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Effect of filler metals on the mechanical properties of Inconel 625 and AISI 904L dissimilar weldments using gas tungsten arc welding

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Abstract: In the present research work, dissimilar welding between Inconel 625 super alloy and AISI 904L super austenitic stainless steel using manual multi-pass continuous current gas tungsten arc (CCGTA) welding process employed with ERNiCrMo-4 and ERNiCrCoMo-1 fillers were performed to determine the mechanical properties and weldability. Tensile test results corroborated that the fracture had occurred at the parent metal of AISI 904L irrespective of filler used for all the trials. The presence of the macro and micro void coalescence in the fibrous matrix characterised for ductile mode of fracture. The hardness values at the weld interface of Inconel 625 side were observed to be higher for ERNiCrMo-4 filler due to the presence of strengthening elements such as W, Mo, Ni and Cr. The impact test accentuated that the weldments using ERNiCrMo-4 filler offered better impact toughness (41J) at room temperature. Bend test results showed that the weldments using these fillers exhibited good ductility without cracks.

1. Introduction

Dissimilar metal welding of Inconel 625 and AISI 904L super austenitic stainless steel is widely used in thermal, nuclear power plants due to their economic potentials. Inconel 625 is a nickel-chromium alloy derived from by adding the strengthening elements of molybdenum (Mo) and niobium (Nb) on its matrix of nickel-chromium. But Inconel 625 is a comparatively expensive alloy, so to reduce the cost; a cheaper material can be used with same properties [1]. AISI 904L is a prevalent material have broad range of applications in thermal and nuclear power plants, chemical and petro-chemical industries due to excellent corrosion resistance and high temperature strength [2]. Super austenitic stainless steels (904L) are a Fe-based system is a highly alloyed austenitic low carbon stainless steel containing high amounts of Cr, Ni and Mo. NASA employed the dissimilar joints of 625 with 304L stainless steel were used in the construction of the sub scale boiler to boil the NaK at the temperature between 700-750°C for 791.4 hours to check the boiling stability in high temperature [3]. Vandervoort [4] investigated the tensile and fracture properties of the bimetallic joints of Inconel 625 welded with 21Cr-6Ni-9Mn austenitic stainless steel employed by the SMAW, GTAW and GMAW process and reported that the weldments by all the 3 welding techniques offered good strength, toughness, ductility at the cryogenic temperature of 4 K.

Lee et al. [5] studied the bimetallic joints of Inconel 690 and 304L and stated that the yield strength increases while employing the Nb- rich filler and significantly reduces the tensile strength. Naffakh et al. [6] studied the dissimilar joints of AISI 310 and Inconel 657 employed by GTA welding techniques using Inconel 617, Inconel 82, and austenitic SS filler 310 wire and reported that fully



austenitic fusion microstructure was found while employing all the above filler wires. Also the authors reported that the solubility of niobium austenite phase is lowered in nickel based super alloys due to the presence of iron in nickel.

Devendranath et al. [7] studied the bimetallic joints between AISI 304 and Inconel 625 and reported that in the HAZ of Inconel 625, segregation were observed due to the use of high Nb rich filler metal (ERNiCrMo-3) and also in the heat affected zone of stainless steel, the precipitation of chromium carbides was observed. The authors recommended that while employing PCGTA welding, the secondary phase effects were lowered slightly. By using the Nb rich filler the Cr-carbides precipitation could be mitigated at the interdendritic regions [8].

Joining the Inconel 625 with 904L by adopting suitable fillers with lower impurity level and welding techniques which offers the same mechanical properties is one of the cumbersome tasks and also from the literature it is evident that, by using CCGTA welding techniques, joining of Inconel 625 with AISI 904L has not been reported hitherto.

The main objective of this research is to investigate the mechanical property and weldability on the bimetallic joints of Inconel 625 super alloy with AISI 904L super austenitic stainless steel obtained by continuous current GTA welding process. By employing Nb free and Ni, Mo and Cr rich based fillers of ERNiCrMo-4 and ERNiCrCoMo-1 is to improve the mechanical properties. These bimetallic joints were subject to micro-hardness, tensile, impact and bend test to interpret the mechanical properties. The results revealed in this paper will be really useful to the Original Equipment Manufacturers (OEM) operating with these bimetallic joints.

2. Experimental Procedure

As-received base metal plates of Inconel 625 and AISI 904L were 5mm thick. By using spectroscopy method the chemical compositions studies were carried out and also represented in the Table -1 along with the filler metals (ERNiCrMo-4 and ERNiCrCoMo-1) used for this study. By using the wire cut EDM the base metals were machined to have the dimensions of 155 x 55 x 5mm. The process parameters were obtained based on bead on plate welding and resulted in the Table -2. Before welding, standard butt joint configuration (V-groove with an included angel of 70°, with the root gap of 1mm) were used in the present study. Continuous Current GTA welding was carried out in a specially designed fixture (holding the plates with accurate grip to avoid bending and distortion during welding) with a copper back plate. After welding, the gamma ray radiography technique were used to determine, if there are any flaws to in micro level surface defects like lack of penetration, under cut and inclusions. After ensuring that the weldment is defect free from NDT results, the coupons were sliced from the welded samples as per ASTM standards by using the wire cut Electrical Discharge Machining (EDM) to study the mechanical properties as shown in the Figure 1.

