Journal of Manufacturing Processes 32 (2018) 582–594

Contents lists available at ScienceDirect

Journal of Manufacturing Processes

journal homepage: www.elsevier.com/locate/manpro

Development of improved microstructural traits and mechanical integrity of stabilized stainless steel joints of AISI 321

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ARTICLE INFO

Keywords:
Ti stabilized stainless steel
Consumables
Pulsed current gas tungsten arc welding
Microstructure
Tensile strength
Impact toughness

ABSTRACT

AISI 321, Ti Stabilized austenitic stainless steel joints obtained by pulsed current gas tungsten arc welding process (PCGTAW) using ER347, ERNiCrMo-3 and ERNiCrMo-4 is addressed. The formation of delta ferrite was observed in the fusion zone of ER347 welds. A slight micro-segregation enriched with Mo content was observed in the fusion zone of ERNiCrMo-4 weldments. Tensile studies demonstrated that the failures occurred in the weld zone for ER347 and ERNiCrMo-3 and in base metal for ERNiCrMo-4 weldments. The formation of deleterious Laves phase in the fusion zone lowered the notch impact toughness and weld tensile properties for ERNiCrMo-3 weldments. The structure-property relationship of AISI 321 welds are addressed in detail and suitable recommendation on the choice of filler material is made based on the research findings.

1. Introduction

AISI 321, a general purpose Ni-Cr-Ti stainless steel, has potential applications for devising heat exchangers in nuclear, solar power plant [1] and also in chemical industries for the production of Nitric Acid. This alloy offers excellent strength, impact toughness at room and low temperatures, better resistance to corrosion and oxidation. In general, austenitic stainless steels have higher coefficient of thermal expansion than other grades of stainless steels; however thermal conductivity is normally lower [2]. This would result in thermal stresses during the welding. Similarly high magnitude of tensile residual stresses will be developed due to constrained weld geometry employed during welding. Also, amongst the various challenges involved in the welding of austenitic stainless steels, the foremost one is sensitization. The stabilized stainless steels containing either Ti (AISI 321) or Nb (AISI 347) have strong affinity with carbon than Cr and thus results in TiC or NbC. The formation of TiC/NbC could help in avoiding chromium impoverishment due to the chromium carbide precipitation and in fact, the sensitization could be controlled [3]. Although stabilized stainless steels are lesser prone to sensitization than conventional austenitic stainless steels, it is usually recommended to employ appropriate post weld heat treatment to avoid the knife-line corrosion attack or intergranular corrosion cracking. Also, it is the fact that the addition of stabilizing elements such as Nb/Ti also brings about the instability of austenite owing to the formation of secondary/ intermetallic phases when exposed to high-temperature [4]. Similarly, the formation of σ (sigma) phase is one of the serious problems in welding of austenitic grade stainless steel. The persistence of this phase not merely lowers the resistance to corrosion by removing the elements such as Cr and Mo from the austenitic matrix, but also detriments to the weld mechanical properties especially impact toughness [5]. Hence, selecting the appropriate filler and appropriate welding technique becomes challenging in welding stabilized stainless steels.

Kamal Mankari and Swati Ghosh Acharyya [1] investigated the failure of 3 mm diameter AISI 321 pipes which were seam welded by Laser beam welding (LBW) and/or Metal Inert Gas (MIG) welding. These pipes were used in solar thermal power plant for the transfer of thermic fluid from the parabolic heat concentrators to the heat exchangers. The authors observed that the laser welded pipers underwent knife-line attack due to improper post weld heat treatment of the welds. Higher amount of σ phase precipitation near the fusion zone, which caused erratic damage of the MIG welded pipes. Hussain et al. [6] studied the CO_2 laser welding of stabilized stainless steel, AISI 321. The authors observed the formation of streaky delta ferrite in the laser welds of AISI 321 and also reported the occurrence of tensile failures in the heat affected zone (HAZ).

Also, there are few studies on bimetallic combinations of AISI 321 with low alloy steel [7] AISI 630 [8], Ti alloy [9] and Ni based superalloy [10] which investigated the microstructure and mechanical properties of these dissimilar welds. However, it is evident from the literature that even though AISI 321 ha s potential application in various industries, the weldability and choice of filler materials have not

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https://doi.org/10.1016/j.jmapro.2018.03.029
Received 1 January 2018; Received in revised form 10 March 2018; Accepted 25 March 2018
1526-6125/

Table 1
Chemical composition of the base and filler metals.

Chemical Composition (% by weight)									
Base or Filler Metal	C	Si	Mn	Cr	Mo	Ni	Cu	Fe	Others
AISI 321	0.036	0.472	1.11	17.04	–	9.07	–	Rem.	P-0.033; S-0.008; Ti-0.335
ER347	0.062	0.41	1.35	20.2	0.22	9.1	0.18	Rem.	P-0.012; S-0.002; Nb-0.8
ERNiCrMo-3	0.05	0.20	0.18	21.2	9.2	Rem.	0.25	0.8	P-0.0001; S-0.004; Al-0.30; Nb-3.8
ERNiCrMo-4	0.009	0.055	0.52	15.66	15.81	57.88	0.026	Rem.	S-0.004; P-0.007; V-0.041; W-3.98

Table 2
Process parameters employed in PCGTA welding of AISI 321.

