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THERMO MECHANICAL TREATMENT OF 2219 GTA WELDS MADE OF Sc AND Mg MODIFIED 2319 FILLERS

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ABSTRACT

High strength heat treatable aluminium alloy AA 2219 finds application in aero space industries. Though it has good weldability, with AC – TIG welding the joint efficiency obtained is only 40% particularly in thicker plates. In the present study an attempt has been made to improve the weld metal properties by filler modification and post weld thermo mechanical treatments. Additions of Sc and Mg along with 2319 filler and post weld treatments were found to give significant improvement in weld metal hardness. These weld metals were also found to retain properties at higher temperatures even for longer times of exposure.

Key Words: Scandium, 2319, TIG, Post weld treatment.

1. INTRODUCTION

Aluminium copper alloys (2xxx) are widely used in aerospace applications, because of their high strength, lightweight and high machinability. They provide good creep resistance at higher temperatures and maintain toughness at cryogenic temperatures. AA2219 with about 6% copper is considered to be the most weldable among the commercial high strength aluminium alloys, because of its resistance to solidification cracking. AA2219 has high levels of alloying elements and there is excess liquid available during solidification, which flows into the cracks and heals the cracks.

Alternating Current –Tungsten Inert Gas welding is the commonly employed welding technique for AA 2219. Though it has very good weldability when compared to other alloys in the same series, it offers low joint efficiency of about 40%[1].This is because of the dissolution of strengthening precipitates due to high temperature and cooling rates involved in welding. Different techniques like post weld heat treatments and weld composition modification can be employed to improve weld metal strength.

2. LITERATURE

2.1 FILLER ALLOY MODIFICATION:

One of the recent trends in welding of aluminium alloys is to use Scandium as an alloying element in the fillers as well as in base materials. It has been proved that small concentrations of Scandium can produce enhanced weldability in Aluminium alloys that are susceptible to solidification cracking and can also improve the weld metal strength[2].
Addition of Scandium to Aluminium produces Al_3Sc dispersoids. These second phase particles due to their high dispersity cause a noticeable strengthening effect. It has been shown that Al - 0.4% Sc alloy ingots gained 2.5 times increase in micro hardness during annealing. Since Al_3Sc dispersoids and Al have the same lattice type and discrepancy between lattice parameters is only about 1.5%, Sc acts as an effective modifier of grain structure[3].

Addition of 0.6% of Sc to 2024 alloy showed excellent refinement in grain size[2]. This refinement produced an increase in strength with higher level of ductility. Some studies[3] have shown that Zr addition to Al - Sc alloys depresses susceptibility of Al_3Sc particles to coagulation and stabilizes the properties even for prolonged heatings at high temperature. Al – Mg alloy when added with suitable amounts of Sc and Zr gives yield strength up to 640 MPa[4]. It has been shown that for addition of Mg along with Sc, the grain refinement is more when compared to Sc addition alone[4].

2.2 THERMO MECHANICAL PROCESSING:

Thermo mechanical processing is defined in the broadest sense to include any combination of thermal or deformation processes that give rise to favorable microstructure and increment in strength. It has been reported that for Al – Cu – Mg alloy casting, cold deformation prior to aging enhanced the matrix nucleation of precipitates for artificial aging at different temperatures which corresponded with a relative increase in hardness[5]. According to Liu et al synchronous rolling during welding reduces the hot cracking tendency of 2024 – T4 alloy[6]. Effect of thermo mechanical treatment of AA 2219 (T87) multi pass GTA welds have been studied and it is found that simple 10 – 15 % deformation of welds could result in 20 – 25% higher joint strength[7]. It has also become a practice to subject the welds to planishing where in the weld crown is flattened by sending it through a pair of rolls in order to raise the strength of the joint.

In the present study an attempt is made to study the effect of deformation and aging on Sc and Mg modified 2319 filler welds.

