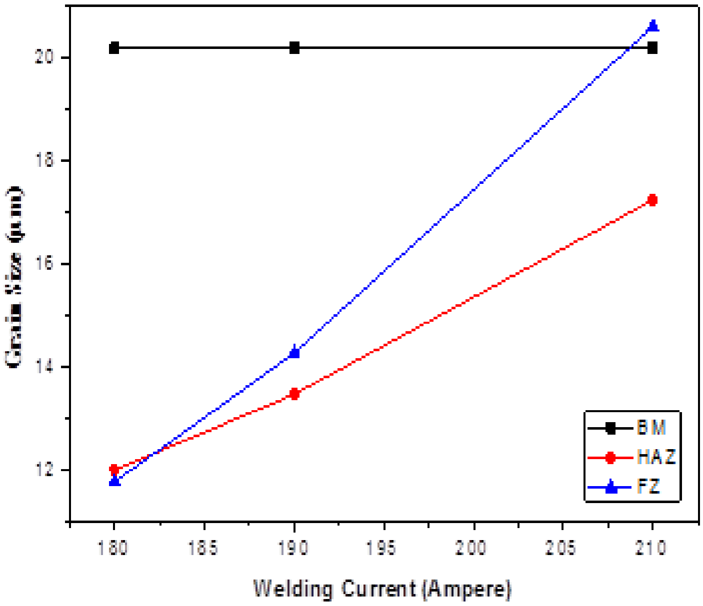
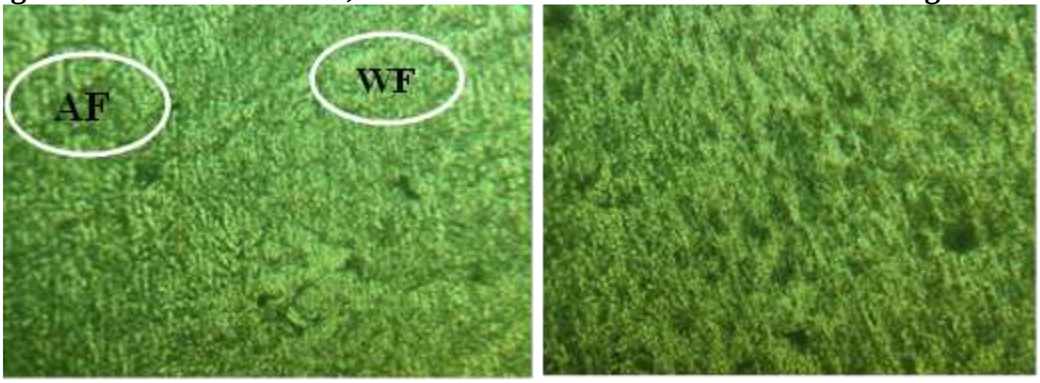
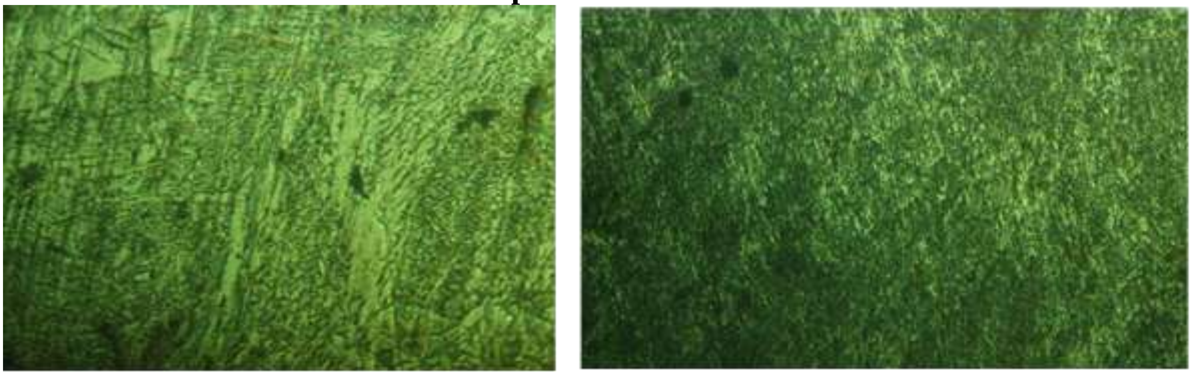


Figure 5. Grain size of BM, HAZ and FZ area as a function of welding current.