Microstructure studies were carried out on the weld coupons using Optical Microscopy (Om). The various mechanical tests like tensile, impact, hardness, and bend test have been conducted at room temperature to ascertain the mechanical properties of the welded samples. Two different tensile specimens (un-notched and notched) were prepared as per ASTM E8/8M-15a to understand the tensile properties of the bimetallic joints in transverse direction such as elongation, tensile strength and yield strength. Whereas notched tensile specimens were prepared to interpret the notch strength ratio (notched tensile strength/un-notched tensile strength) and notch tensile strength. By using the Instron universal testing machine with the attached extensometer tensile test was carried out on the ASTM E8/8M -15a standard dimensional samples. On each weldment three trials were conducted at room temperature to check the repeatability of the results to minimize errors. The test was carried out with a strain ratio of 2 mm/min. Micro hardness studies were carried out at cap, filler-1, filler-2 and root passes across the width on the composite region using the Vicker's micro hardness tester.

The readings were recorded by applied the standard load of 500gf at regular intervals of 0.25mm, for a dwell period of 10 sec across the width on the composite region. As per ASTM E23-12C standards, 4 samples were prepared from each weldment (2-cap notch & 2-root notch) for Charpy V-notch impact test to determine the impact toughness of these joints. To determine the mode of fracture for the fractured samples, the tested samples were subject to SEM fractography. Along with this, the samples were prepared for bend test as per E-190 ASTM standards. The bend test was carried out on 2 samples (1-root bend and 1-face bend) from each weldment to ascertain the occurrence of crack. From the Mechanical characterization of the weldments, the data obtained were interpreted to correlate the mechanical property and weldability. Further in subsequent headings, the results obtained are outlined in details.

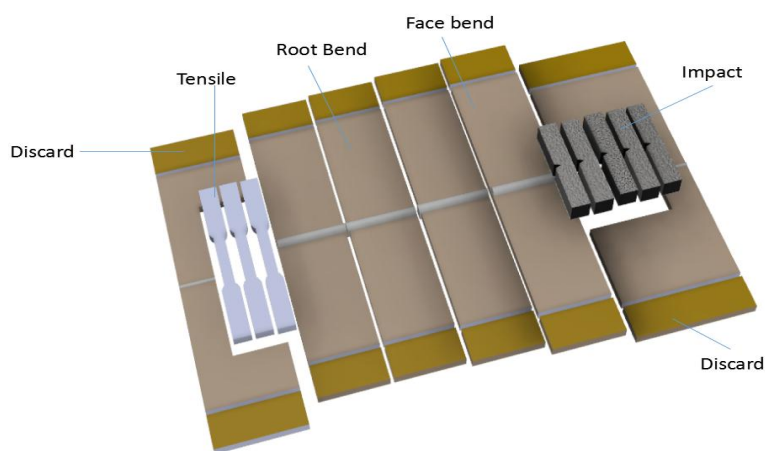


Figure1. Solid works model showing the specimens prepared as per ASTM standards for Mechanical test on the bimetallic joints of Inconel 625 and AISI 904L.

Table 1. Chemical composition (% wt.) of the base metal and filler metal

Base metal / Filler metal	Chemical Composition (% wt.)								Others
	C	Ni	Cr	Mo	Nb	Fe	Mn	Si	
Inconel 625	0.024	Rem.	22.04	9.00	3.47	4.38	0.106	0.203	0.186 (Al); 0.082 (Co); 0.029 (V); <0.001 (Ta); 0.002 (P); <0.001(S)
AISI 904L	0.018	26.1	19.72	3.93	Nil	Rem.	1.65	0.145	0.959 (Cu); 0.036 (Al); 0.034 (Co); 0.007 (Ti) 0.018 (P); <0.001 (S)
ERNiCrMo-4	0.015	57.8	Rem.	16.2	Nil	5.1	0.6	0.002	0.022 (Cu); 2.2 (Co); 4.08 (W); 0.051 (V); 0.001 (P); 0.008 (S)
ERNiCrCoMo-1	0.08	45.8	Rem.	9.4	Nil	2.2	0.05	0.11	0.28 (Ti); 13.2 (Co); 0.08 (Cu); 0.96 (Al); 0.001 (P); 0.002 (S)

*Remainder

Table 2. Process parameters employed in CCGTA welding of Inconel 625 and AISI 904L

Filler Wire	Filler wire dia. (mm)	No. of pass	Voltage (V)	Current (A)	Shielding gas flow rate (l/min)	Heat Input (kJ/mm)
ERNiCrMo-4	2.4	Root	11.0	160	15	3.65
		Filling pass 1	13.0	150		
		Filling pass 2	13.0	150		
		Cap	13.5	150		
ERNiCrCoMo-1	2.4	Root	11.5	160	15	3.76
		Filling pass 1	12.5	150		
		Filling pass 2	13.5	150		
		Cap	13.0	150		

3. Results

3.1 Micro-structure studies

3.1.1 CCGTA weldment employing ERNiCrMo-4 filler

Interfacial microstructures of Inconel 625 and AISI 904L using ERNiCrMo-4 filler are represented in Figure 2(a & b). In the HAZ of Inconel 625 side the grain coarsening effect was observed (Figure 2a), whereas in the AISI 904L side the secondary phases formation and the unmixed zone presence were observed in the HAZ also it was clearly seen from the Figure 2b.

