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On dissimilar metal welding of AISI4140 and AISI410 by GTAW

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Abstract. This paper presents the results of metallurgical and mechanical examinations of Gas Tungsten Arc Welding of dissimilar steels AISI4140 and AISI410. Two different filler materials viz., ERNiCr3 and SS410 were used. The various properties of the weldments made using the fillers were compared to select the most appropriate one to get the sound joint. The ultimate tensile and yield strengths of the weldments of SS410 were greater than those of ERNiCr3. The fracture occurred at the weld in weldments made with ERNiCr3, whereas, in the base metal of AISI410 for weldments made with SS410. Microstructure of fusion zone of ERNiCr3 was fully austenitic. Microhardness values in the weld of SS410 were higher and fluctuating compared to those in the weld of ERNiCr3. From this research work, it shall be concluded that SS410 is the best filler material to weld these base materials.

1. Introduction

AISI 4140(CrMo) is a low alloy steel having high fatigue and torsional strength and high resistance to crack growth, abrasion and impact. AISI 410 (11Cr) is martensitic stainless steel possessing high resistance to corrosion at high temperatures. Due to these properties, the steels are commonly used in turbine rotor of steam turbine [1]. Normally AISI 410 (11Cr) is meant for high pressure and while AISI 4140(CrMo) for inter-mediate pressure conditions. To utilise the benefits of both the steels, they are welded [2], [3]. Fusion methods of joining such steels have been tried earlier[4], [5]. Joining of any combination of dissimilar metals by fusion process without a filler material involves many challenges. The metals need to have mutual solubility to obtain a sound metallurgical bond. The different thermal-expansion coefficients of the metals would lead to the development of residual stresses in the weldments due to uneven thermal strains. Welding of metals with different melting points or thermal conductivities is also problematic. The one with lower melting point will melt earlier than the other with higher. The difference in thermal conductivity would make uneven heating of the metals. The different chemical compositions coupled with high temperatures may cause brittle intermetallic compounds which are detrimental to the performance of the weldments. To counter these problems, a filler material compatible to both the base metals is normally recommended [6-8].

Recently, cold-wire (CW)-GTAW of AISI 410 and Inconel 718 were welded with a novel filler material made of both of these base metals viz., Inconel 718-AISI 410 and another with Inconel 82-AISI 410 [8]. Although steel based filler metals have been employed extensively for DMW of steels, the use of Ni-based superalloy filler metals were shown to improve the performance of the weldments [7]. The use of nickel-filler was reported advantageous over that of austenitic stainless steel-filler metal for DMW of ferritic-austenitic steels [6]. Thus a nickel-based filler-metal and SS410 filler-metal were selected for the present work.

This paper presents the results of Gas Tungsten Arc Welding (GTAW) of AISI4140 and AISI410 by using two different filler materials viz., ERNiCr3 and SS410.

2. Materials and methods

The base metals of AISI 410 (11Cr) and AISI4140 (CrMo) are cut into plates of dimensions 150 mm × 50 mm × 5 mm thick. The filler materials of ERNiCr3 (Inconel 82) and SS410, 2.5 mm in size were used. The plates were initially placed in butt configuration and welded all round at selected points to firmly hold them. At first GTAW was performed with each of the filler materials separately. The welding current and voltage as given in Table 1 was used. Argon gas was used as the protective environment. The number of passes was three. Then test samples[9] for metallography and mechanical tests like tensile, Charpy impact were cut using Wire EDM process as per ASTM standards.

Table 1. Welding parameters of GTAW of AISI4140 and AISI410

Filler materials	Pass number	Current (A)	Voltage (V)	Welding speed (mm/s)	Heat input (kJ/mm)	Total Heat input (kJ/mm)
ErNiCr-3	1	125	15	1.04	1.803	4.696
	2	128	15	1.39	1.381	
	3	125	15	1.24	1.512	
410 SS	1	118	20	1.34	1.761	4.708
	2	115	20	1.61	1.428	
	3	120	20	1.58	1.519	

3. Results and Discussions

3.1 Visual observations

The welded samples are shown in Fig. 1. The visual examination of the samples reveals no weld-defects. The weld-bead appears straight and uniform.

