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Process development of AA3103 aluminum alloy for automotive thins

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Abstract

AA3XXX alloys have been widely used to produce automotives thins. First, these thins are drawed, before the condenser production in which it can be used processes as brazing. These alloys can show a large variability of macrostructure due to different cooling rates used after homogenizing whose diffusion mechanism of manganese in solid solution is prevailing. In this work, they were analyzed as-cast samples involving 3 homogenizing temperatures and 3 different cooling rates. Afterwards, samples were rolled until thickness of 200µm and heated to 6 different temperatures to create the annealing curve for each situation. Macro and microstructure analysis was performed as well as electric conductivity. This last showed that the higher treatment temperature and cooling rate are the lower the electric conductivity is. Manganese diffusion from solid solution to precipitated favors the recrystallization and promotes a more homogeneous and fine distribution of grains.

Introduction

Aluminum foils have large applications as automotive thins, container foil, peel-off, white cap, yogurt, house and hold foil, conversion foil and others. In these cases, aluminum is used due to its high corrosion resistance, impermeability to humidity and oxygen, besides, there is the workability that favors processes as rolling, bending, cutting generating opportunities to transformation industries [1]. The raw material to produces these foils can be produced by DC casting or *Twin Roll Casting* in which the material is produced with thickness from 3 to 7mm. In worldwide outlook, this process produces AA1XXX, AA3XXX, AA5XXX, AA7XXX and AA8XXX alloys [2, 3].

AA3XXX aluminum alloys are considered non-heat treatable and are used in products that need good formability. Beyond this, there is the *Twin Roll Casting* technology to thin sheets production that consists in a casting process between two cylinders in which sheets are produced with gages from 2 to 7mm and with high cooling rate causing a high amount elements in solid solution that affects the recrystallization, recovering and grain coarsening [4].

AA3XXX aluminum alloys are based on Al-Mn system whose effects of alloying elements increases mechanical resistance and decreases the intergranular corrosion and stress susceptibility [5]. On Al-Mn system, the Mn maximum solubility occurs at eutectic temperature on 1,82 weight percentage. During slow cooling, occurs precipitation of intermetallics and reduction of Mn in solid solution that changes the mechanical properties. On AA3103 alloy, the chemical composition takes to a quaternary system Al-Fe-Mn-Si that generates the phases $(Fe\ Mn)Al_6$, $(Fe\ Mn)_3Si_2Al_{15}$ e Mg_2Si [6].

The homogenization treatment is essential on as cast sheets produced by *Twin Roll Casting* in which the amount of manganese in solid solution is high due to the high cooling rate. Thus, homogenization is necessary to promote the precipitation of Mn excess in solid solution and then, reduce the risk of coarse grains.

Electrical conductivity measurement is the best solution to evaluate the effects of homogenization on metallic structure. As the alloy is heated from 350°C, the electrical conductivity increases showing the decomposition of supersaturated solid solution. The maximum is reached between 500 and 530°C and starts decreasing due to dissolution of dispersoids rich in Mn to solid solution [7, 8].

The aim of this work is studying the effect of homogenization temperature and cooling rate on macro and microstructure of AA3103 alloy obtained by raw material from *Twin Roll Casting* and then, have a final structure more homogeneous to produce automotive thins.

Experimental procedure

AA3103 rolls were produced *Twin Roll Casting* PAE™ with thickness of 7 mm with the following chemical composition:

Table 1. AA3103 chemical composition (wt%).