(a) FZ: specimen 1 (b) HAZ: specimen 1

Figure 6. Microstructure of butt joint of specimen 1 at I: 170Amp, V: 20.2volt, S: 200mm/min and heat input 5.151 KJ/mm. 500X



(a) FZ: specimen 3 (b) HAZ: specimen 3

Figure 7. Microstructure of butt joint of specimen 3 at I: 185Amp, V: 20.2volt, S: 200mm/min and heat input 5.605 KJ/mm. 500X

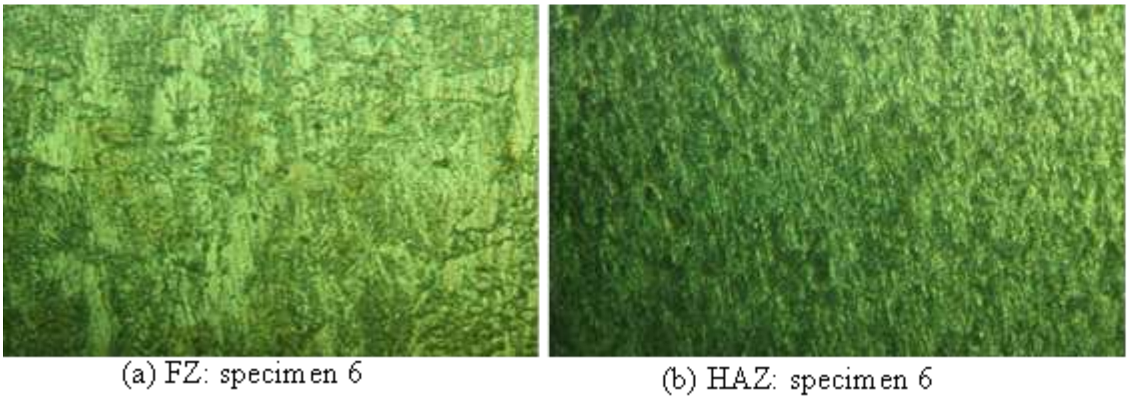

(a) FZ: specimen 6 (b) HAZ: specimen 6

Figure 8. Microstructure of butt joint of specimen 5 at I: 210Amp, V: 20.2volt, S: 200mm/min and heat input 6.363 KJ/mm. 500X

B- Effect of welding heat input on corrosion rates

Corrosion rate was calculated by the following equation (1):

$$C\,.R = \frac{3.27\times10^{-3}\times i_{corr}\times W}{\rho} \quad ---(2)$$

Where*: C.R:* corrosion rate in millimeters per year (mm/year), W: equivalent weight in grams, ρ: the density of the metal or alloy in g/cm^3, and *icorr* : corrosion current density in μA/cm^2. The equivalent weight (W) for carbon steel is (27.92) and the density is (7.87 g/cm^3).The results of corrosion rates calculation are tabulated in table 5. The results shown that corrosion rates increasing with increase Icorr. It is clear from that the corrosion rate is affected by the values of welding current and heat input, therefore, it can be seen that the increasing welding current led to increment in heat input and that is negatively effect on corrosion resistance of low carbon steel. Figures 9, 10 and 11, shows the Tafel plots which obtained for three specimens in this work. Extrapolation of the applied current density from either cathodic or anodic Tafel region to the open-circuit potential in a plot of potential vs. log I0, gives the corrosion current density Icorr. These results are agreement with (9). Besides, higher corrosion rate 0.1460 (μm/yr) is developed at (210 Amp) welding current. Figure 12, shows that the corrosion rate increases as heat input increase. From these results we can conclude:

* Increasing welding current leads to increase heat input: that's effects to formation of, acicular ferrites (AF), Widmanstatten ferrites (WF) and polygonal ferrites (PF) phases in weld metal (WM).

* Increasing welding current leads to increment the heat input, that's effects to a reduction in cooling rate and increases the grain size of weld metal (WM) and heat affected zone (HAZ) .

* Increasing the welding current leads to increment in heat input, that's effect to increase in corrosion rats in welding joint.

Table 5. Corrosion rates of AISI 1005 low carbon steel in salt concentration (3.5% NaCl) at temperature 25°C

No.	Corrosion Potential Ecorr (mV)	Corrosion Current icorr (μA/cm^2)	Corrosion rate C.R (μm/yr)
1	-646.7	6.54	0.0757
2	-713.3	7.34	0.0850
3	-636.4	10.85	0.1257
4	-620	11.0	0.1274
5	-550	11.5	0.1332
6	-500	12.6	0.1460

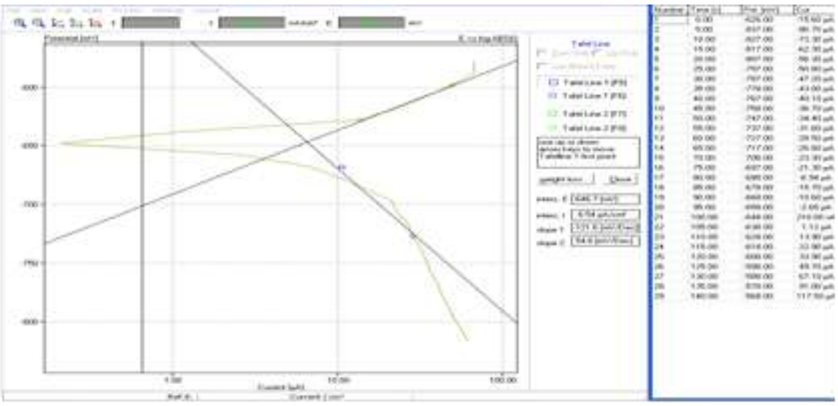


Figure 9. Current density vs. potential at salt concentration (1.5% NaCl) at temperature 25°C, for specimen 1 (at I: 170Amp, V: 20.2volt and S: 200mm/min).

