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The Similar and Dissimilar Spot Welding of 304 and 316L Austenitic Stainless Steels

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Abstract

Being one of the oldest electric welding processes, the resistance spot welding offers practical and time saving applications in the field of joining metals of several manufacturing industries such as automotive, white goods and machinery. Even light weight metals, i.e. aluminum and magnesium has lately been taking attention of researchers and producers, the steels, especially austenitic stainless steels are still being used in wide range of applications due to their combination of excellent corrosion resistance with comparably low price, good machinability, reasonable weldability and good mechanical properties. Spot welding process is controlled by three essential parameters; mechanical (pressure), electric (heat) and electronics (time). In this study, AISI 304 and 316L stainless steel sheets of 1 mm of thickness were used as welding metals. Thus, AISI 304 welding metal couples, AISI 316L welding metal couples and AISI 304 and 316L welding metal couples were selected to ensure a combination of similar and dissimilar metals. Welding procedures were carried out using a current and time controlled electric spot welding machine. To investigate the influence of the parameters (pressure, heat and time) on the welding of the different types of stainless steels and their combination, the parameters were set constant. The current was set to 10,000 A, the pressure was 4 kN and the duration was 10 seconds for each. After spot welding applications, some of the specimens were cut and prepared for metallographic examination and hardness measurements. The rest of them was shaped for tensile strength measurement using Instron Universal Testing Machine. The hardness of the specimens were observed being altered in the range of 186-240 HV(average) and their tensile shear forces in the scale of 1486-1549 N (average).

Keywords: Spot Welding, AISI 304 and 316L stainless steels

1. INTRODUCTION

Amongst more than forty different metal welding processes available nowadays, it's important to choose the correct one for a specific manufacturing procedure [1]. In order to provide this accuracy, manufacturers need to take account of several selection criteria such as;

•Design properties of the product (joint type, shape, etc.)

•Material characteristics (type, thickness, etc.)

•Process parameters to obtain the final desired product attributes (method, electrical current, gases if used, etc.)

Resistance spot welding (RSW) utilized in many manufacturing and maintenance industries (automotive, aero-naval, nuclear, etc.) is controlled by three main parameters; energy input (intensities of the welding current, low voltage and high amperage), compressional force applied (mechanical pressure on electrode) and duration [2,3,4].

Thanks to relatively simple equipment need, it can be fully automated and the RSW is used for almost all types of metals such as titanium [5], steels, dissimilar welding of steels with other metals [6] and especially chosen for forming of stainless steel sheets [5,6,7].

The aim of this study is detect the differences related to metal composition on the resistance spot welding of austenitic stainless steels, here AISI 304 and 316L stainless steels. To investigate the influence of the parameters (pressure, heat and time) on the welding of the different types of stainless steels and their combination, the parameters were set constant.

2. EXPERIMANTAL PROCEDURE

In this study, AISI 304 and 316L stainless steel sheets of 4 mm of thickness were provided as welding metals. Thus, AISI 304 welding metal couples, AISI 316L welding metal couples and AISI 304 and 316L welding metal couples were selected to ensure a combination of similar and dissimilar metals. Austenitic stainless steels grade 316L and 304, with a thickness of 1 mm and given chemical composition in Table 1 and 2, respectively, were used. Firstly, the stainless steels as provided about 4 mm of thickness were cold rolled, then tempered for stress relieving at 500 oC. Afterward the obtained metal sheets were linearly overlapped and spot welded by RSW. Welding procedures were carried out using a current and time controlled electric spot welding machine. To investigate the influence of the parameters (pressure, heat and time) on the welding of the different types of stainless steels and their combination, the parameters were set constant. The current was set to 10,000 A, the pressure was 4 kN and the duration was 10 seconds (5 welding cycles) for each. After spot welding applications, some of the specimens were cut and prepared for metallographic examination. After treatment specimens were cleaned with acetone, mounted, subsequently ground, polished and finally etched by Aqua regia etching solution for about 30 sec. The microstructure were observed by optical microscope (Olympus). The hardness measurements of the samples were done using FM-ARS 7000 (Future Tech Corp Tokyo, Japan) Full-Automatic Micro hardness Testing System, 100 g load for 15 s. The rest of them was shaped for tensile strength measurement using Instron Universal Testing Machine with a cross head speed of 1 mm/min.

