Light Metals 2013 *Edited by: Barry Sadler*
TMS (The Minerals, Metals & Materials Society), 2013

THE INFLUENCE OF CASTING SPEED IN THE AS CAST STRIP MECHANICAL PROPERTIES OF 8079 AND 8006 ALLOYS

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Keyword: microhardness, mechanical properties, conductivity, casting speed

Abstract

The influence of casting speed on mechanical properties from twin-rolled cast strip was investigated. Low and high speed coils of 8079 and 8006 alloys were produced from FATA HUNTER twin roll caster of ELVAL.

Microhardness and tensile tests of low casting speed coils for both alloys exhibit higher hardness and mechanical properties compared to the higher casting speed coils.

Electrical Conductivity measurements and metallographic examinations helped to explain the difference in mechanical properties between the high and low casting speed coils. Increased microstructural knowledge allowed ELVAL to optimize the cold rolling and annealing processes to meet customer specifications.

Introduction

The twin roll casting process is a well-established process for 8079 and 8006 foil stock alloys. The casting speed is one of the major controlling parameters of the metallurgical quality of the caster product. Low and high casting speed coils of 8079 alloy and 8006 alloy were produced from FATA HUNTER twin roll caster of ELVAL SA.

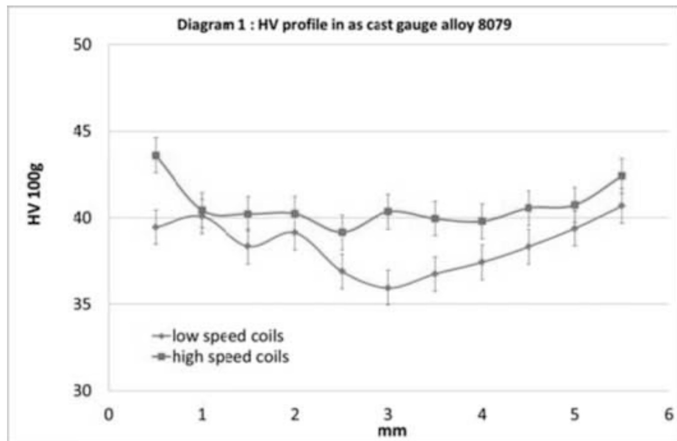
In order to fully characterize the metallurgical quality of the twin roll caster product, hardness and mechanical properties were determine on low and high speed as-cast strips from both alloys.

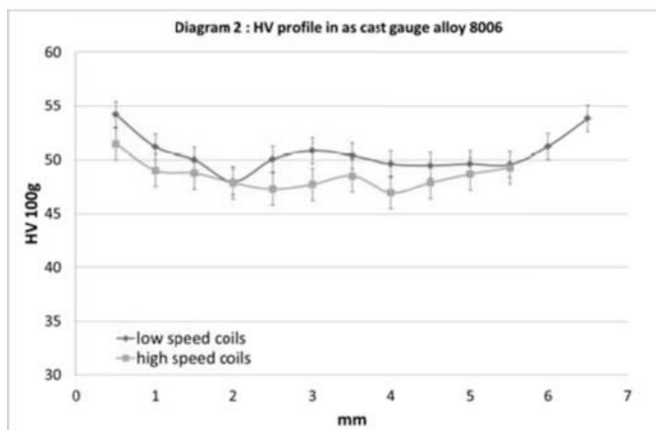
Further material characterization was done by strip grain structure study and Electrical conductivity measurements. A strong correlation of the as-cast strip mechanical properties and hardness with the caster speed was observed.

Vickers Microhardness Results

Strip hardness was measured by Vicker's microhardness indentation method. Indentations were done across the strip thickness for low and high casting speed coils. The indentation load was constant at 100g and the indentation spacing was 0,5 mm, well above the recommended closest permitted spacing between adjacent indentations (3 times the Pyramid indentation diagonal distance) [1].

