www.rspsciencehub.com Volume 03 Issue 07S July 2021

INTERNATIONAL RESEARCH JOURNAL ON ADVANCED SCIENCE HUB
e-ISSN : 2582 - 4376
Open Access

RSP SCIENCE HUB
(The Hub of Research Ideas)
Available online at www.rspsciencehub.com

Special Issue of Second International Conference on Advances in Science Hub (ICASH 2021)

Effect of Prior Deformation In Post Weld Heat Treatment of Aluminium Alloy 2219 Gas Tungsten Arc Welds

Vijayalakshmi Manugula
Assistant Professor, Metallurgical and Materials Engineering, Mahatma Gandhi Institute of Technology, Hyderabad, Telangana, India.
mvijayalakshmi_mme@mgit.ac.in

Abstract

In this paper the effect of arc oscillation and pulsed current of gas tungsten arc welding (GTAW)on the microstructure and mechanical properties of aluminium alloy 2219 was studied. Microstructural characterisation of the weld region was carried out using optical micros copy and Electron probe micro analysis (EPMA). Hardness measurements were carried out using Vickers hardness tester to evaluate the hardness in the base metal and weld zone. The microstructures of Arc oscillation and pulsed current (AOPC) welds and continuous current (CC) welds were compared and their hardness were correlated. It was observed that arc oscillation and pulsed current weld resulted in fine equiaxed grain structure whereas continuous current welds resulted in columnar structure. The significant improvement in mechanical properties of arc oscillation and pulsed current welds may be attributed to the discrete copper segregation. Post weld deformation has improved the mechanical properties of arc oscillation and pulsed current welds significantly. Aging can be carried out at lower temperature with prior deformation to improve the mechanical properties of the weld

Keywords: GTA welds, Arc Oscillation Pulsed current, Continuous Current, EPMA, AA2219

1. Introduction

Aluminum alloy 2219 is an age-hardenable copper containing alloy of aluminum. It is noted for application at elevated temperatures (-270°C to 300°C). Applications include welded space booster, oxidizer, fuel tanks, supersonic air crafts and skin structural components. Alloy 2219 is the most weldable of the commercial high strength heat treatable aluminum alloys bearing superior to other alloys of this group with respect to freedom from cracking smooth flow and reproducibility of weld strength. In conventional gas tungsten arc (GTA) welding process the as-solidified weld resulted in columnar grain structure. The pulsing of welding current influences the solidifying pool thermally and mechanically causing periodic shaking of the liquid metal with a frequency equal to that of pulses the force of the mechanical action of the arc on the weld is proportional to the square of the current amplitude. A number of advantages of the pulsed current have been identified by several investigators [8-12]. The metallurgical advantages which have been reported include refined solidification structure and reduced segregation of alloying elements. Arc oscillation in directions parallel to and transverse to the welding directions can be achieved through different techniques including mechanical vibration of the torch /electrode and through an imposed A.C. magnetic field. In principle arc oscillation introduces thermal fluctuations along the solidification front. These may lead to grain refinement through a combination of suitable temperature gradient and solidification velocities along with dendritic fragmentation and inoculants. It has been reported that arc oscillation resulted in grain refinement in Al alloys [1-8]. The grain structure in Al-Li alloy AA2090 became finer and more equiaxed with the introduction of current pulsation [2]. The combination of arc oscillation and pulsed current (AOPC) resulted in fine equiaxed grain structure in Al-Li alloy than what was possible with these techniques individually. Fine grains in the fusion zone help improve the mechanical properties ductility and fracture toughness and reduce the susceptibility of the weld metal to solidification cracking during welding [9-12]. Therefore, in the present work an attempt has been made to study the effect of prior deformation on AOPC welds of 2219 aluminum alloy and its comparison with that of Continuous current (CC) welds. The effect of post weld aging and coldwork post weld aging has been studied. Hardness measurements were carried out using Vickers microhardness tester to study the mechanical properties. Optical microscopy, Transmission electron microscopy and electron probe micro analysis (EPMA) were carried out to substantiate the hardness values. The microstructure of AOPC welds and CC welds were compared and their properties were corelated.

