The Mechanical Properties and Corrosion Behavior of an Al-Fe-Si (AA8079) Twin Roll Cast Foil

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Abstract. This paper describes the mechanical properties and corrosion behavior of AA8079 foils containing 0.89 wt. percentage of Fe and 0.15 wt. percentage of Si. AA8079 sheets/foils show higher strength and similar plasticity as Al99.7 sheets/foils. Recrystallization response curves show no significant difference between AA8079 and Al99.7 hardened foils in the sense of the characteristic temperatures. Corrosion rate of AA8079 and j_{corr} are higher, and values of R_{pol} are lower for about 15-17%, in comparison to the Al99.7 in both fresh water and 0.51 mol NaCl. Minimizing of the earing for as/rolled and annealed products is achieved by the high degrees of cold rolling deformation applied in a final stages of material processing.

Introduction

After the introducing of aluminum foil, aluminum producers are competing in the world market of thin sheets/foils and, to the consumer, undoubtedly there is a little discernible difference between the various available foils. However, within certain limits the different foils produced by the aluminium industry can vary considerably in their chemistry, mechanical properties and microstructure [1]. This means, for example, Si could vary from about 0.05-0.65 wt.%, Fe from around 0.25-1.75 wt.% and Mn from less than 0.01-0.5 wt.%. Furthermore, previous reviews suggest that at least twelve different phases may be present in the structure, depending on alloy chemistry, processing history and Fe/Si ratio. These parameters significantly affect the mechanical properties, corrosion behavior, anisotropy and other foil properties [2-5].

The aim of this paper was to examine the mechanical and corrosion behavior of an AA8079 aluminium alloy (a popular alloy with an Fe/Si ratio substantial higher than the other alloys from ternary Al-Fe-Si system), containing 0.89 wt.% of Fe and 0.15 wt.% of Si, produced by cold rolling of twin roll cast strip, in comparison with Al99.7 foils properties. The effect of cold rolling reductions on earing behavior was also analyzed, and recrystallization response curves were determined.

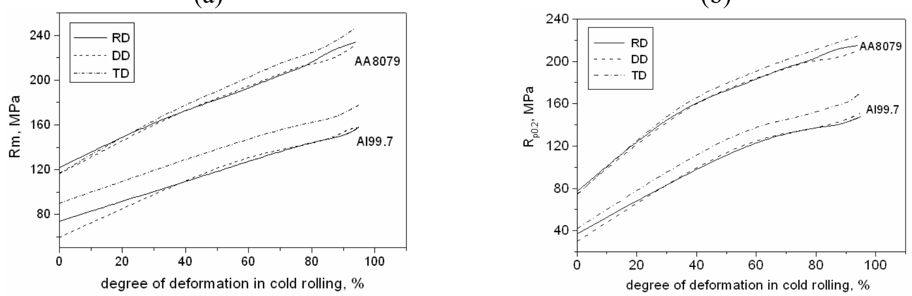
Experiment

The material used in the present investigation was commercial Al-Fe-Si alloy (AA8079 type)containing 0.89 wt.% of Fe and 0.15 wt.% of Si. The as-received material was continuous cast and cold rolled, without prior homogenisation, to a final thickness of 0.009 mm, with an intermediate annealing at gauge of 0.5 mm in industrial conditions. The mechanical behavior of the alloy during cold rolling was monitored in the sense of changing the tensile properties. Uniaxial tensile tests were performed at 0^0, 45^0 (DD) and 90^0 (TD) to the rolling direction (RD). Recrystallization response curves were determined by tensile measurements. Some samples were laboratory cold rolled ("Joliot" rolling mill) in order to investigate the influence of cold rolling deformation degree on the earing. The corrosion characteristics were determined by accelerated methods: monitoring of the corrosion potential E_{corr} during 3600 seconds; determination of the polarization resistance values R_{pol}, corrosion current j_{corr} and corrosion rate. The corrosion investigations were performed by the PAR-332 system (potentiostat-galvanostat mode 273, MK-047 cell, software PAR SOFTCORR 352 II), in natural water and 0.51 mol NaCl solution. Mechanical and corrosion properties of Al99.7 foil were also determined and compared to the AA8079 alloy.

Results and Discussion

Figs. 1 and 2 illustrate the influence of cold rolling reductions on the mechanical properties of continuous cast AA8079 and Al99.7 strips. Tensile properties were determined at 0^0, 45^0 (DD) and 90^0 (TD) to the rolling direction (RD). Strength level of AA8079 twin roll cast and cold rolled strip is substantial higher, for about 30%, in comparison to the strength level of Al99.7.