3. EXPERIMENTAL WORK

The welding process and parameters that were used are given in table 1. Two different filler compositions (namely KC3 and KC6) were used. The compositions of the base metal (2219 T87) and fillers are given in table 2. KC3 has Sc addition to 2319 filler. KC6 has addition of Sc and Mg to 2319. Fillers were made through casting route by melting the predetermined weight compositions of alloys in a ceramic crucible and then pouring in to a metal mould. Al – 2% Sc master alloy was used for Sc addition. Welding was done by placing the cast filler rods in a rectangular groove machined in 2219 T87 base plate and running a gas tungsten arc to make welds of at least 6 mm deep in a plate of thickness 7.5 mm. The schematic diagram of the joint preparation is given in Figure1. Coupons of width 20mm were sliced from the joint and used for rolling and aging treatments. There was a lapse of several days between welding and the subsequent work and natural aging could have taken place in the material. The coupons were passed through rolls at room temperature to get two different percentages of deformation, 4% and 8% in the thickness direction. Rolling was done such that only the crown gets flattened and there is no deformation in the base metal. For all the deformed samples Vickers hardness measurements were taken in the weld region. For 8% deformed samples aging was done at 190°C up to 100 hours and hardness measurements were taken in regular intervals. Hardness values presented are an average of at least 4 values. The load used for testing was 5kg. Transmission Electron Microscope studies were done for some samples. Specimens for TEM were prepared by electrochemical thinning in a twin jet apparatus using a mixture of 25% nitric acid and 75% methanol cooled by liquid nitrogen. An applied potential of 12 – 15 V with a corresponding current of 20 – 30mA produced electron transparent foils.

4. RESULTS AND DISCUSSION

4.1. EFFECT OF FILLER MODIFICATION:

The as welded microstructures of 2319, KC3, and KC6 filler welds are given in fig.2. Compared to 2319 filler weld, both KC3 and KC6 welds show significant weld metal grain refinement. In case of KC3, equiaxed dentritic grains can be seen. Where as in KC6 weld the grain size is much smaller and non dentritic grains are found. This shows that addition of Mg along with Sc results in more Al_3Sc nuclei[8].

The weld metal hardness values for 2319, KC3 and KC6 welds are given in fig.3. Compared to the base metal (2219 T87), the weld metal strength obtained with 2319 and KC3 welds is only around 50%. This could be because of the presence of less amount of strengthening precipitates in the as welded condition. The TEM pictures of base metal, 2319 and KC3 welds are given in fig.4. The rounded precipitates in KC3 weld could be Al_3Sc. The amount of precipitates obtained with 2319 and KC3 weld is low, which is responsible for the lower weld metal hardness.

For KC6 weld, the weld metal hardness is nearly 30% higher than that of 2319 weld. The reasons could be:

1. Fine equiaxed weld metal grain structure.
2. Mg clusters act as a nucleation site[8] for Al_3Sc particles during solidification.
3. Presence of Ω, θ' and S' phase precipitates.

Usually Ω phase forms in the Al - Cu – Mg alloy system along with θ' and S' phases. Some studies[5] have shown that presence of Ag can enhance Ω phase precipitation .These precipitates are hexagonal shaped plates with orthorhombic structure. They are considered to be the modified form of Al_2Cu (θ) with segregation of Mg atoms near α/ Ω interface[9]. S' phase precipitates are Al_2CuMg with long thin cylindrical shape. The TEM for the distribution of precipitates in KC6 weld and the EDX study of a plate like precipitates are given in fig.5. From the EDX values it is clear that the composition of these plates is close to that of θ.

4.2. EFFECT OF MECHANICAL PROCESSING:

The response of KC3 and KC6 welds for varying percentages of deformation are given in fig.6. For KC3 weld mere deformation could lead to good amount of strengthening (up to 30%). The crystal imperfections produced during rolling provide sites for nucleation and thus natural aging. The TEM picture for KC3 weld after deformation is given in fig.7a. For KC3, compared to as welded condition, after deformation the amount of Al_2Cu and Al_3Sc precipitates is more, which is responsible for the increment in strength.

For KC6 weld the deformation up to 8% doesn’t give any significant improvement in weld metal hardness. This response may be because of the following reasons:

1. Presence of enough amount of strengthening precipitates in the as welded condition itself.
2. At room temperature, there is no significant nucleation of new precipitates on the crystal imperfections created by deformation (Fig 7b).