	Si	Fe	Cu	Mn	Mg	Cr	Zn
AA3103	0,5	0,7	0,1	0,9-1,5	0,3	0,1	0,2

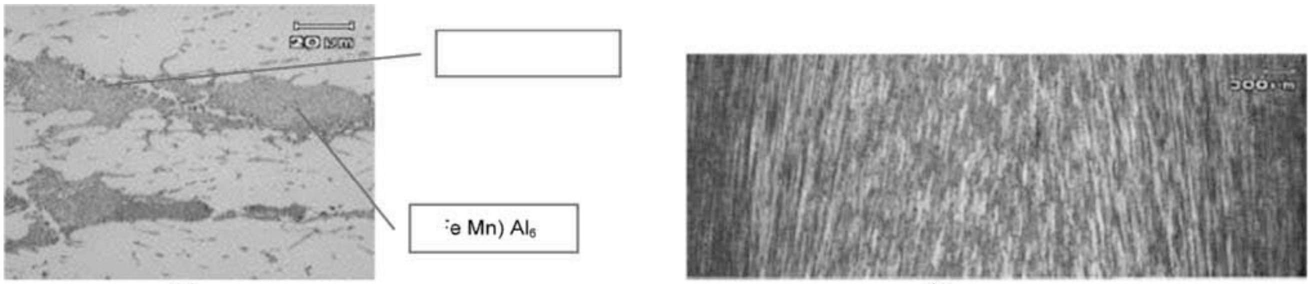
One part of the roll was submitted to a homogenization treatment in as cast condition. The other part was cold hardened (by rolling) and then homogenized. The homogenization treatment involved 3 temperatures (480, 500 and 520ºC), bath time of 12hs and 3 different cooling rates (10, 20 e 60ºC/h). Afterwards, both samples were cold rolled until gage of 200µm and annealed in 6 different temperatures (260, 280, 300, 340, 360 and 380°C) in order to build the recrystallization curve.

After final treatment metallografic analysis was performed using HBF_4 and Keller´s reagent for macro and microstructure characterization using the microscope Olympus BX51M. Tensile tests and electrical conductivity measurements were also performed.

Results and Discussions

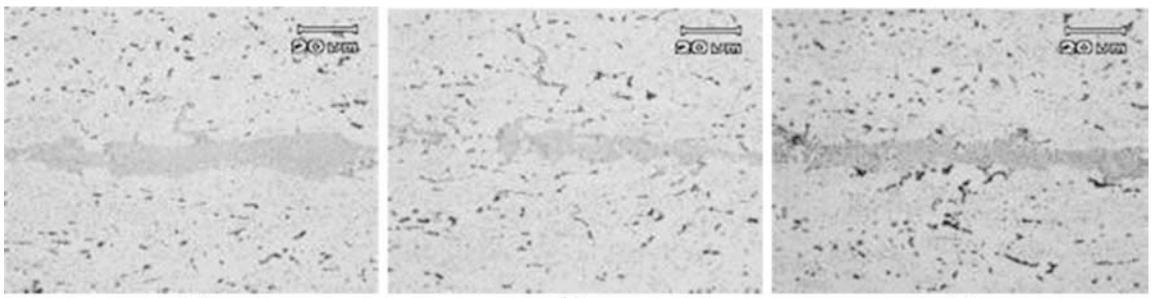
Figure 1 shows the macro and microstructure of AA3103 as-cast. Micro shows the central line segregation rich in $(Fe\ Mn)_3Si_2Al_{15}$, darker particles, Mg_2Si as chinese script and $(Fe\ Mn)Al_6$ as alternate lamellas. Macro shows the typical structure of as-cast material from Twin Roll Casting with fine grains in the edges and coarsened grains in the middle. The electrical conductivity in as-cast condition is 30,2%IACS.

Figure 2, 3 and 4, shows the microstructure of homogenized samples with thickness of 7 mm. It can be seen that as the temperature increases the amount of darker phase also increases on the edges of the center line segregation and along inter dendritic arms. It means the manganese precipitates as $(Fe\ Mn)_3Si_2Al_{15}$ that coalesces and spheroidizes. Center line segregation is rich in (Fe Mn)Al_6, that dissolves partly and Mg_2Si precipitates on aluminum matrix as fine particles.