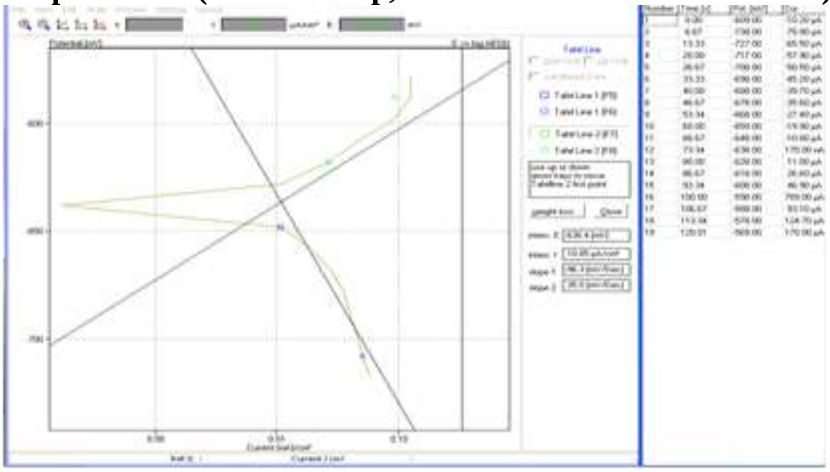


Figure 10. Current density vs. potential at salt concentration (1.5% NaCl) at temperature 25°C, for specimen 3 (at I: 185Amp, V: 20.2volt and S: 200mm/min)

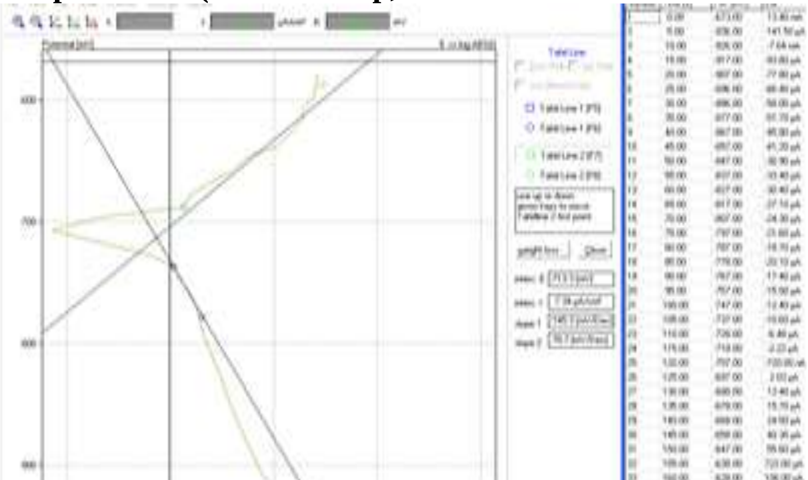


Figure 11. Current density vs. potential at salt concentration (1.5% NaCl) at temperature 25°C, for specimen 6 (at I: 210Amp, V: 20.2volt and S: 200mm/min

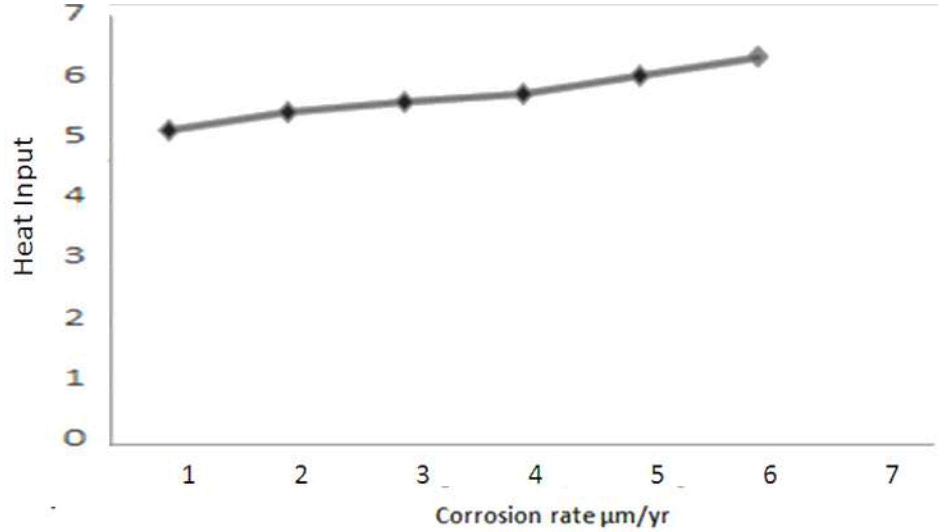


Figure 12. The Relationship between Corrosion Rate and Heat Inpu

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