Diyala Journal of Engineering Sciences

Journal homepage: https://en.enginmag.uodiyala.edu.iq/

ISSN: 1999-8716 (Print); 2616-6909 (Online)

Study the Effect of Welding Current and Time on The Microstructure and Strength of Dissimilar Weld Joint AISI 303/AISI 1008

Firas H. Hajim[1*], Sami A. Nawi[1], Muzher T. Mohamed[2]

[1] Department of Mechanical Engineering, College of Engineering, University of Diyala, 32001 Diyala, Iraq
[2] Department of Materials Engineering, College of Engineering, University of Diyala, 32001 Diyala, Iraq

ARTICLE INFO

Article history:
Received 15 July 2020
Accepted 8 February 2021
Keywords:

Arc stud welding; AISI 303 stainless steel; AISI 1008 low carbon steel; Dissimilar metals; Microstructure; Mechanical properties.

ABSTRACT

The welding of metals is one of the most important processes that require high control for obtaining a good quality of weldments. Joining of dissimilar metals is a more complex operation compared to joining of similar metals due to the differences in physical, metallurgical and mechanical properties. In this article, austenitic stainless steel AISI 303 studs were welded to low carbon steel AISI 1008 plate using arc stud welding (ASW) process. An experimental procedure was applied to estimate the effect of welding parameters namely welding current and welding time on microstructure and mechanical properties of the joint. The optical microscope was used to show microstructure properties while both the micro-Vickers Hardness and tensile test were adopted to evaluate the mechanical properties. The results revealed that the presence of carbides at the fusion zone FZ towards AISI 303 leads to the maximum value of hardness (501) HV. The best welding parameters were 600 AMP 0.25 second at which joint tensile strength of 515 MPa was recorded. Welding time was the effective parameter in the ASW process followed by welding current, proper selection of welding time and welding current produces good joint quality.

1. Introduction

Arc Stud Welding (ASW) process considers one of an efficient welding technique that uses to join stud metal on the base metal [1]. The products of ASW can be utilized in various mechanical fields such as manufacturing products, mechanical structures, and automotive industries [2]. The most important issue can be determined in the effect of the welding parameters on the process. The quality of welded parts produced by ASW strongly depends on the welding parameters such as current required for the process, time of the process, length of the stud, and gab r between the stud tip and the plate.

Austenitic stainless steel is commonly applied for the manufacturing of the steam boiler because of the high corrosion resistance. The high strength with the appropriate cost for low carbon steel is one of the essential properties that led to use it in the manufacture of vessels, evaporators, petrochemical industries, and heat exchangers [3]. The manufacture can reduce the cost of welding through the choice of joining dissimilar materials [5]. The brittleness part of weldments is one of the most metallurgical problems that lead to the degradation of mechanical properties. In the joining of dissimilar metals, the difference in physical metallurgical and mechanical properties is a more complex task compared to the joining of similar metals [6-7]. The welding between austenitic stainless steel and low alloy steel leads to poor mechanical properties and corrosion resistance. Therefore, it is necessary to choose appropriate welding parameters that have good quality with minimum mechanical defects according to the work done by Arivazhagan et. al

[*] Corresponding author.
E-mail address: firasrockt71@gmail.com
DOI: 10.24237/djes.2021.14106

[8]. Their study has been shown both the microstructure and mechanical properties for joints based on AISI 304 stainless steel and AISI 4140 low alloy steel. They proved that the high tensile strength can be obtained joint made by Electron Beam Welding (EBM) while joint produced by Gas Tungsten Arc Welding (GTAW) and Friction Welding (FRW) has lower tensile strength. Venkata et. al. [9] identified the residual stress distribution in dissimilar metal welds of maraging steel by means of the effect of heat treatment condition for the metal using quenching and tempering medium alloy medium carbon steel. The study revealed that the similar and dissimilar metal welds exhibited the fusion and heat-affected in symmetrical and unsymmetrical regions respectively due to the materials of welded have different thermal conductivity. The effect of the welding current and welding time on microstructure and mechanical properties of the weldments was performed by Abbas E.N. et. al. [10]. The results showed the high heat input based on welding current and welding time at the carbon steel side raises the diffusion of carbon at HAZ and encouraged martensitic transformation. Showon et.al.[11] conducted the research on the effect of welding current according to the rang 3-9 KA on the behavior of welded joint employing the structural and mechanical properties. They revealed the nugget size of the welded coupons increases with the raise the welding current. On the other hand, the high heat input based on welding current and welding time leads to an increase in the diffusion of carbon at HAZ and encouraged martensitic transformation. Shazarel et al. [12] performed the weld with good tensile strength, minimum heat-affected zone (HAZ), and acceptable welding profile, via carefully selecting peak power, pulse duration, and welding speed. They concluded that the minor effects on the tensile strength can be obtained by both the welding speed and percentage of weld bead overlap. Moreover, the peak power and pulse duration have an impact effect on the tensile strength and weld bead geometry. Fatima et al. [13] gave the effect of welding current and welding speed on the quality of the welded joints for plasma arc welding. It was found that weld can be obtained by direct fusion at a higher welding speed.