Table 1. Composition of AISI 316L stainless steel (wt %) [1].

Fe	C	Ni	Cr	Mn	Mo	Si	Co
68.49	0.029	10.02	16.67	1.65	2.05	0.37	0.21
Cu	Nb	Ti	V	W	Al	P	N
0.28	0.037	0.022	0.048	0.06	0.002	0.034	0.024

Table 2. Composition of AISI 304 stainless steel (wt %) [7].

Fe	C	Ni	Cr	Mn
Balance	0.05	7.84	18.07	1.537
Cu	**Nb**	**V**	**Si**	**Mo**
0.389	0.047	0.089	0.572	0.332

3.RESULTS AND CONCLUSIONS

The overall summary of the welding conditions and results are summarized in Table 3. In Fig. 1 and 2, the microhardness and tensile shear force values were drawn and shown graphically.

Table 3. Summary of welding conditions and results of mechanical testing.

Welding couple	Energy (Amperage)	Time (s) /Cycle	Pressure (kN)	Micro Hardness (HV0.1)	Max. Tensile Shear Force (Peak Load) (N)
S1 (304-304)	10000	10 / 5	4	208 ± 11	1549 ± 20
S2 (316L-316L)	10000	10 / 5	4	186 ± 13	1546 ± 23
S3 (304-316L)	10000	10 / 5	4	240 ± 9	1486 ± 15

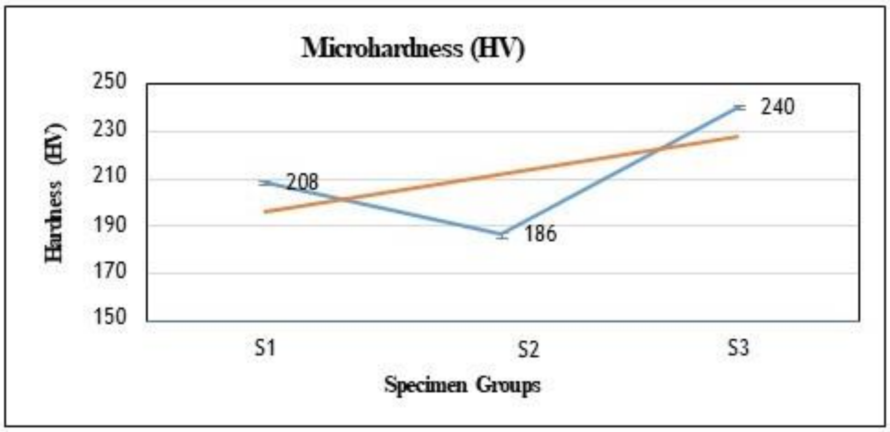

Fig. 1. Comparison of microhardness values of specimen groups (shown as blue line) and tendency curve (shown as orange line)

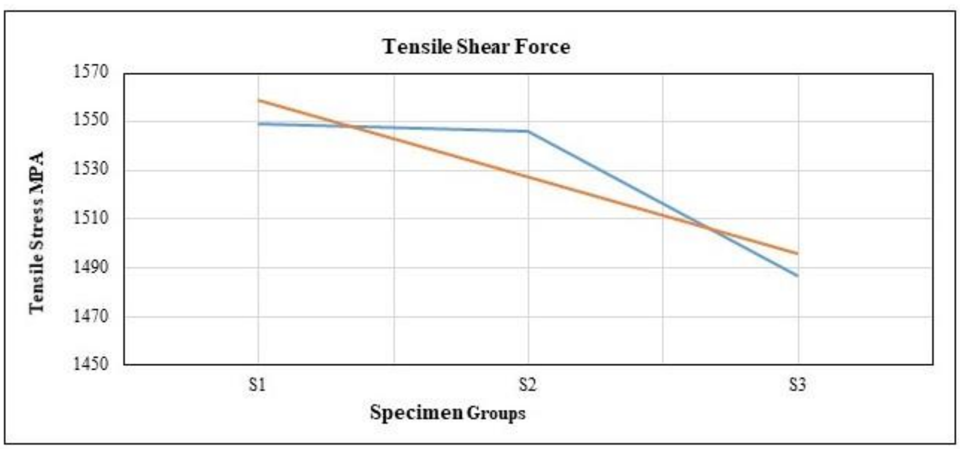

Fig. 2. Comparison of tensile shear force values of specimen groups (shown as blue line) and tendency curve (shown as orange line).