(a) (b)



(c)

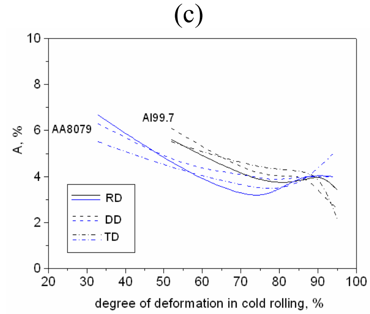


Fig. 1. *Dependence of (a) Rm, (b)* $R_{p0.2}$*, and (c) A, on the degree of cold rolling deformation and orientation in the plane of the sheet during the rolling of twin roll cast strip.*

Both materials show the highest strength at 90^0 (TD) to the rolling direction, but the strength difference between three selected directions in the plane of the sheet is smaller in the case of AA8079 alloy. The anisotropy of tensile strength, and especially the yield stress, is significant in the Al99.7 rolled sheets. The elongation of cold rolled sheets of both alloys is on similar level. The Al99.7 sheets show slightly higher elongation.

Recrystallization response curves were determined for two foils of both materials by tensile measurement. The final gauges of foils were 9µm and 150µm, produced by cold rolling (without prior homogenization) of continuous cast strip with one intermediate annealing. It was found that recrystalization starts, and is completed, at almost the same temperatures for both alloys and foil gauges, Figure 3. The effect of the degree of cold rolling before the annealing on the temperature of the recrystalization start have also been explored, and the results show that temperature decreases from 250^0C to 200^0C in the range of deformation between 40% to 98%, Figure 4. There is no significant difference between AA8079 and Al99.7 curves and they are almost linear.

(a) (b)

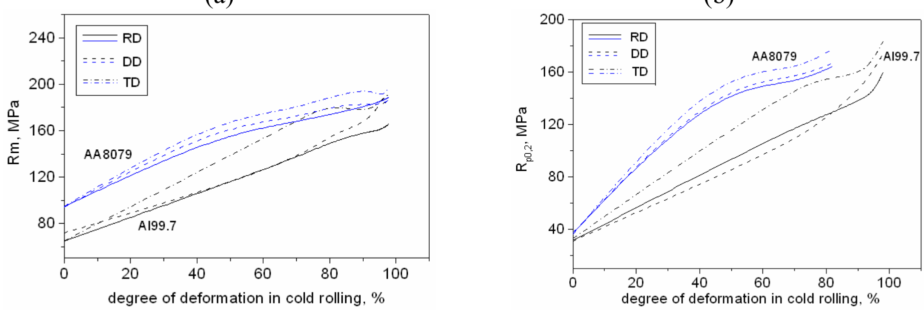


Fig. 2. *Dependence of (a) R_m, (b) $R_{p0,2}$, on the degree of cold rolling deformation and orientation in the plane of the sheet during the rolling of 0.5 mm thick sheet to the final thickness.*

(a) (b)

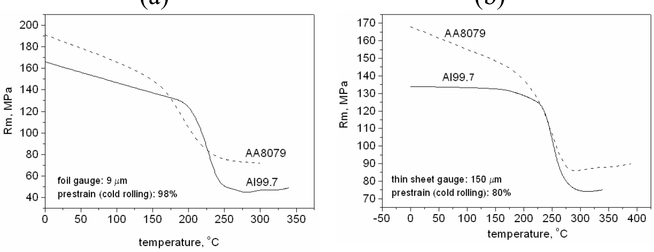


Fig. 3. *Recrystalization response curves of (a) 9µm and (b) 150 µm foils produced by cold rolling of 0.5mm thick sheet of AA8079 and Al99.7.*

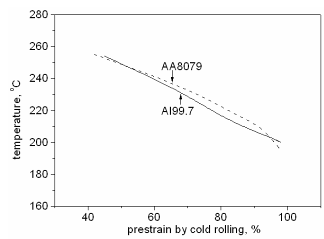


Fig. 4. *Temperature of recrystallization start vs. cold rolling prestrain of foils.*

(a) (b)