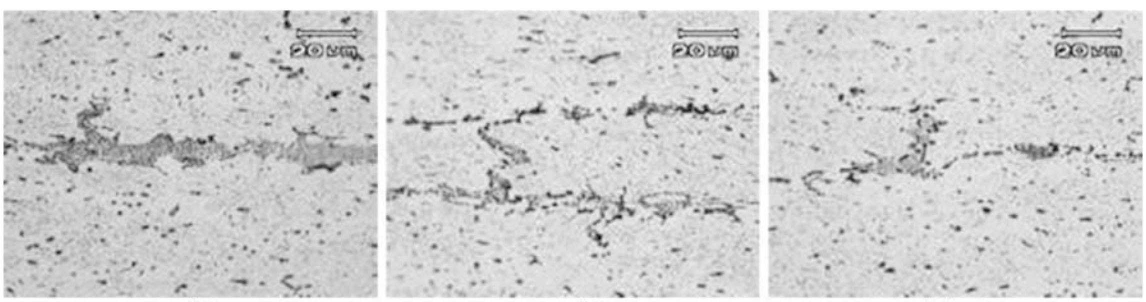
(a) (b)

Figure 1. Micro (a) and Macrostructure (b) of AA3103 in as cast condition.



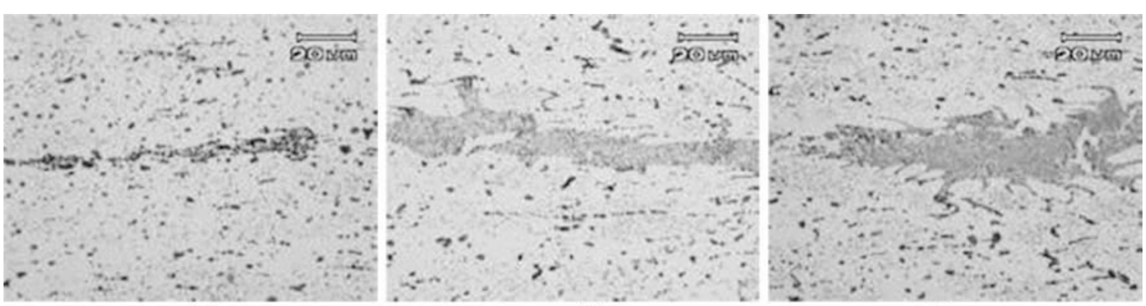
(a) (b) (c)

Figure 2. Homogenization temperature 480ºC. (a) 10ºC/h (b) 20ºC/h e (c) 60ºC/h



(a) (b) (c)

Figure 3. Homogenization temperature 500ºC. (a) 10ºC/h (b) 20ºC/h e (c) 60ºC/h



(a) (b) (c)

Figure 4. Homogenization temperature 520ºC. (a) 10ºC/h (b) 20ºC/h e (c) 60ºC/h

It can be seen that above 500°C aluminum matrix becomes lighter. This fact suggests the dispersoids dissolution riches in Mn and Mg that means a reduction on electrical conductivity.

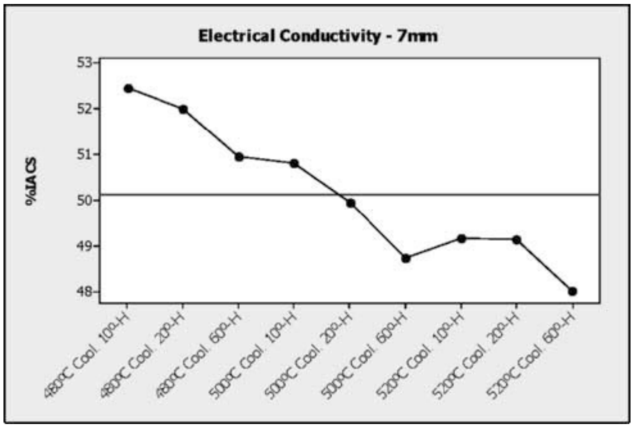


Figure 5. Electrical conductivity of AA3103 with thickness 7mm homogenized (as-cast condition).

During homogenizing, it can be seen (figure 5) that the higher the cooling rate is the lower the electrical conductivity is. It is due to the absence of time to manganese precipitation that was in solid solution.

