Study the Change of Current Weld on Mechanical Properties and Microstructure of Low Carbon Steel Welded by Electric Arc Welding

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Abstract

The welding is one of necessary and important process which is used in manufacturing operations to join two or more materials of the similar or dissimilar pieces to achieve complete cohesion. This work focuses on the effect of current change and welding method during welded low carbon steel (steel 37) by electric arc welding on microstructure and mechanical properties such as (tensile strength, hardness and impact strength). The welding currents were chosen are (60, 80, 100, 120, 140 and 160A), and the weld was done by two directions (top and bottom sides). The tensile, impact, hardness and microstructure tests were done to locate the mechanical properties of the welded joint. The results showed that when the welding current increase, the tensile strength was increase from (349.07 to 369.44)MPa while the impact strength and hardness decrease. Microstructure of welding region has been dealt with it for each sample and for every increase of welding current.
Key words: Electric arc welding, Low carbon steel, Microstructure, Mechanical properties.

الخلاصة :

اللحام هو واحد من العمليات الضرورية و التي تستخدم في عمليات التصنيع لربط قطعتين او اكثر من مواد متشابه او غير متشابه لتحقيق التماسك الكامل. في هذا العمل تم التركيز على تأثير تغير التيار وطريقة اللحام خلال لحام الفولاذ الواطئ الكاربون (فولاذ37) بلحام القوس الكهربائي على البنية المجهرية و الخواص الميكانيكية مثل (مقاومة الشد، الصلادة و مقاومة الصدمة). وقد تم اختيار تيارات اللحام (60، 80، 100، 120، 140، 160 أمبير) و تم اللحام باتجاهين (من الاتجاهين الاعلى والاسفل). وقد اجريت اختبارات الشد، الصدمة، الصلادة والبنية المجهرية لتحديد الخواص الميكانيكية لربطة اللحام. اظهرت النتائج انه عند زيادة تيار اللحام، مقاومة الشد تزداد من (349.07 الى 369.44) ميكا باسكال بينما مقاومة الصدمة والصلادة تقل. البنية المجهرية لمنطقة اللحام سجلت لكل عينة ولكل زيادة لتيار اللحام.

الكلمات المفتاحية: لحام القوس الكهربائي، فولاذ واطئ الكاربون، البنية المجهرية، الخواص الميكانيكية.

Introduction

The arc welding is developed in the mid-1800, it is one of fusion welding process in which the welding heat is obtained from an electric arc between the base metal and an electrode by use of an AC or DC power supply. The coarse initial grain size with vary current had a large effectiveness on the microstructure, hardness and toughness of HAZ of low carbon steel **(Aksoy *et.al.*, 1999**). In low carbon steel, it was seen that the fine initial grain size was effectiveness on the formation of ductile phases and on the higher toughness, while the coarse initial grain was effective on the formation of brittle phases and on the lower toughness at the same heat input. As a result, considering the microstructure, hardness and toughness of the inter critical HAZ, a higher heat input for both the coarse initial grain size and fine initial grain size gave good results. However, it was also seen that a lower heat input can be used in the welding of low carbon steel with fine initial grain size with respect to the toughness of the inter critical HAZ (**Aksoy and Eroglu, 2000)**. All materials (metals, plastics, ceramics and composites) can be welded but not by the same process, therefore, the welding process can be classified into two states, fusion state (chemical, electrical) and solid state (electrical, chemical and mechanical), the arc welding process contains either consumable or non-consumable electrode (rod or wire), such as electric arc welding, Tungsten Inert Gas (TIG), Metal Inert Gas (MIG), oxyacetylene welding, laser welding and friction welding **(Parmar , 2010)**. In low carbon steel have (0.19

