Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 4645-4651/Pour and Salmani
Research Article

EFFECT OF GTAW WELDING PARAMETERS ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF CARBON STEEL ALLOYS BY STELLITE 6 FILLER

Mahdi Karami Pour and *Mohamad Reza Salmani
Department of Material Engineering, Islamic Azad University Save Beranch, Iran, Save
**Author for Correspondence*

ABSTRACT
In this study, the effects of GTAW welding parameters such as speed and amperage on the mechanical properties and microstructure of steel DIN1.0254 by filler stellite 6 were examined. For this purpose, DIN1.0254 steel plates with dimensions of 15×30×0.3 cm were prepared and welded using filler stellite 6 (ERCoCr-A) at different speeds of 0.6, 1.2, 2 and 2.8 mm per second and 80,110 and 130 amperes. The metallographic test, tensile test, hardness test and scanning Electron Microscope (SEM) were used to test specimens. The results from optical metallography and SEM show that weld zone microstructure consists of carbides that have precipitated between base dendrites of cobalt matrix. The size of carbide precipitations and the size of dendrites increase with increasing ampere and decreasing speed. The tensile test results indicate that the best yield strength is obtained in welding with 110 amperes and speed of 1.2 mm/s.

Keywords: *Stellite 6, GTAW Welding, Micro Hardness, Microstructure*

INTRODUCTION
Carbon steels refer to those of kinds of steels that carbon is their most principal alloy element and elements such as manganese, Silesia and aluminum are present in them with a little amount and these elements are added to the for deoxidation. Carbon steels are broadly used in industry and usually are applied at anile or normalized form, but in specific cases, they are applied in hardening and tempered form. The simple carbon steels are the important group of engineering alloys that are at first order of importance among engineering materials due to their relatively low cost of production and having a wide range of properties. These steels can usually be welded by any conventional welding methods that based on the thickness of the segment, the required quality, cost and other factors, the specific method and process are chosen. Over the steel of 0.29% carbon, and at maximum 1.6% manganese and thickness less than 2.5cm without preheating or specific post-heating, we can create a completely satisfactory welding. But at values higher than 0.20% carbon and 1% manganese, it is better the low-hydrogen electrodes are used (Kawkabi, 2006).
GTAW Welding method is of arc welding methods with a shielding gas. The possibility of using helium to protect the welding arc and weld pool was studied for the first time in 1920, but until the beginning of World War II and the need to use it in the aircraft industry instead of riveting to join the active metals like aluminum and magnesium, the helium gas did not have any use in welding. By using the tungsten electrode and direct current in the electrode negative polarity (DCEN), an effective source of heat was generated by which the high quality welds were created. Since that time helium was the most available inert gas, it was used as a shielding gas. This process was called the welding of tungsten inert gas (TIG) or gas tungsten arc welding (GTAW).
Great progress was made in the process and its equipments. Supply sources of this process were made that some of them generated DC current pulse and some alternating current (AC). In order to enhance the capability of tungsten electrode radiation, small quantities of active compounds were added to improve arc starting, arc stability and longer life of the electrode. Also, different combinations of the shielding gas were used to make better the welding.
In GTAW welding, the non-consumable tungsten electrode which is placed inside the torch is used. The shielding gas is also directed through the torch thereby the electrode, melt pool and welding thread at

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 4645-4651/Pour and Salmani
Research Article

freezing state are protected against air pollution and absorption of impurities. Electrical arc is created by passing the electric current through a conductor and ionized shielding gas (Rafiei, 2013). The variables of GTAW Welding process includes speed voltage-ampere and type of consuming gas that in this research, we have changed the parameters of ampere and speed and by considering the effect of these two parameters on the internal heating, the infrastructure changes and mechanical properties are investigated.
In this study, we have used the metal filler of stellite 6 that is the basic alloy of cobalt base. Stellite 6 with chemical composition of 5% C and W and 28% cr and Co is one of the most consumable basic alloys of cobalt that is used in conditions that the hot stability and hardness and resistance against corrosion and abrasion are required. The use of this alloy as a hard cover at high temperatures causes considerable increase in resistance against abrasion (Rezaei, 2012).

