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STUDIES ON PARTIALLY MELTED AND FUSION ZONE OF GTA WELDED Al-Zn-Mg ALLOYS

R.Ananda Selvi and K.Prasad Rao
Indian Institute of Technology, Chennai

ABSTRACT

In Al-Zn-Mg alloy, where the total amount of alloying elements exceeds 6-7 wt%, several problems may arise during welding. A high level of alloying elements will promote the formation of unfavourable microstructures in the area adjacent to the fusion zone of the weld. In the present investigation three different aluminium alloy plates within the AA7000 series have been studied under GTA welded and naturally aged condition. Since the alloys under investigation are weldable, this paper describes the role played by the various major and minor alloying elements on partially melted and fusion zone characteristics and associated problems. Partially melted zone of these alloys were also compared with non weldable high copper content Al-Zn-Mg alloy. Microscopic studies revealed the presence of equiaxed zone (EQZ) adjacent to the fusion boundary. In comparison of four different Al-Zn-Mg alloys it is observed that the EQZ formation was strongly influenced by the base metal composition. As a thumb rule, it is proved that highly alloyed, rich concentration alloys and presence of minor alloying element of copper are highly responsible in producing embrittlement effect in partially melted and heat-affected zone.

Key words: Al-Zn-Mg alloy, GTAW, Fusion zone, EQZ

1. INTRODUCTION

Al-Zn-Mg alloys (7xxx series) are widely used for structural applications in the aerospace and automotive industry due to their high specific mechanical properties [1]. Less attention has been paid to weldability, although welding is frequently being used in production. It was reported that rich alloys containing higher amount of zinc and magnesium together with minor addition of copper between 0.18-0.3% promote the liquation cracking in Heat affected zone(HAZ) and thereby introducing embrittlement effect in HAZ[2].This cracking phenomenon has been attributed to the presence equiaxed grains surrounded by grain boundary eutectic constituents. Most of the Aluminium alloy in this series contains minor alloying elements such as Zr in the base metal shows EQZ adjacent to the fusion boundary [3].Several reports have focused on the occurrence of stress corrosion cracking in this zone [4].Normally, the addition of copper is considered favourable to reduce or prevent this type of corrosion in Al-Zn-Mg alloys. Unfortunately copper may also contribute to the formation of low melting phases at the grain boundaries in the high temperature regions of the weld [5].To date two hypotheses have been used to explain this EQZ .The first hypothesis proposed that the EQZ is located in the partially – melted zone and forms by a recrystallization mechanism[6]. The second hypothesis, involves a solidification mechanism requiring both nucleation and growth. It is based on heterogeneous nucleation within a stagnant liquid layer adjacent to the fusion boundary and defined by the unmixed zone [7].

In this paper, the nature of EQZ formation is reported by studying the effect of chemical composition of the base metal.

2. EXPERIMENTAL PROCEDURE

Four different Al-Zn-Mg plates containing varying levels of Zn, Cu and Zr were used in the present investigation. The nominal alloy compositions are shown in Table 1.and the materials were received as a plate material in T6 condition. Bead deposition was done using the automatic GTA welding process and by using a commercial Al-Mg filler wire. The heat input was approximately 0.45 kJ/mm. The welds were deposited transverse to the rolling direction in a single pass using a copper baking plate. After welding the material was left to room temperature where natural ageing occurs. Micro structural characterization was carried out by optical. Micro hardness measurements were performed on a LEITZ apparatus under a 200g load from the weld centerline to the location where the hardness results are equal to the hardness of the parent metal and the width of the EQZ was measured.

3.0 RESULTS AND DISCUSSION

3.1 Metallurgical Characterization

3.1.1 Fusion Zone Microstructures

The micrographs in Fig.1 shows the details of the Fusion zone microstructures. The microstructures were all taken from the weld interior top surface sections. The fusion zone fairly similar in the case of Zn-Zr-Cu and LZn-Zr, shows dendritic structure in Fig.1 (a) and 1(b), but the dendrite spacing is very less in the case of Zn-Zr-Cu weld. Fig.1(c) and 1(d) shows the fusion zone of Zn –Zr and HZn-Cu alloys, which reveals the columnar structure. This might be very less Zr content about 0.10% in Zn –Zr alloy and the absence of Zr in HZn-Cu alloy as compared to other two materials. At higher magnification Optical micrographs shows low melting eutectics in the grain boundary. The nature of the eutectics is smaller and almost discontinuous in the fusion zone.