wt.% C), the microstructure of the center of weld zone contains large grains of ferrite and colonies of pearlite and they found that maximum hardness values are situated in the area of weld metal and HAZ which indicates its specificity(**Zakaria *et.al.*, 2010**). To supply additional material to the weld zone during welding, filler metals are used, they are find as rod or wire made of metals compatible with those to be welded **(Serope and steven, 2012)**. The tensile strength of low carbon steel decrease about 40% when welded by electric arc welding and it disposal as a brittle material according to (**Ali , 2012**). Hardness of weldment increase, impact amount and yield strength decrease when electrode stick increase while ultimate tensile strength of the joint initially decrease and then increases with increase welding current and voltage are kept at constant levels in electric arc welding (**Prakash and Mahima, 2014)**. **(Suhail *et.al.*, 2014**)studied that the good weld quality can be found when the sample has better mechanical properties such as tensile strength, hardness and impact strength. According to **(Asibeluo and Enifoniye, 2015)** the growing of the arc welding current from 70-120A in A36 carbon steel will increase the welding heat input, it will affect the microstructure of the weld itself and award impact on the strength and hardness of the material.(**Sameer , 2015**) studied the effect of weld parameters (current and voltage) on the weld ability of mild steel specimen having dimensions (80mm x 50mm x 6mm), which is welded by arc welding, butt joint, and he found that maintain constant voltage and current, depth of penetration varies with speed, and it have maximum value when the speed increase but if speed increase beyond optimum value results to decrease in depth of penetration.

In electric arc welding, the electrode or wire of welding consumable during welding, therefore, the welding wire must be change and these causes reduced arc welding time.

This research aims to reinforces the weld zone by weld the steel 37 pieces from both sides by electric arc welding with change the weld current and studied effect this change of current on mechanical properties and microstructure.

Experimental part

1. Material and method

Steel 37 is using in plate shape with required dimension and the samples for testing were prepared from it. According to (Rahbar and Zakeri 2010) the chemical composition of steel 37 by wt. % is showing in table 1.

Table 1. The chemical composition of steel 37 (wt. %)

Element	C	Si	Mn	P	S	Fe
Wt. %	0.17	(0.12-0.3)	0.5	0.04	0.035	Rem.

The electric arc welding was used to weld the steel 37 pieces from both sides. The currents (60, 80, 100, 120, 140 and 160A) were chosen with DC electrical power and the specifications of weld electrode were (E6013, D=3.2mm, L=350mm) and have a chemical composition that detail in table 2 according to [Asibeluo and Emifoniye].

Table 2. The chemical composition of welding electrode (wt. %)

C	Mn	Si	S	P
0.12	0.3-0.6	0.35	0.35	0.040

2. Mechanical tests

a. Tensile test :

The tensile test is the widespread for determining the mechanical properties of materials as strength, ductility, toughness, elastic modulus and strain hardening. The samples were prepared according to ASTM E8/E8M, with factor of 0.45 to get proper dimensions of tensile device showing in fig. 1 and the sample before and after test shows in fig. 2.

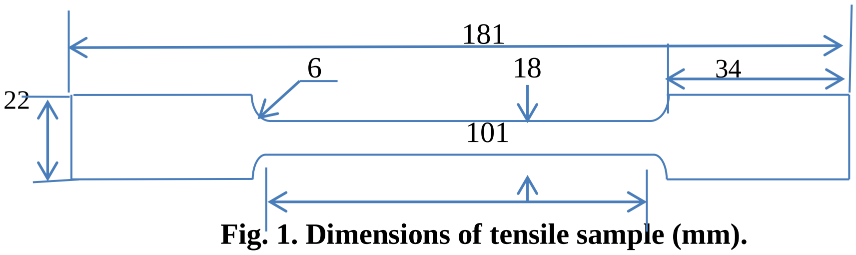
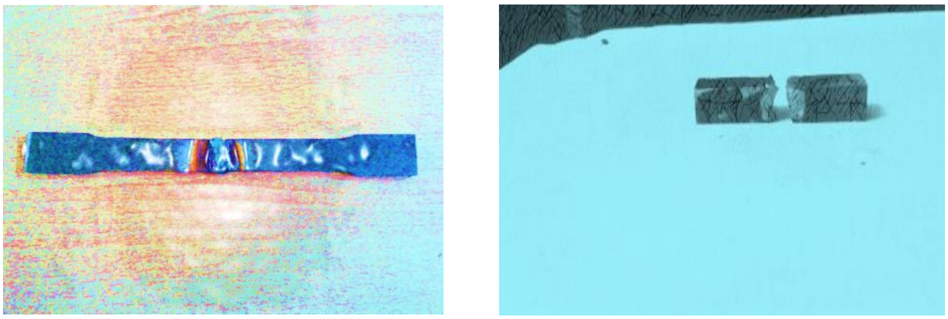


Fig. 1. Dimensions of tensile sample (mm).