MATERIALS AND METHODS

Research Method

14 plates made from simple steel with carbon DIN 1.0254 and dimensions 150×300×3mm were prepared. In order to avoid errors (lof and lop) in samples, the edges of the workpiece was prepared as zigzag v (form) for easy access of the melted material to the root of joints. To remove residual contamination of machining, before welding the samples were chemically cleaned by alcohol 99vol% c_2H_2OH+1vol% HCL. Welding of the samples was done using TIG process by Ferrinus Magic wave 5,000. One of the most influential variables in each process of welding is the type of metal filler. In this study, the metal filler of stellite 6 that is in agreement with ERCOCR-A5, 19AWS A, was used that its diameter was 4.2 mm and its chemical composition is as shown in Table 1.

Table 1: Chemical composition of the metal filler ERCOCR-A

CO	MO	Mn	Fe	Si	C	Ni	W	Cr	Alloying element
BASE	>0.1	0.3	1.9	1.1	1.3	2.2	4.9	28.6	% by weight

The consumption gas required is Argon gas with high purity that its flow rate of consuming gas has been considered as 12lit/min. Then, the samples were assembled as butted welding and welded in accordance with the parameters of welding in Table 2.

Table 2: Executive parameters of the research in different amperes of welding

Sample	Current (A)	Voltage (V)	The time (S)	Length (mm)	Speed (mm/s)	Gas flow rate (lit/min)	Work joint (Mm)
A	80	10	242	300	1.23	12	2.4
B	110	11.2	228	300	1.31	12	2.4
C	130	11.8	230	300	1.30	12	2.4

Criterion for determining the parameters in Table 2 were such that first, we obtained the optimal current rate using the data accessible from the existing resources in the field and the trial and error method, and then according to this obtained rate, a sample with a higher current rate and a sample with lower current rate and 30% 0f difference were elected and welding operation was performed on the samples; the speed was fixed in all samples.

Table 3: Executive research parameters at different speeds of welding

Sample	Current (A)	Voltage (V)	The time (S)	Length (mm)	Speed (mm/s)	Gas flow rate (lit/min)	Work joint (mm)
A	1 10	3/11	500	300	6.0	12	4.2
B	110	5/11	246	300	2/1	12	4.2
C	110	9/11	150	300	2	12	4.2
D	110	4/11	105	300	8.2	12	2.4

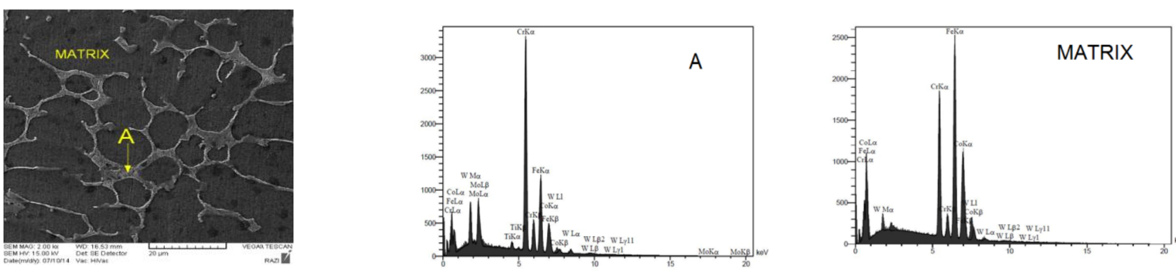
Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 4645-4651/Pour and Salmani
Research Article