3.1.2 FUSION LINE AND HAZ MICROSTRUCTURES

Fig.2 shows the details of the fusion boundary microstructures. The equiaxed fine grain zone is distinctly seen at the fusion boundary in three specimens. This equiaxed zone formation reveals that these materials have been recrystallised in the area near to the fusion boundary. If the material is heated to temperatures above the ternary eutectic temperature, there is a potential for local melting also as shown in Fig. 4.In the case of Zn-Zr-Cu and LZn-Zr material a narrow white zone was observed between the fusion zone and Equiaxed zone in Fig.2 (a) and 2(b). But the fusion line of Zn-Zr material Fig.2(c) did not show such white narrow zone. It is observed that the equiaxed grains have slightly moved in to the weld zone as well. The fusion boundary microstructure of HZn-Cu is entirely different from other materials, Fig.3 (d) did not show any EQZ, but there is an evidence of partially melted grains was observed. Lipold et al (8) and Yunjia et al (7) have suggested that the EQZ forms due to the heterogeneous nucleation in a stagnant liquid boundary layer defined by the unmixed zone. According to this mechanism, the EQZ forms in these materials by the existence of heterogeneous nuclei Al_3Zr.

In Zr contain materials the width of the equiaxed zone is least at the bottom of the weld bead and increasing in the surface. It varied from 200µm to 600 µm depends upon the chemical composition of the base material. Guttirez et al [9] reported that for particular material when the heat input in to the weldment is same the width of this EQZ as well as the size of the equiaxed grains is almost similar.

In contrast, alloy LZn –Zr (Fig.3 (b)) which is considered to have good weldability contains few grain boundary particles in the equiaxed zone of this magnitude. In the Zn-Zr-Cu weldment the equiaxed grain boundaries almost covered by a thin film of eutectics (Fig.3 (a)) and the width of EQZ is higher than the other two materials. Such type of structure impairs the fracture toughness and lead to intergranular fracture [10].In HZn-Cu alloy also , the partially melted grains completely covered by a thin film of eutectics(Fig.3(d)). A very few pores up to 25 μm dia. are observed. They are predominantly seen at the fusion boundary and within the EQZ. Since the cooling rate is the highest at the fusion line, it is generally expected that the pores formed do not have sufficient time to escape to the top portion of the weld resulting in fusion line porosity [11].

Because weld solidification normally occurs epitaxially from partially melted grains, the microstructure which developed at the fusion boundary is greatly influenced by the initial base metal microstructure and chemical composition.

3.2 MICROHARDNESS STUDIES

The weld metal in all the cases shows minimum hardness level of 65-75 VHN as against the base metal hardness of 130-140VHN. All materials shows three different regions in heat affected zone, identified as solution treated zone, partially annealed zone and over aged zone. Immediate to the fusion boundary white zone was observed in the case of Zn-Zr-Cu and LZn-Zr material for this given heat input. The measured hardness in this zone was 78-84VHN.

Equiaxed zone shows very high hardness of 125-145VHN compared to other regions of heat affected zone. This zone shows high hardness than the parent metal hardness .This might be due to the entrapment of alloying elements during welding as solid solution. Dissolved alloying elements are retained into the solid solution due to rapid cooling of this zone compared with fusion zone cooling rate. With the same heat input depends upon the chemical composition of the base metal the EQZ width is varied. Zn-Zr-Cu shows the width of 500-600 μm , HZn-LZr material shows 200-300 μm .This might be due to the presence of very less Zirconium content in the base metal. From this it is proved that the fusion boundary EQZ formation is not attributed by recrystallization mechanism. It is formed by heterogeneous nucleation mechanism aided by Al_3Zr particles.

4. CONCLUSIONS

The Microstructure revealed a fine equiaxed grain Zone on the fusion line, but the width of such zone is much smaller when the amount of Zr is less in the base material. This may lead to embrittlement within a narrow region close to the fusion boundary due to the presence of second phase particles at the grain boundaries. In certain case the local melting of the grain boundary precipitate was observed.