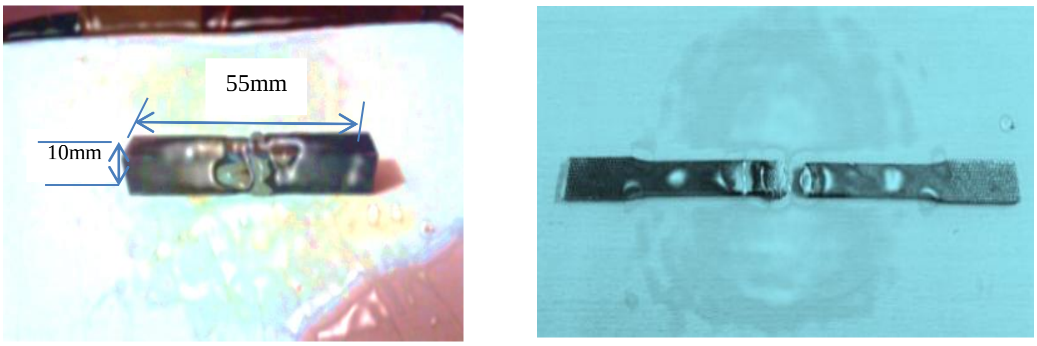


(a) (b)

Fig. 2. Welding samples: (a) Before tensile test, (b) After tensile test

b. Impact test :

In many industrialization operations, as well as during service life of components, materials are subjected to impact (or dynamic) loading. This test performed on Charpy testing machine, the sample was supported at both ends and the pendulum was raised to certain position and then fall down to the notch on half of welding area that cause fracture the sample from the welding area. The dimensions of samples are (55mm in length, square section 10mm x 10mm) with 45˚ V-notch, 2mm depth according to ASTM E23. The sample before and after test shows in fig. 3.



(a) (b)

Fig. 3. Welding samples: (a)Before impact test, (b)After impact test

c. Hardness test :

Hardness is usually defined as resistance to permanent indentation, therefore, it test was used to give indication of the strength of the metal and of its resistance to scratching and to wear. Brinnel method was used to find the hardness number by using Brinnel testing device type (ReicherterUH250) with (13.25Kg) load for 10 seconds and 2.5mm diameter, the BHN was taken for three locations in welding zone.

d. Microstructure test:

To analysis the microstructure by optical microscope with camera 60 and eye piece 10 (magnification 10 x 60 = 400), many processes such as grinding, polishing and etching by Nital solution for 20 second and then washed by water with dry by electric hand dryer were done before test.

Results and Discussions

1. Tensile test

Table 3. Shows the yield and tensile strength of steel 37 were (347.22, 369.44) MPa respectively and elongation was (9.39%) when the welding current was 60A, they have been (291.66, 294.44) MPa and elongation was (8.84%) when current become 80A, after then they were increased with increased the welding current but the elongation was decrease when the current increase. From figs. (4and5),can be considered that the decrease and increase in yield and tensile strength and the decrease in elongation resultant from the increase in weld current and then increase in heat input to weld zone .