4.3 EFFECT OF ARTIFICIAL AGING AFTER DEFORMATION:

For KC3 weld aging after 8% of deformation doesn’t show any improvement in hardness (Fig. 8). This may be because of the formation of strengthening precipitates in the as deformed condition itself by natural aging. Though there is no increment in hardness, the hardness values are maintained even up to 100 hours of exposure at 190ºC. So Sc addition helps to maintain the properties at high temperatures even for prolonged exposure.

For KC6 weld three hours of aging after 8% of deformation shows drastic improvement in VHN (Fig. 9). This increment may be because of the simulation of Ω precipitation on Mg clusters and heterogeneous nucleation of competing phases such as θ' and Al_2CuMg. Here aging helps to accelerate the kinetics of precipitation, in the matrix dislocations produced by cold working. This weld also maintains the hardness at 190ºC even for exposure up to 100 hours. The distribution of precipitates after deformation and aging is given in fig.10.

5. CONCLUSIONS

- The response of weld metal hardness to thermo mechanical processing significantly varies with filler alloy composition.
- Addition of Mg along with Sc in 2319 filler results in significant improvement in weld metal hardness in as welded condition.
- 2319 + Sc filler welds harden significantly after deformation.
- 2319 + Sc + Mg filler welds can be hardened significantly, up to about 85% of base metal 2219 T87 hardness, by employing 8% deformation followed by 3 hours of aging at 190ºC.

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TABLES

Table 1: Welding parameters used

Process	Welding current (A)	Gas flow rate (cf/h)	Welding speed (mm/min.)
AC - TIG	210	20	80

Table 2: Compositions of fillers and base material used

Filler metal	Cu	Mg	Sc	Zr	Ti	Fe	Si	Mn	Cr	V
2219(Base material)	6.2	-	-	0.1	0.1	0.3	0.2	0.4	-	0.1
2319	6.2	-	-	0.1	0.1-0.2	0.3	0.2	0.4	-	0.1
KC3	6.5	-	0.8	0.1	0.15	-	-	-	-	-
KC6	6.5	1.2	0.8	0.1	0.15	-	-	-	-	-

FIGURES

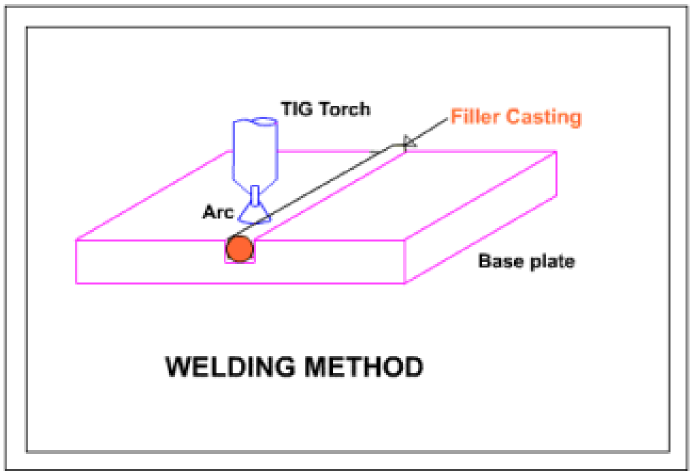
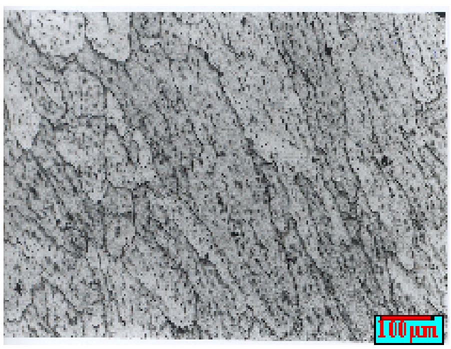
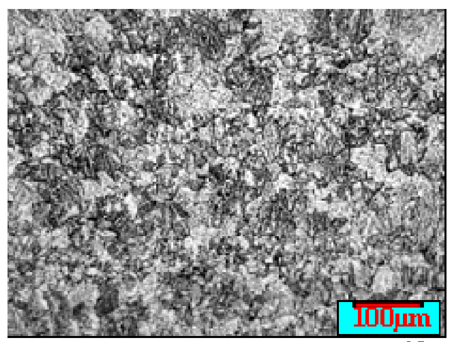