From the previous articles presented in this paper, it is a great need to show the effects of welding parameters for the arc stud welding (ASW) of dissimilar metals on the microstructure and mechanical strength of the joint. In this paper, arc stud welding of austenitic stainless-steel studs AISI 303 to low carbon AISI 1008 steel plates was carried out. The study aimed to correlate arc stud welding parameters with microstructure and mechanical properties of the joint by means of tensile, hardness, microstructure, SEM, and EDS.

2. Experimental Procedure

In this work, austenitic stainless-steel stud AISI 303 and low carbon steel plate AISI 1008 were selected as the material of the joint. The diameter of the stud is 10 mm and length 57 mm, plate dimensions are 100×100×6 mm. The chemical composition and mechanical properties are reported in tables 1 and table 2 respectively for the AISI 303 and AISI 1008.

Table 1. Chemical composition of AISI 303 and AISI 1008

Element%	C	Si	Mn	P	S	Cr	Ni
AISI 303	0.08	0.81	1.52	0.02	0.04	15.77	8.42
AISI 1008	0.10	----	0.50	0.04	0.05	----	----

Table 2. Mechanical properties of AISI 303 and AISI 1008

Material type	Tensile strength Mpa	Yield strength Mpa	Elongation%
AISI 303	690	415	40%
AISI 1008	305	170	30%

The welding process was carried out using arc stud welding machine Dabotek type DT 1000 to join the studs to plates as shown in Fig.1. The machine contains unit time control which utilized to change the time of welding and unit current control that used to change the current of welding, current of machine start from 200 AMP to 1000 AMP. Fig.2 illustrates the principle of arc stud welding with ceramic ferrule gradually. In the first step, the stud is loaded into the weld tool and properly positioned against the base metal. Second step, the trigger is depressed, stud lifts, creating an arc. In step three, arcing periods completed, and the stud is plunged into a molten pool. In forth step, welding is done, the weld tool is withdrawn, and the ferrule removed for inspection.

Figure.1 Arc stud welding machine DT (1000) (a) control system and (b) Pistol

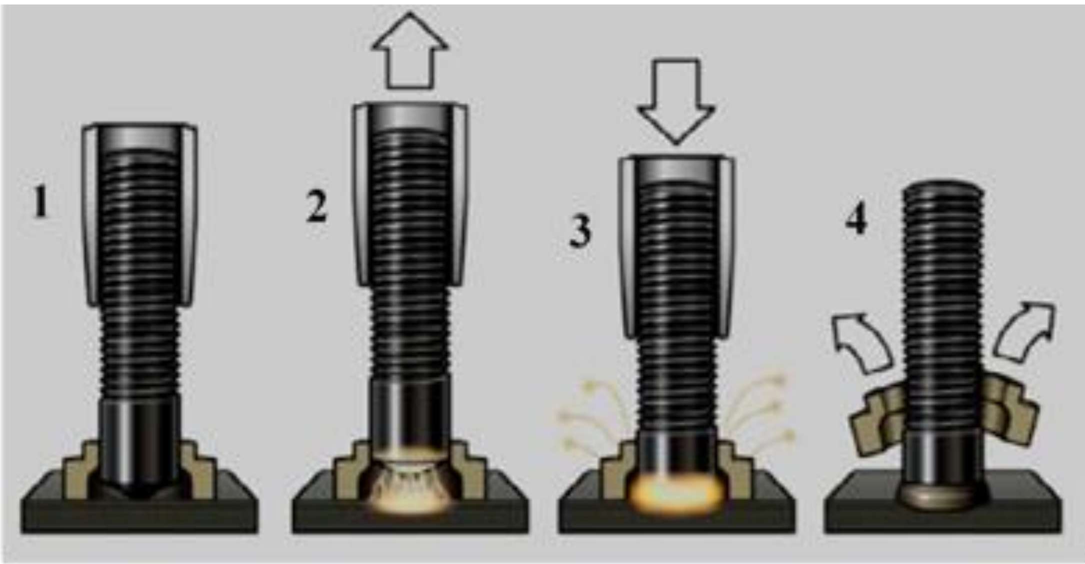

Figure 2. Principle of arc stud welding [12]

In this study, the welding current of 400 and 600 AMP were selected while the welding time of 0.2, 0.25, 0.3, 0.35, 0.4, and 0.45 seconds were applied. A wire cutting machine was used to prepare the weldments for the metallographic and microhardness test follow standard grinding and polishing methods.