Table 3. Results of tensile test of steel 37 after weld

Current (Ampere)	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)
Base metal	326.38	453.58	10.49
60	347.22	369.44	9.39
80	291.66	294.44	8.84
100	324.07	322.22	8,28
120	328.70	329.62	7.73
140	337.96	338.88	7.18
160	342.59	349.07	6.63

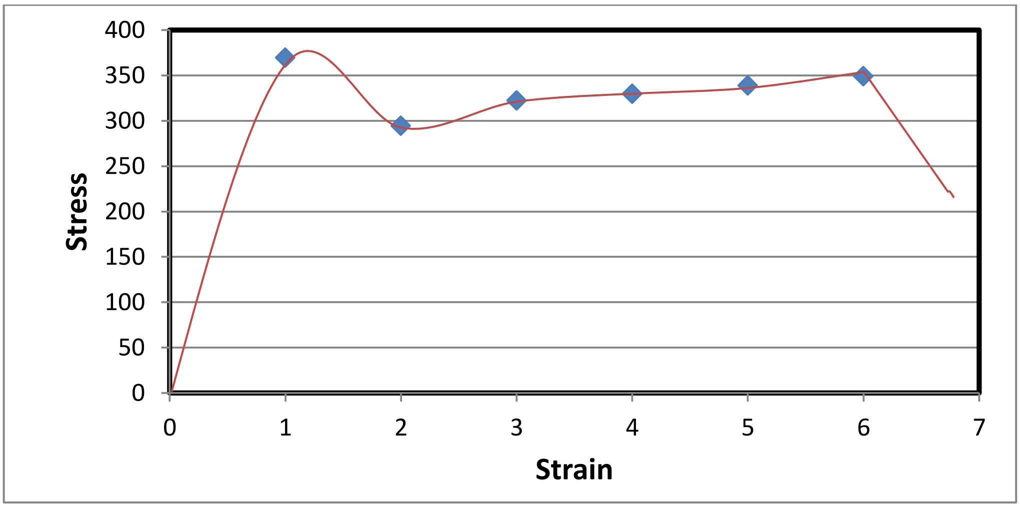


Fig. 4. Stress and Strain curve of steel. 37 after weld

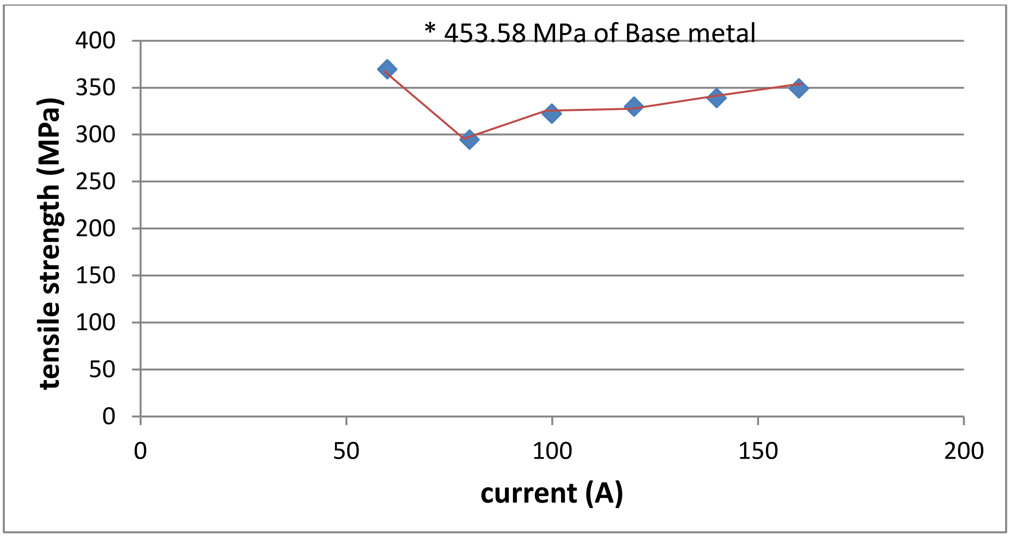


Fig. 5. Current and Tensile strength curve of steel 37 after weld

2. Impact test

From the table 4 and fig.6, note that the maximum and minimum values of impact strength were (24, 16) joule by weld current were (60, 160)A. The decrease in impact strength with increase in weld current can be explication that the ability of metal to withstand to applied load reduced and then the toughness of metal reduced by increase in heat input that resulting from increase in weld current. And the coarse grains that formed after high heat input during arc welding may be caused reduction in impact resistance compared with the base metal.

