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ELECTROCHEMICAL CHARACTERIZATION OF TRC 7072AA FOR HEAT EXCHANGERS

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Abstract

We present the results of corrosion potential measurements of DC and TRC cast 7072AA used as a fin material in mechanical heat exchanger applications. The alloys used were continuously cast to two different gauges and Zn,Ti Fe and Si content, using twin roll casting technology. Optic and electron microscopy was used to correlate the electrochemical results with microstructure at the surface. It was shown that higher solidification rates developed during twin roll casting at much thinner gauges resulted in much lower corrosion potentials. This in turn made us possible to reduce Zn content to improve the thermal conductivity while maintaining the desired corrosion potential. Unlike Zn and Ti, higher concentrations of Fe and Si added with the purpose of retaining adequate strength at much thinner thicknesses do not have an adverse effect on corrosion potentials.

1. Introduction

The high thermal conductivity of aluminium, combined with lower corrosion potential, makes aluminium alloys especially AA7072 an ideal fin material for use in *mechanical* heat exchanger applications[1]. Heat exchangers are assembled so that the fins made from AA7072 aluminium alloy are inserted between extruded or drawn Cu or Al tubes to enlarge the surface area available for heat release. Corrosion resistance and thermal conductivity of aluminum fins are the two most crucial properties affecting the performance of the heat exchangers which are commonly exposed to aggressive corrosive environments.
While the fins with a high thermal conductivity increases the heat exchange rate, the fins with a lower corrosion potential provide a cathodic protection to the tube material by preferentially corroding in a corrosive media and increases the service life of the heat exchanger[2-3]
The corrosion potential of an aluminium alloy is usually associated with its Zn content. While, higher concentrations of Zn results in a more negative corrosion potential, it leads to a lower thermal conductivity due its high solid solubility(0.85at%) in Al as the conductivity of an alloy decreases with the amount of solid solution. Therefore the Zn content in Al needs to be optimized for a better thermal conductivity and a lower corrosion potential.

Furthermore, the growing interest in weight reduction in heat exchangers due to production cost issues and environmental concerns have forced the manufacturers to seek ways of making thinner fin materials. However, a reduction in thickness of the fin material while keeping the other parameters constant (chemical composition etc.), results in a volume decrease, accordingly a decrease in thermal conductivity and loss of rigidity. In brazed heat exchanger applications, Kawahara et.al showed that small amount of Ni addition improved the post-braze strength of 3000 series aluminum alloys due to dispersion enhancement of intermetallic compounds in Al-Fe-Ni-Si without compromising the conductivity[4]. However, dispersion enhancement in

7072AA is not possible since the alloy has not been subjected to any heat treatment process during sheet production and/or assembling of heat exchangers.

In our previous publication, it was shown that twin roll cast aluminum alloys exhibit lower corrosion potentials compared to direct cast Al alloys[5]. This is attributed to the very high solidification rates developed at the surface of the strip during twin roll casting process. It was found that higher solidification rates resulted in a supersaturated region at the surface which contains very fine and evenly distributed intermetallics serving as cathodic sites during corrosion process.

The purpose of this work is therefore to study the electrochemical behavior of twin roll cast 7072 AA produced at different casting gauges and different Zn,Ti, Fe and Si content, in 1M NaCl. It was aimed to investigate the effect of cooling rate and chemical composition on corrosion and thermal properties of 7072 aluminium alloy. This will lead to better understanding the effect of cooling rate and Zn content on performance of 7072AA thereby optimization of casting process and Zn,Fe and Si content. Optimization of chemical composition with a suitable casting technology will then lead to produce much thinner heat exchanger fin materials of lower corrosion potential without compromising the thermal conductivity while retaining adequate strength.

2. Experimental Procedure

The samples of aluminum alloys used in this study was cast at two different gauges(referred as thick and thin gauge) using twin roll casting technology and cold rolled down to a final thicknesses between 50 to 60 μm under industrial scale production routes at Assan Aluminium, located in İstanbul,Türkiye. The DC cast samples were provided by one of our customers.
Prior to the experiments, all sample surfaces were degreased with hexan following acetone and rinsed with deionized water. A home-made poly(aryl-ether-ether-ketone) PEEK sample holder exposing a surface area of 3.46 cm^2 was used for all electrochemical measurements. The potentials were measured and reported with respect to a saturated calomel electrode (SCE, 0.242 V vs. NHE). Corrosion potential transients were obtained in 1M NaCl solutions at room temperature for a period of 2-4 hours. Electrolytes were not dearated as this was found to make the corrosion potentials unstable, continuously shifting in the negative direction. The potentiostat used to conduct all experiments was a Princeton Applied Research Instruments model VersaSTAT 3. All measurements were repeated for reproducibility of the electrochemical data.
SEM with x-ray EDS capability was used to correlate the electrochemical results with microstructure and chemical composition at the surface.