2. Experimental Methods

The material used in 2219 Aluminium alloy in T6 temper condition (solutionised at a temperature of 535°C for I hour and artificially aged at temperature of 190°C for 36 hours) and has dimensions (150X75X3.5 mm). The chemical composition is given in Table.1.The plates in T6 temper were mechanically milled to achieve flat surface and to remove the oxide layer. The plates were chemically cleaned with caustic soda and acetone prior to welding. The plates were welded by AOPC, A.C. GTA welding process using MILLER automatic TIG welding machine. The current was maintained at 130 Amps and pulse frequency was varied between 2 Hz to 8Hz and oscillation frequency was varied between 1 to 3 Hz. The oscillation amplitude was made constant. The oscillation pattern was elliptical across the weld and speed was maintained at 250 mm/min. For comparative studies, plates were also welded by continuous current (CC) A.C. GTAW process. The PWHT was carried out in a muffle furnace. The welded samples were aged at a temperature of 190°C for 18 hours and then air cooled upto room temperature. The welded samples were given 3 to 4 pct deformation prior to heat treatment using two high hand rolling mill. In this one set of samples were aged at a a temperature of 190°C for 18 hours. Another set of samples were aged 150°C for 20 hours, at regular intervals of 2 hours the samples were removed from the furnace and air cooled to room temperature. Vickers microhardness measurements were carried out at the weld region using 200 g load for 15 sec. The parent metal and welds were subjected to metallographic preparation to observe the microstructure using Kellers reagent (2 ml HF,3ml HCl,5ml HNO_3,190 ml H_2O). Metallurgical polishing of the samples was accomplished with belt grinding, different grades of emery papers and then finally to disc polishing. The samples after polishing were cleaned in running water and acetone and etched for 3 min at room temperature followed by drying. The etched samples were observed under optical microscope.CM12 PHILIPS microscope was used for TEM and foils were prepared from the weld metal. Sliced of the sample to thin specimen was carried out by slow speed diamond saw cutting machine. The sliced samples were ground with emery papers to thickness of 100-200 microns and 2 mm discs were punched from the specimen and electropolished to produce electron transparent thin section using 37 ml nitric acid solution in 63 ml methanol at sub-zero temperature using liquid nitrogen.

Table.1Chenical Composition of AA2219

Elements	Cu	Mn	Zn	Ti	V	Zr
wt%	6.7	0.3	0.10	0.06	0.07	0.06
Elements	Fe	Si	Mg	Al		
Wt%	0.14	0.1	0.01	Bal		

3. Results and Discussion

3.1 Hardness

The hardness values of welds in AOPC and CC in as-welded, post weld aged and cold work post weld aged condition were shown in Fig.1. The hardness values of AOPC weld displayed an increase in hardness when compared to CC welds. The hardness in post weld aged condition showed an increase in hardness in the weld in both the AOPC and CC conditions, but the increase in hardness in case of AOPC welds was more when compared to CC welds. Cold work post weld aging condition showed an increase in hardness when compared to that in post weld aged condition [13-

15]. The hardness values were taken at regular intervals of 2 hours upto 18 hours. It was found that the peak hardness was obtained at 3 hours. The hardness values in this condition showed an increase in hardness when compared with the values in post weld aged condition. However, the increase in hardness was more pronounced in case of AOPC welds.

3.2 Metallography

The microstructures of AOPC welds showed fine equiaxed grain structure whereas CC welds resulted in columnar grain structure Fig.2(a,b). In the as-welded condition the AOPC welds and CC welds showed no evidence of precipitates. Therefore, the decrease in hardness in the welds in as-welded condition may be attributed to the dissolution of precipitates in the weld region. The EPMA micrograph of AOPC welds displayed discrete precipitates at the grain boundary as shown in Fig.3(a,b). In case of CC welds there is continuous copper segregation along the grain boundary. Therefore, the significant improvement in mechanical properties of the AOPC welds may be attributed to the discontinuous copper segregation.

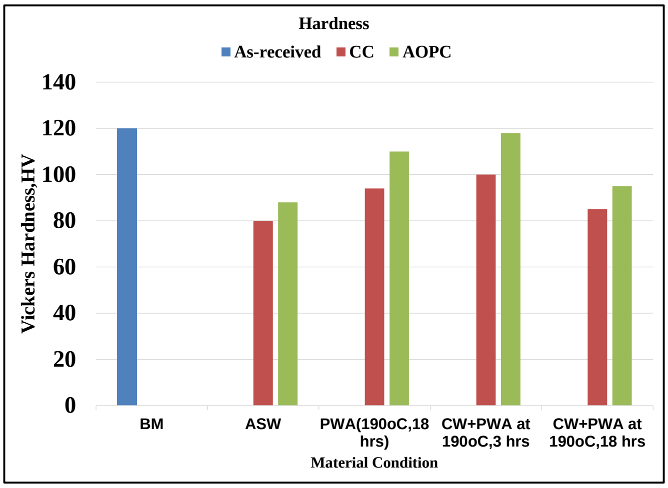

Fig.1.Comparison of hardness values of AOPC and CC welds in various conditions.