With this method, four obtained samples with the optimal ampere from the previous stage with different speeds were welded as shown in Table 3.
The purpose of doing these experiments is to find the presence or absence of internal defects, therefore all samples were tested using radiographic device, model Rigaku with power of 300kw and 5mA current in accordance with EN 1435 standard. To compare the tensile strength of the weld joint sections at different welding conditions, the test specimens were prepared in accordance with ASTM-B557M standard. The samples were prepared in such a way that the welding section was quite in the center. Of the welded specimens, 3 samples of each type and of the base metal, 2 samples were also extracted. In this project, in order to determine and compare the rigidity (hardness) of the connecting sections in the heat conditions of different inputs, Vickers hardness test with applied force of HV 10 (Kgf) and the applied force time for 10 seconds was carried out in accordance with ASTM E384-12 standard.

Presentation and Analysis of the Results

Microstructure

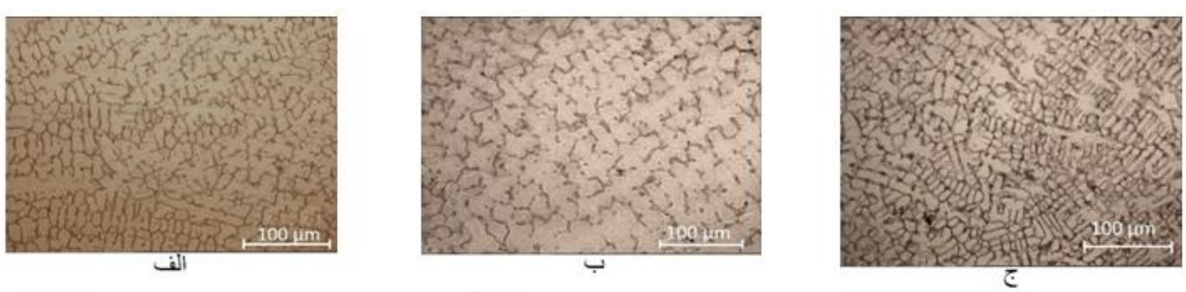
The microstructure of stellite 6 alloy weld created by the process of GTAW has been shown in figure 1. As shown, this microstructure includes carbides that have deposited between the base dendrites of cobalt. Carbides are generally of M7C3 and M23C6 types (Van Otterlo and De Hosson 2010) The microstructure of the weld zone has been shown in figure (1a). As it can be seen, the microstructure consists of dendrites (bright areas) inter-dendritic eutectic (dark areas). Figure (1b) shows the EDS analysis of dark and bright areas. The results of this analysis indicate that the dark areas are rich in cobalt and iron that are as solution in the area. The bright areas are also rich in chromium and carbon, which indicates the existence of carbide in the area. These carbides are formed during the freezing of weld pool.



(a) (b) (c)

Figure 1: (a) SEM image of the weld zone; (b) EDS analysis of zone A (light); (c) EDS analysis of base zone (dark)

As it is evident, in the weld areas with different amperes, by increasing of ampere and as a result the increased input heat, dendrites are larger and have much growth; this is because of much heat input, as a results, settling the weld zone at higher temperature and cooling it late.



(a) (b) (c)

Figure 2: Optical microscope image of the microstructure of welded stellite 6: a) 80 amps; b) 110 amps; c) 130 amps

In the welded samples at different speeds, by reducing speed and increasing input heat, we can see the greater growth of dendrites of chromium carbide and enlarging them.