Figures 6, 7 and 8 show the microstructures of AA3103 homogenized after cold rolling. In this case, the cold hardening generated a large amount of energy due to dislocations formation and favors the precipitation of critical elements as manganese and recrystallization. Also, there is an increasing of dispersoids dissolution as the temperature increases, the same behavior noted in homogenized as cast samples. And then, it is not possible to see any microstructural changing according to cooling rate, though there is a electrical conductivity reducing as the cooling rate increases according to figure 9.

Figure 9 also shows that there is not influence of homogenizing temperature on electrical conductivity only the cooling rate.

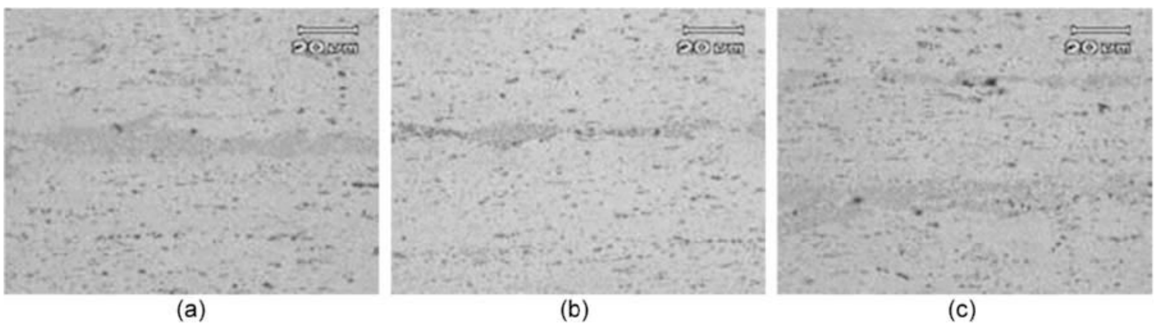


Figure 6. Homogenization temperature 480ºC. (a) 10ºC/h (b) 20ºC/h and (c) 60ºC/h

