Characterization of Microstructure and Mechanical Properties of Inconel 625 and AISI 304 Dissimilar Weldments

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This investigation has been performed to characterize the microstructure and mechanical properties of the GTA and PCGTA welded dissimilar combinations of Inconel 625 superalloy and AISI 304 austenitic stainless steel. These welds were obtained by employing ERNiCrMo-3 filler metal. The weldments were characterized by the combined techniques of optical microscopy and SEM/EDAX analysis. Hardness and tensile studies were conducted to assess the mechanical properties of the weldments. Tensile studies showed that the fracture had occurred at the parent metal of AISI 304 side in both the cases.

KEY WORDS: gas tungsten arc welding; pulsed current gas tungsten arc welding; alloy 625; austenitic stainless steel AISI 304; filler metal.

1. Introduction

Nickel base superalloys, Inconel 625 have been used for critical components such as bellows expansion joints, fasteners, exhaust systems, hydrographic and towing cables, *etc.* Inconel 625 has very high resistance to marine environments and the only factor retarding their widespread use in marine applications is their cost.[1] Bimetallic joints of Inconel 625 superalloy and 304 austenitic stainless steel are widely used for high-temperature applications in power and nuclear industries because of their higher corrosion resistance, high strength *etc.* and also these combinations are used in the cryogenic applications. One of the critical issues in the dissimilar welding of a superalloy with stainless steels is the selection of appropriate filler metal. It was reported by Belloni *et al.*[2] that weldability of Inconel 657 is generally weaker as in the fusion welding, mainly because of precipitation of hard brittle α-Cr phase in the fusion zone (FZ) and heat affected zone (HAZ). Because of the formation of these elements, the alloy Inconel 657 exhibits weaker resistance to weld solidification cracking. The use of filler metal employing higher Nb constituent enhances the mechanical properties but however the segregation of Nb forms the Nb-rich phase, which is a brittle compound that have detrimental effect on weldability and weld mechanical properties such as ductility, fracture toughness, fatigue and creep rupture as well as consuming significant amounts of useful alloying elements such as Ni, Ti, Mo *etc.* (Caironi *et al.*[3]). Despite the fact that Inconel 625 as a nickel based superalloy possesses a great corrosion resistance, the high production cost has restricted the individual application of this alloy.[1] It was reported by Shah Hosseini *et al.*,[4] as the Inconel is a relatively expensive alloy, a cheaper material with good properties can be used in lower risk conditions experienced in ambient and hot corrosive environments to reduce material costs. Austenitic stainless steel is a prevalent material used in high temperature applications. This alloy would be a good alternative for Inconel alloy. Hence welding techniques were adopted to join Inconel 625 and cost effective stainless steel grade which offers almost the same corrosion resistance.

NASA[5] employed stainless steel AISI 316 for the condenser and Inconel 625 with a type 304L stainless steel wick as boiler material in the construction of subscale boiler. This type of subscale boiler was examined to evaluate boiling stability after being operated with boiling NaK for 791.4 hr at temperatures from 700 to 750°C. Results showed that a crack in the heat affected zone of the Inconel 625 near the Inconel 625 to stainless steel AISI 316 butt joint was probably caused by excessive heat input. Wu *et al.*[6] employed the wide gap brazing of Nickel based superalloy Inconel X-750 and stainless steel, AISI 304. These brazed joints were developed to withstand high temperatures widely designed for aeroengine hot section components. Further the authors reported that brazing temperature plays major role in determining the mechanical properties.

Vandervoort[7] studied the tensile and fracture properties of 21%Cr-6%Ni-9%Mn austenitic stainless steel welded with Inconel 625 at the cryogenic temperature of 4 K. Welds were made by the shielded metal-arc, gas tungsten-arc, and gas metal-arc processes. Results from this study showed that base metal, the heat-affected-zone, and the weld zones of all the three welding techniques had good strength, ductility,

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and toughness at low temperatures.

Shah Hosseini *et al.*[4] carried out the investigations on the mechanical properties of Inconel 617 and AISI 310 stainless steel. Three different filler wires were employed in this study vis-à-vis Inconel 82, Inconel 617 and 310SS. It was reported that the weld microstructure was found to have fully austenitic structure for all the filler wires. The presence of 3% Nb stabilizes the austenitic matrix. Naffakh *et al.*[8] employed gas tungsten arc welding (GTA) for joining Inconel 657 and AISI 310 using nickel-based corresponding to Inconel 82, Inconel A, Inconel 617 and 310 austenitic stainless steels. Authors reported that the presence of iron in nickel based superalloys lowers the niobium solubility in austenite phase and the presence of Niobium not only lowers the melting point constitutionally, but also forms low-melting carbide-austenite eutectics during solidification. Also it was evident from the tension tests, all weldments failed in the weaker parent metals (*i.e.*, Inconel 657).

Patterson *et al.*[9] reported the use of autogeneous gas tungsten arc welds to join alloy 625 and 304L stainless steel. The author reported that the welds produced from autogeneous GTA welding technique were found to be susceptible to weld solidification cracking. Also they insisted that utilization of pulsed current GTA welding produced a higher sensitivity to solidification cracks than continuous current welding. Comparative studies on the direct and pulsed current GTA welding of Inconel 617 superalloy was carried out by Farahani *et al.*[10] It was reported that the grain refinement occurred on employing pulsed current. Devendranath *et al.*[11] investigated the performance of Monel 400 and AISI 304 dissimilar weldments using ER309L and ERNiCu-7 filler metals. Secondary phases were formed at the weld interface of AISI 304 on employing ER309L filler metal. The authors reported that secondary phase formation usually deteriorate reduce the mechanical properties of the weldments.