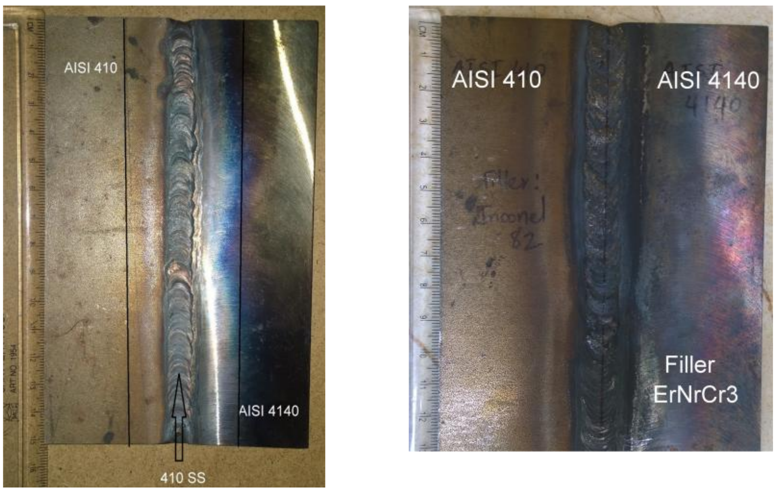

Figure 1. Welded samples, using (a) filler rod SS410 and (b) ERNiCr3

3.2 Microstructures

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Microstructures at the interface are shown in Fig. 2. It is observed that the weld interface is free from defects. The fusion of base metals and the weld metals is clearly seen. The weld of ERNiCr3 is fully austenitic with dendrites [10], [11].

3.3 Microhardness

The microhardness values across the weld interface including those of base metals are compiled as Table 2. The values in the heat affected zone (HAZ) of both the metals are higher than the corresponding base metals. Moreover, the values fluctuate in the range 427-482 HV in the weld of SS410 and do not fluctuate in ERNiCr3. This confirms the homogeneous structure of the ERNiCr3-weld. The very high value of 649 HV suggests the presence of martensitic structure in the HAZ of AISI 4140. The minimum value at ERNiCr3 weld justifies the fracture in the weld during tensile test. On the other hand, HAZ of AISI410 has the lower hardness compared to the HAZ of AISI4140, which is the reason for the fracture at AISI410 (HAZ).

