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Effect of post weld heat treatment (PWHT) on the microstructure, mechanical properties, and corrosion resistance of dissimilar stainless steels

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A R T I C L E I N F O

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A B S T R A C T

The dissimilar austenitic stainless steel (AISI304L) and ferritic stainless steel (AISI430) have been welded with two types of filler metals (316L and 2594L) by GTAW. Then, the effect of heat treatment on the microstructure, mechanical properties, and corrosion properties of welded joint was investigated. Due to remove chromium carbide created during welding process and homogenize the microstructure, heat treatment was carried out on the whole series of the samples at 860 °C and 960 °C. The microstructural, fracture cross-section and corrosive areas of the samples were investigated by SEM. Tensile, bending and potentiodynamic polarization tests were employed to characterize mechanical and corrosion performance of the samples. The results indicate that the welded joints had good mechanical properties after heat treatment so that the best tensile strength was obtained at 960 °C. Due to reduce grain size, the heat treatment samples show minimum corrosion resistance at 960 °C in comparison to 860 °C.

1. Introduction

Due to high flexibility, low production costs, and joint ability of ferritic stainless steels (AISI400) have been used as the resistant steels against corrosion in different industries such as oil and gas, electricity, chemical, petrochemical industries and etc [1–4]. These steels are suitable replacement to austenitic steel in chloride environments and its microstructures undergo many changes like reduce of toughness and ductility properties during welding [1].

Today, in major industries are trying to optimize materials composition and properties for achieving to high quality products and low production costs. One of the ways to manufacture high quality products is the use of jointing of dissimilar metals [3]. In recent years, the joint of austenitic steels to ferritic steels have attracted more attention. One the most important issues must be considered to avoid chromium carbide formation in different areas of the junction [5]. In fact, the precipitates are developed into the intergranulars besides the insulating grain boundaries due to welding on these steels at jointing different areas. There are various carbide precipitates at different steels such as $M_{23}C_6$ type in unstabilized AISI 430 ferritic stainless steels and MC type in stabilized AISI 444 ferritic stainless steels [3,6]. When the stainless steels are subject to temperature range 550–850 °C during welding, they are formed the chromium carbide, hence, it cause to decrease the corrosion properties lower than base metal [7]. There are various methods to remove chromium carbide like reduce volume of carbon in base metal, using laser welding and electron beam welding to reduce the heat input to the base metal during welding, consequently the base metal be less at the temperature range of formation chromium carbide. However, they are so expensive methods [8]. The addition to stainless steels of elements such as Nb, V and Ti which have a higher affinity of carbon in comparison to chrome and they prevent the formation of chromium carbide [6,9]. Heat treatment is another process to remove chromium carbide. In dissimilar joints, for decreasing metallurgical destructive effects on the base metal, it is essential to select a suitable temperature for removal of chromium carbide in heat-affected zones (HAZ) and weld metal [10,11].

The previous work in this field have focused on modern and expensive welding methods such as laser welding and electron beam welding for reducing formation of chromium carbide in ferritic-austenitic stainless steels joint. The particular aims of present work were to investigate the effect of heat treatment on complete removal of chromium carbide, the microstructure and improvement of mechanical and corrosion properties of ferritic-austenitic stainless steels joint. After heat treatment the welding joins, they have been characterized

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Table 1
Chemical composition of base and filler metals.

Element	Chemical compounds											
	Fe	C	Si	Mn	P	S	Cr	Mo	Ni	Co	Cu	W
AISI304L	71.8	0.03	0.5	0.96	0.03	0.01	18.3	0.27	8.24	0.1	0.14	0.02
AISI430	82.4	0.18	0.42	0.42	0.02	0.006	16.1	0.03	0.17	0.02	0.14	0.02
ER316L	BAL	0.03	0.5	1.8	–	–	19	2.8	11.5	–	0.3	–
ER2594L	BAL	0.02	0.4	0.4	–	–	25	4	9.8	–	≥0.3	≥1

Table 2
Heat treatment parameters.