No EQZ was produced in the alloy without containing Zr in the base metal. From this investigation it is concluded that the nondendritic , fusion boundary EQZ is not formed by a recrystallization mechanism in the PMZ, but it is formed by a heterogeneous nucleation mechanism aided by Al_3Zr particle.

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TABLES

Table 1.Nominal Alloy compositions in wt%

Alloy	Zn	Mg	Cu	Zr
Zn-Zr-Cu	4.83	1.30	0.23	0.18
Zn-Zr	4.52	1.3	0.08	0.10
LZn-Zr	3.61	1.5	-	0.14

FIGURES

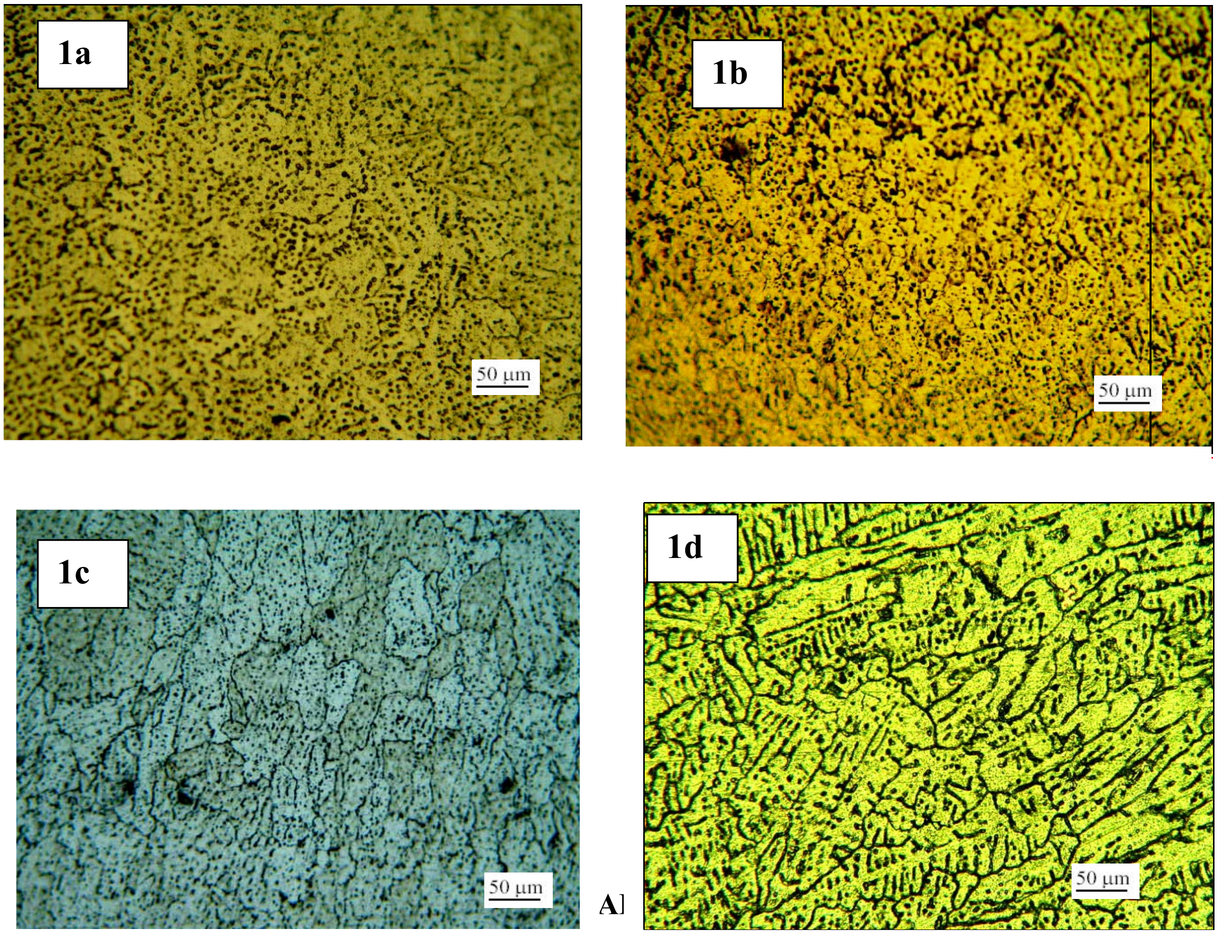


Fig.1 Fusion zone microstructures