3. Results and Discussion

The chemical composition of TRC cast materials are given in Table I. ZnTi refers having less amount of Zn,Ti and FeSi having higher Fe and Si content compared to reference material(Material A).

Table1. Chemical composition (in wt%) of TRC samples.

	ID
Thick gauge standard	**A**
Thick gauge ZnTi*	**B**
Thin gauge ZnTi	**C**
Thin gauge FeSi**	**D**
Thick gauge FeSi/ZnTi	**X**

* ZnTi indicates less Zn and Ti content
**FeSi indicates higher Fe and Si content

Figure 1 shows the corrosion potential-time behavior of 7072 fin stock aluminum alloys casted at two different casting gauges and different chemical compositions. The corrosion potential of 7072AA used in heat exchanger applications as a sacrificial anode is usually associated with its Zn content. The effect of Zn on corrosion potential could clearly be identified by comparing the corrosion-time behavior of samples A and B. Reduction in Zn content for about wt%0.3 in sample B, resulted in an increase in the corrosion potential by 30 mV_{SCE} compared to sample A. Therefore every 1wt% of change in Zn content increased the corrosion potential by ~ 10 mV_{SCE}. Despite of its positive effect in reducing the corrosion potentials, higher concentrations of Zn leads to a lower thermal conductivity as elements like Zn having higher solid solubility with Al degrade the thermal performance. For the purpose of obtaining a higher thermal conductivity and yet a lower corrosion potential, alloys with different amount of Zn and Ti content is cast at two different casting gauges using twin roll casting technology.

Material C, containing Zn almost half the amount of A, was cast at a thinner gauge, wherein the alloy is exposed to very high solidification rates. From Figure 1, it was found that sample C exhibited a slightly negative (~5mV) corrosion potential compared to sample A. This result shows the profound effect of the solidification rate on the corrosion potential of aluminium alloy. Casting at thinner gauges which resulted in a significantly faster cooling rates at the surface of the material, compansate the reduction in corrosion potential casued by redcution in Zn content. The desired corrosion potential is therefore achieved with less Zn content in the alloy. Therefore the thermal conductivity of the sample would expected to be higher since the amount of solid solution in the matrix is reduced. Unfortunately, at the time of preparation of this manuscript, the thermal conductivity measurements were not completed yet.

From electrochemical data, it was found that addition of higher concentrations of Fe, with the purpose of retaining adequate strength at much thinner thicknesses, do not have an adverse effect on the corrosion potential. It is also not expected to have a negative effect on the thermal conductivity of the material. It is because that Fe has a very low solid solubility in Al(max 0.05wt%) and excess Fe reduces the solute content in the matrix by enhancing the decomposition of the supersaturated volume during casting.

Figure 2 shows SEM images of Material B and X. The difference in size and number density of particles are clearly be seen between B and X. The intermetallics in Material X are much larger in both size and number compared to Material B due to its higher Fe and Si content.