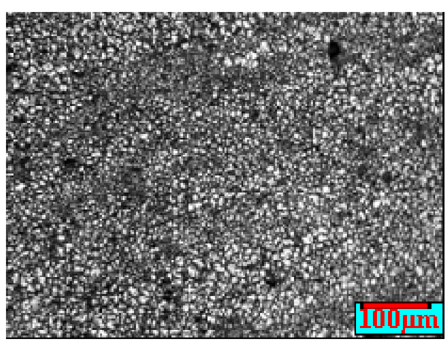
Fig.1



(a) 2219 T87 Base Metal



(b) 2319 + Sc Filler Weld[10]



(c) 2319 + Sc + Mg Filler Weld[10]

Fig 2. As welded Microstructures

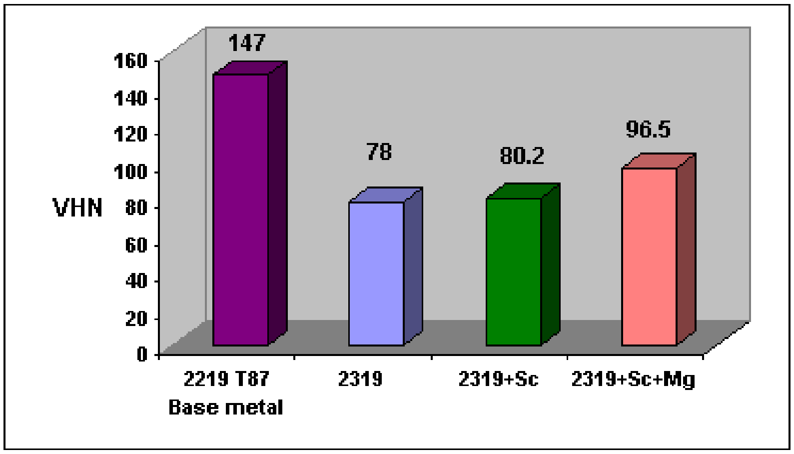
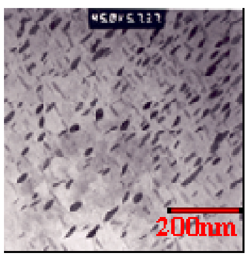
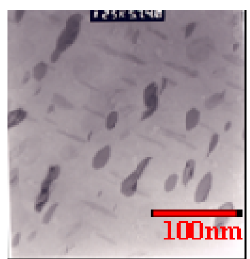


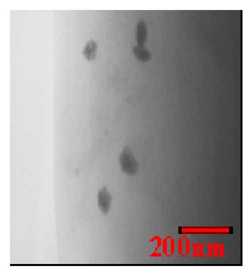
Fig.3. Comparison of weld metal hardness values



(a) 2219 T87 Base Metal

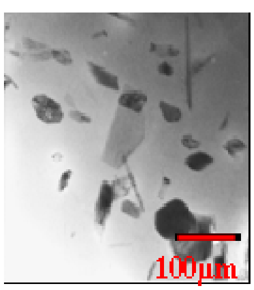


(b) 2319 Weld

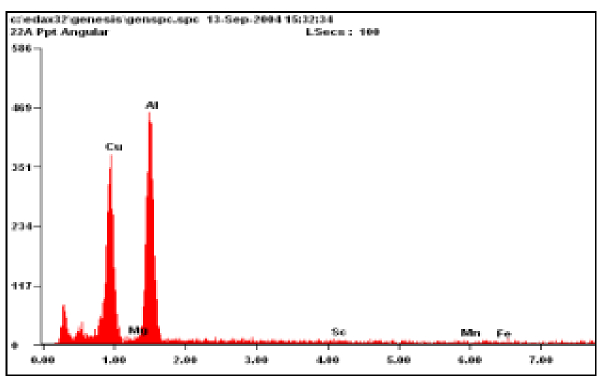


(c) KC3 Weld

Fig.4. TEM pictures in as welded condition



KC6 Weld



Element	Wt %	At %
CuL	46.55	26.97
MgK	01.01	01.53
AlK	52.32	71.40
ScK	00.08	00.07
MnK	00.02	00.02
FeK	00.02	00.01