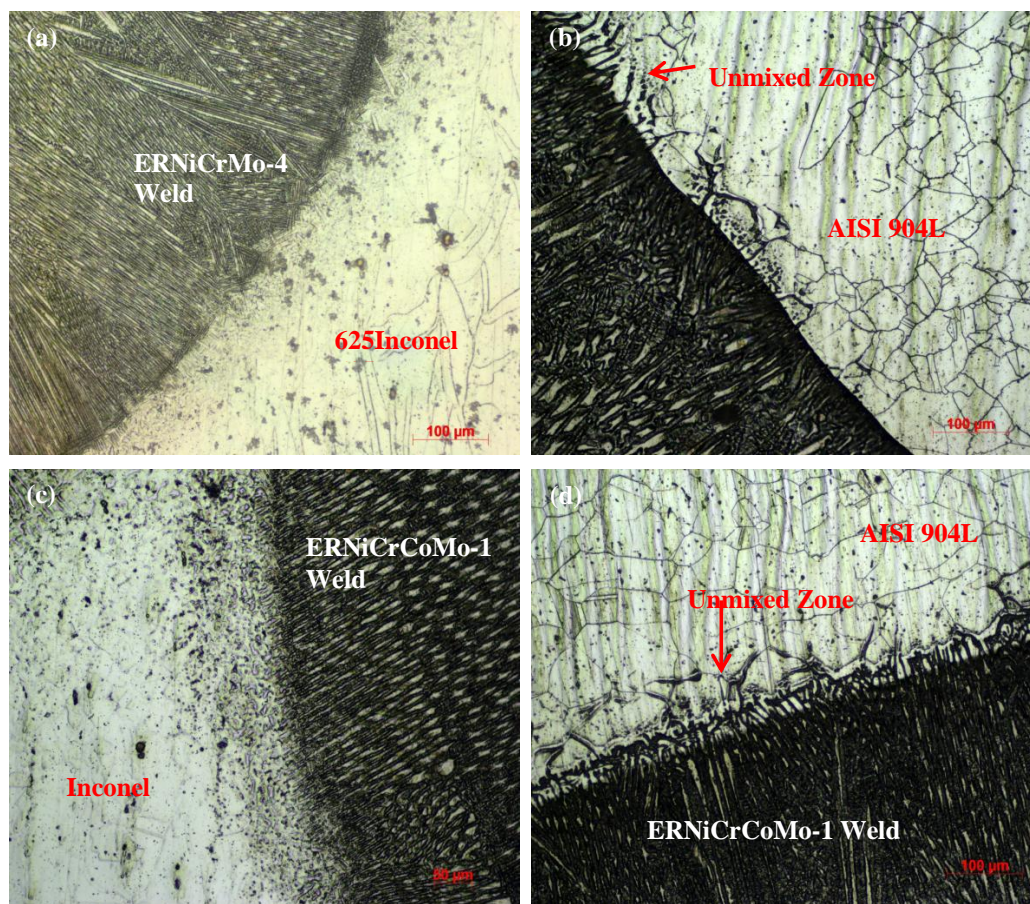


Figure 2. Microstructures of bimetallic joints of Inconel 625 and AISI 904L employing (a) & (b) ERNiCrMo-4; (c) & (d) ERNiCrCoMo-1 fillers

3.1.2 CCGTA weldment employing ERNiCrCoMo-1 filler

Interfacial microstructures of Inconel 625 and AISI 904L using ERNiCrCoMo-1 fillers are represented in Figure 2(c& d). Grain coarsening was observed in the interface of Inconel 625 (Figure 2c). The presence of unmixed zone has been seen at the HAZ of AISI 904L (Figure 2d).

3.2 Mechanical characterization of the weldments

3.2.1 Micro-hardness test

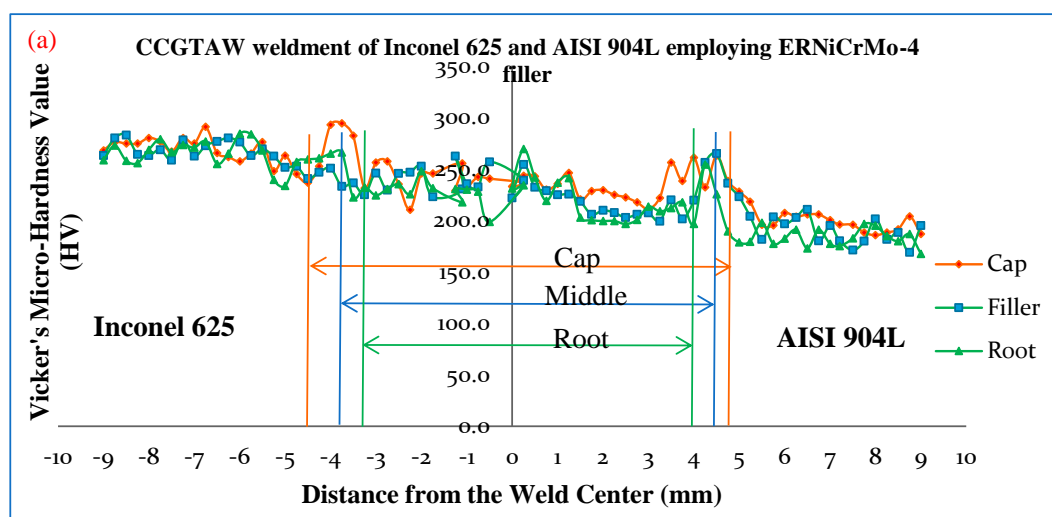
Figure 3(a & b) depicts the hardness profile of the bimetallic joints obtained from the CCGTA welding technique of Inconel 625 and AISI 904L employing ERNiCrMo-4 and ERNiCrCoMo-1 fillers. On a transverse cross section of the weld bead the micro-hardness (VHN) tests were performed across the width of the composite zone (cap, filler-1, filler-2 and root passes) were represented in the Table 3.