The optical microscope V83MC50 was chosen to evaluate microstructure in detail when the samples were etched with fresh mixed acids (two parts of acetic acid, two parts of HNO3, and three parts of HCL) at the stainless-steel side and Nital solution at the carbon steel side.

The TE-scanning (Czech Republic) for SEM examination, Digital Micro-Vickers Hardness Tester model no. (HVS-1000 / China) was used to determine the microhardness as seen in Fig.3.

On the other hand, the tensile test was performed using a universal testing machine (40 KN & hydraulic load) to determine the tensile strength of dissimilar materials of arc stud welding joints as presented in Fig 4. The dimensions of welding samples are $100 \times 100 \times 6$ mm stud with a diameter 10 mm and length 57 mm.

3. Results and discussion

3.1. Weld appearance

Figs. 5a and 5b depict the weld appearance of dissimilar weld joint AISI 303/AISI 1008 at 600 AMP with 0.25, and 0.4 seconds respectively. It can be noticed that the size of the weld pool presented in Fig.5 b is larger than the size of the weld pool presented displayed in Fig 5a because of the higher heat input with 0.4 second welding time for the same welding current 600 AMP. The weld pool looks wavier for higher heat input as a result of dramatic fluid flow during the welding process.

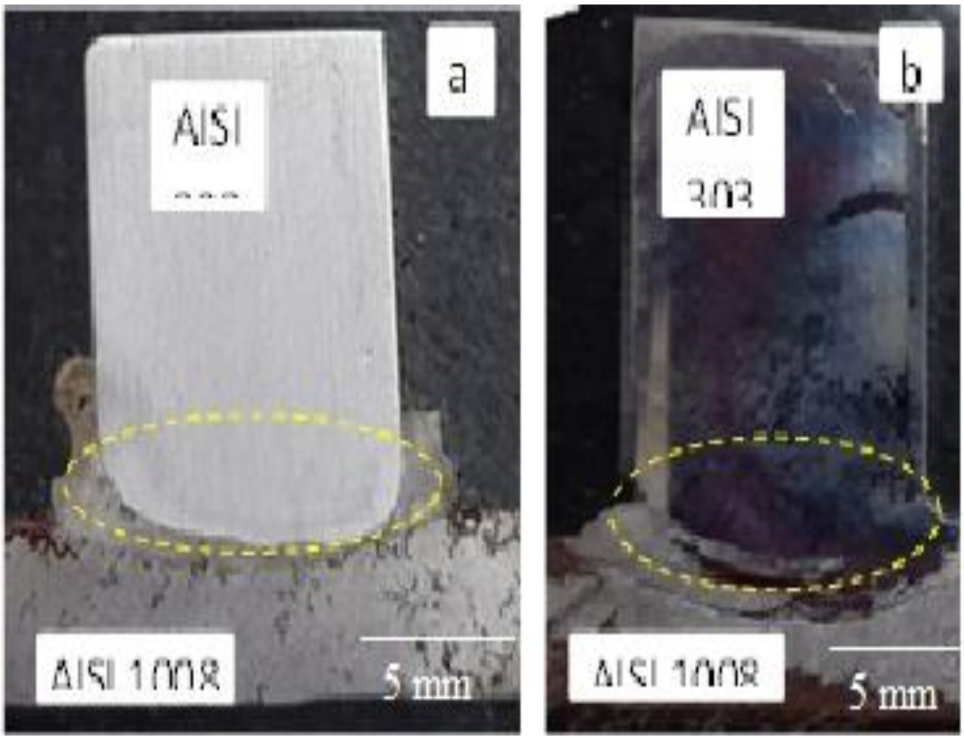

Figure 5. Weld appearance of dissimilar welds joint AISI 303/AISI 1008: (a) 600 AMP, 0.25 second, and (b) 600 AMP, 0.4 second

3.2. Weld Microstructure

The microstructure of dissimilar weld joint AISI 303/AISI 1008 at 600 AMP, 0.25 second, and 600 AMP, 0.4 second is illustrated in Figs 6 and 7 respectively. It can be seen that the microstructure of the weldment and parent metal undergoes considerable changes due to the heating and cooling cycle of the welding process. The heat-affected zone maintains its granules within the normal size. The granules are larger in size when moving away from the weld zone to indicate the presence of recrystallizing areas down to the base metal. Fig.6 and fig.7.

Fig.8 displays the SEM image of the AISI 303 / AISI 1008 weld zone. It can be observed that some porosities appear in the weld pool, which refers to oxide inclusion. This result agrees with the result presented by Ref. [19].

