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THE EFFECT OF HOMOGENIZATION AND ANNEALING ON IGC SUSCEPTIBILITY OF HOT-ROLLED AA5182 ALUMINUM ALLOY

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Abstract

In this study, we report on the influence of homogenization temperature on the evolution of the microstructure, recrystallization behavior during hot deformation, and corrosion response of Al-Mg AA5182 alloy. Optical microscopy, SEM/EDS techniques and standard NAML test were employed. Various processes, such as phase transformations, dissolution, and morphological changes of constituents, occurred during homogenization. However, results indicated that the precipitation and distribution of Mn-bearing dispersoids controlled recrystallization behavior and IGC susceptibility. It has been shown that the annealing treatment after hot deformation could lead to significant improvement in corrosion response.

Keywords: *AA5182 alloy, homogenization, Mn-bearing dispersoids, recrystallization, IGC.*

1. INTRODUCTION

5xxx series Al-Mg alloys have a wide range of applications in the transportation and automotive industries due to a good combination of strength, excellent ductility, weldability, and corrosion resistance. However, increased Mg content leads to plastic instability phenomena and surface quality degradation [1]. For the alloys with Mg >3.5 wt%, an additional problem, related to the alloy's susceptibility toward intergranular (IGC) and stress corrosion cracking (SCCS) susceptibility arises [2,3]. Precipitation of β-Al_3Mg_2 phase as a continuous film along the grain boundaries is considered to be responsible for the deterioration of the corrosion properties. A common approach to mitigate the problem is alloying with the elements that form precipitates at the grain boundaries and disrupt the continuity of the β-Al_3Mg_2 film [3]. However, Fe- and Mn-bearing intermetallic secondary phases present in the Al-matrix are also favored nucleation sites for β-Al_3Mg_2 phase, which can act as a gather for β-Al_3Mg_2 within grains, decreasing the fraction of β-Al_3Mg_2 precipitated at the grain boundaries [4].

Although Al-Mg alloys belong to the class of non-heat-treatable alloys as they derive their strength from solution-strengthening and work-hardening, high-temperature treatments such as homogenization do affect phase composition of the alloys via phase transformations and dissolution of microconstituents as well as precipitation of dispersoids. [5]. It is well-established that dispersoids can influence recrystallization and texture development as well as corrosion properties. In this paper, the influence of homogenization conditions on the dynamic recrystallization during hot rolling and IGC susceptibility, including the effect of high-temperature annealing following the hot rolling, was examined.

2. EXPERIMENTAL

The material used in this work was an industrially DC cast slab of AA5182 alloy provided by Impol Seval Aluminium Mill company. The chemical composition of the alloy is shown in Table 1.

Table 1. *Chemical composition of the studied AA5182 alloy*

Mg	Mn	Cu	Fe	Si	Zn	Cr	Na	Ti	Zr
4.217	0.460	0.018	0.323	0.137	0.048	0.072	/	0.014	0.001

The as-received portion of the slab was cut into110 × 60 × 25 mm blocks that underwent further processing in the lab including homogenization, hot-rolling, and annealing. To evaluate the effect of homogenization temperature on recrystallization and corrosion properties of hot-rolled material, two thermo-mechanical processing routes were employed. The first regime involved homogenization for 16 h at 490°C and the second 16 h at 550°C. Homogenization was followed by hot rolling in 10 passes with a total reduction of ~85%. Hot-rolled bands were divided into two parts. One was left in a hot-rolled state, and the other was annealed for 1 h at 490°C for the first regime and 550°C for the second.

Specimens for optical microscopy (OM) and SEM/EDS characterization were viewed parallel to the longitudinal cross-section. Following mechanical grinding and polishing, SEM/EDS characterization of microconstituents and dispersoids in as-cast and homogenized samples was conducted in FEI SEM at 15 kV. The grain microstructure of hot-rolled and annealed samples was characterized after anodization under polarized light in the Reichert Jung OM.

To assess IGC susceptibility, both hot-rolled and annealed samples were sensitized for 17 h at 130°C. Sensitized samples underwent a nitric acid mass loss test (NAMLT) according to the standard G67. Sensitized samples were also polished and etched in the solution of H_3PO_4 to reveal β-Al_3Mg_2 pits. Characterization was conducted in OM dark field.

3. RESULTS AND DISCUSSION

The microstructure of the initial, as-cast state consisted of an Al-solid solution matrix and intermetallic constituents in interdendritic channels. Among the Fe-bearing constituents, the predominant phases were Al_3(Fe,Mn) and Al_m(Fe,Mn), which are seen in Figure 1a. Smaller fractions of Al_6(Fe,Mn) and α-Al(Fe,Mn)Si were observed. Dark phase, Mg_2Si lined interdendritic channels. Homogenization treatments brought phase transformations of Fe-bearing constituents and morphological changes such as rounding and fragmentation (Figures 1b and e). Mg_2Si constituent stayed unchanged during the treatment at 490°C (Figure 1b). Moreover, additional Mg_2Si precipitated at the Al-matrix/Fe-bearing constituents interfaces (Figure 1c) as well as fine particles in the dendritic core. Homogenization at 550°C led to dissolution of Mg_2Si (Figure 1e). Homogenization treatments resulted in the precipitation of Mn-bearing dispersoids. At 490°C (Figure 1b), precipitation occurred throughout the Al-matrix, in interdendrite channels (Figure 1c) and dendrite cores (Figure 1d). Dispersoids adopted two distinct morphologies: acicular and rounded (Figure 1b-d). Precipitation at 550°C (Figure 1e) was followed by dispersoid coarsening and redistribution: coarser acicular particles were found in interdendritic regions (Figure 1e), while dendrite cores contained a mixture of fine needles and rounded particles (Figure 1f). Homogenization led to the grain boundary precipitation

(Figures 1b and e) with a larger fraction of grain boundaries covered with coarser particles after treatment at 550°C.