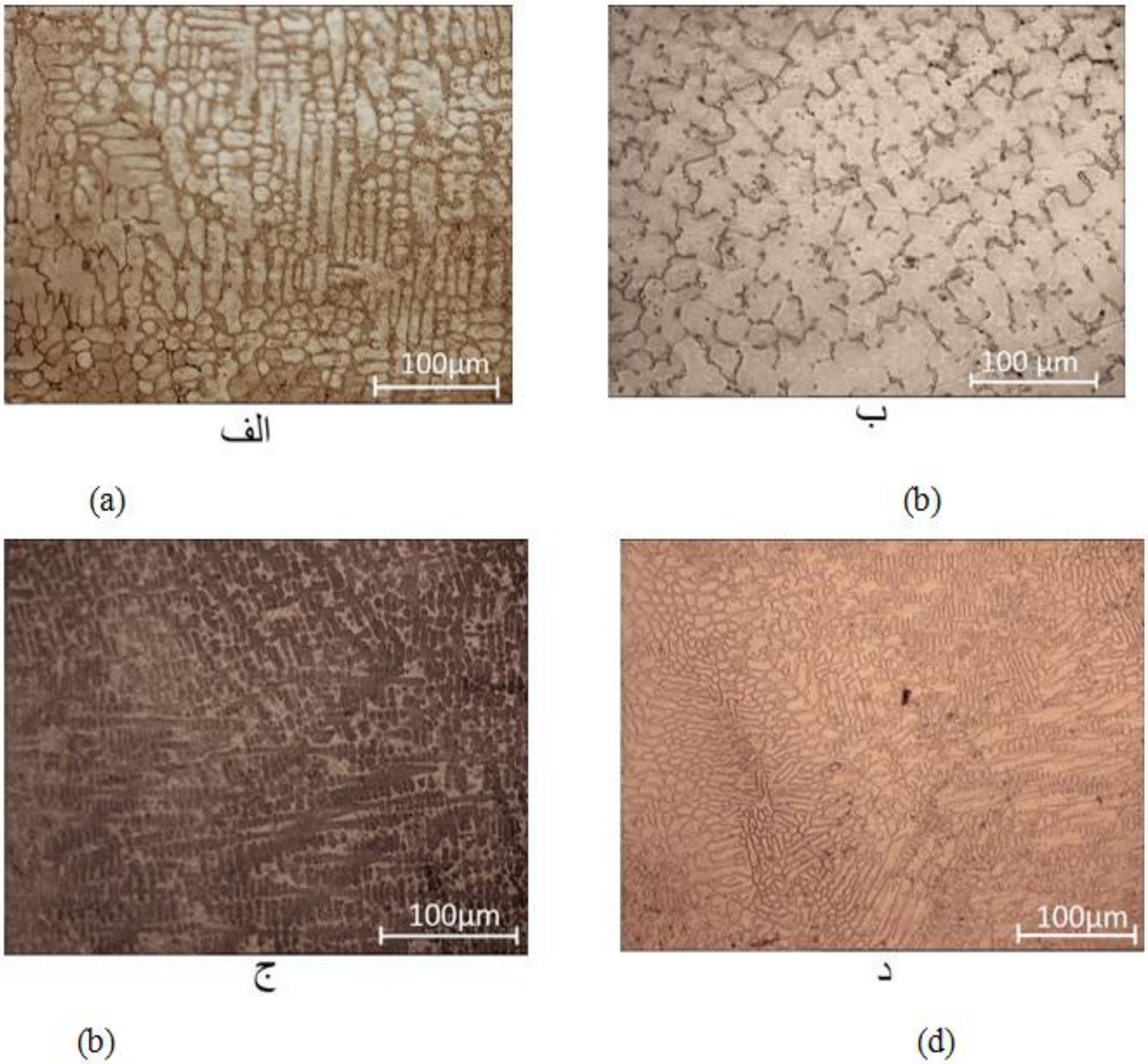


Figure 3: SEM image of the microstructure of Stellite 4 weld zone with different speed: a) 0.6mm/s; b) 1.2mm/s; c) 2mm/s; d) 2.8mm/s

The Results of Tensile Test

The results of tensile tests at three different amperes have been shown in Figure (4). As it can be seen, the maximum tensile strength was obtained in the welded sample B with 110 amperes with strength of 388Mpa, and the minimum tensile strength in sample A (367 Mpa). Reducing the strength of the sample A (80 amps) is due to reduced input heat and lack of full penetration at the welded zone that causes the failure from this region. Strength reduction at amperes higher than 110 suggest that with increasing input heat in this sample up to 826J/mm and cooling with delay of the weld zone and the zone affected by heating and grain growth resulting from it (in accordance with Hall patch relation), the strength is reduced; and since the maximum grain growth occurs in the heat-affected region, the possibility of failure is high in this region, unless the specific interactions have been occurred or its chemical composition is different from the base metal.