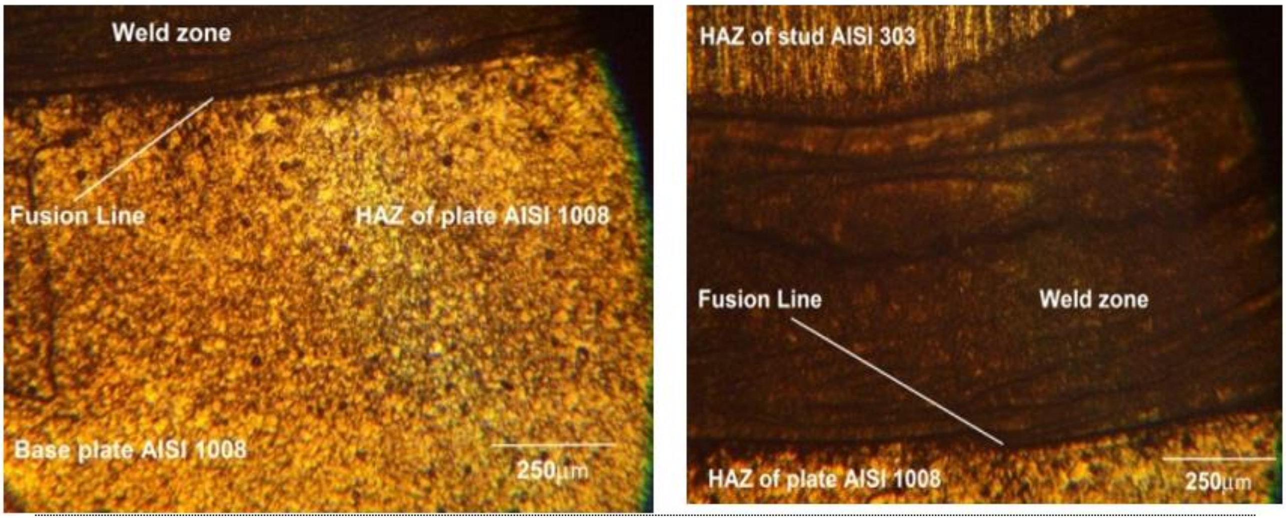

Figure 6. Microstructure of stud AISI 303/AISI 1008 at current 600-0.25

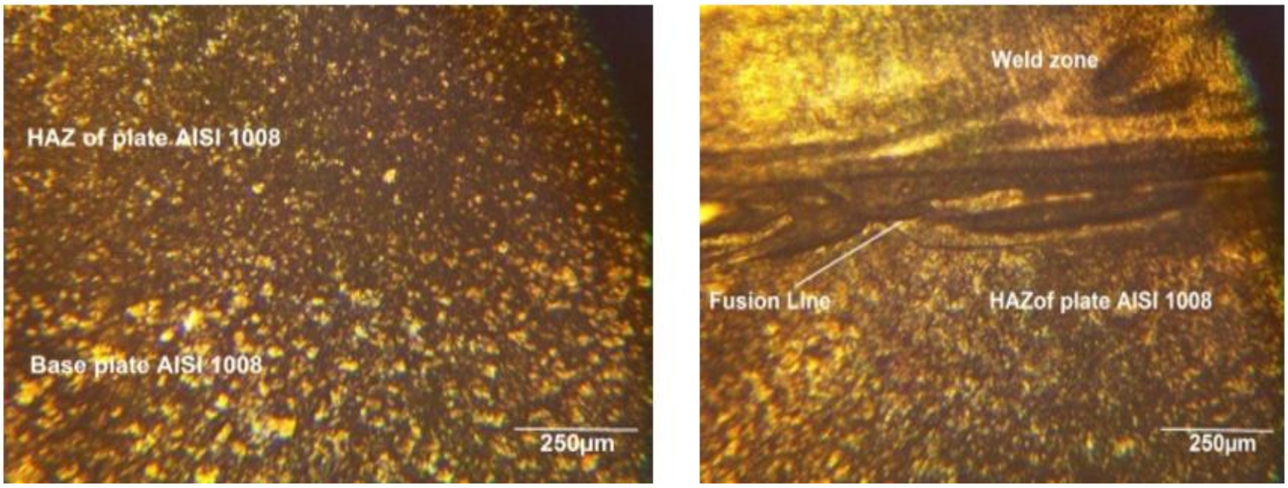

Figure 7. Microstructure of stud AISI 303/AISI 1008 at current 600-0.4

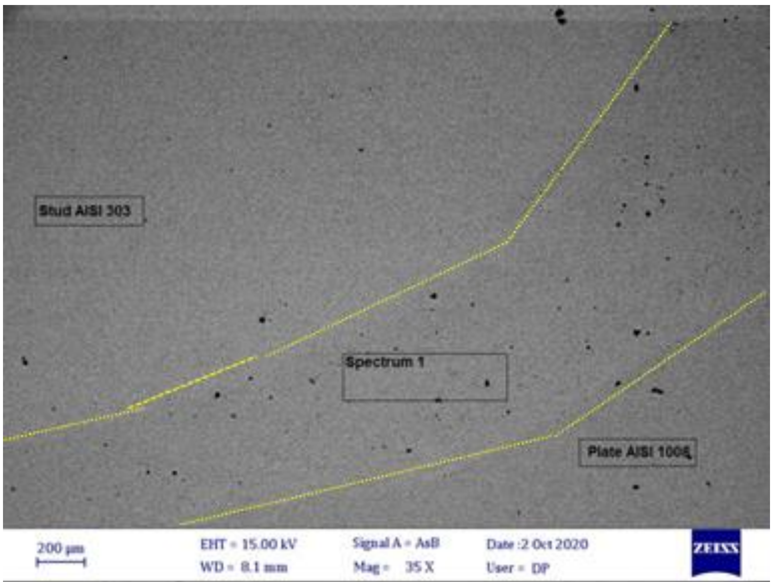

Figure 8. High magnification SEM images of the AISI 303 / AISI 1008 weld zone

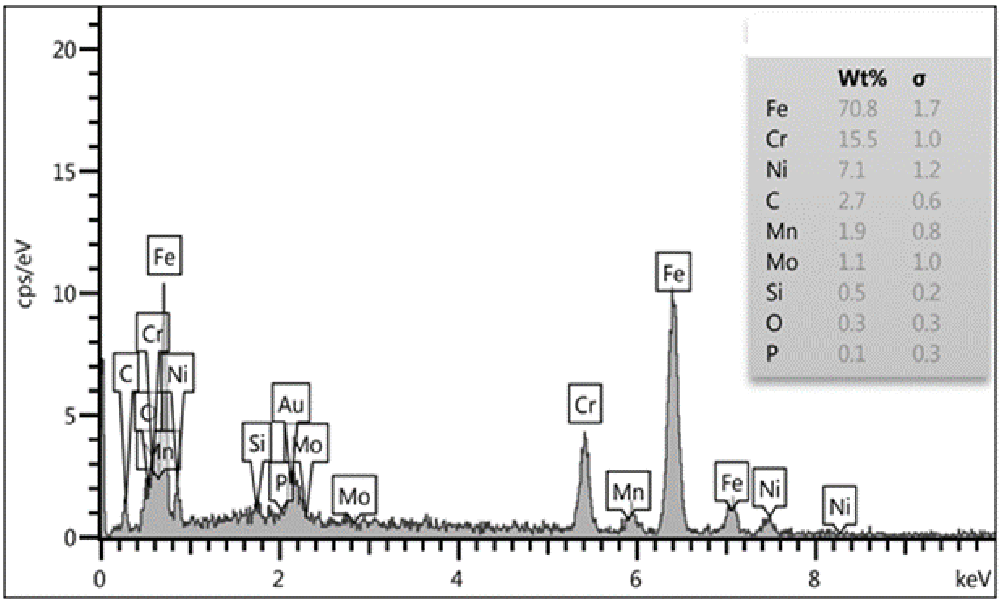

Figure 9. EDS line at 600 AMP, 0.25 second

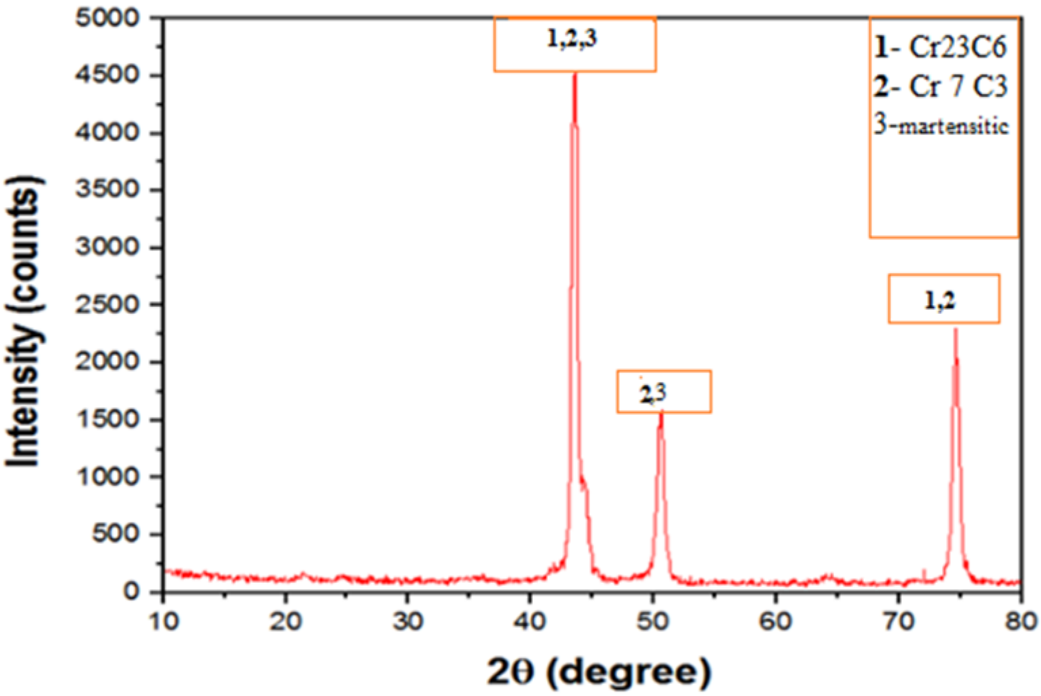

Figure 10. XRD AISI 303/AISI 1008

Line mapping analysis (Energy Dispersive Spectroscopy (EDS point)) was performed to determine the distribution of element across the arc stud welding dissimilar weldments Fig.9. The distribution of carbon is randomly along thermal pool. The high percentage of carbon and chromium distribution from the stud (AISI 303) towards the weld pool indicates carbides CrC phases' formation.

3.3. Mechanical behavior

3.3.1. Microhardness of the joint

Vickers microhardness measurements covering BM, HAZ, and FZ are presented in Fig. (11). It was noticed that there is no significant difference in the hardness values in HAZ for both metals due to the different value of heat input of the ASW