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Microstructure and mechanical properties of AISI 347 stainless steel/A335 low alloy steel dissimilar joint produced by gas tungsten arc welding

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ABSTRACT

In the present study, microstructure and mechanical properties of AISI 347 austenitic stainless steel/ASTM A335 low alloy steel dissimilar joint were investigated. For this purpose, two filler metals including ER309L and ERNiCr-3 were selected to be used during the gas tungsten arc welding process. In tension tests, all weldments failed in the HAZ of A335. The impact test results indicated that all specimens exhibited ductile fracture. The maximum fracture energy was related to the ERNiCr-3 weld metal specimen. The maximum and minimum hardness corresponded to the ERNICr-3 and ER309L. Finally, it was concluded that ERNiCr-3 filler metal was the best choice for the joint between 347 austenitic stainless steel and A335 low alloy steel.

1. Introduction

Three hundred and forty-seven austenitic stainless steel is one of the most common types of steel used in industries, especially in oil and gas industry, refinery and electric power stations because of its corrosion resistance to water environments and high temperatures [1,2]. This alloy has good resistance to intergranular corrosion in many corrosive environments [3,4]. Chromium–molybdenum low alloy steels are other types of steel which are resistant to erosion and corrosion [5,6]. These steels are mostly used in producing gear wheels, steam utilities, petroleum and power stations [7,8]. Dissimilar joint of 347 austenitic stainless steel and A335 low alloy steel pipes have been widely employed in the oil and gas industry especially in heat exchangers. In dissimilar welding, one of the most important concerns is the selection of a proper filler material. In recent years, some studies on the evaluation of dissimilar welding of stainless steel and low alloy steel have been conducted.

Klueh and King [9] investigated the failure of a transferred joint between 2.25Cr–1Mo steel and 321 austenitic stainless steel which was made using Ni-based Inconel 182 filler metal. It was illustrated that after heating this joint in high temperatures for 10–15 years, the heat-affected zone contained large ferrite grains; and hence, cracking happened in this zone. Also Arivazhagan et al. [10] studied the effect of heat input on the microstructure and mechanical properties of welding sections of 304 austenitic stainless steel and 4140 low alloy steel by gas tungsten arc welding (GTAW). The results showed that high heat input enhanced the micro-segregation of alloy elements and created a non-chromium zone in the grain boundaries; therefore, the mechanical properties of the joints decreased [11,12].

In another study, Falat et al. [13] investigated the microstructure and creep characteristics of dissimilar T91/TP316H martensitic/austenitic welded joint with Ni-based weld metal, and realized that microstructure of Ni weld metal was very heterogeneous. Also, the martensitic part of the welded joint showed a wide heat-affected zone (HAZ). Conversely, the HAZ of the austenitic steel was limited to only a narrow region with coarsened polygonal grains.

Rao et al. [14] investigated the structure–property correlations in weld overlay clad high strength low alloy steel with austenitic stainless steel (AISI) grade 347. It was observed that grain coarsening and decarburization occurred near the interface and that there was maximum microhardness on the clad layer near the interface. It was also found that Charpy impact specimens of the interface failed in the mixed mode while impact specimens of the base plate failed in the ductile mode. The effect of Nb and Mo on the microstructure, mechanical properties, and flow behavior of Ni–Cr–Fe GTAW welds was investigated by Jeng and Chang [15,16]. They illustrated that Nb and Mo increased the tensile strength, and that the hardness measurements of the fusion zone increased

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Table 1
The chemical composition of used materials (based on wt.%).

Element	C	Cr	Ni	Mo	Mn	Si	Ti	Cu	Nb	Fe
A335	0.1	1.12	–	0.5	.03	1.0	–	0.08	–	BAL
AISI 347	0.08	17.36	10.65	0.37	2.0	1.0	0.01	0.35	0.55	BAL
ER309L	0.02	23.7	13.9	0.04	1.8	0.51	–	0.05	–	BAL
ERNiCr-3	0.1	16	BAL	3	0.5	0.75	.05	0.12	3	3

Table 2
The welding parameters and the heat input in each welding pass.

Filler metal	Welding parameters				
	Pass no.	Current (A)	Volt (V)	Welding speed (mm s^{-1})	Heat input (kJ mm^{-1})
ER309L	1	150	12	1.1	0.981
	2	140	10	1.0	0.840
	3	130	11	1.1	0.709
	4	110	12	1.1	0.720
ERNiCr-3	1	150	10	1.1	0.818
	2	140	10	1.0	0.840
	3	140	10	1.0	0.840
	4	130	11	1.2	0.715

proportionally with the content of Nb and Mo. However, no systematic work has been conducted on the joint between 347 austenitic stainless steel and A335 low alloy steel pipes. The aim of this study is to investigate the mechanical properties and microstructure of different welding zones in order to find the best filler metal with the proper engineering properties for these dissimilar joints.