Table 4. Results of impact strength (Joule) of steel 37 after weld

Current(A)	Base metal	60	80	100	120	140	160
Energy(J)	29.5	24	21	20	19	18	16

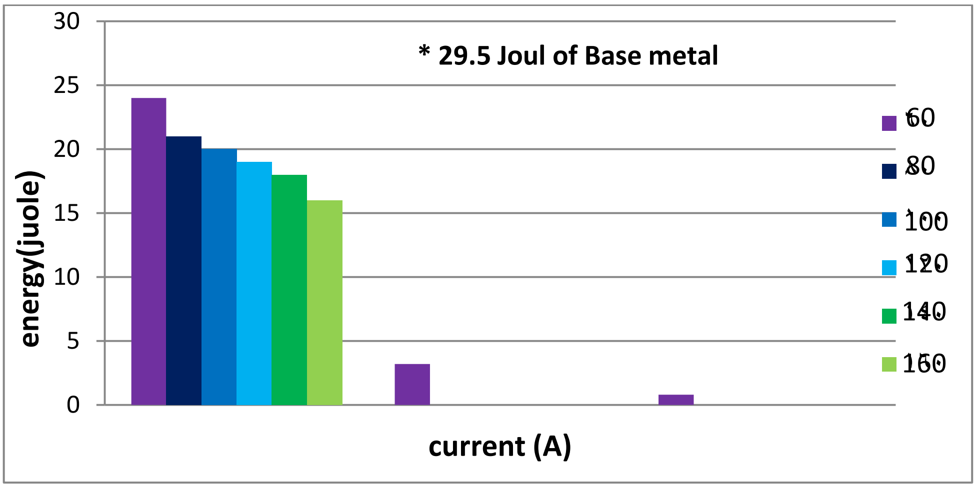


Fig. 6. Effect of current on energy absorbed of steel.37 after weld

3. Hardness test

The Brinnel hardness number BHN was taken in different locations on welding zone. From the results in Table 5, the greatest hardness is with less value of current 60A in arc welding of steel 37. Fig. 7 shows the hardness is decrease with increase welding current because of the increase in heat input and the time of cooling was increase which gives rise to rapid growth of the grain and then the microstructure of weld zone was coarse and then the hardness of metal reduced.

Table 5. Brinnel hardness number of steel 37 after weld

Current (Ampere)	BHN Trace1	BHN Trace2	BHN Trace3	Average BHN
Base metal	198	180	170	182.66
60	195	174	166	178.33
80	160	166	178	168
100	156	169	178	167.66
120	177	163	147	162.33
140	140	166	176	160.66
160	158	143	152	151