process that limits any changes in heat-affected zone HAZ mechanical properties. At the fusion zone FZ towards AISI 303 side, a drastic increase in hardness was recorded compared with HAZ with hardness peaks more than 370, 500 HV for the welding conditions of 600AMP, 0.25second, and 600AMP, 0.4second respectively. The maximum hardness in the base metal plate AISI 1008 (167HV) and (175HV) at current (600 AMP) and time of (0.25, 0.4) second respectively were examined. Moreover, the hardness in the base metal stud AISI 303 (281HV) and (177HV) at current 600AMP and time 0.25,0.4 second in order. The hardness in the HAZ of plate AISI 1008 (243HV) and (483HV) at current 600AMP and time 0.25, 0.4 second respectively were determined. The measurements were engaged along with the BM, HAZ, and FZ, using 4.9 N load and 15s time.

This could be related to the union of chromium with carbon constituting chromium carbide (CrC) which has a property of high hardness in the hardening line as a result of carbon spread from the base metal to the welding metal. It can be said that the increment in hardness for 600AMP, 0.4second welding conditions compared with of 600AMP, 0.25second is an effect of a large amount chromium carbide (CrC) that formed in FZ, as a result of longer welding times that allows for the higher amount of carbon spread from the base metal to the welding metal. This indicates similar results shown by Ref. [7].

3.3. 2 Tensile strength of the joint

Fig. 12 indicates the tensile stress values of the joint at 400, 600 AMP welding current and 0.2, 0.25, 0.3, 0.35, 0.4, 0.45 second welding time respectively. It is observed that the peak value of 490, 514 MPa is obtained at 400 AMP, 0.35 second, and 600 AMP 0.25 second welding conditions respectively, and then the value of tensile stress decreases. This decreases due to the presence of defects (porosity) associated with increases in the heat input [21]. Besides the increase in the heat input may lead to excessive fusion [2, 21]. Increasing the welding current leads to a larger size of the weld zone which explains a stronger joint obtained at a welding current of 600AMP rather than 400 AMP.

The phenomena of melting and solidification during welding process is very complicated due to metal and transfer which governs the phenomena formed and the porosity and the decrease and increase may related to theses phenomena.