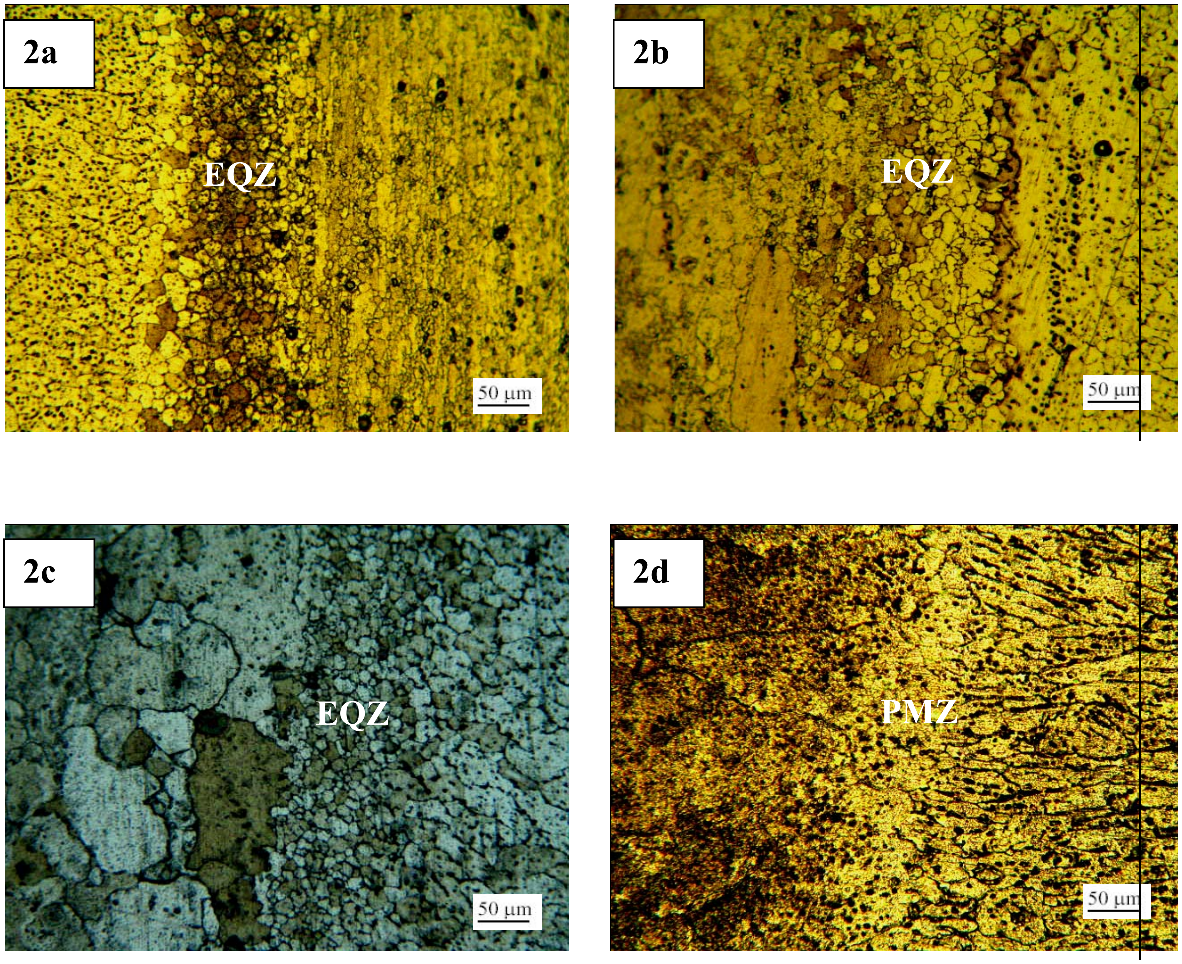


Fig.2 Fusion Zone, Fusion Boundary and HAZ Microstructures

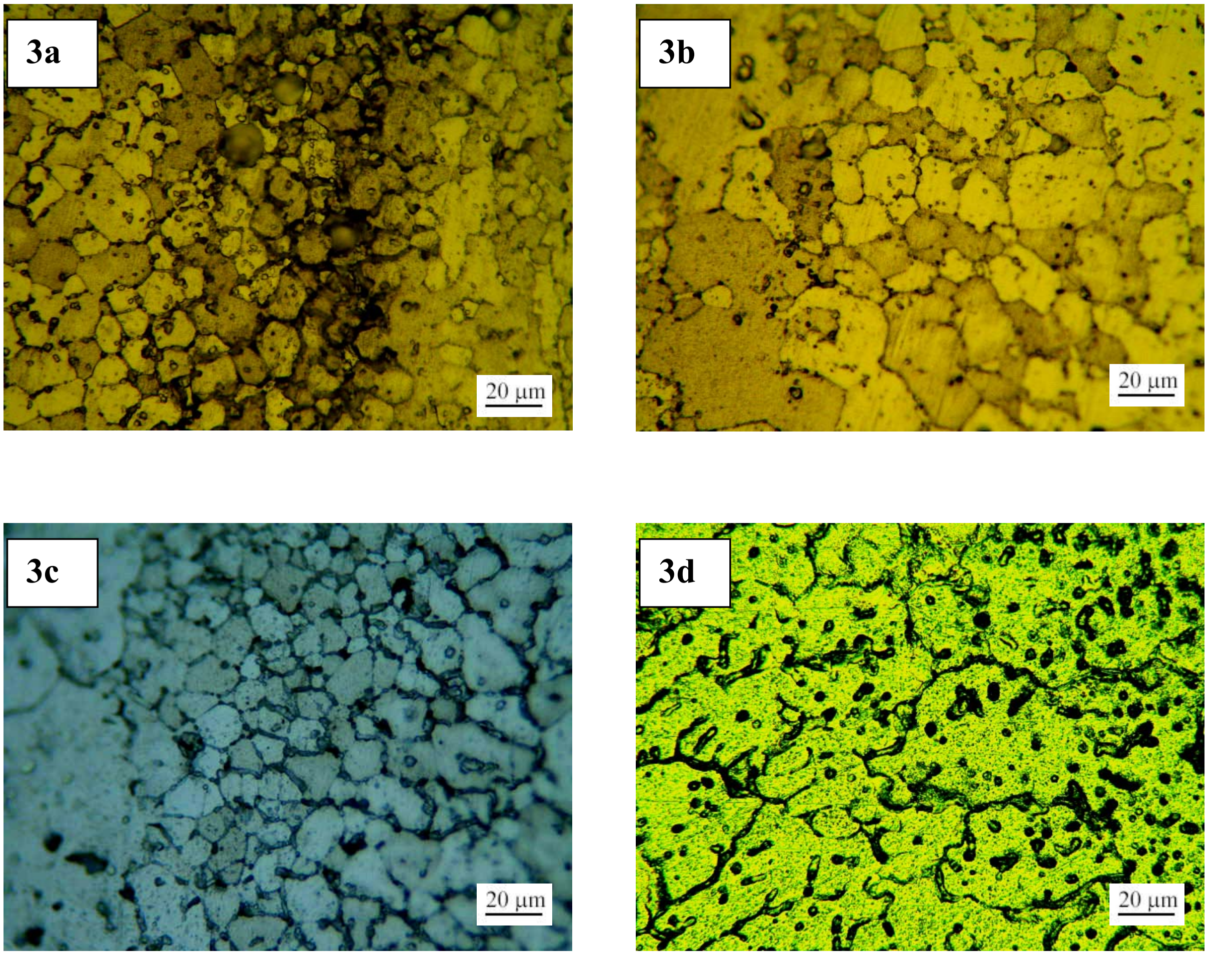
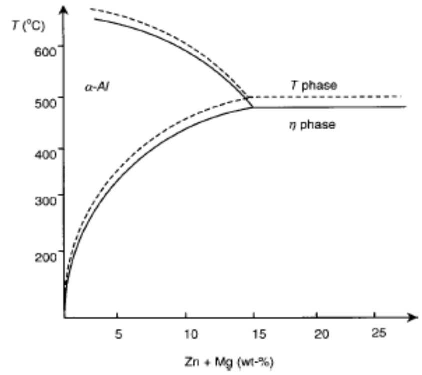


Fig.3 Equiaxed Zone Microstructures



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