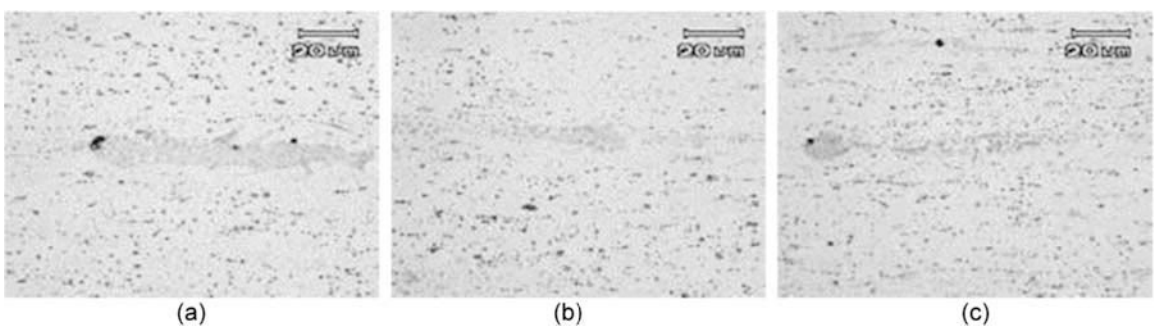


Figure 7. Homogenization temperature 500ºC. (a) 10ºC/h (b) 20ºC/h and (c) 60ºC/h

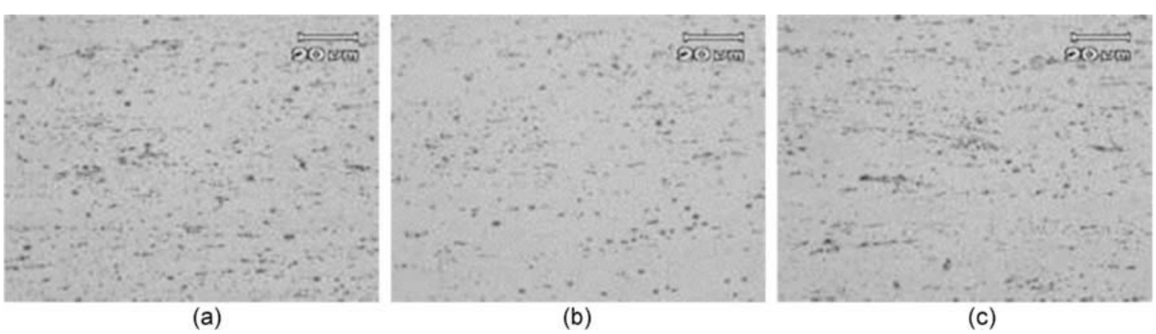


Figure 8. Homogenization temperature 520ºC. (a) 10ºC/h (b) 20ºC/h and (c) 60ºC/h

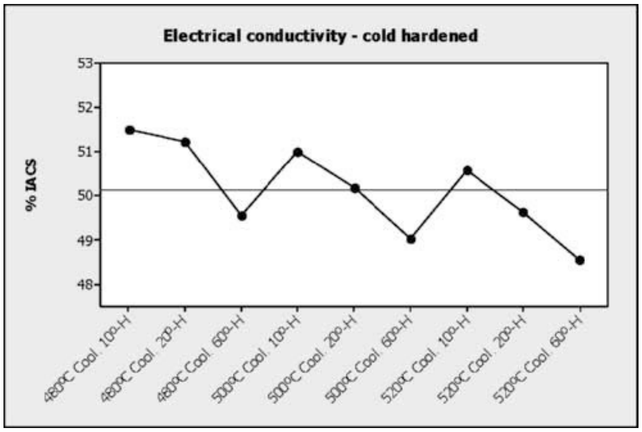


Figure 9. Electrical conductivity of AA3103 homogenized (cold hardened condition).

Figure 10 shows the comparison between homogenized material after cold hardening and as-cast. Although comparing the electrical conductivity means it is observed that there is no difference between the curves, when the variance is compared, it is observed that after cold hardening it is lower. That is a very important fact that ensures more homogeneous feed stock and reduces the variability of grain size and mechanical properties.

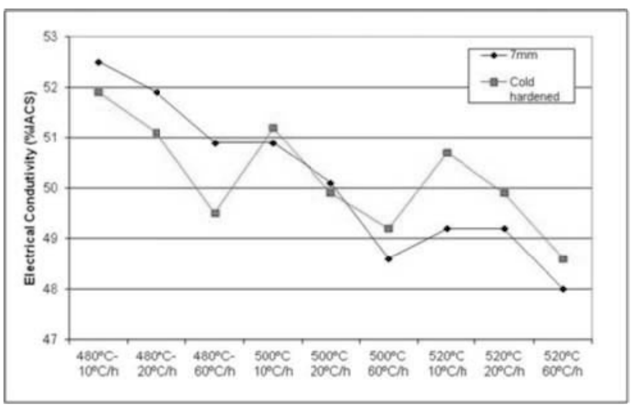
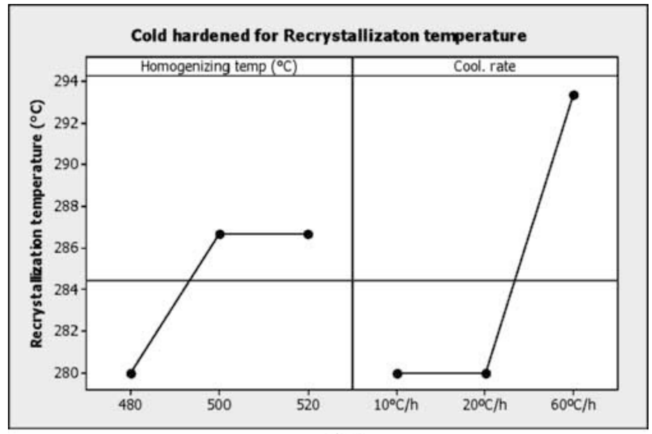