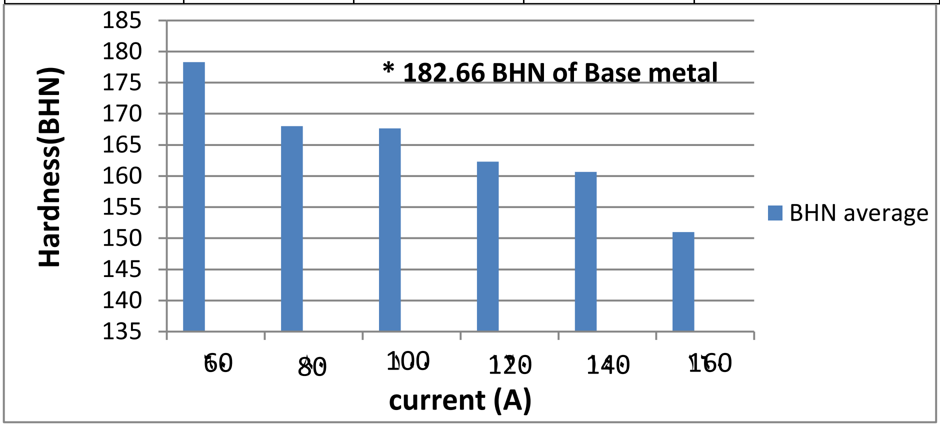
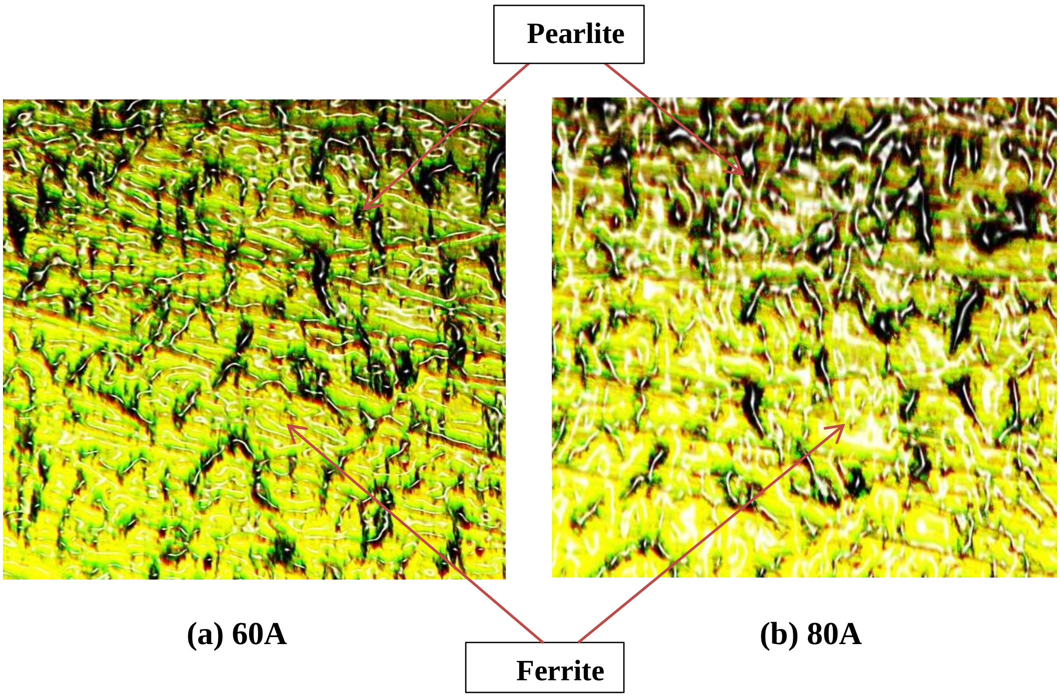


Fig. 7. Current and Hardness curve of steel 37 after weld

4. Microstructure test

The test was done by optical microscope with magnification (600). From the microstructure in (fig.8,a) the grains were less coarseness at weld current (60A) but when the weld current becomes 80A (fig.8,b) the heat input increase then the microstructure becomes more coarse and the pearlite phase was less than ferrite phase at current 60A and 80A then grow up whenever the weld current increase to become greater at current 100A (fig.8,c) reverse ferrite phase which taking opposite path. (fig.8,d,e,f) showing that when weld current becomes 120A, 140A and 160A, the heat input increases and the time for cooling was increase therefore the grains become coarse (pearlite phase greater than ferrite phase).