In the as-welded condition the AOPC and CC welds showed no evidence of precipitates therefore the decrease in hardness in the welds may be attributed to the dissolution of precipitates in the weld.In post weld aged condition, the AOPC and CC welds revealed fine precipitates of $CuAl_2$ as shown in Fig.4(a, b) Therefore, the increase in hardness in the weld after post weld aging may be attributed to the formation of fine strengthening precipitates. In cold work post weld aged condition, the dislocations introduced during deformation provides numerous sites at which heterogeneous nucleation may occur with the result that the precipitates are uniformly dispersed and enhances aging kinetics, therefore aging at longer time leads to coarsening of precipitates. The TEM micrograph of arc oscillation and pulsed current (AOPC) welds revealed fine $CuAl_2$ precipitates at 5 hours as shown in Fig. 5(a). The arc oscillation and pulsed current (AOPC) welds revealed coarse precipitates and more density as shown in Fig.5(b). Therefore, the decrease in hardness when compared to post weld aging condition may be attributed due to precipitate coarsening because deformation prior to aging enhances the aging kinetics [16-18].

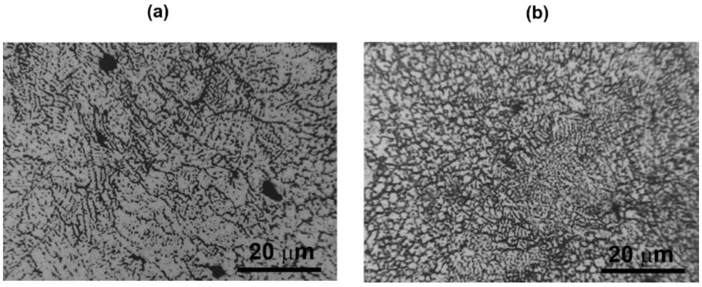

Fig.2.Optical microstructures of (a)CC weld (b) AOPC weld

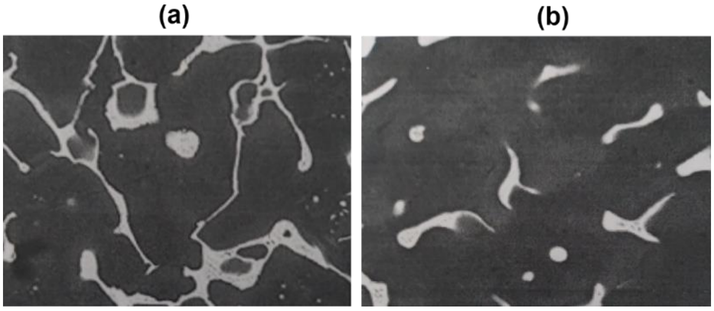

Fig.3. EPMA of weld in as-welded condition (a) CC (b) AOPC

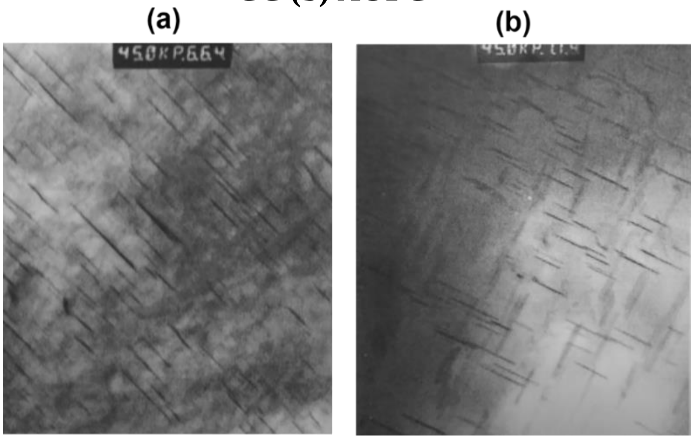

Fig.4 TEM of weld in post weld aged at 190°C, 18 hrs (a)CC (b)AOPC

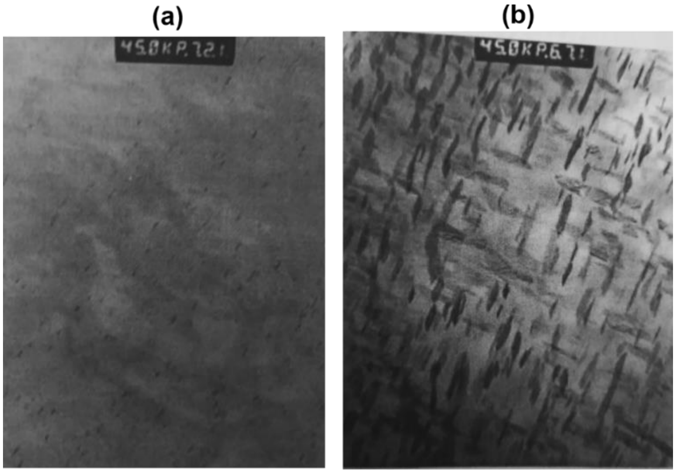

Fig.5 AOPC weld in (a) cold work post weld aged at 150 ^{o}C ,5 hrs (b) cold work post weld aged 190^{o}C ,18 hrs