Table 3. Vickers hardness values of the bimetallic joints employed by CCGTA Processes at different passes of weldments

Filler wire	Description	Vickers hardness value (HV)			
		Cap	Filler	Root	Avg.
ERNiCrMo-4	Avg. hardness of the weldment	238.3	230.7	225.4	231.5
	Avg. hardness at the weld zone	241.1	229.8	221.5	230.8
	Peak hardness at the weld zone	294.1	264.6	269	275.9
ERNiCrCoMo-1	Avg. hardness of the weldment	231.1	230.4	224.7	228.7
	Avg. hardness at the weld zone	229.3	233.2	218.4	227.0
	Peak hardness at the weld zone	250.5	257.7	241.4	250.0

3.2.1.1 CCGTA weldment employing ERNiCrMo-4 filler

The avg. hardness at the weld zone was observed to be 230.8 HV whereas the peak value of hardness at the weld zone was found in the cap region (294.1 HV) in the weld interface of Inconel 625.



3.2.1.2 CCGTA weldment employing ERNiCrCoMo-1 filler

The avg. hardness at the weld zones was observed to be 227 HV while employing ERNiCrCoMo-1 filler. The peak value of hardness was found at the fusion zone is in the filler pass (257.7 HV). The hardness value in the root pass of ERNiCrCoMo-1 is lower (241.4 HV) compared to the cap and filler passes. In both cases, the interface of Inconel 625 side and weld zone exhibited higher hardness compared to the interface and base metal of AISI 904L side.

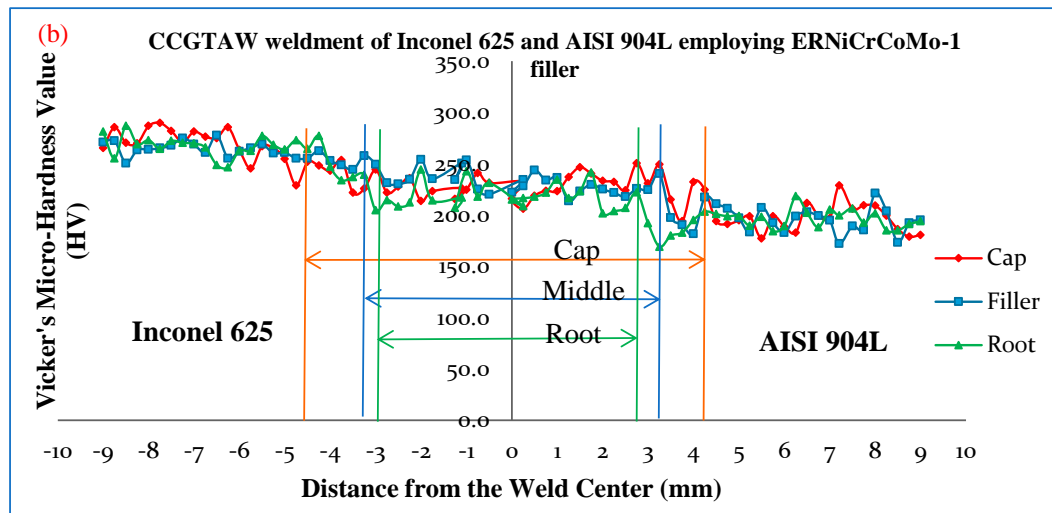


Figure 3. Hardness plots of bimetallic joints of Inconel 625 and AISI 904L employing (a) ERNiCrMo-4; (b) ERNiCrCoMo-1 fillers

3.2.2 Tensile test

Tensile test was performed on ASTM: E8/E8m-15a standard tensile specimens (un-notched and notched) to interpret the tensile properties in the transverse direction such as tensile strength, yield strength, and percentage of elongation for un-notched smooth tensile specimens and notch strength ratio (notched tensile strength/un-notched tensile strength) and notch tensile strength for notched specimens are tabulated in Table 4(a & b). The photographs of the notched (Figure 4(a & b)) and un-notched (Figure 5(a & c)) tensile specimens of Inconel 625 and AISI 904L bimetallic joints employing ERNiCrMo-4 and ERNiCrCoMo-1 fillers at room temperature were presented.

Table 4. (a) Tensile Properties of Inconel 625 and AISI 904L bimetallic joints employed by CCGTA Processes

Filler Wire	Maximum Tensile strength (MPa)	Average Young's modulus (GPa)	Average Proof Stress (0.2%) (MPa)	Average ductility (%)	Fracture Zone
ERNiCrMo-4	650	71.1	312.95	23.58 %	Parent metal of 904L
ERNiCrCoMo-1	592	67.5	302.4	18.85 %	Parent metal of 904L

3.2.2.1 CCGTA weldment employing ERNiCrMo-4 filler

During the transverse tensile test, failures occurred at AISI 904L parent metal in all the 3 trials of CCGTA weldments employing ERNiCrMo-4 filler and also evident from the Figure 5a. It was observed that before the occurrence of fracture, the weldments undergone with severe plastic deformation in all the trials. The ultimate tensile strength and avg. proof stress values for un-notched specimen of ERNiCrMo-4 filler were 650 and 313 MPa, for notched specimen it was 720 and 365.1 MPa and the notch strength ratio (NSR) is 1.11 respectively (Table 4b). The average ductility exhibited in terms of elongation (%) at brake load was found to be 23.58 % whereas for notched is 30.4%. Figure 5b depicts the SEM fractography of un-notched tensile specimen, reveals that dimples and macro/micro voids coalescence the fibrous network shows the ductile mode of fracture.