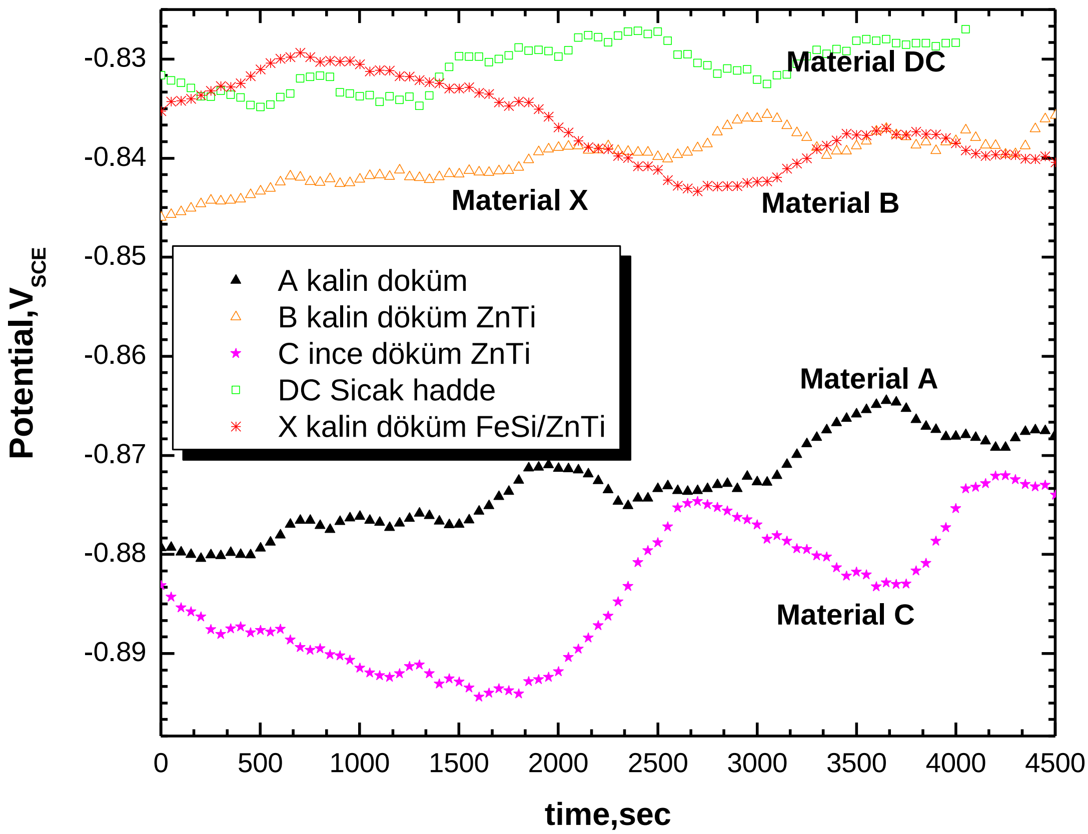

Figure 1. Corrosion potential transients of 7072 AA samples cast at two different casting gauge and chemical compositions.

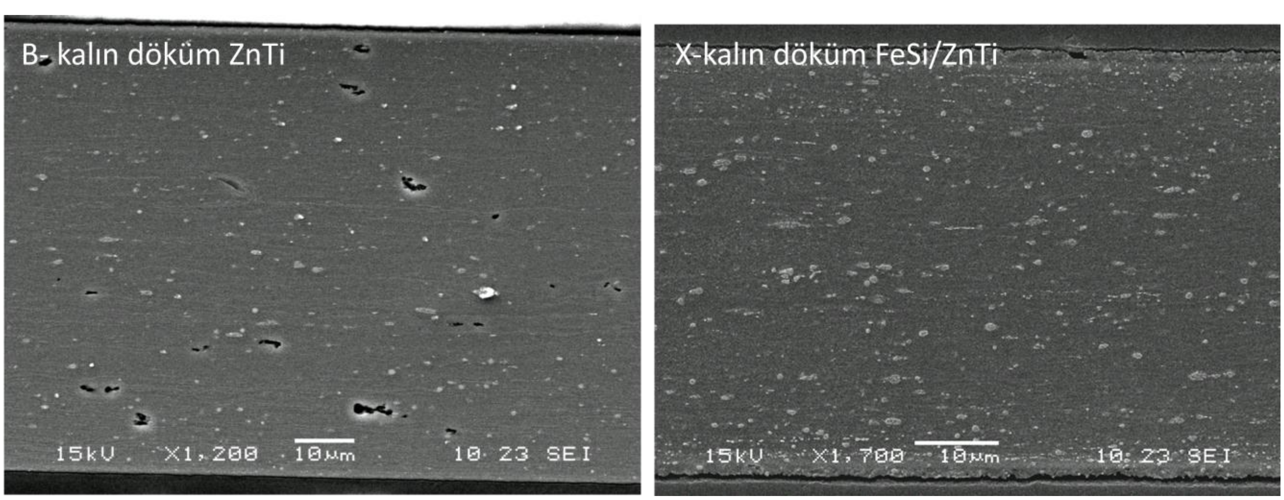

Figure 2. Cross-section SEM images of samples B and X.

5. Conclusions

The present work showed that the corrosion potential of the 7072AA fin material could be lowered successfully by changing the solidification rates (i.e reducing the casting gauges) during twin roll casting. Reduction in casting gauge and therby corrosion potential allows us in turn to lower the Zn content and therefore increase the thermal conductivity of the heat exchanger fin material. It is also found that addition of higher concentrations of Fe, with the purpose of retaining adequate strength at much thinner fin thicknesses do not have an adverse effect on the corrosion potential.The corrosion potentials of all the TRC cast samples were found to be lower than those of DC cast samples.

6. References

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