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 4645-4651/Pour and Salmani
Research Article

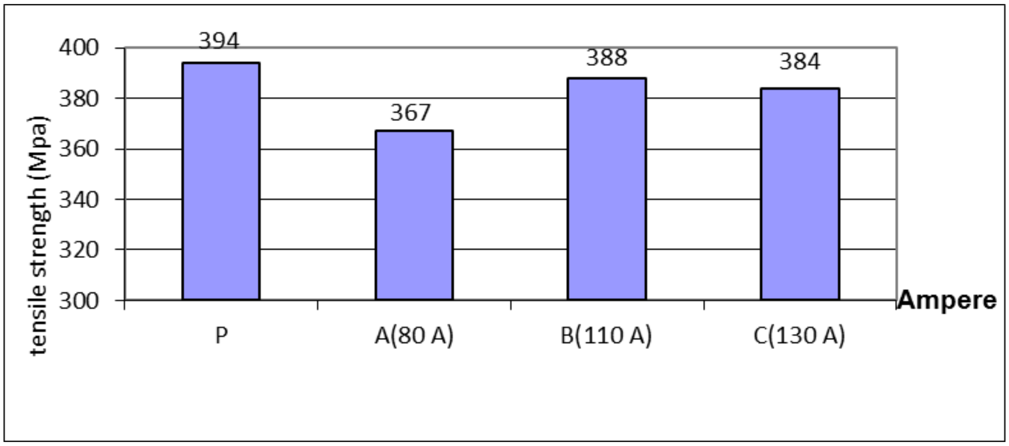


Figure 4: Diagram of the comparison of the yield strength of samples

Also Figure (5) shows the results of tensile tests at four different speeds. As it is shown, the maximum strength is obtained at speed of 1.2mm/s; and it was discussed above, at high and low speeds of welding due to the lack of melting and full penetration of the weld and also because of high input heat and becoming coarse the grains, we are facing with reducing the size of the grain.