As reported by Lee *et al.*,[14] the increased content of Nb results in a denser spacing of the dendrite arms normally result in the weld hardness. The authors further reported that the non-uniform distribution of Nb throughout the fusion zone would be due to the compositional difference between the alloy 690 and SUS 304L using different filler wires and may also be influenced by the variation in constitutional super-cooling on employing SMAW. Jeng *et al.*[15] investigated the microstructure of the Alloy 690 and SUS 304L stainless steel weldments obtained by GTA welding techniques employing different filler metals. They observed the precipitation of Cr-carbides at the inter-dendritic regions due to the multi-pass welding. The Cr content near the grain boundary decreases as a result of Cr-carbide precipitates. It has been proposed that the Cr depletion caused by the Cr-carbide precipitation along the grain boundary results in a reduction in the corrosion resistance to inter-granular attack.

As evident from literatures, GTA and pulsed current gas tungsten arc (PCGTA) welding of Inconel 625 superalloy and stainless steel AISI 304 has not been reported hitherto even though it has potential advantages in the high temperature applications. Hence this forms the major goal of the research work. This work aims at investigating the dissimilar combinations of Inconel 625 and AISI 304 using Ni based filler wire ERNiCrMo-3 by GTA and PCGTA welding techniques. Comparative studies on the microstructure and mechanical properties characterization have been carried out using the optical microscopic techniques. Furthermore the weldments are also characterized for their mechanical properties. Also the various zones of the GTA and PCGTA weldments of Inconel 625 and AISI 304 have been characterized using SEM/EDS analysis to correlate the structure - property relationships.

2. Experimentation

The base metals employed in this study were 5 mm thick plates of Inconel 625 and AISI 304 and the filler metal ERNiCrMo-3. The chemical composition studies were carried out by spectroscopic methods and the nominal chemical composition of the base metals and the filler metal are represented in **Table 1**. The process parameters were established after conducting iterative studies based on the bead on plate welding on individual plates. The process parameters employed in the GTA and PCGTA welding of Inconel 625 and AISI 304 is shown in **Table 2**. Standard V- groove butt joints with an included angle of 60° and a root face of 1 mm was employed for welding these bimetals. A specially designed fixture that could clamp the base metals firmly and

Table 1. Chemical composition of the base metals and filler metal.

Chemical Composition (% Weight)										
Base/Filler Metal	C	Cr	Ni	Si	Mn	P	S	Mo	Nb	Fe	Others
Inconel 625	0.059	21.05	62.1	0.434	0.235	0.009	0.014	8.23	3.3	Bal	Co - 0.024 Cu - 0.01 Al - 0.004 Ti - 0.016 V - 0.02 W - 0.15
AISI 304	0.063	18.4	8.11	0.28	0.9	0.032	0.001	0.22	0.01	70.83	Co - 0.15 Cu - 0.35 Al - 0.006 Ti - 0.005 V - 0.048 W- 0.065
ERNiCrMo-3	0.1	21.5	50	0.5	0.5	0.02	0.015	9.0	3.565	5.0	Co - 8.0 Cu - 0.5 Al - 0.4 Ti - 0.4

with a copper back plate was employed to avoid distortion and bending while welding. After welding, the weldments were characterized for NDT examination to determine for any flaws, porosities, undercut *etc.*

Ensuing to NDT analysis, the welded samples were cut using wire cut Electrical Discharge Machining (EDM) to different coupons of various dimensions to assess the metallurgical and mechanical properties. It is really cumbersome task to reveal the microstructure of the welded bimetallic joints due to the existence of different chemical compositions across the weldments. The macro and microstructure studies were performed on the coupons termed as "composite regions" which cover all the zones of the weldment. Composite region of the weldments was polished using the emery sheets of SiC with various grit sizes from 220 to 1 000 which was then followed by disc polishing using alumina solution so as to obtain a mirror finish of 1 μ on the weldments. Electrolytic etching (10% oxalic acid solution; 6V DC supply and 1 A/Cm^2) was employed to examine the microstructure of Inconel 625 whereas glyceragia was used for AISI 304 side. The weldments were cut to different coupons as per the standards to estimate the mechanical properties. Tensile studies were performed on the weldments which were made as per the ASTM E8 standards. Three trials on the weldments were conducted to check the reproducibility of the results. The samples were tested at a strain rate of 2 mm/min at room temperature. Furthermore the fractured samples were characterized for SEM analysis to determine the mode of fracture. Hardness measurement was carried out on the composite region of the weldment using Vicker's Micro-hardness tester with a load of 500 gf for a dwell time period of 10 s at regular intervals of 0.25 mm. Further the SEM/EDS analysis was performed on the various zones of the weldments to determine the presence of various elements and also helpful to assess the structure - property correlations. The following chapter addresses the results and discussions of the experimental work.

3. Experimental Results

3.1. Macro and Microstructure Studies

Figures 1(a)–1(d) shows the photograph and macrographs of these joints and it is well clear that the joints are free from defects such as lack of fusion, incomplete penetration and macro level cracks. Also from the visual examination, the HAZ of both the weldments is also clearly visible. The optical micrographs of various locations are presented in **Figs. 2**(a)–2(e). Microscopic examination of

Table 2. Process parameters employed for welding Inconel 625 and AISI 304.