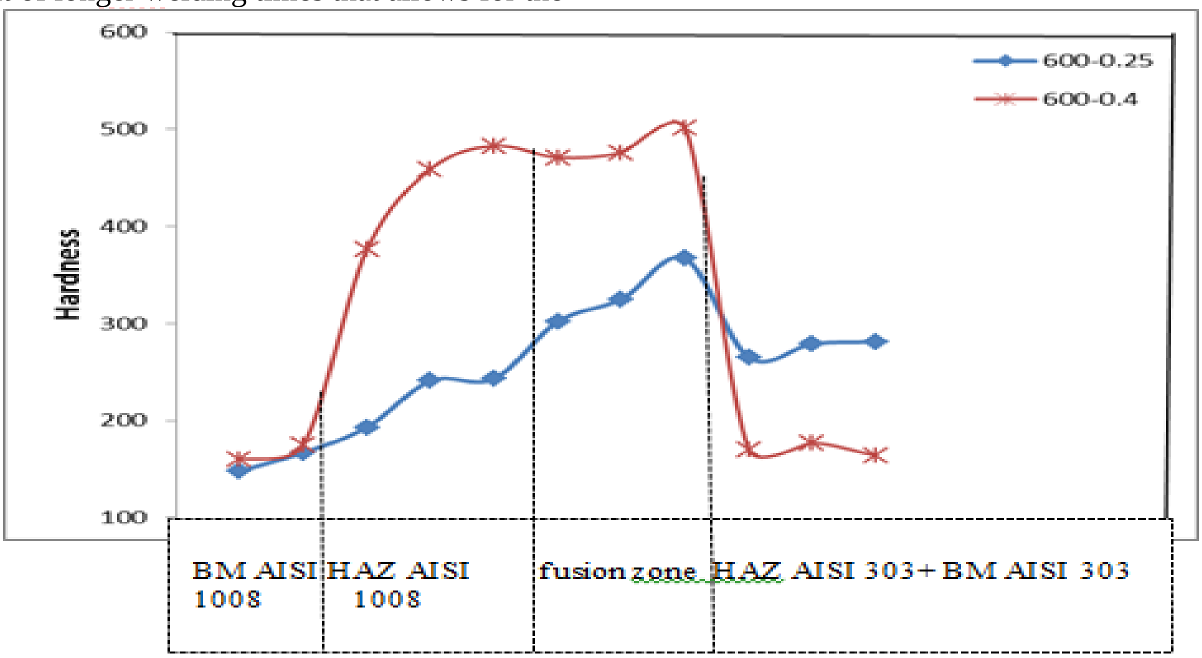

Figure 11. Microhardness values across BM, HAZ, and FZ of the AISI 303 / AISI 1008 dissimilar joint

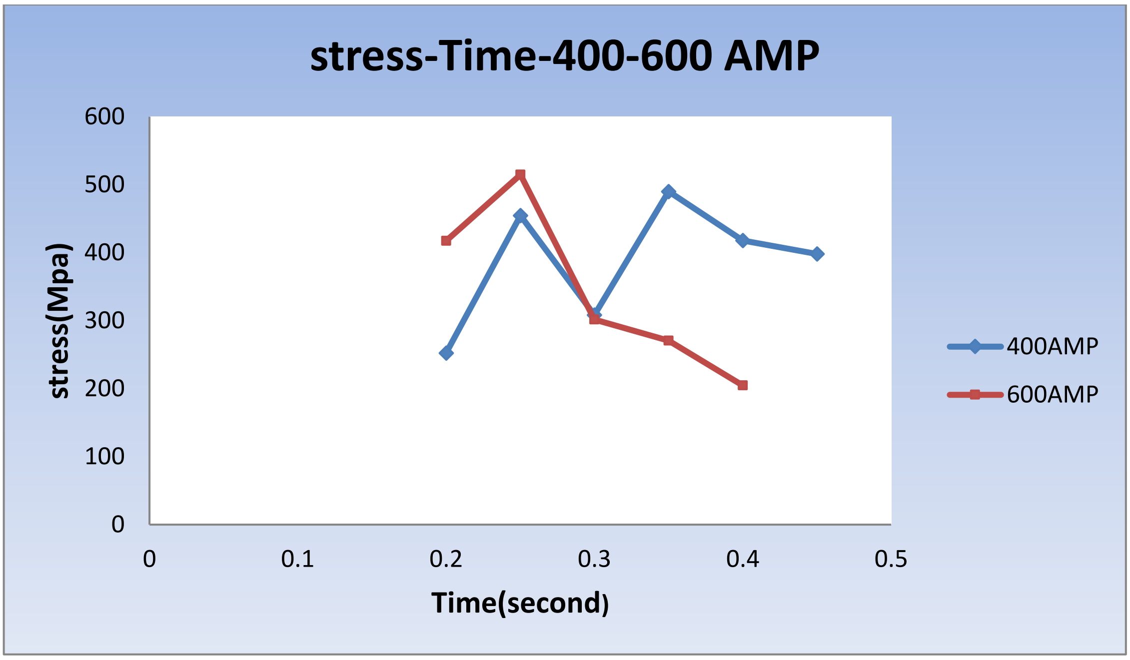

Figure12. Stress vs. time of the joint at 400 and 600AMP welding current

4. Conclusions

- Arc stud welding process ASW of AISI 303 stainless steel studs to AISI 1008 plate was successfully performed using a range of welding currents and times.
- The optimum welding parameters were 600 AMP 0.25 second based on the hardness and tensile test.
- The highest value of hardness 500 HV was recorded at the fusion zone FZ towards AISI 303 side, as a result of the carbide phase's formation.
- The value of tensile 515 Mpa at current 600 AMP ,0.25 second
- Welding time was the effective parameter in the ASW process followed by welding current, proper selection of welding time produces good joint quality.

References

[1] K Hartz-Behrend, J L Marqués, G Forster1, A Jenicek, M Müller, H Cramer, A Jilg4, H Soyer4 and J Schein "Stud arc welding in a magnetic field – Investigation of the influences on the arc motion": Journal of Physics: Conference Series 550 ,2014

[2] Yilmaz N, Hamza A 2014" Effect of Process Parameters on Mechanical and Microstructural Properties of Arc Stud Welds". Materials Testing for Welding Applications, 56: pp806-811,2010

[3] Reddy MP, William AA, Prashanth MM, kumar SN, Ramkumar KD, Arivazhagan N, Narayanan " Assessment of Mechanical Properties of AISI 4140 and AISI 316 Dissimilar Weldments". Procedia Engineering, vol.75: PP29-33, 2014

[4] Ramasamy S, Gould J, Workman D " Design-of-Experiments Study to Examine the Effect of Polarity on Stud Welding". Welding Journal, PP19-28,2002.