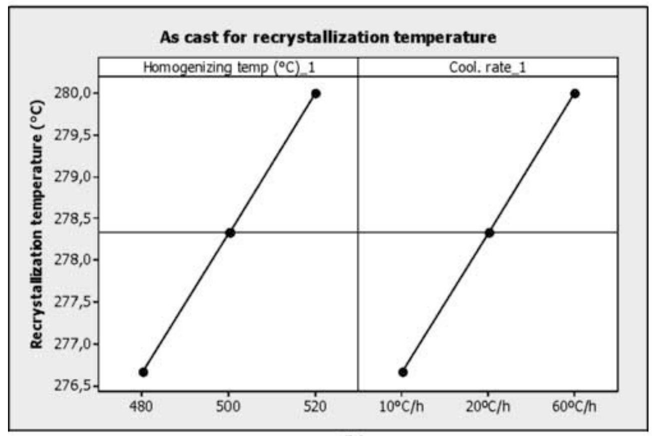
Figure 10. Electrical conductivity comparison after homogenizing: as-cast and cold rolled.

After that, samples were submitted to a final heat treatment in order to measure the recrystallization temperature. Figure 11 (a) shows the effect of homogenizing temperature and cooling rate on recrystallization. At 500°C is possible to see an increasing of recrystallization temperature. It is due to the dissolution of manganese rich phases to solid solution. About the cooling rate, it is possible to see the increasing of recrystallization temperature in 60°C/h showing that the highest this value is more manganese is kept in solid solution. Figure 11 (b) shows the same effect for as cast condition.

Figure 12 shows the macrostructures of AA3103 alloy with thickness of 200μm after final heat treatment simulation. Figures (a), (b) and (c) shows the variability of grain size in cases in which the as cast material is homogenized. Figure (d) shows the grains morphology of samples homogenized after cold hardened and rolled up to thickness 200μm. The structure is more homogeneous. In figure (a), the grain size is about 224μm. Figure



(a)



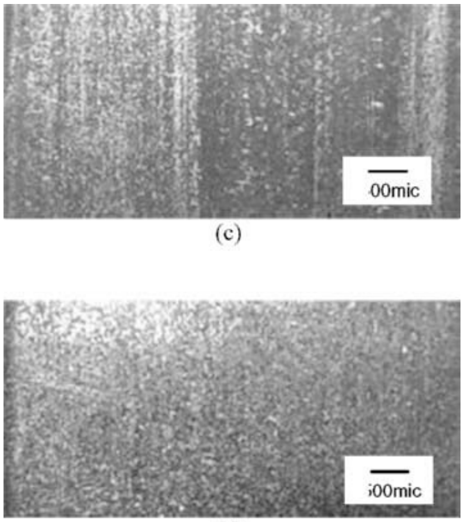
(b)

Figure 11. Recrystallization curve results. (a) Cold hardened and (b) as cast.

(b), grain size is 159μm. Figure (c), grain size is 80μm and figure (d)56μm. Homogenizing after cold hardening promotes more homogeneous final product.

(a)

(b)



(d)

Figure 12. Macrostructures of AA3103 alloy. (a), (b), (c) homogenized in as-cast condition. (d) homogenized after cold hardening.

Conclusions

It can be concluded that dispersoids dissolution is more evident above homogenizing temperature of 500ºC. This fact is related to recrystallization behavior during homogenizing because Mn in solid solution difficults the ocurrence of this phenomena. It could be seen that the homogenizing treatment performed in the cold hardened material generates less variation on final macroestructure than homogenizing performed in as-cast material. It is due to the accumulated energy during cold hardening that favors the precipitation of Mn rich phases during heating. Besides, it was observed that the recrystallization temperature is also influenced by the homogenizing temperature and the cooling rate. As the homogenizing temperature increases, recrystallization temperature increases due to the Mn dissolution. Cooling rate also show the same influence on the recrystallization temperature.

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