Welding Type	Filler wire	Peak Current (Amps)	Background current (Amps)	Voltage (V)	Shielding Gas Flow Rate (lpm)	Filler Wire Dia. (mm)	Frequency (Hz)	Heat Input (KJ/mm)
GTAW	ERNiCrMo-3	160–170	—	16–17	15.5	2.4	—	0.87
PCGTAW		160–170	85	16–17	15.5	2.4	6	0.76

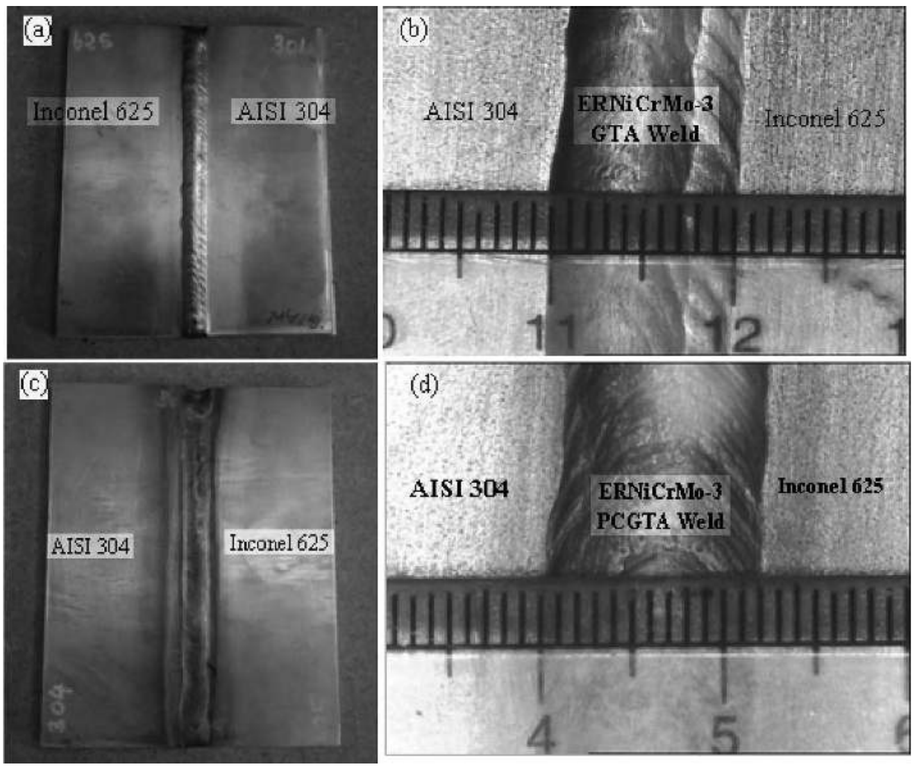

Fig. 1. (a) GTA weldments of AISI 304 and Inconel 625 (b) Macrograph of the dissimilar GTAW joints (c) PCGTA weldments of AISI 304 and Inconel 625 (d) Macrograph of the dissimilar PCGTAW joints.

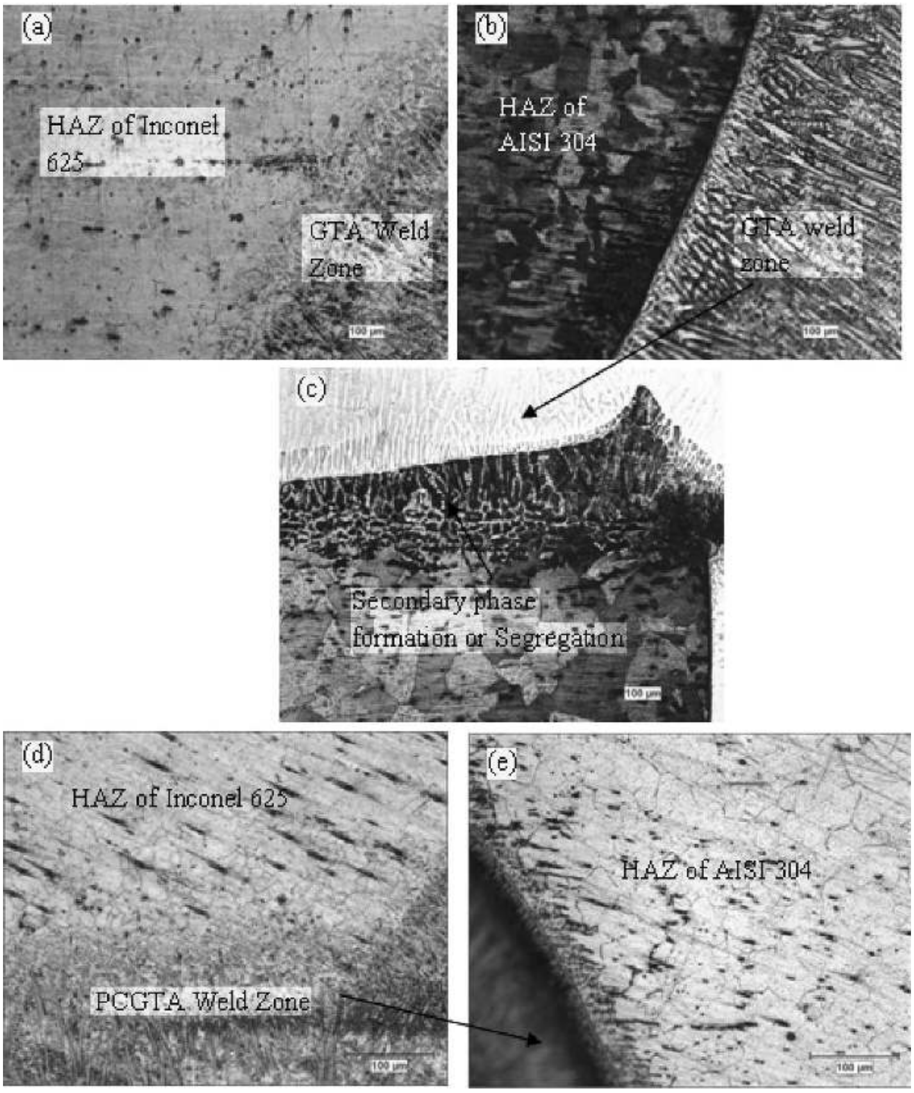

Fig. 2. Microstructure showing (a) HAZ of Inconel 625 - weld region (b) Weld region - HAZ of AISI 304 of GTA weldments; (c) Magnified view of the segregation or secondary phase formation at the HAZ of AISI 304 of GTA weldments; (d) HAZ of Inconel 625 - weld region (e) Weld region - HAZ of AISI 304 of PCGTA weldments respectively.