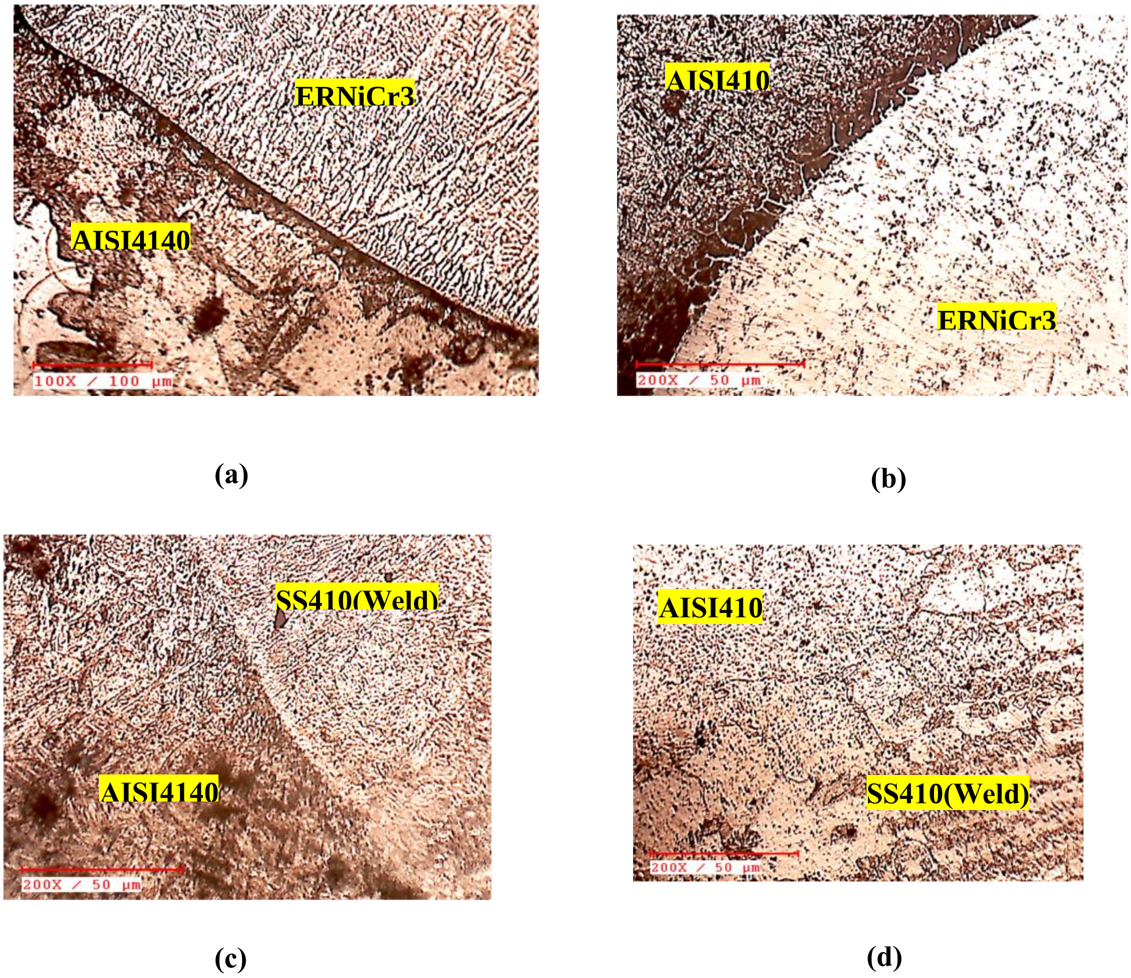


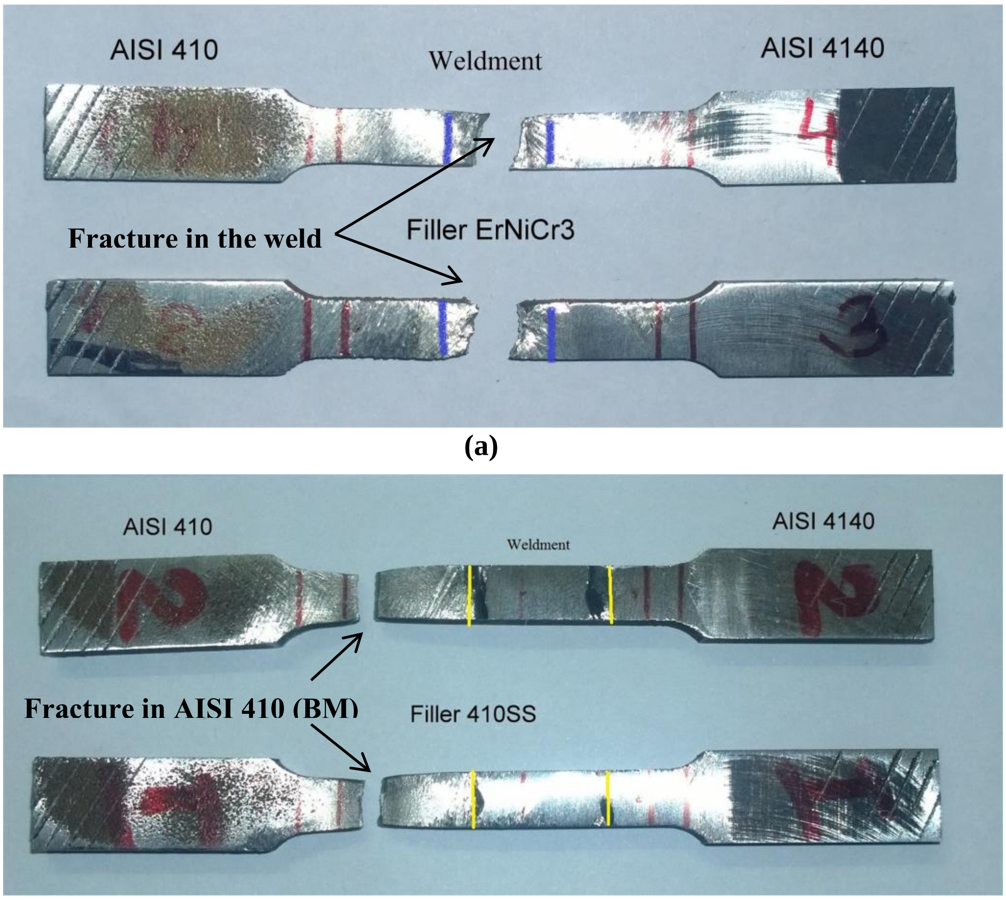
Figure 2. Microstructures at weld interface of (a) AISI4140-ERNiCr3 (Weld) (b) AISI410-ERNiCr3 (Weld) (c) AISI 4140-SS410 (Weld) (d) AISI410-SS410 (weld)