Conclusion

AOPC GTA welds resulted in fine equiaxed grain structure, whereas CC welds resulted in columnar grains. Post weld aging resulted in increase in hardness of the weld in both AOPC and CC welds. The result may be attributed to the formation of fine $CuAl_2$ precipitates but the increase in hardness is more pronounced in case of AOPC welds. Cold work post weld aging enhances the aging kinetics. The result may be attributed to the dislocations introduced during deformation provides numerous sites at which heterogeneous nucleation may occur with the result that precipitates are uniformly dispersed and enhances aging kinetics. Post weld deformation has improved mechanical properties of AOPC welds significantly. Aging can be carried out at lower temperature with prior deformation to improve the mechanical properties of the weld.

References

[1].S.Sunderesan et al., “Microstructural refinement of weld fusion zones in titanium alloys using pulsed current welding”,Materials Science and Engineering, sept 1998,pp 88-100.

[2].G.Madhusudhan Reddy et al., “A comparision of continuous and pulse current gas tungsten arc welds of an ultra-high strength steels”, Journal of Materials Processing Technology,69,19197,pp 222-226

[3].G.D.Janakiram et al., “Fusion zone grain refinement in aluminium alloy welds through magnetic arc oscillation and its effect on tensile behaviour”, Journal of Materials Engineering and Performance,vol8(5),oct 1999,pp 513-520.

[4].Elangovan K, Balasubramanian V. Influences of tool pin profile and tool shoulder diameter on FSP zone formation in AA6061 aluminium Alloy, Journal of Materials & Design, 2008, 28 (2): 362−373.

[5].Kumar T S, Balasubramanian V, Sanavullah M Y. Influences of pulsed current tungsten inert gas welding parameters on tensile properties of AA6061 aluminium alloy, Journal of Materials & Design, 2007, 28(2): 2080−2092.

[6].Davies C J, Garland J G. Solidification structures and properties of fusion welds Int Mater Review, 1975, 20: 83−106.

[7].Kou S, LE Y. Nucleation mechanism and grain refining of weld metal Welding Journal, 1986, 65: 305−313.

[8].Madhusudhan Reddy G, Gokhale A A, Prasad R K, Optimization of pulse frequency in pulsed current gas tungsten arc welding of aluminium-lithium alloy sheets Journal of Material Science &Technology, 1998, 14: 61−66.

[9].Potluri N B, Ghosh P K, Gupta P C, Reddy Y S, Studies on weld metal characteristics and their influences on tensile and fatigue properties of pulsed current GMA welded Al-Zn-Mg alloy Welding Research Supplement, 1996, 75: 62s−70s.

[10].Mohandas T, Madhusudhan R G, Effect of frequency of pulsing in gas tungsten arc welding on the microstructure and mechanical properties of titanium alloy welds J Mater Sci Lett, 1996, 15: 626−628.

[11].Balasubramanian V, Ravisankar V, Madhusudhan Reddy G, Effect of pulsed current and post weld aging treatment on tensile properties of argon arc welded high strength aluminium alloy, Materials Science and Engineering A, 2007, 459: 7−18.

[12].Balasubramanian M, Jayabalan V, Balasubramanian V, A mathematical model to predict impact toughness of pulsed current gas tungsten arc welded titanium alloy International Journal of Advanced Manufacturing Technology, 2008, 35: 852−858.

[13].S.P.Ringer et al., “Effects of cold work on precipitation in A-Cu-Mg(Ag) and Al-Cu-Li(Mg-Ag) alloys”, Metallurgical and Materials Transactions, Vol 26 A ,July 1995. Pp 1659-1671.

[14].S.Sunderesan et al., ”Combined effect of inoculation and magnetic arc oscillation on microstructure and tensile behaviour of type

2090 Al-Li alloy weld fusion zones", Science and Technology of Welding and Joining,2000, Vol 5,257-264.

[15].Gopinathan, V. Effect of cold rolling on mechanical properties of weld seam steels. Ph.D. Thesis. Indian Institute of Technology Madras, India, 1974.

[16].Gladstein, L.I., 1959. The influence of internal stresses and plastic deformation on mechanical properties of seam metal. Weld. Prod. 10, 83–90.

[17].Kurikino, S.A., Vinokurov, V.A., Parakhin, V.A., 1960. Strength of welded joints improved by roller treatment of welds. Weld. Prod. 8, 33–36.

[18].Zhu, A.W., Starke Jr., E.A., 2001. Stress aging of Al–Cu alloys: computer simulation. Acta Mater. 49, 3063–3069.