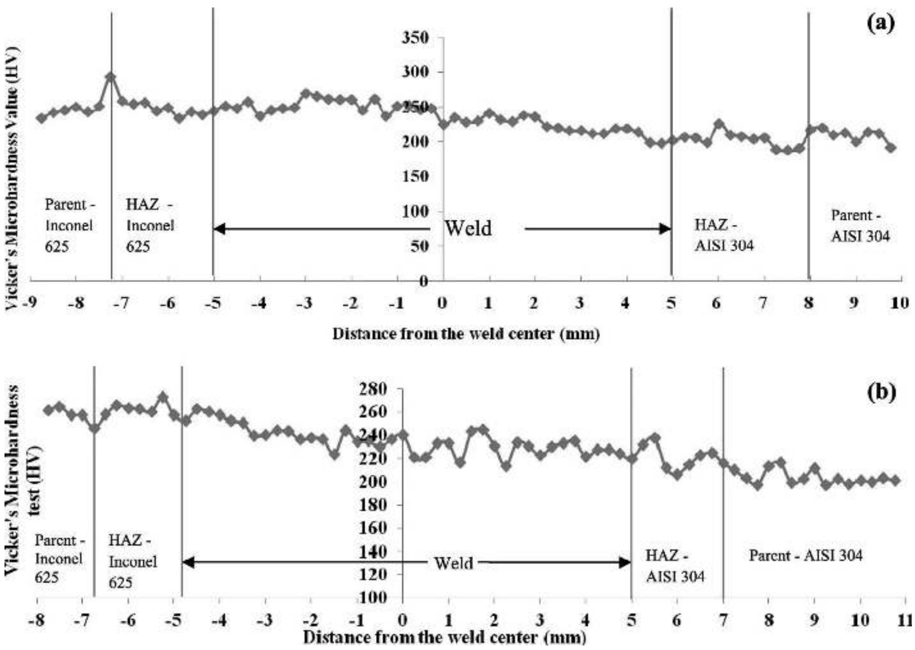

Fig. 3. Hardness profile of Inconel 625 and AISI 304 (a) GTA and (b) PCGTA weldments employing ERNiCrMo-3 filler metal.

the composite region of the weldments had clearly shown the segregation or formation of secondary phases at the weld interface of AISI 304. Segregation effects were found to be more on the weld interface of AISI 304 GTA weldments as compared to the PCGTA weldments. Also the grains were found to be coarser in the HAZ of AISI 304 in case of GTA weldments as compared to PCGTA weldments. Long dendritic growth had been observed at the weld zone in both