Table 4. (b) Notch tensile properties of Inconel 625 and AISI 904L bimetallic joints employed by CCGTA Processes

Filler Wire	Maximum Tensile strength (MPa)	Average Young's modulus (GPa)	Average Proof Stress (0.2%) (MPa)	Average ductility (%)	Notch strength ratio (NSR)
ERNiCrMo-4	720	235.5	365.1	30.4 %	1.11
ERNiCrCoMo-1	740	246.7	405.9	23.9 %	1.25

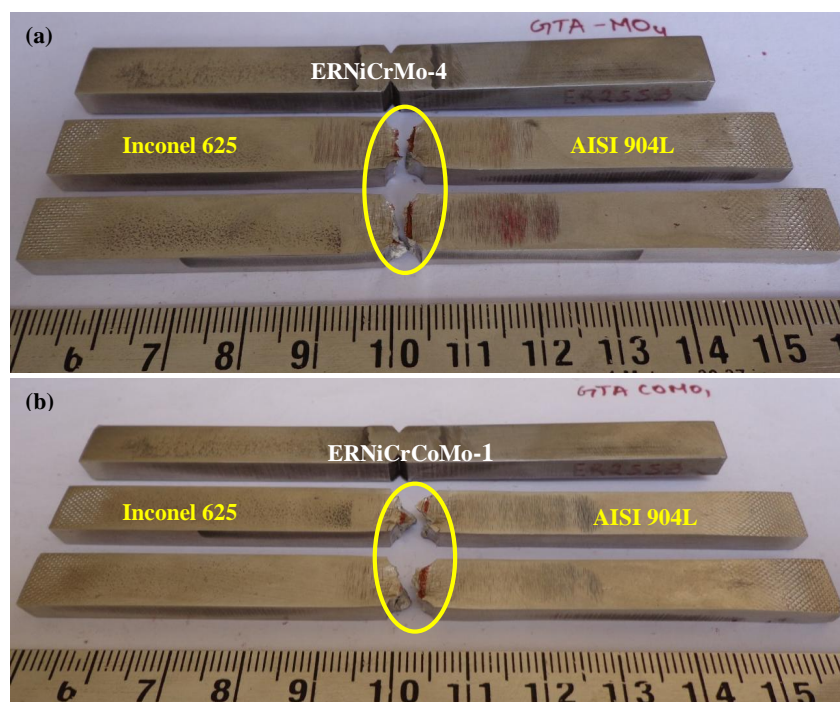
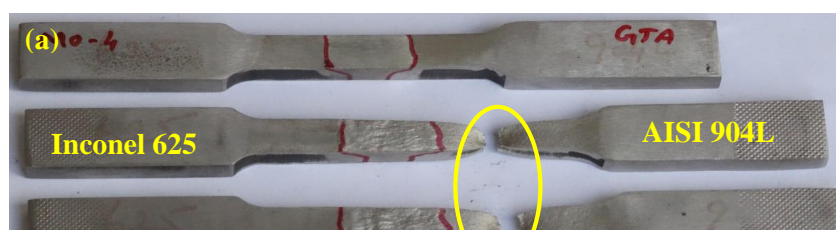


Figure 4. V-notch tensile test fractured samples of Inconel 625 and AISI 904L bimetallic joints employing (a) ERNiCrMo-4; (b) ERNiCrCoMo-1 fillers