Even though the tendencies of both graphs point out an increase in micro hardness and a decrease in tensile shear forces, the standard deviation values of the similar welding couples –S1 and S2 type specimens- indicate the convergence and overlapping of mechanical results. Thus, this can be explained by the similar material characteristics of austenitic stainless steels, AISI 304 and 316L respectively. But their combination as a dissimilar welding couple behaves more weakly may be clarified as slightly different material properties possibly resulted in more interfacial cracks, cavities, porosities and even micro local degraded sites, also possible precipitations due to unequable relatively fast solidification under higher energy –heat-input at the atmospheric conditions.

In Fig. 3, 4 and 5 welding beads –also nuggets- of the specimen couples are given for similar welding of AISI 304 and 316L and for dissimilar welding of 304-316L couples, respectively. The heat affected zone (HAZ) site is very visible in Fig. 3. The difference of base and weld metals is apparent in Fig. 5. Possible discontinuities in weld beads for all types of specimens cannot be detected by the optical microscope. Nonetheless, the weld penetration of the S1 type specimens are qualified by optical microscope, the weld nuggets are about more than 20 microns, meanwhile the thickness of HAZ area is measured about 4 microns, which are coherent with literature survey.

The main objective of the studies in undergraduate level was actually to collect the necessary values to improve overall quality of the process application meanwhile helping future engineers to acquire a specific knowledge by experience. In order to attain this objective, the detection of material based differences and the investigation of the influence of the welding parameters (pressure, heat and time)) on the welding of the different types of stainless steels and their combination, while was the aim of this study. Therefore the results have been sorted as;

- The obtained mechanical properties–microhardness and tensile shear forces- of the specimens S1 and S2 after welding procedure were very close to the similar material characteristics.
- However, their dissimilar welding due to behaviour of different type of austenitic weld and base metals at the elevated temperature under atmospheric conditions also, to the possible failure modes present in the joint interfacial area was not as successful as previous ones.
- To acquire more data, the specimens should have been observed using SEM with EDX attachment.

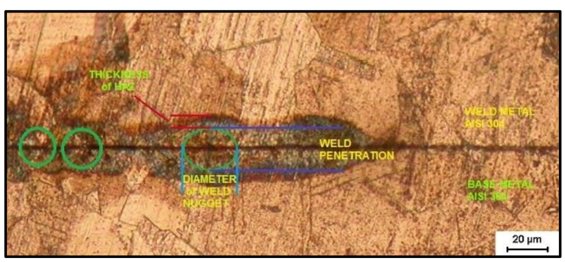

Fig. 3. The weld bead, heat affected zone (HAZ) and the weld penetrated area of similar welding of AISI 304 type metal couples –base and weld metals- (Magnification 20x).

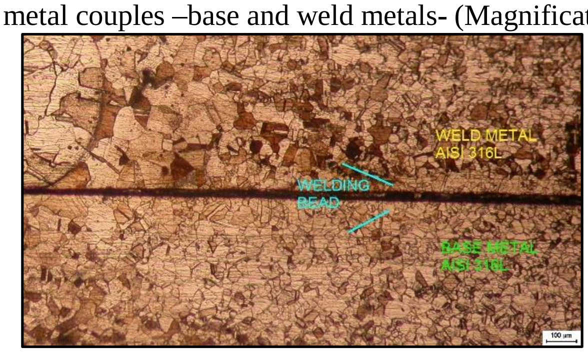

Fig. 4. The weld bead, of similar welding of AISI 316L type metal couples –base and weld metals- (Magnification 5x).

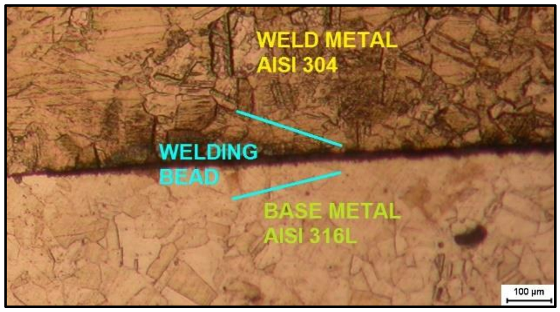

Fig. 5. The weld bead, of dissimilar welding of AISI 304 and 316L type metal couples –base and weld metals- (Magnification 5x).

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