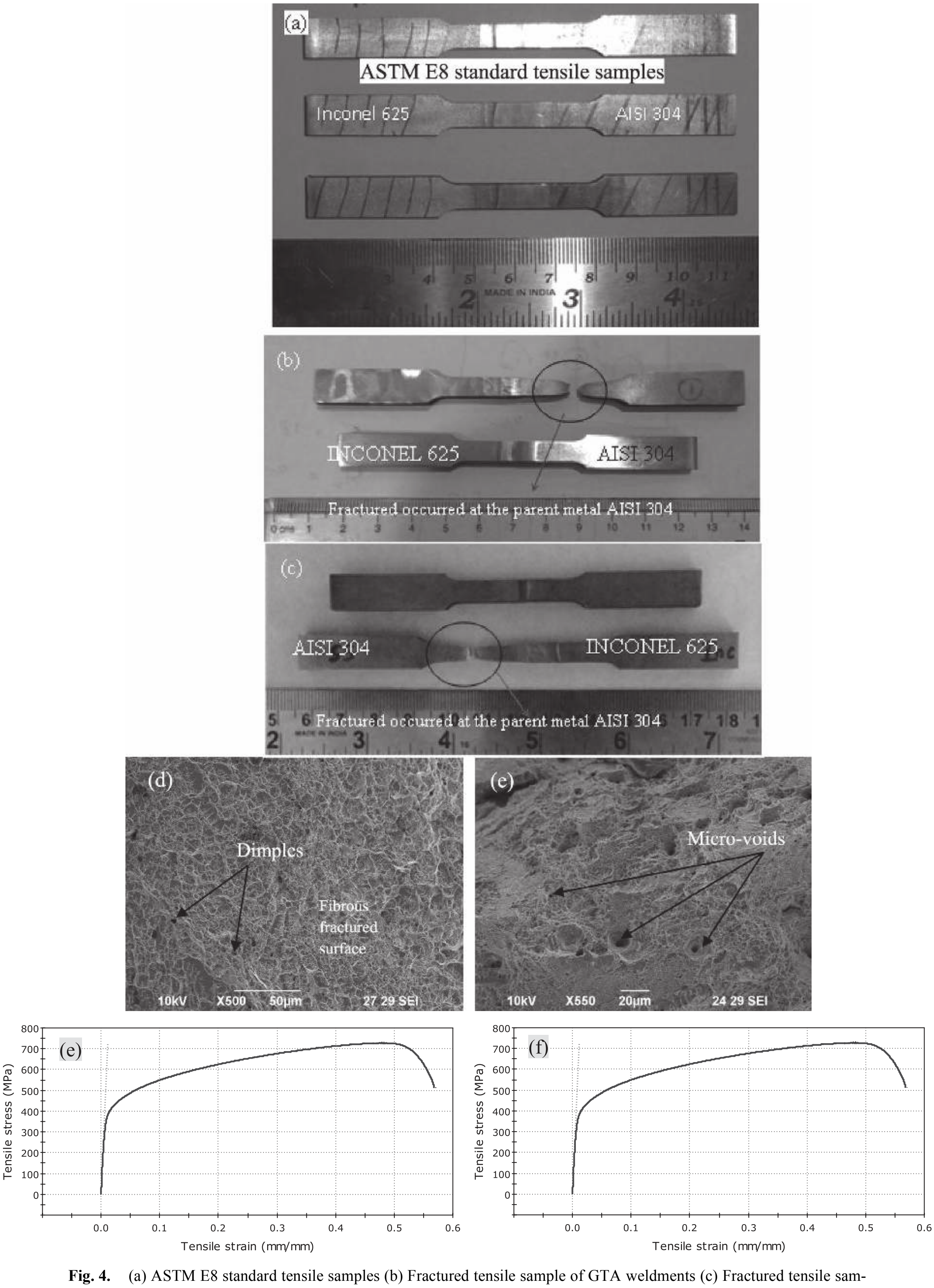

Fig. 4. (a) ASTM E8 standard tensile samples (b) Fractured tensile sample of GTA weldments (c) Fractured tensile sample of PCGTA weldments; SEM fractographs of (d) GTA weldments (e) PCGTA weldments; Stress-strain curves of the Inconel 625 and AISI 304 (e) GTA weldments (f) PCGTA weldments.

GTA and PCGTA weldments [Fig. 2].

3.2. Hardness Test

Hardness studies were carried out across the cross section of the dissimilar weldments of Inconel 625 and AISI 304 and presented in **Figs. 3**(a) and 3(b). By comparing the hardness graphs, it is observed that there is almost uniform hardness value in all the weldment regions (Base/HAZ/Weld). The weld region of GTA weldments has the average hardness value of 236.4 HV which is slightly higher than that of the HAZ (204.3 HV) and the parent metal of AISI 304. Similarly the average hardness value of the weld region (239.5 HV) is slightly higher as compared to base metal AISI 304 (201.4 HV). It is also noted that the hardness value is higher in weld interface of Inconel 625 side (273 HV) and the interface at AISI 304 side (237.6 HV) for PCGTA weldments.

3.3. Tensile Properties

Typical stress-strain curves of GTA and PCGTA weldments obtained at room temperature is shown in **Figs. 4**(d)–4(e). During the transverse tensile tests, in all the trials, both GTA and PCGTA weldments failed at the parent metal of AISI 304 stainless steel. Significant plastic deformation had been observed before the fracture occurs in all the cases. The average tensile test properties of the GTA and PCGTA weldments are represented in **Table 3**. It was observed from the results that tensile fracture had occurred at the parent metal of AISI 304 in all the weldments for both the cases [Figs. 4(b) and 4(c)].

The ductility measured in terms of percentage elongation at the break load was found to have an average of 56.28% for PCGTA and 55.11% for GTA weldments and the average ultimate tensile strength of these dissimilar combinations was found to be as 726 and 721 MPa for GTA and PCGTA weldments respectively. Figures 4(d) and 4(e) represents the SEM fractographs of the tensile failure samples. SEM fractographs confirmed the formation of micro-voids and small dimples which were dispersed at the fibrous fractured zone.

Table 3. Average tensile properties of Inconel 625 and AISI 304 GTA and PCGTA weldments.

Welding	UTS (MPa)	Young's Modulus (GPa)	% Elongation at Break Load	Fracture Zone
GTA	726	62.2	55.11	Parent Metal of AISI 304
PCGTA	721	61.6	56.28	