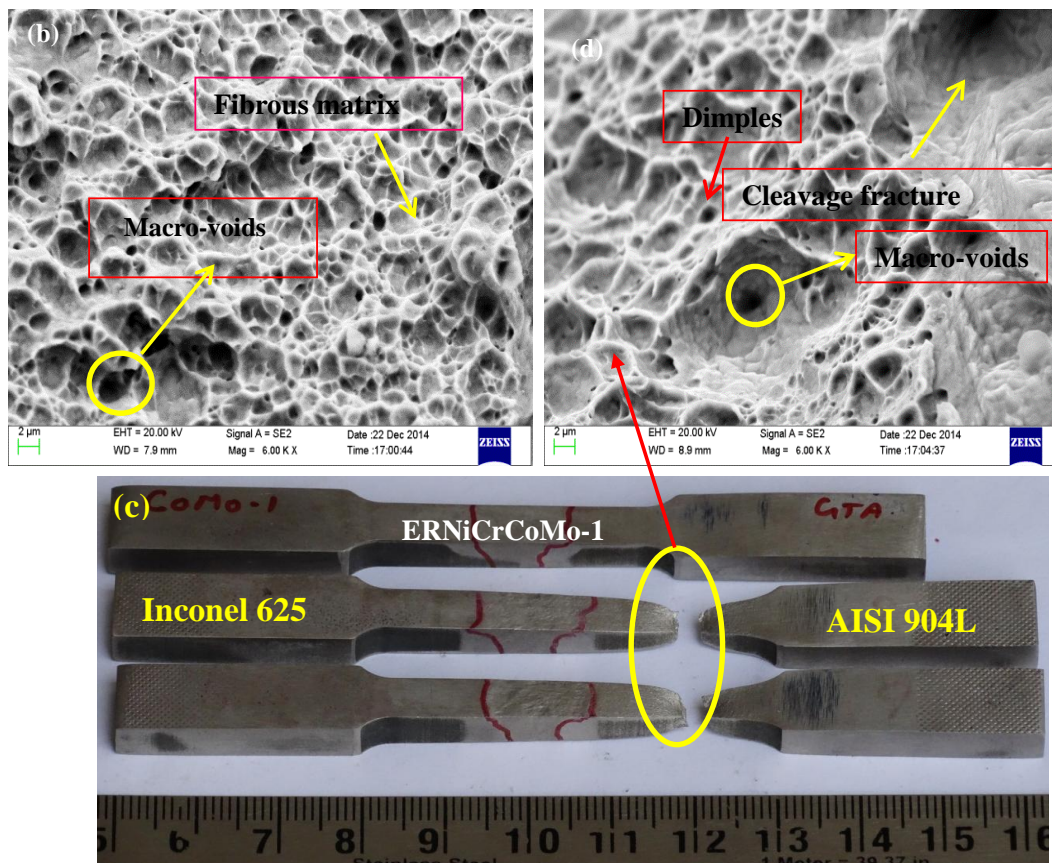


Figure 5. Fractured tensile test samples and fractography of Inconel 625 and AISI 904L bimetallic joints employing (a) & (b) ERNiCrMo-4 filler and (c) & (d) ERNiCrCoMo-1 filler

3.2.2.2 CCGTA weldment employing ERNiCrCoMo-1 filler

The tensile test results of ERNiCrCoMo-1 filler are listed in the Table 4a. In all the 3 trials, the fractured occurred at AISI 904L parent metal, evident from the Figure 5c. The ultimate strength and proof stress values for un-notched smooth tensile specimen were 592.5 and 302.4 MPa whereas for notch test (Table 4b) 740 and 405.9 MPa and the notch strength ratio (NSR) is 1.25 respectively. SEM fractography (Figure 5d) depicts the presence of micro voids shows ductile mode of fracture and cleavage fracture was also been observed shows partially brittle failure. The average ductility exhibited in terms of elongation (%) at brake load was found to be 18.85 % whereas for notched is 23.9% respectively.

3.2.3 Impact test

Figure 6(a &c) depicts the photograph of impact tested (Charpy V-notch) samples of the dissimilar weldments of CCGTA welding employing ERNiCrMo-4 filler and ERNiCrCoMo-1 filler. The Impact energies (J) are tabulated in Table 5.

Table 5. Impact Energy (J) of Inconel 625 and AISI 904L bimetallic joints employed by CCGTA Processes

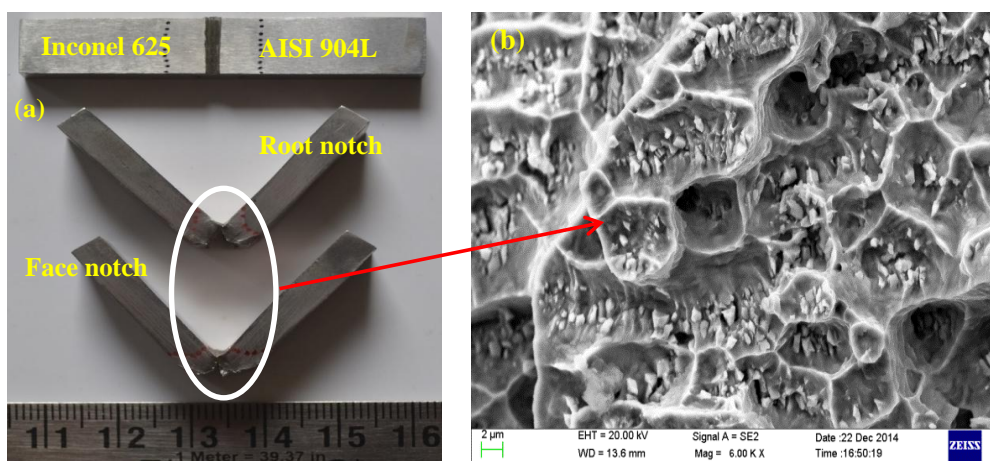
Filler Wire	Face Notch	Root Notch
ERNiCrMo-4	44 J	38 J
ERNiCrCoMo-1	37 J	32 J

3.2.3.1 CCGTA weldment employing ERNiCrMo-4 filler

From the Figure 6a, it is inferred that the weldments have undergone a V-notch deformation in all the (face and root) notched section upon the impact loading. From the Table 5 it clearly envisaged that the average impact toughness obtained was 41J. SEM fractography (Figure 6b) of the impact test samples shows the dimples coalescence formation in the fibrous matrix contributed for the ductile mode of failure.

3.2.3.2 CCGTA weldment employing ERNiCrCoMo-1 filler

The mixed mode of completely ruptured and V-notch deformation upon impact loading was observed for CCGTA weldment employed with ERNiCrCoMo-1 filler (Figure 6c). The average impact toughness obtained was 34J. However the average impact toughness of ERNiCrMo-4 weldments is greater than the ERNiCrCoMo-1 weldments. Due to the presence of macro-voids shows the ductile mode but it influence the deterioration of the impact energy it is evident from the SEM fractography (Figure 6d).