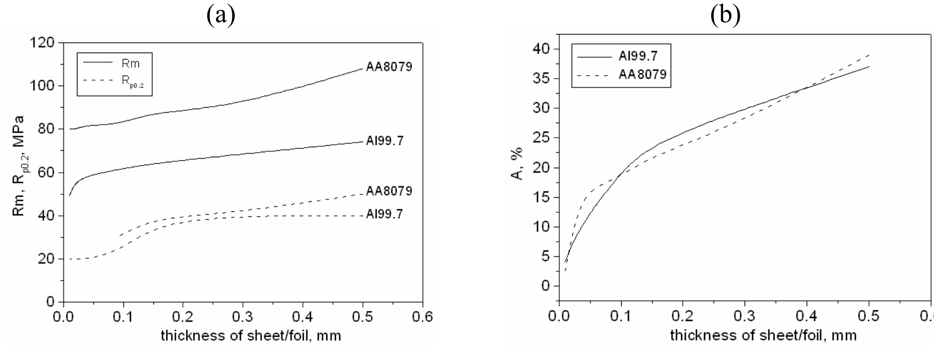


Fig. 5. *The sheet/foil thickness influence on the (a) strength and (b) plasticity of AA8079 and Al99.7 annealed sheets/foils.*

Figure 5 shows the mechanical properties of thin sheets and foils of AA8079 and Al99.7 of gauges from 1mm to 9μm in final annealed temper. Tensile strength and yield stress of AA8079 thin sheet/foil is higher for about 30% and 15% respectively, but the elongation is almost the same, compared to the Al99.7 sheet/foil.

Figure 6 illustrates the influence of sheet/foil thickness on forming ability of AA8079 sheet/foil in biaxial conditions. Two forming limit curves (for 1mm thick sheet and for 90μm thick foil) illustrate that formability decreases with decreasing of the thickness.

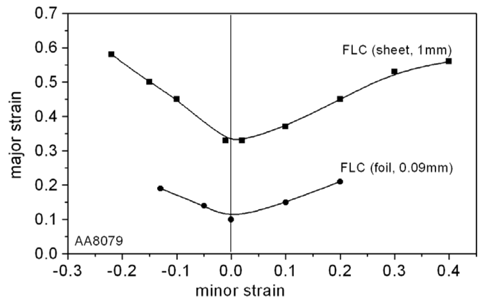


Fig. 6. *Forming limit curves (FLC) of two annealed AA8079 sheets/foils.*

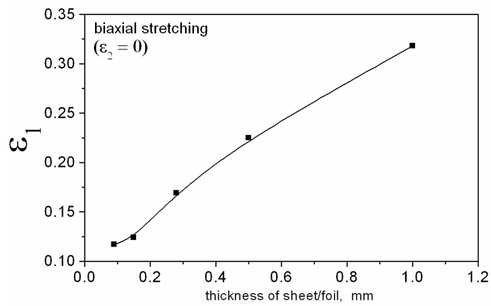


Fig. 7. *Major strain vs. sheet/foil thickness in biaxial stretching for $\varepsilon_2=0$.*

Figure 7 shows that change more specific, presenting the influence of the AA8079 sheet/foil thickness on the major strain (ε_1) in the plate of the sheet/foil, in case of plane strain ($\varepsilon_2=0$), indicated on the FLC.

Minimizing of earing is an important request if the cold rolled products have to be deep drawn subsequently. Earing of aluminium products can be controlled by the chemical composition, casting process, ingot/strip homogenization, hot and cold rolling practice and final annealing [7]. The effect of rolling schedule on the earing of AA8079 sheets was analyzed for two processing schemes given in Figure 8. The final products were the annealed sheets and hardened sheets.

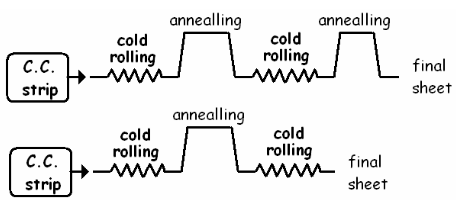


Fig. 8. *The processing schemes for the production of annealed and hardened AA8079 sheets in laboratory conditions.*

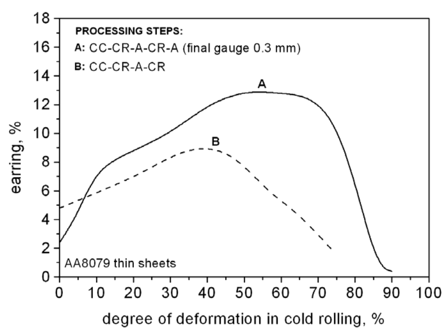


Fig. 9. *Earing vs. degree of rolling deformation according to schemes on Fig.8.*

The acceptable levels of earing can be achieved (if desired level of earing is maximum 3%) if degree of cold rolling deformation exceeds 80% before final annealing. Low level of earing in hardened sheets can be achieved on similar way: final degree of rolling deformation must be higher than 65%, if the initial earing of the sheet in annealed temper is relatively high (about 5%), Figure 9.