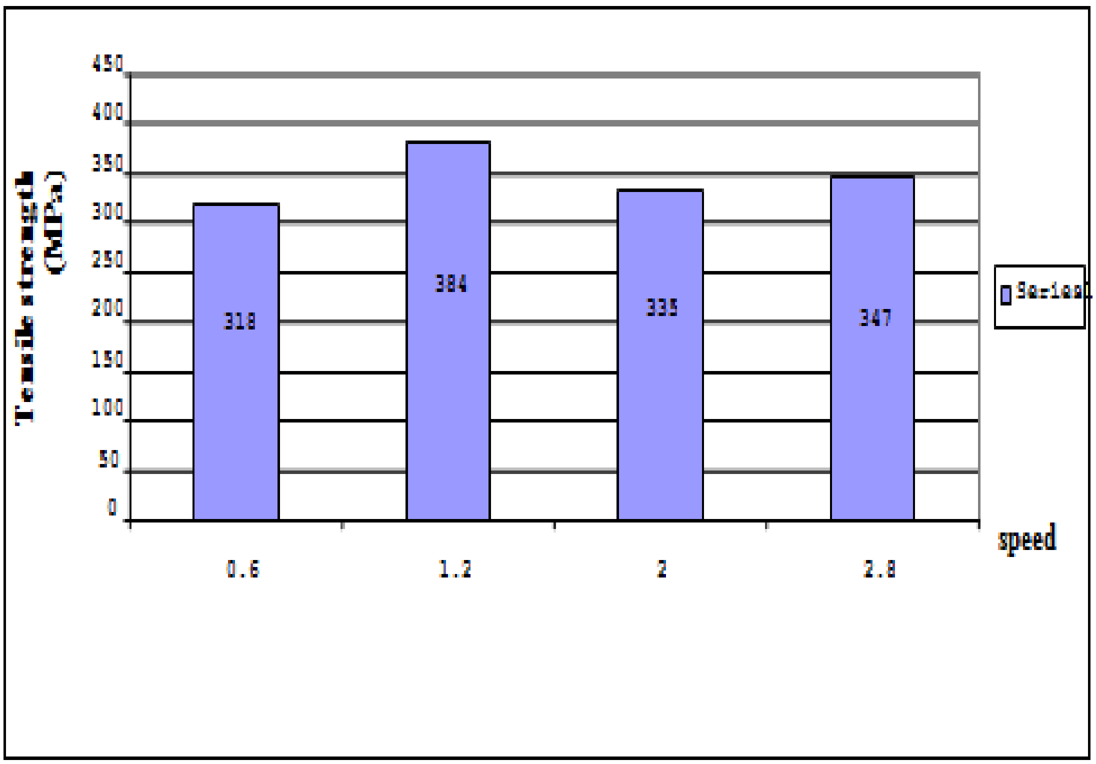


Figure 5: The comparison of the tensile curve - elongation for the different specimens

The Results of Hardness Test

Hardness profile of the weld zone in welded samples have been compared with different amperes that the results indicate that the lowest hardness of the sample has occurred in Vickers sample C (365) that has been exposed to the minimum input heat and the highest hardness was obtained in samples A and B of Vickers 574 and 575 respectively.

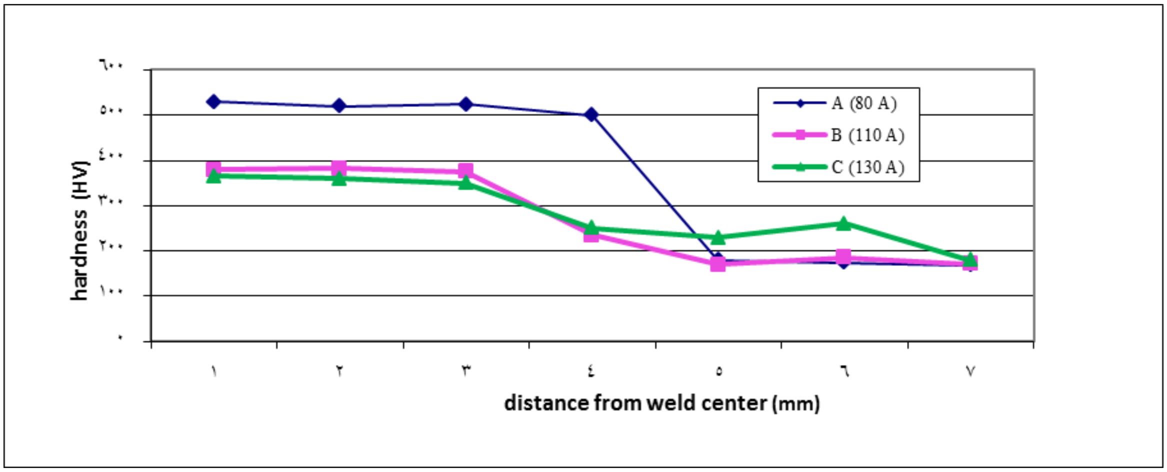


Figure 6: The curve of comparison of weld hardness profile in the welded samples with different amperes

In Figure (7) also the weld hardness profiles of the welded samples were compared with different speeds, that the lowest hardness has occurred in HAZ region of sample A that with the lowest speed (0.6mm/s) has been exposed the maximum input heat and the highest hardness was obtained in the sample of Vickers 570 that has been welded at speed of 2mm/s.