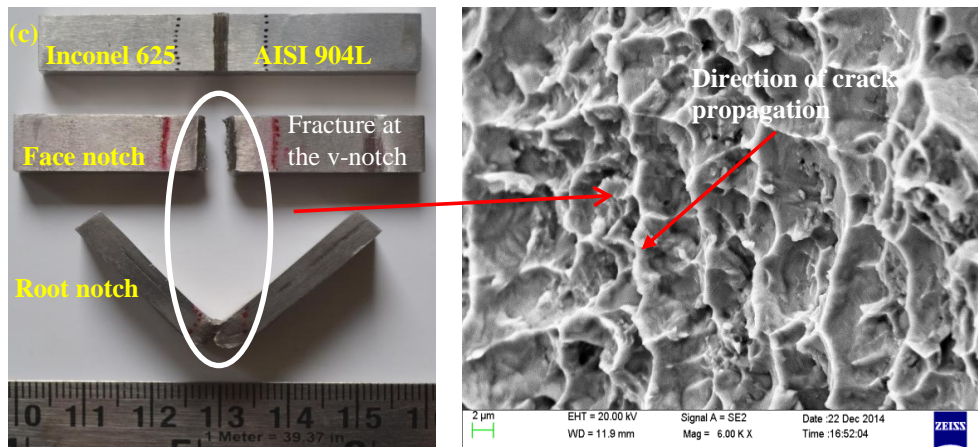


Figure 6. Fractured impact test samples and fractography of Inconel 625 and AISI 904L bimetallic joints employing (a) & (b) ERNiCrMo-4; (c) & (d) ERNiCrCoMo-1 fillers

3.2.4 Bend test

The Fig. 7(a & b) depicts the photograph of bend test samples (face and root bend) of the dissimilar weldments of CCGTA welding employing ERNiCrMo-4 and ERNiCrCoMo-1 fillers. Bend test results corroborated that there were no any occurrence of fracture or micro fissure cracks on both the weldments during 180 deg. bend, it clearly shows that the sound dissimilar welds has been obtained using ERNiCrMo-4 and ERNiCrCoMo-1 filler wires.

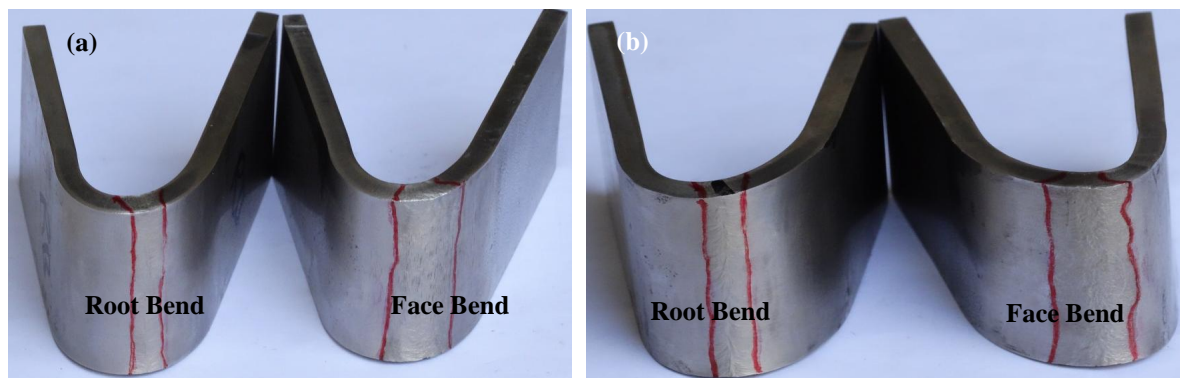


Figure 7. Bend test photographs of Inconel 625 and AISI 904L bimetallic joints employing (a) ERNiCrMo-4; (b) ERNiCrCoMo-1 fillers

4. Discussion

The present study investigates the mechanical properties of Inconel 625 and AISI 904L bimetallic joints using multi-pass continuous current GTA welding process employing ERNiCrMo-4 and ERNiCrCoMo-1 fillers.

Interfacial microstructures of the Inconel 625 employed by both fillers clearly showed the grain coarsening and segregation at the HAZ (Figure 2a &c). The width of the segregated zone in the weld interface of Inconel 625 is meagre for ERNiCrMo-4 compared with ERNiCrCoMo-1 welds, might be due to the filler metal diluted properly with the base metals. These are predominantly more visible in the ERNiCrCoMo-1 weld (Figure 2c) due to the migration of carbon from the weld metal

towards the side of Inconel base metal, due to the higher carbon percentage in the filler ERNiCrCoMo-1 than base metal as it is evident from chemical composition analysis (Table 1). According to Mortezaie et al. [10] the migration of elements is inevitable during the welding process especially the migration of carbon. Due to high penetration rate of carbon in Ni, carbon easily diffuses from the weld metal into the Inconel 625 base metal during welding.

Due to the variances in chemical compositions and melting temperatures between the filler metal and base metal of AISI 904L, the unmixed zone was found in the interface of AISI 904L (Figure 2b&d). The unmixed zone width was observed to be more in ERNiCrMo-4 weld compared to ERNiCrCoMo-1 filler. During dissimilar welding, the base metal melts as small fraction if the filler metals melting range are greater than the base metal, results in the unmixed zone as stated by Sireesha et al. [10].

The micro-hardness plots envisaged that the hardness of CCGTA welding (Figure 3a) employed by ERNiCrMo-4 filler was higher at the heat affected zone of Inconel 625 and in the weld interface might be due to the strength increasing elements such as W, Mo, Ni and Cr. The values observed to be higher in the weld interface of AISI 904L (Figure 3a) employed by ERNiCrMo-4 filler compared to ERNiCrCoMo-1 filler due to the presence of W and Mo leads to increase in strength and hardness. Whereas in the weldment employed by ERNiCrCoMo-1, the formations of Cr-rich carbide ($M_{23}C_6$) in the weld interface of AISI 904L due to the enrichment of Mo and Cr, results in lower strength and hardness also evident from the hardness plot (Figure 3b). The hardness value of the weld zone in the root pass of ERNiCrCoMo-1 is lower (241.4 HV) compared to the cap and filler passes.