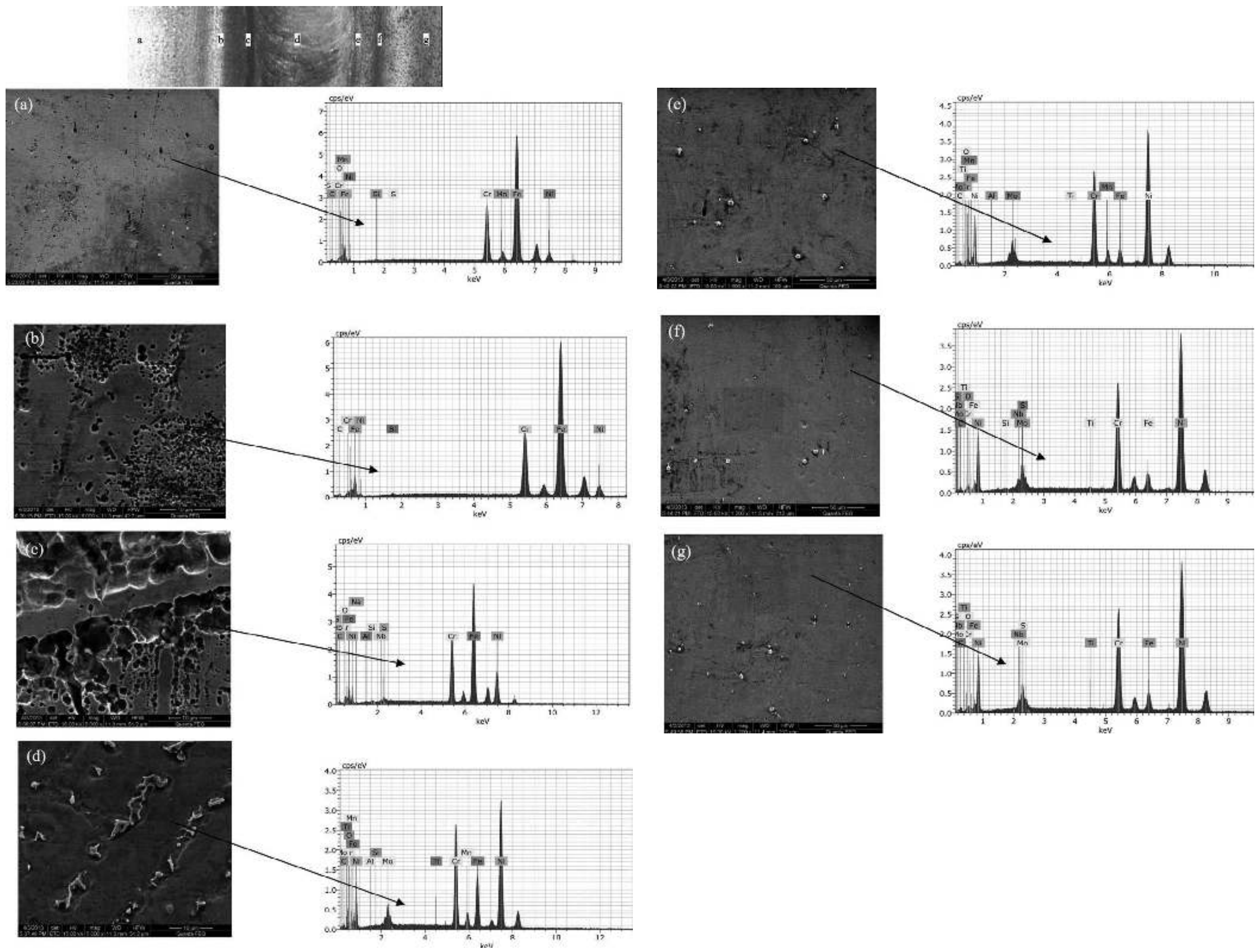

Fig. 5. SEM/EDAX analysis on the GTAW Inconel 625 and AISI 304 GTA weldments showing the regions (a) Parent metal - AISI 304; (b) HAZ of AISI 304 (c) weld interface at AISI 304 (d) weld region (e) weld interface at Inconel 625 (f) HAZ of Inconel 625 and (g) Parent metal - Inconel 625.

3.4. SEM/EDAX Analysis

SEM/EDAX analysis was performed on the various zones of the weldments shown in **Figs. 5** and **6**. It was inferred from these studies that parent metal, weld interface at Inconel 625 and weld region has significant amounts of the elements such as Ni, Cr, Mo and Nb. Whereas the parent metal, HAZ and weld interface of AISI 304 side has the greater amounts of Fe, Ni, Cr and Mo. The percentage of Mo and Nb at the HAZ of AISI 304 was lesser. Further at the weld interface of AISI 304 side, the percentage of Nb and Mo was found to be greater for both GTA and PCGTA weldments. The EDS analysis represented in **Tables 4** and **5** clearly con-