(a) 60A **(b) 80A**

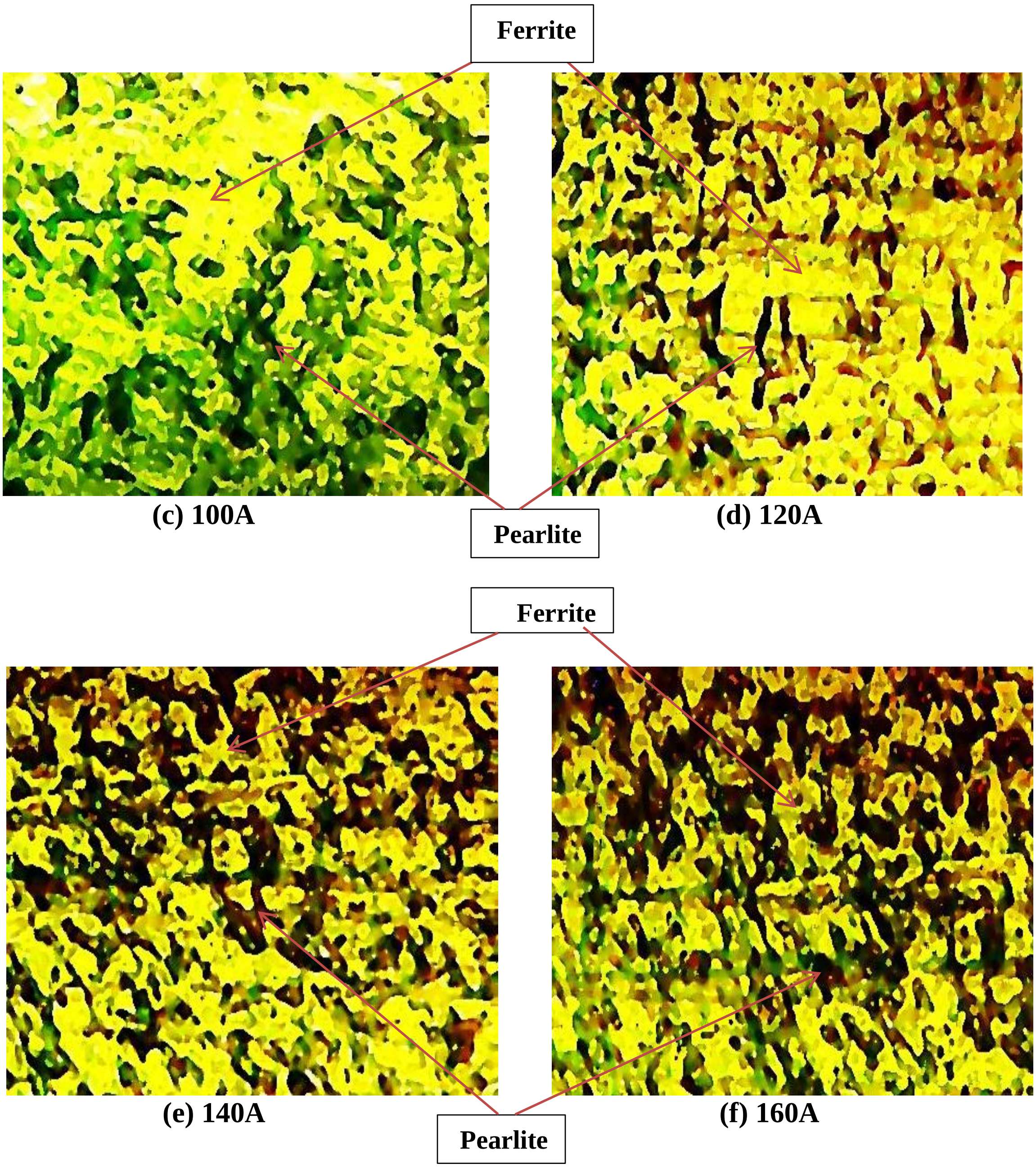


Fig.8 .Microstructure of steel 37 at different welding current

Conclusions

From the results of mechanical and microstructure tests to steel 37 which welded by electric arc welding, it can be concluded:

1. The increase of heat input to the weld zone result from the increase of welding current from 60 to 160A.
2. Whenever increase current, the grains was coarse and effect on mechanical properties of welding zone.
3. From the microstructure of weld zone, the ferrite phase become more great when the weld current increase but the pearlite phase become more less when the weld current increase (the grains became coarse with increase of weld current).
4. The hardness and impact strength decrease to (151BHN, 16Joul) respectively with increase welding current.
5. The yield and tensile strength were decrease (291.66, 294.44)MPa at first and then increase to (342.59, 349.07)MPa respectively with increase welding current of electric arc welding.

6. The decrease in percentage of elongation resultant from the increase of tensile and yield strength and increase in metal ductility and also decrease in metal hardness because of increase in heat input when the weld current increase.

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