From the transverse tensile studies (un-notched specimens), it was found that the fracture occurred at AISI 904L parent metal in all the trials irrespective of the fillers used for this study i.e. the strength of the weld was observed to be greater than one of the parent metals (AISI 904L). Due to the ferrite stringers presence at the HAZ region of AISI 904L (irrespective of fillers) contributed for better strength compared to base metal (fracture occurred) where the ferrite presence is low in the parent metal after welding, also this could be explained from the microstructure and it is well agreement with the hardness plot. Alongside the weldment of CCGTA techniques employed by ERNiCrMo-4 filler have better ductility, proof stress and tensile strength compared to ERNiCrCoMo-1 filler. The average tensile strength values reported from the study are 650 MPa and the % elongation is 23% for ERNiCrMo-4 filler found to be greater than the 592 MPa and 18% for ERNiCrCoMo-1 filler, whereas the tensile strength of AISI 904L parent metal was found to be 605 MPa. From the notched tensile test (Table 4b) the average tensile strength values 720 MPa and the % elongation is 30% for ERNiCrMo-4 filler found to be nearer to the filler strength (744MPa) whereas for ERNiCrCoMo-1 filler is 740 Mpa and the % elongation is 23.9% which is found to be greater than the filler strength (689 MPa). The average notch strength ratio was 1.25 for ERNiCrCoMo-1 filler, which is observed to be greater than the ERNiCrMo-4 filler (1.11).

Impact tests (Charpy V-notch) were carried on these dissimilar joints. It was inferred that the average impact toughness value obtained for ERNiCrMo-4 filler is 41J whereas the toughness reported is 34J for ERNiCrCoMo-1 filler. The average toughness of ERNiCrMo-4 weldments is observed to be greater than the ERNiCrCoMo-1 weldments. The reason might be due to the migration of carbon from the weld metal towards the Inconel side, because of the higher carbon percentage in the ERNiCrCoMo-1 filler than base metal, the elemental constituents such as Nb, Cr and Mo enrichment could probably be the precipitates such as MC system carbides results in low impact strength and hardness [11].

Further to support the tensile and impact test results of the bimetallic joints, the bend test was also carried out. Bend test results corroborated that there were no any occurrence of fracture or micro fissure cracks during the 180 deg. bend, it clearly shows that the sound dissimilar welds has been obtained by CCGTAW techniques using ERNiCrMo-4 and ERNiCrCoMo-1 filler wires.

This present study outlined the mechanical properties at room temperature of the weldments. Further studies are also required to assess the same as these dissimilar joints are operated in altered environments at high temperature. Further to improve the mechanical properties of Ni-base super alloys such as tensile strength, hardness etc., it was proposed to have the post weld heat treatments, which result in gamma double prime precipitation in the grains and also the carbides $M_{23}C_6$ in the grain boundaries which plays vital role [12]. But it is a challenging task to perform post weld heat treatments for the bimetallic joints due to their variance in chemical composition and thermal coefficient of expansion.

From the present studies, it was evident that the process parameters selection and use of appropriate filler wire ERNiCrMo-4 results in improvement of mechanical properties. Also it was witnessed from the microstructure studies that the deleterious phases were minimal on the HAZ of Inconel 625 side. From the outcomes of the investigation, it is recommended to use ERNiCrMo-4 filler for joining the Inconel 625 and AISI 904L bimetallic joints as this technique showed better weld strength and improved mechanical properties.

The results revealed in this work will be really useful to the Original Equipment Manufacturers (OEM) operating with these bimetallic joints.

5. Conclusion

The present study investigates the mechanical properties and weldability of dissimilar welds between Inconel 625 and AISI 904L obtained by continuous current GTA welding techniques employing ERNiCrMo-4 and ERNiCrCoMo-1 fillers and there by following conclusions are summarized:

- (1) Successful and defect free dissimilar weldments of Inconel 625 and AISI904L could be obtained by continuous current GTA welding techniques employing these fillers.
- (2) Microstructure observation reveals the grain coarsening effect at the HAZ of Inconel 625 was observed to be meagre for ERNiCrMo-4 filler compared to ERNiCrCoMo-1filler.
- (3) Tensile test results (un-notched) corroborated that the fracture had occurred at AISI 904L parent metal for all the trials in both cases. However the weld tensile strength was observed to be higher than that of AISI 904L parent metal strength.
- (4) Notched tensile test results envisaged that the average weld strength for ERNiCrMo-4 filler is 720 MPa which is nearer to the filler strength (744MPa), whereas for ERNiCrCoMo-1 was to be 740 MPa which is higher than the filler strength (689MPa).
- (5) The avg. hardness at the fusion zones was observed to be greater for ERNiCrMo-4 filler compared to ERNiCrCoMo-1 filler might be due to the strength increasing elements such as W, Mo, Ni and Cr presence.
- (6) Impact energies were experienced to be higher for the weldments employed by ERNiCrMo-4 than that of ERNiCrCoMo-1, this might be due to the strength increasing elements such as Nb, W and Mo presence in the fibrous weld matrix and the mode of fracture is ductile in nature.
- (7) Bend test results corroborated that there were no any occurrence of fracture or micro fissure cracks on both the weldments during the 180 deg. bend, it clearly shows that the sound dissimilar welds has been obtained by the CCGTAW process using ERNiCrMo-4 and ERNiCrCoMo-1 filler wires.
- (8) Based on the present investigation on mechanical property, for joining these bimetallic combinations employing ERNiCrMo-4 filler could be better compared to ERNiCrCoMo-1 filler.

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