[5] Yilmaz N, Hamza A " Effect of Process Parameters on Mechanical and Microstructural Properties of Arc Stud Welds. Materials Testing for Welding Applications, vol.56: PP806-811,2014.

[6] Reddy G, Rao K " Microstructure and Mechanical Properties of Similar and Dissimilar Stainless Steel Electron Beam and Friction Welds". The International Journal of Advanced Manufacturing Technology, vol.45: PP875-888, 2014.

[7] Ai Y, Shao X, Jiang P, Li P, Liu Y, Liu W "Welded joints integrity analysis and optimization for fiber laser welding of dissimilar materials". Optics and Lasers in Engineering, vol.86: PP62-74,2016

[8] Arivazhagan N, Singh S, Prakash S, Reddy GM "Investigation on AISI 304 Austenitic Stainless Steel to AISI 4140 Low Alloy Steel Dissimilar Joints by Gas Tungsten Arc, Electron Beam and Friction Welding". Materials & Design, VOL32:PP3036-3050, 2011.

[9] Ramana PV, Reddy GM, Mohandas T, Gupta A "Microstructure and Residual Stress Distribution of Similar and Dissimilar Electron Beam Welds-Maraging Steel to Medium Alloy Medium Carbon Steel". Materials and Design, VOL31: PP749-760,2010.

[10] Abbas EN, Omran S, Alali M, Abass M, Abood AN " Dissimilar welding of AISI 309 stainless steel to AISI 1020 carbon steel using arc stud welding. International Conference on Advanced Science and Engineering (ICOASE). IEEE,2018.

[11] M.R.A.shawon, F.Gulshan.A.S.W.Kurny "Effect of welding current on the structure and properties of resistance spot welded dissimilar (austenitic stainless steel and low carbon steel) metal joints". of____the institution of engineers, volume 96, pages29–36,2015

[12] Shazaral Shamsudinand Phoon chee Yoon "Investigation on Mechanical Properties of Pulsed Nd:YAG Laser Welding on AISI 304 Stainless Steel to AISI 1008 Steel Mechanics and Materials" : 117-119,p 402-408,2012.

[13] Shane Fatima,Mushtaq khan,Syed Husain Imran Jaffery,LIaqat Ali,Mohammed Mujahid and Shahid Butt "Optimization of process parameters for plasma arc welding of austenitic stainless steel(304L)with low carbon steel"(A-36.Materials design and applications ,2015.

[14] Hamid M.Mahan "Effect of heat treatments on the mechanical properties of welded joints of alloy steel by arc welding".Diyala journal of engineering sciences :Vol . 12, No02, p 44-53,2019.

[15] Stud weld inspection and Testing. www.cwbgroup.org

[16] Samantaray, Dipti,Kumar, Vinod,Bhaduri, AK "Microstructural evolution and mechanical properties of type 304 L stainless steel processed in semi-solid state", international journal of metallurgical engineering,Vol 2:p149-153,2013.

[17] Alali, Muhaed,Abass, Mohammed H,Abbas, Waseem S,Shehab, Abeer A "Effect of Nickel Powder Buffering Layer on Microstructure and Hardness Properties of High Carbon Steel/Stainless Steel Arc Stud Welding", Materials Research,2020

[18] Kuo, Tsung-Yuan,Jeng, Sheng-Long" Porosity reduction in Nd–YAG laser welding of stainless steel and inconel alloy by using a pulsed wave", Journal of physics D: applied physics,Vol 38:p 722,2005

[19] Kurşun, T "Effect of the Gmaw and the Gmaw-P Welding Processes on Microstructure, Hardness, Tensile and Impact Strength of Aisi 1030 Steel Joints Fabricated by ASP316 L Austenitic Stainless Steel Filler Metal", Archives of Metallurgy Materials,VOL 56,P 955-963,2011.

[20] Marashi,Pirooz,Pouranvari, ajid ,Amirabdollahian, Sasan,Abedi, A,Goodarzi, M "Microstructure and failure behavior of dissimilar resistance spot welds between low carbon galvanized and austenitic stainless steels",Materials science engineering,VOL 480:P 175-180,2008.

[21] M.N. Abass, M.S. Alali,W. S. Abbas, A. A.Shehab" Study of solidification behavior and mechanical properties of arc stud welded AISI 316L stainless teel", Journal of achievements in materals and manufacturing engineering,vol. 97,2019.