As can be seen in Figure 2, homogenization conditions had a profound effect on the grain microstructure evolution during hot rolling. High density of fine dispersoids forming during the homogenization at 490°C effectively suppressed recovery and recrystallization during hot deformation (Figure 2a). The region close to the hot-band surface of the hot-band, which was exposed to the higher strain, was characterized by thin, long grains. Occasional grain fragmentation and small, rounded grains near constituent particles suggest that a certain degree of restoration processes occurred. However, in the center of the hot-band, lamellar grain structure and Cu-type shear bands pointed out suppression of restoration processes. Coarser and less dense dispersoids, which appear after homogenization at 550°C, did not suppress dynamic recovery and recrystallization processes. The microstructure is characterized by a mixture of irregularly shaped elongated grains and small, polygonal grains close to intermetallic particles.

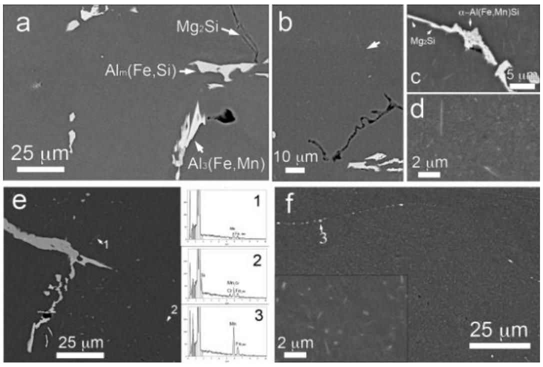

Figure 1. *BSE SEM micrographs of the microstructure: (a) as-cast; (b-d) homogenized for 16h at 490°C; (e-f) homogenized for 16h at 550°C*

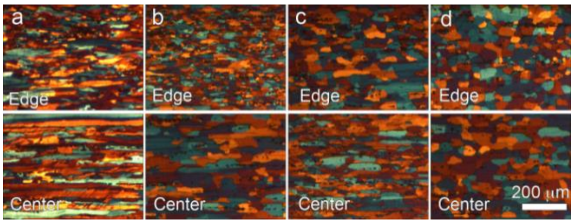

Figure 2. *OM in polarized light of grain microstructure of hot-rolled band homogenized for 16 h at (a) 490°C and (b) at 550°C; after annealing of respective samples for 1 h at (c) 490°C and (d) at 550°C*

Annealing of hot-bands for 1h at respective homogenization temperatures resulted in recrystallization throughout the samples' thickness. However, homogenization parameters exerted an influence on the grain morphology. Grains in the sample homogenized and annealed at 490°C remained elongated, while polygonal grain morphology and grain coarsening characterized one homogenized and annealed at 550°C.

The effect of different treatments on susceptibility toward IGC is shown in Figure 3. It is clear that the samples homogenized at 550°C had the worst resisance that can be related to the grain microstructure. Figures 4a and b showed grain boundaries of hot-rolled samples covered by the β-Al_3Mg_2 phase. However, samples homogenized at 550°C had finer grains that caused larger mass loss since the primary corrosion attack was along grain boundaries. Significant improvement in the corrosion response of the annealed samples was accompanied by a smaller fraction of grain boundaries covered by the β-Al_3Mg_2. During annealing and recrystallization, new grain boundaries were formed which were not covered by Mn-bearing particles. It appears that Mn-bearing particles at the grain boundaries facilitate the precipitation of unwanted β-Al_3Mg_2.

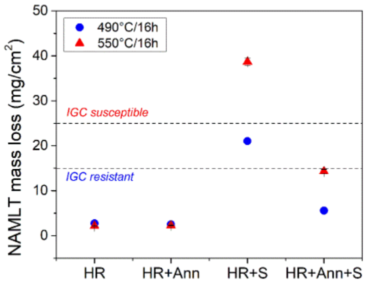

Figure 3. *Plot of the NAML test results. Mass loss ≤15 mg/cm^2 corresponds to IGC resistant and ≥25 mg/cm^2 to IGC susceptible material*

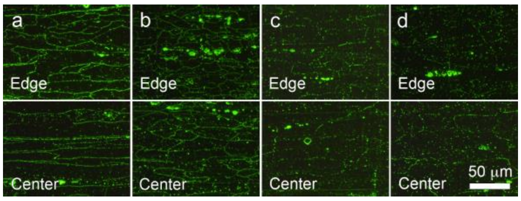

Figure 4. *Dark field OM showing distribution of β-Al_3Mg_2 phase in the sensitized samples of hot-rolled band homogenized for 16 h at (a) 490°C and (b) at 550°C; and annealed for 1 h at (c) 490°C and (d) at 550°C, respectively*

4. CONCLUSION

The results showed a strong effect of homogenization treatment on recrystallization behavior and susceptibility toward IGC of AA5182 alloy. Significant improvement of the corrosion properties after annealing treatment is likely related to the creation of grain boundaries free of Mn-bearing dispersoids which are preferential sites for precipitation of the β-Al_3Mg_2 phase.

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