ISMSIT2017

1st International Symposium on Multidisciplinary Studies and Innovative Technologies Proceedings Book

(November 2-4, 2017, Tokat, Turkey)

Symposium homepage: www.ismsitconf.org

The resistance spot weldability of AISI 430 ferritic stainless steel

Yahya Altunpak*

[1]*Mechanical Engineering, Abant Izzet Baysal University, Turkey*

**altunpak_y@ibu.edu.tr*

Abstract – In this study, AISI 430 ferritic stainless steel sheet with 0.6 mm thickness was joined by resistance spot welding at different welding times and currents. The effects of welding parameters on the mechanical properties of welded samples are defined in terms of peak load. The hardness profile and the microstructure of the joint were also evaluated. Experimental results have shown that the welding time must be reduced while the welding current is increased in order to increase the tensile strength. According to microstructure investigation, the grain coarsening occurs in the HAZ in all the samples.

Keywords – Resistance spot welding; CuCr electrode; ferritic stainless steel

I. INTRODUCTION

Resistance spot welding (RSW) is one of the widely used welding methods in mass production industry. Even though it is a conventional technology of welding which has been used for a long time in practice, it is necessary to find true welding parameters for the stainless steel. AISI 430 is widely used in less severe corrosive environments such as some chemical processing equipment, automobile exhaust systems, oven parts, food industry, architecture and decoration works. They are cheaper than austenitic stainless steels, can be easily formed and exhibit good resistance to atmospheric corrosion [1-6]. Ferritic stainless steels, which are an iron-chromium alloy containing chromium in the range of usually 11-30%, have mainly cubic (bcc) crystal structure with good shape-taking ability. But the ferritic stainless steels are generally considered to have poor weldability when compared to the austenitic stainless steels. The microstructure of AISI 430 is ferritic as is known, there will be some martensite in HAZ (heat-affected zone) after welding, due to high carbon content and the absence of stabilizing elements. Grain coarsening is a major problem in ferritic stainless steels and such grain coarsening causes lower toughness. Therefore, it can be used as a suitable welding method for decreasing grain growth. For example low heat input is recommended to prevent grain growth [1, 4].

CuZr, CuCrZr, CuCoBe, CuNiSi etc. materials are used for tip production in the resistance spot welding of hard sheet materials such as stainless steels. For example, alloys of CuCrZr are used because of their high strength, corrosion resistance and electrical conductivity. These alloys could be hardened by ageing. The strength of hardened CuCrZr alloy is almost double in comparison with pure copper (220 MPa) and its conductivity is lower by only about 15 % than conductivity of Cu. These alloys keep their strength also at high temperatures (1000 °C) [3, 7].

Few systematic studies have been conducted on resistance spot weldability quality of the ferritic stainless steels when looking at the literature. It is thought that this work will be useful for the white goods industry where 0.6 mm ferritic stainless steel sheet is heavily used. Therefore, the aim of present research is investigating the effect of welding parameters on resistance spot weld quality of AISI 430 FSS.

II. MATERIALS AND METHOD

AISI 430 ferritic stainless steel (FSS) was used as the Base Metal (BM). The mechanical properties and the chemical composition of the sheet are given in Table 1. The chemical composition and mechanical properties of the electrode materials used in this study are also given in Table 2. The thickness of the stainless sheet for all samples is 0.6 mm. The RSW was performed using a 120 kVA ac pedestal type RSW machine operating at 50 Hz controlled by a programmable logic controller (PLC). Welding was conducted at the constant electrode pressure of 2 bar using Cu-Cr electrodes having a 45 º truncated cone resistance tips with 8 mm face diameter (Le Bronze Industriel CRM16 alloys electrodes). For joining 5, 10 and 15 cycles (1 cycle=0.02 s) weld time and 5.4, 6 and 6.6 kA welding current were applied.

Table 1. Chemical composition and mechanical properties of the AISI 430 ferritic stainless steel

Chemical composition (wt%)								Mechanical properties	
C	Mn	Si	Cr	Ni	P	S	Fe	YS (MPa)	UTS (MPa)
0,12 max	1,0	1,0 max	16,0-18,0	0,75 max	0,045 max	0,03 max	Base	250 MPa	520 MPa
YS, yield strength; UTS, ultimate tensile strength									

Samples for metallographic examination were prepared using standard metallography procedure and the specimens were etched by nitric acid (HNO3 in a ratio of 1 part nitric acid to 3 parts water). Optical microscopy was used to examine the microstructures of the joints. The load of 100 g was applied for 20 s in Vickers microhardness test. Tensile-shear test samples were prepared according to ASTM: E8M and tested using an Instron universal testing machine. The crosshead speed was kept constant 1 mm min-1..