A substantial portion of aluminium foil for packaging applications in manufactured from the Al-Fe-Si system. The performance of the packaging foil, in such cases, depends on the corrosion resistance of the aluminium foil [6]. In that sense the corrosion investigation, we made on selected materials, covered: the monitoring of corrosion potential during the 3600 seconds (accelerated methods) in fresh water and in 0.51 mol solution of NaCl, determining the R_{pol}, j_{corr} and corrosion rate.

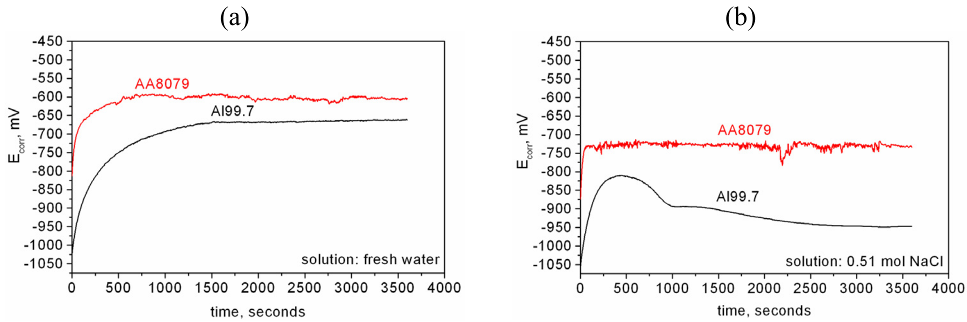
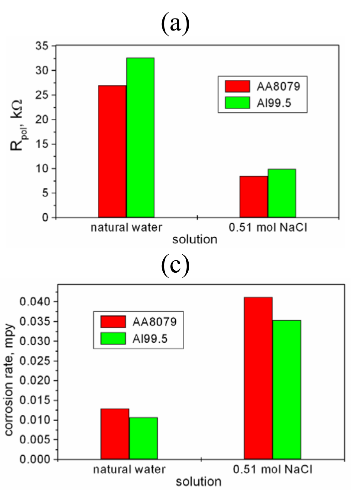


Fig. 10. *Changes of corrosion potential of AA8079 and Al99.7 annealed thin sheets in (a) fresh water, and (b) 0.51 mol solution of NaCl.*

Figure 10 shows the changes of corrosion potential during the 3600 seconds of AA8079 and Al99.7 fully annealed thin sheets. The AA8079 sheet exhibits less negative corrosion potentials for 8% in fresh water and approximately 15% in chloride solution compared to the Al99.7 sheet. Method of linear polarization of both sheet materials gave the results presented in Figure 11. The Al99.7 sheet shows 15% higher values of polarization resistance, almost 16% lower corrosion current and 17% lower corrosion rates.



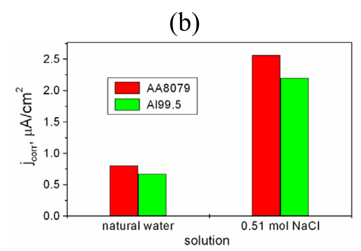


Fig. 11. *The influence of the ambience and the type of sheet/foil material on (a) polarization resistance (b) corrosion current and (c) corrosion rate.*

Conclusion

Thin sheets and foils of AA8079 aluminium alloy, produced by cold rolling of twin roll cast strip have higher strength and almost the same plasticity as the Al99.7 sheets/foils in both hardened and annealed temper. Recrystallization response curves show no significant difference between AA8079 and Al99.7 hardened foils in the sense of the characteristic temperatures. Corrosion rate and j_{corr} of AA8079 are higher, and values of R_{pol} are lower for about 15-17%, in comparison to Al99.7, in both fresh water and 0.51mol NaCl. On the other hand, the AA8079 sheet exhibits less negative corrosion potentials for 8% in fresh water, and approximately 15% in chloride solution compared to the Al99.7 sheet. Minimizing of earing for as/rolled and annealed products is possible in the case of high degrees of cold rolling deformation applied in final stages of material processing. The combination of these characteristics can recommend AA8079 alloy to replace CP aluminium for some applications in thin sheet and foil gauges.

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