Table 2. Microhardness (HV300g) values of weldments of AISI4140 and AISI410

Material Zone	Filler	
	ERNiCr3	SS410
AISI410 (*BM)*	181.5	182
AISI410 (*HAZ*)	197	250-260
Weld Centre	162.5	427-482
AISI4140 (*HAZ*)	460-492	596-649
AISI4140 (*BM*)	350	350

3.4 Tensile properties

The tensile tested samples of the weldments are shown in Fig. 3. From figure 3(a), it shall be observed that the fracture occurred at the centre of the ERNiCr3 (weld). This is due to its lowest strength, as seen in the microhardness. From figure 3(b), it shall be observed that the fracture occurred at the base metal side of AISI410. This is due to its lowest strength, as seen in the microhardness. In both the weldments, fracture occurred at the weakest material zone. From the Table 3, it is observed that the weldments made of SS410 filler material showed highest tensile strength and strain to fracture. Thus, SS410 is the best choice of filler material to weld these base materials



(a)

(b)

Figure 3. Tensile tested samples of weldments made with (a) ERNiCr3-filler (b) SS410-filler.

Table 3. Tensile properties of the base metals and weldments

Material	Sample No.	Yield strength (MPa)	Ultimate tensile strength (MPa)	% Elongation (Gauge length 25mm)	Strain to fracture
AISI 4140 (BM)	1	---	837	5.63	0.07
	2	---	832	5.89	0.08
	Average	**---**	**834.5**	**5.76**	**0.075**
AISI 410 (BM)	1	---	490	37.95	0.38
	2	---	493	36.35	0.39
	Average	**---**	**491.5**	**37.15**	**0.385**
AISI4140-410 weldment (ERNiCr3-filler)	*N1*	---	333	8.57	0.12
	N2	---	395	8.13	0.15
	Average	**---**	**364**	**8.35**	**0.13**
AISI4140-410 weldment (410SS-filler)	*S1*	280	365	17.8	0.25
	S2	300	395	15.1	0.25
	Average	**290**	**380**	**16.45**	**0.25**

4 Conclusions

Gas Tungsten Arc Welding of dissimilar steels AISI4140 and AISI410 was performed with two different filler materials viz., ERNiCr3 and SS410. The various metallurgical and mechanical tests were carried out. From this research work, the following conclusions are drawn.

- Weld interfaces were defect-free.
- Fracture occurred at the base metal side of AISI410, for weldments made with filler material SS410. While it occurred at the ERNiCr3-weld. The SS410weld remained intact.
- The tensile strength and strain to fracture of weldments made with SS410 was more than that with ERNiCr3.
- Thus, SS410 filler rod is the best choice to weld AISI4140 and AISI410 steels by GTAW.

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