Table 2. Spectral analysis of the electrode material

Alloy Standard	Chemical Composition (%)	Hardness (HB)	Electrical Conductivity (IACS %)

CuCr1Zr (Class 2) DIN 2.1293 CRM16	Cr 0,7 Zr 0,05 Fe 0,02 Cu residue	163	86

III. Results

A. Metallurgical characterization

It is very important to understand the phase transformations during the welding for mechanical behaviour of the joint. Fig. 1a shows the typical microstructure of the FZ of AISI 430 indicating columnar ferrite grains. The average grain size of the HTHAZ is larger than that of the LTHAZ and the BM. It is shown that the chromium-rich carbides were evenly distributed throughout the matrix. Some martensite is present in the grain boundary of the ferritic grains (Fig. 1b). Figure 1a shows the typical microstructure of fusion zone (FZ) and heat affected zone (HAZ).

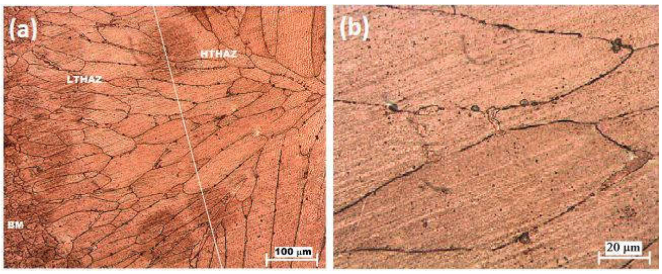

Fig. 1. Microstructure profile of the HAZ (a) Columnar ferrite grains and fine dispersion of chromium-rich carbides (b) Martensite formation along in the ferrite grain.

Microstructural investigations show that in all the samples the grain coarsening occurs in the HAZ. The HAZ can be divided into two separate metallurgical conversion zones according to the temperature distribution, i.e., the high temperature heat-affected zone (HTHAZ) and the low temperature heat-affected zone (LTHAZ).

A typical hardness profile of the FSS resistance spot welding at 5,4 kA and 6,6 kA for 5 cycle is shown in Fig. 2. Ferrite grain size, carbide precipitation and the amount of martensite formation affect the hardness of the FSS. Although the grain size of FZ is larger than that of BM, its hardness is higher due to the formation of martensite phase and dispersion of fine precipitates at this zone, as shown in Fig. 1a and b. The volume fraction of precipitates in LTHAZ zone is higher than HTHAZ resulting in higher hardness value. Also, the higher hardness of LTHAZ compared to HTHAZ is due to the finer ferrite grain size and the formation of martensite at the ferrite grain boundaries. As seen Fig. 2a and b, increased welding current has little effect on the hardness of the 430 HAZ

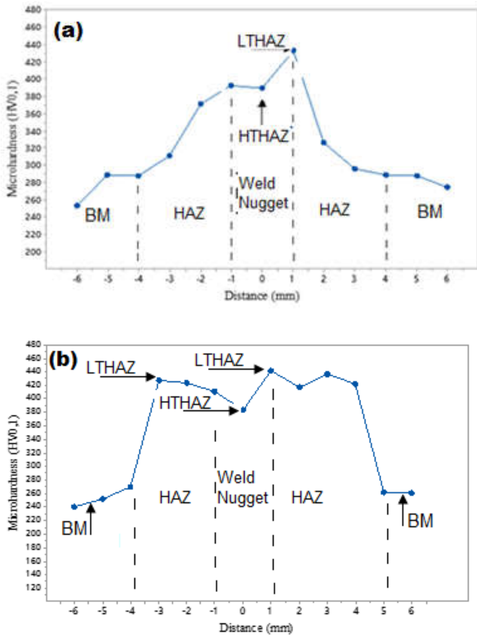

Fig. 2. Hardness profile of AISI 430 resistance spot welding a) welding at 5,4 kA for 5 cycle b) welding at 6,6 kA for 5 cycle)

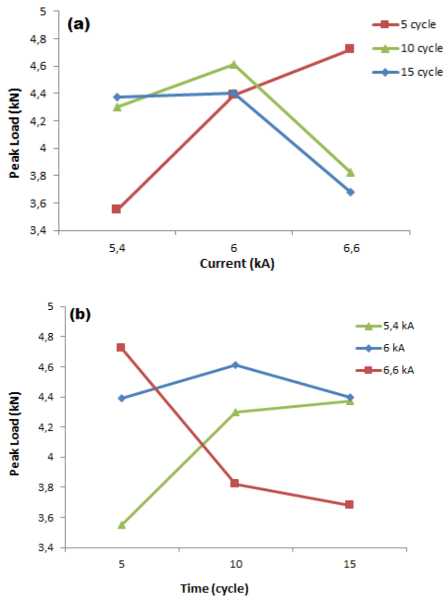

Fig 3. The effect of welding current and welding time on peak load of resistance spot welds