Fig.5. TEM and EDX pictures for KC6 weld

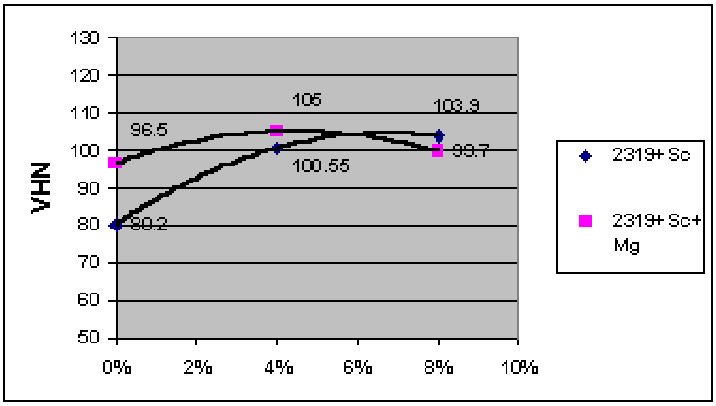
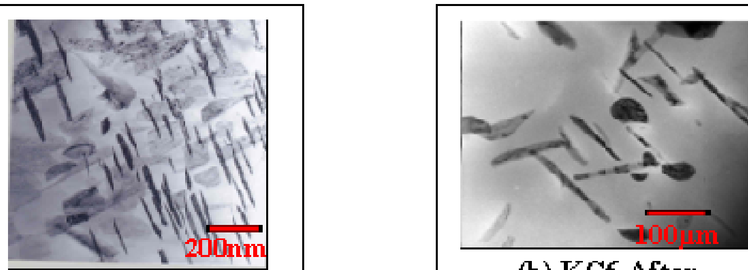


Fig.6. Effect of Deformation



(a) KC3 After Deformation

(b) KC6 After Deformation

Fig.7. TEM pictures in deformed condition

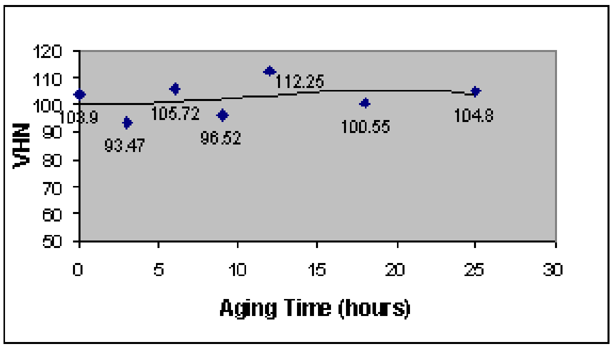


Fig.8. Effect of Aging after 8% Deformation for KC3 Filler weld

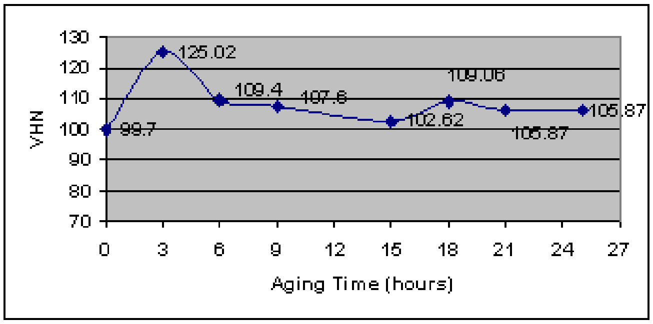


Fig.9. Effect of Aging after 8% Deformation for KC6 Filler weld

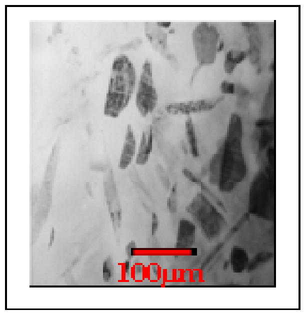


Fig.10. TEM picture for KC6 weld after Deformation + Aging