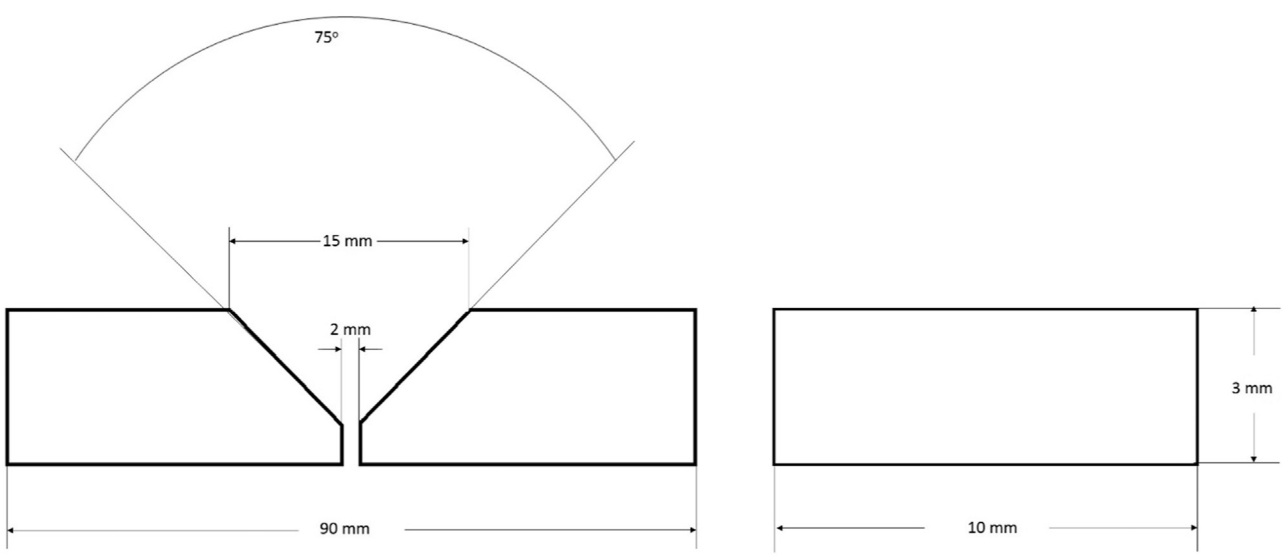
Base metal	Filler metal	Heat treatment temperature (°C)
304L & 430	2594	860
304L & 430	2594	960
304L & 430	316L	860
304L & 430	316L	960

using scanning electron microscopy (SEM). Potentiodynamic polarization tests were used to study the corrosion behavior of the welding joints, and mechanical properties of them was investigated using tensile and bending tests.

2. Experimental method

The tests were performed using plates of austenitic stainless steel (AISI304L) and ferritic stainless steel (AISI430) welded by the gas tungsten arc weld (GTAW) process using a 316L and 2594L filler metal. The chemical composition of materials used in this study are shown in Table 1. The corresponding welding parameters are shown in Table 2. Samples with the dimensions of 3 mm×90 mm×300 mm welded by GTAW process in a single pass. V-shaped butt welds with the dimensions shown in Fig. 1. Furthermore, the schematically of different zone of specimens after welding was shown in Fig. 2.

The mechanical evaluation was also done through tensile mechanical test (INSTRON, 4486, USA) according to AWS instructions. Transverse tensile specimens with a gage length of 24 mm and a width of 6 mm (overall length: 100 mm) were prepared from the weld coupons in as-welded condition. Room-temperature tensile tests were conducted on three samples as per ASTM E8 on a universal tensile testing machine. To minimize the machining error (noise) three specimens were prepared at each levels of the designed matrix. The dimensions of tensile specimen are shown in Fig. 3. The prepared tensile specimens were subjected to tensile test and their ultimate tensile strengths were evaluated. Bending test was also according to ASME Sec IX standard. Metallographic and microstructural studies



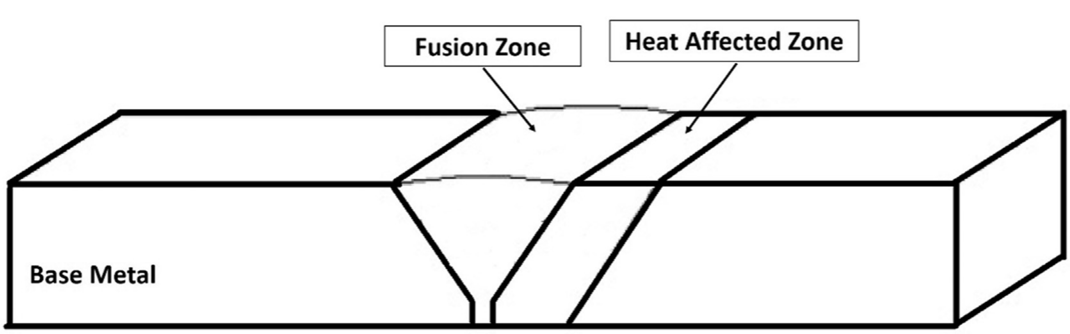


Fig. 1. Dimension of welding plate of 304/430 dissimilar metals.