Filler wire	Pass	Current (A)		Voltage (V)	Frequency (Hz)	Duty cycle (%)	Heat Input at every pass (kJ/mm)	Total Heat Input (kJ/mm)
		I_b	I_p					
ER347	Cap	90	160	10.7-11.5	10	50	0.733	2.1796
	Filling pass 1	90	160	10.8-12.4	10	50	1.520	
	Root	90	160	10.8-12.6	10	50	1.197	
ERNiCrMo-3	Cap	90	160	10.3-11.9	10	50	0.856	2.0389
	Filling pass 1	90	160	10.4-12.2	10	50	1.281	
	Root	90	160	11.0-12.4	10	50	1.091	
ERNiCrMo-4	Cap	90	160	10.5-11.4	10	50	0.7941	2.5496
	Filling pass 1	90	160	11.9-13.3	10	50	1.3437	
	Root	90	160	11.4-12.5	10	50	0.9232	

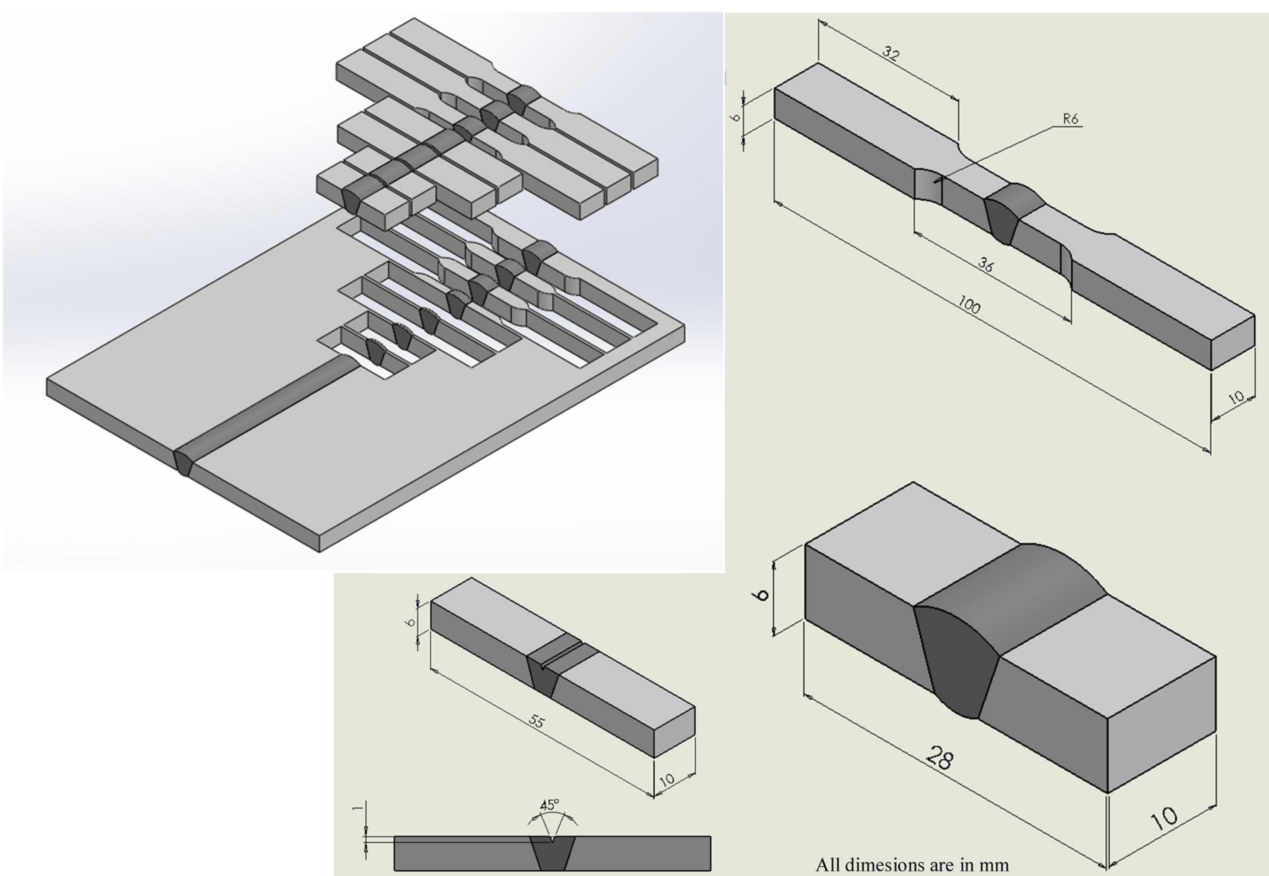

Fig. 1. CAD model showing the welded joint of AISI 321 and the samples extracted for microstructure traits and mechanical integrity tests.