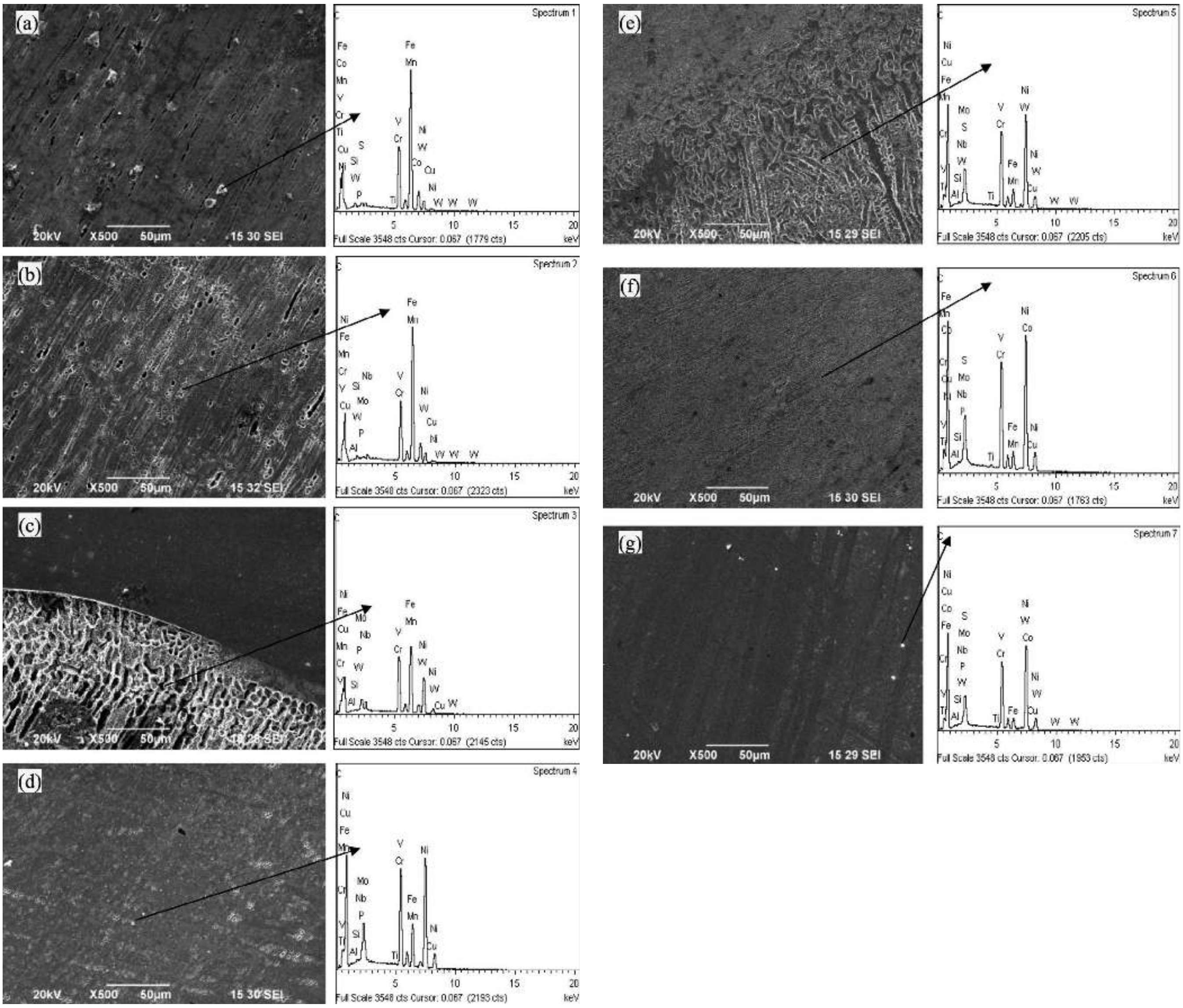

Fig. 6. SEM/EDAX analysis on the Inconel 625 and AISI 304 PCGTA weldments showing the regions (a) Parent metal - AISI 304; (b) HAZ of AISI 304 (c) weld interface at AISI 304 (d) weld region (e) weld interface at Inconel 625 (f) HAZ of Inconel 625 and (g) Parent metal - Inconel 625.

Table 4. EDAX analysis (wt%) on Inconel 625 and AISI 304 GTA weldments.

Element Zone	Fe	Cr	Ni	C	Si	P	S	Ti	Mn	Al	Mo	Nb
(a)	66.57	16.28	7.53	7.00	0.41	–	0.11	–	0.77	–	–	–
(b)	68.73	16.61	7.30	6.66	0.41	0.09	–	–	–	0.18	–	0.50
(c)	47.43	15.98	20.31	8.88	0.11	0.49	0.79	–	0.42	0.47	4.03	0.77
(d)	13.72	19.18	51.82	7.45	0.18	–	–	0.12	0.11	0.16	6.11	3.25
(e)	4.60	20.51	59.88	7.13	0.28	–	0.16	0.22	0.14	0.12	7.04	4.43
(f)	4.14	18.51	57.6	7.79	0.09	0.25	0.21	0.28	0.24	0.11	6.58	4.16
(g)	4.35	18.81	58.51	8.02	0.06	0.02	0.06	0.19	–	0.3	5.64	3.62

Table 5. EDAX analysis (wt%) on Inconel 625 and AISI 304 PCGTA weldments.

Element Zone	Fe	Cr	Ni	C	Cu	Si	P	S	Ti	V	Mn	Co	W	Al	Mo	Nb
a.	66.18	18.72	7.47	3.31	1.57	0.5	0.1	0.37	0.02	0.03	0.79	0.51	0.44	–	–	–
b.	64.5	17.25	7.36	5.67	1.25	0.32	0.09	–	–	0.32	1.2	–	0.62	0.18	0.72	0.53
c.	35.71	19.92	29.8	7.63	0.48	0.11	0.16	–	–	0.05	0.42	–	0.27	0.1	4.03	1.24
d.	12.7	20.07	49.1	5.28	0.57	0.27	0.04	–	0.07	0.27	0.14	–	–	0.11	8.2	3.19
e.	6.65	19.75	52.7	6.1	0.88	0.28	–	0.16	0.15	0.14	0.21	–	0.01	0.15	8.94	3.88
f.	4.32	20.4	55.13	5.3	0.4	0.26	0.25	0.05	0.31	0.02	0.24	0.12	–	0.11	9.05	4.04
g.	4.19	20.84	56.63	4.64	0.65	0.06	0.02	0.07	0.26	0.07	–	0.11	0.28	0.3	8.73	3.17

veyed the presence of various elements in weight percentage.

4. Discussions

NDT examination clearly divulged that there were no weld defects including the porosities, undercut and lack of fusion in both the welding techniques. On employing the set parameters for both GTA and PCGTA welding techniques, the solidification cracking tendency could be totally being avoided. The microstructure examination revealed the formation of secondary phases at the weld interface and HAZ of AISI 304 for GTA weldments and the quantum of segregation was found to be lesser in PCGTA weldments.

The microstructure examination revealed the formation of secondary phases at the weld interface and HAZ of AISI 304. As mentioned earlier, this region is enriched with Fe, Ni, Cr, Mo, Nb and also greater amounts of carbon. The segregation would be probably the formation of inter-metallics such as NbC, $Cr_{23}C_6$, precipitation of γ'-Ni_3(Ti) and γ''-Ni_3Nb phases and these phases are responsible for strengthening of the nickel-base superalloy weld metal which was also evident from the SEM/EDS analysis in case of GTA weldments.[12] It was reported by Naffakh *et al.*[8] that higher amounts of nickel and lower amounts of chromium can dissolve the Nb in Inconel A austenite matrix to a superior extent and as a result the formation of low melting phases in the inter-granular region decreases. The results reported by the authors were in agreement to this work such that the weld interface of AISI 304 side was found to have the formation of secondary phases where the amounts of Ni and Cr was almost equivalent (EDAX analysis). Also the weld region and HAZ of Inconel 625 has significant amounts of Ni and the lesser amounts of Cr would probably dissolve Nb in the austenite matrix and hence no secondary phases had been witnessed at these regions. The use of appropriate filler metal ERNiCrMo-3 almost eradicated the formation of unmixed zone at the Inconel side. The presence of significant amounts of Nickel (49%) envisaged that the weld zone is fully austenitic. Also the presence of Nb (3.19%) at this zone stabilizes the austenite phase at high temperature. This result is in agreement with the work reported by Shah Hosseini *et al.*[4] The authors reported that the weld metal contains about 67 wt.% nickel and is fully austenitic. Due to the presence of 3% Nb, the austenite is stabilized at a high temperature. In addition, the solidification mode is changed from cellular to dendritic as Nb has an intense tendency to increase the degree of constitutional under-cooling.