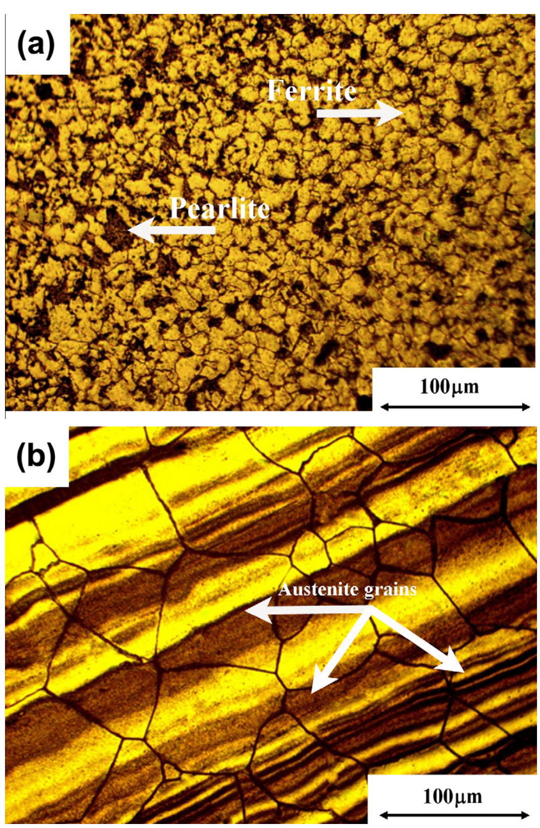

Fig. 1. Optical micrographs (a): A335 low alloy steel and (b): 347 austenitic stainless steel.

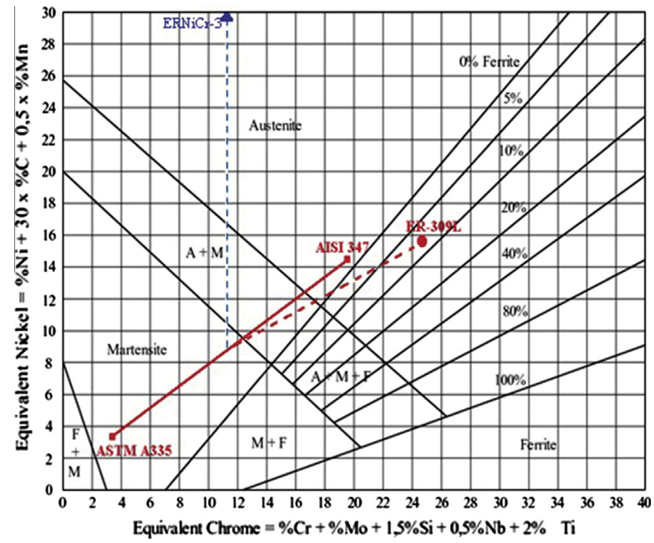

Fig. 2. Schaeffler diagram for both 309L and ERNiCr-3 filler metal.

Table 3
The calculated values of Cr_{eq}/Ni_{eq} base and filler metals.

Type	Cr_{eq}/Ni_{eq} values calculated		
	Cr_{eq}	Ni_{eq}	Cr_{eq}/Ni_{eq}
AISI 347	19.52	14.05	1.39
ASTM A335	3.12	3.15	0.99
ER309L	24.50	15.40	1.59
ERNiCr-3	19.75	71.50	0.27

Table 4
Percentage changes of austenite for both weld filler metal.

Filler metal	Percentage of austenite	Percent of error
ERNiCr-3	99.7	0.1
ER309L	94.5	1.5

2. Experimental procedure

The base metals used in this study were A335 low alloy steel and 347 austenitic stainless steel pipes which were under rolled

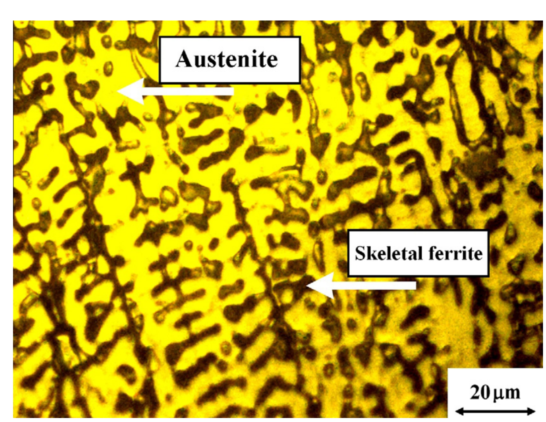

Fig. 3. Microstructure of ER309L weld metal.