B. Mechanical Properties

The mechanical properties of the welded parts are defined in terms of peak load. The relationship between welding time and peak load is shown Fig 3a and b. As can be seen in the figures, the lowest load value was obtained at 5.4 kA welding current in 5 cycles welding time. But the maximum peak load was obtained at 6.6 kA welding current in 5 cycles welding time. That is 5 cycles welding time is sufficient for 6.6 kA welding current, but not enough 5.4 kA and 6 KA welding currents. In 5.4 kA welding current, increasing welding time increases load values. But the best welding time for 6 kA welding current is 10 cycles.

IV. DISCUSSION

Phase transformations in the HAZ of the steel can be explained with the help of Fe–Cr–C pseudo binary diagram at 17 % Cr. Under the equilibrium cooling condition, the austenite phase will be transformed into α–ϕerrite and Cr23C6 carbides; however, after cooling, the ferrite austenite transformation at high temperature is suppressed due to non-equilibrium cooling conditions (such as welding operations) and therefore, no martensite phase occurs at the grain boundaries in this region [1-2].

Experimental results have shown that the welding time must be reduced while the welding current is increased in order to increase the tensile strength in the study. Alizadeh-Sh et al reported that increasing welding current increases fusion zone (FZ) size and peak load of AISI 430 ferritic stainless steel joint. There is a direct relationship between FZ size and mechanical performance of welded parts. According to the research, the peak load and energy absorption of the welds were improved as the welding current increases at constant welding time [2].

V. CONCLUSION

From the result given above, the following conclusions can be drawn from this research:

FZ is featured by columnar ferrite grains and fine dispersion of carbide precipitates at ferrite grain boundaries.

The HTHAZ exhibited ferritic microstructure with excessive grain coarsening. The volume fraction of precipitates in LTHAZ zone is higher than HTHAZ resulting in higher hardness value.

The maximum peak load was obtained at 6.6 kA welding current in 5 cycles welding time. In this study, high welding current and low welding time are recommended for maximum strength

ACKNOWLEDGMENT

This work is supported by Abant Izzet Baysal University under Contract Number AIBU, BAP – 2016.09.05.1048.

REFERENCES

[1] M. Alizadeh-Sh, S. P. H. Marashi, and M. Pouranvari, “Resistance spot welding of AISI 430 ferritic stainless steel: phase transformations and mechanical properties,” *Materials & Design*., vol. 56, pp. 258-263, 2014.

[2] M. Alizadeh-Sh, M. Pouranvari, and S. P. H. Marashi, “Welding metallurgy of stainless steels during resistance spot welding Part II–heat affected zone and mechanical performance,” *Science and Technology of Welding and Joining.*, vol. 20.6, pp. 512-521, 2015.

[3] J. VIŇÁŠ, Ľ. KAŠČÁK, and M. Abel, "Analysis of Materials for Resistance Spot Welding Electrodes." *Strojarstvo: časopis za teoriju i praksu u strojarstv.,*, vol. 54.5, pp. 393-397, 2012.

[4] P. Sathiya, S. Aravindan, and A. N. Haq, “Effect of friction welding parameters on mechanical and metallurgical properties of ferritic stainless steel,” *The International Journal of Advanced Manufacturing Technology,* vol. 31.11-12, pp. 1076-1082, 2007.

[5] A K. Lakshminarayanan, K. Shanmugam, and V. Balasubramanian, “Effect of Autogenous Arc Welding Processes on Tensile and Impact Properties of Ferritic Stainless Steel Joints, *Journal of Iron and Steel Research International.,* vol. 16(1), pp. 62-68, 2009.

[6] L. Wang, C. Song, F. Sun, L. Li, and Q. Zhai, “Microstructure and Mechanical Properties of 12 wt.% Cr Ferritic Stainless Steel with Ti and Nb Dual Stabilization,” *Materials and Design*., vol. 30, pp. 49–56, 2009.

[7] Ó. Martín, P. De Tiedra, M. López, M. San-Juan, C. García, F. Martín, and Y. Blanco, “Quality prediction of resistance spot welding joints of 304 austenitic stainless steel,” *Materials & Design.*, vol. 30(1) pp. 68-77, 2009.