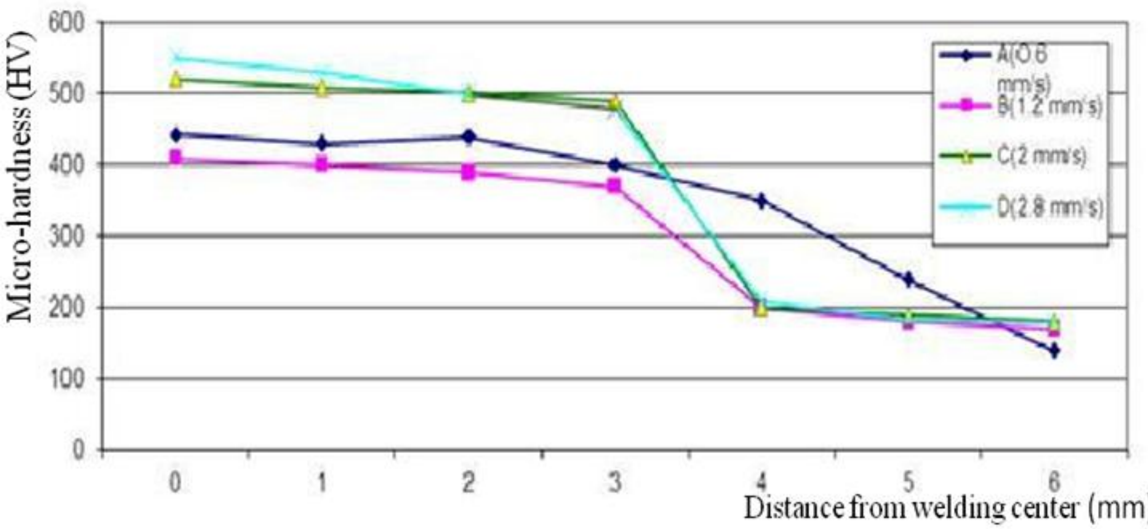


Figure 7: The curve of comparison of weld hardness profile in the welded samples with different speeds

Conclusion

1- The microstructure of stellite-6 weld zone on the simple carbon steel is as rich solid solution of cobalt and chromium- and carbon-rich dendrites indicating the presence of carbides M7C3 and M23C6.
2. By comparing SEM images of the microstructure of the weld regions, we find that the welded samples with different amperes, by increasing ampere the carbide precipitations grew more and enlarged and this is due to the increased input heat and later subsequent cooling of the weld zone. And also, at welded samples with different speeds, by increasing the speed the carbide dendrites grow fewer and become smaller.
3. Comparison of yield strengths obtained show that the yield strength of the welded sample with 110 amperes has the best yield strength and also at welded sample with different speeds, the specimen welded

with a speed of 1.2 mm/s has the maximum yield strength. In other cases, the reason for loss of strength is due to lack of penetration and incomplete fusion, or the reason for becoming coarse grain is the seam of the welded samples with high input heat.

4. Comparison of the results of micro-hardness shows that the minimum hardness is in HAZ region of the welded samples with high input heat and in the weld regions, the maximum hardness is related to the welded specimen with a speed of 2mm/s, and in the welded samples with different amperage, the sample was welded with 80 amperes that in both specimens the input heat is the minimum rate; and in other cases, the reason for hardness loss is due to high input heat and grain growth and the increase of dilution of the base metal in the weld metal.

REFERENCES

Kawkabi AH (2006). *Welding Technology*, 7^{th} edition (Azadeh publications).

Rafiei A (2013). Evaluation of welding parameters on the microstructure and mechanical properties of titanium alloys AZ91 by GTAW method, Islamic Azad University, Science and Research Branch, Tehran.

Rezaei Salim R (2012). The study the effect of adding Etheria and Ceria on microstructure and abrasive behavior of the satellite 6 cover created by TIG welding method on the stainless steel AISI316, Islamic Azad University, Ahwaz.

Van Otterlo J and De Hosson JTHM (2010). Microstructure and Abrasive Wear of Cobalt Based Laser Coating. *Scripta Materialia* **39**.