There is no evidence on the formation of topologically close packed structures such as Laves phases at Inconel 625 side and is also confirmed from the optical and SEM microscopy techniques. Furthermore the absence of porosity, solidification cracking and grain growth in the HAZ of steel could be probably due to the presence of deoxidizers (Mn, Ti), high Mn/S ratio and less carbon content, and the formation of various grain growth suppressing carbide formers in the nickel-filler metal respectively[13]

Mo has been found as richer constituent in the weld region, weld interface and the HAZ of Inconel 625 in the PCGTA weldments as compared to GTA weldments. It is known fact the PCGTA welding employs lower heat input which resulted in higher cooling rates. This would normally result in the dendritic, finer microstructure which is evident from Fig. 2(c). It was reported by Shah Hosseini *et al.*[4] that a lower heat input significantly forms the finer microstructure which has a lower segregation ratio of Mo which in turn makes the welds brittle at room temperature. Therefore, the solidification cracking tendency is reduced. This is exactly matching with the results of this work in such a way that on employing PCGTA welding, the hot cracking tendency could be totally avoided due to the lower segregation of Mo at the weld region. In the similar manner, the chromium carbide precipitation effect at the weld interface of Inconel 625 has not been observed on employing the PCGTA welding and using appropriate filler metal which is also in agreement with other researchers[14,15]

It is evident from the SEM/EDAX analysis at the HAZ of AISI 304 that there is a region of the base metal that was heated to below the liquidus temperature but above the solidus temperature, so it was only partially melted. This zone is known as the partially melted zone. The partially melted zone on the AISI 304 side of the joint is formed and appears to be wider. The tendency of dendritic boundaries to melt in alloy AISI 304 is attributed to the enrichment of niobium in these boundaries. As reported by Naffakh *et al.*,[8] Niobium not only lowers the melting point constitutionally, but also forms low-melting carbide-austenite eutectics during solidification.

It is evident from the hardness tests that the weld region and weld interfaces have acquired the maximum hardness which is due to the presence of higher amounts of Nb, Ni, Cr and C. This could be due to the formation of significant amounts of NbC, (Nb,Ti)C and $Cr_{23}C_6$ [Figs. 5(c) and 5(d)]. The results obtained from the hardness measurement data gave a clear indication that the parent metal AISI 304 has lower hardness as compared to other zones of the weldment [Fig. 3]. The maximum hardness at the weld interface and in the weld zone could also be attributed due to the formation of equiaxed dendrite due to the higher amounts of Nb. This is also well matching with the results of Lee *et al.*[14] such that the Nb addition enhanced the hardness of the fusion zone.

It is also well proven from the tensile studies that the fracture occurred at the parent metal of AISI 304 giving an indication that the weld region was found to be stronger than the parent metals. Owing to the formation of NbC, $Cr_{23}C_6$ and other phases such as precipitation of γ'-Ni_3(Ti) and γ''-Ni_3Nb present at the weld region and weld interfaces resulted in higher hardness [Fig. 3] and contributed for the greater tensile strength. Jeng *et al.*[15] observed the tensile fracture at the fusion zone for Alloy 690 and SUS 304L SMA weldments. The authors further witnessed the non-homogeneous distribution of Nb had occurred at the fusion zone due to the welding techniques employed in this study. It is observed clearly that the filler wire and the process parameters employed in this study were optimal and also clearly indicate that the weld strength would be higher than the strength of the candidate metals as obtained from the results on employing PCGTA welding technique for joining these bimetallic combinations. SEM fractographs also clearly indicates that the weldments had undergone the ductile fracture [Fig. 4(c)] owing to the micro-void coalescence and the appearance of dimples and fibrous networks.

5. Conclusions

(1) Successful, defect free Inconel 625 and AISI 304 weldments could be obtained using GTA and PCGTA welding process employing ERNiCrMo-3.

(2) Use of this filler wire ERNiCrMo-3 avoids the hot cracking that could be due to lower segregation of Mo in the weld as well as weld interface. This is also due to the controlled heat input developed during PCGTA welding technique.

(3) Segregation or secondary phase formation was found to be more at the HAZ of AISI 304 in GTA weldments as compared to PCGTA. The segregation effects found in the GTA weldments could probably affect the corrosion resistance to inter-granular attack.

(4) Both GTA and PCGTA welded joints exhibited better mechanical properties in the room temperature; The joints fabricated by these welding techniques exhibited very high strength and the enhancement in strength is approximately 40% compared to base metal AISI 304. Whereas the strength is found to be 15% less as compared to base metal Inconel 625. The enhancement of tensile strength could be due to enrichment of Mo in the weld region.

(5) The secondary phases including NbC, $Cr_{23}C_6$ and other phases such as precipitation of γ'-Ni_3(Ti) and γ''-Ni_3Nb contributed for the increase in the strength of the weldments.

(6) Hardness is higher in weld interface of Inconel 625 side (273 HV) compared to weld, Base AISI 304, and HAZ of AISI 304. Higher hardness is recorded in weld interface adjacent to Inconel 625 could be due to enrichment of Mo, Cr, Nb and C.

(7) It is also evident that the Nb addition in the filler wire has detrimental effect on weldability and weld mechanical properties such as ductility, tensile strength of the weld.

(8) The results showed that the PCGTA weldments receive a lower total heat input and experiences a more rapid heating and cooling effect. In addition, Nb presence in the weld metal consequences on lowering the effect of segregation and sensitization in the weldment which enhance the mechanical and metallurgical properties.

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