Diagram 1 presents the Vickers hardness measurements across the strip thickness of the alloy 8079. **Diagram 2** presents the Vicker's hardness measurements across the strip thickness of the alloy 8006. The error bars in Diagram 1 and Diagram 2 represents the standard deviation of the hardness measurements (St Div. = 1,5 Vicker hardness).



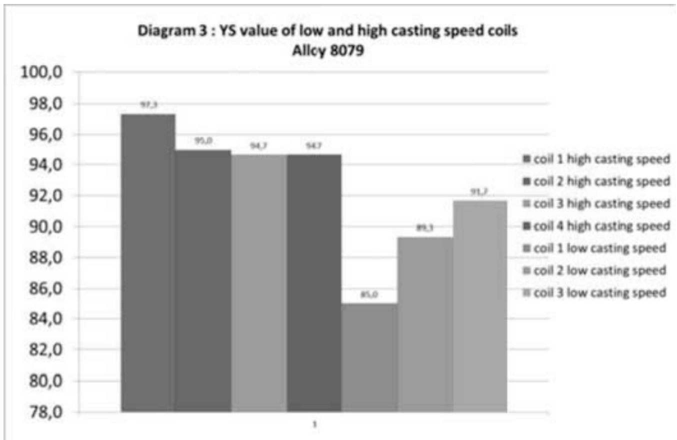


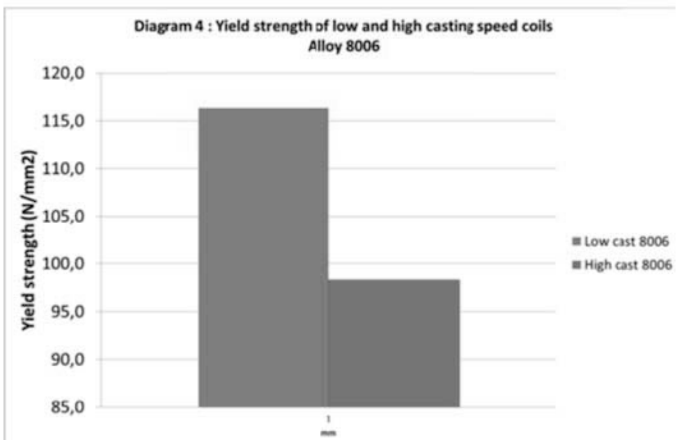
The higher manganese (Mn) and iron (Fe) containing 8006 alloy showed higher hardness relative to 8079. Reducing the casting speed for both alloys cause a displacement of the hardness curve to higher hardness values.

Tensile yield strength results of the as cast strip

Tensile test specimens parallel to the casting direction were prepared from the as cast strip. **Diagram 3** and **Diagram 4** show the yield strength of low and high casting speed coils for 8079 alloy and 8006 alloy. Both alloys, exhibits significant higher yield strengths when the casting speed is reduced.

It is obvious that the yield strength data confirms the micro hardness testing results. The yield strength difference between the two casting speeds for 8079 alloy is almost 13 N/mm2 and for 8006 alloy is almost 19 N/mm2.

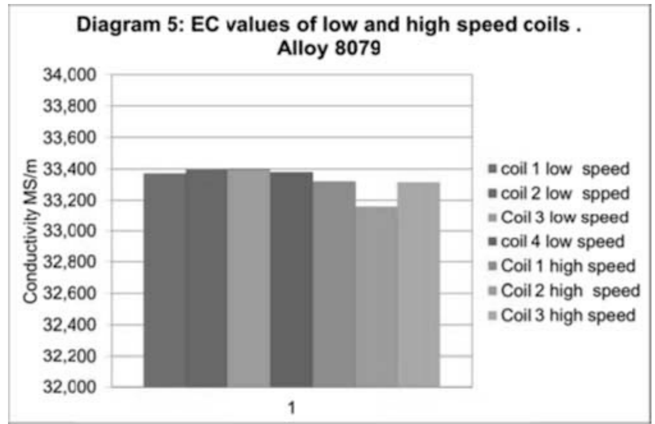


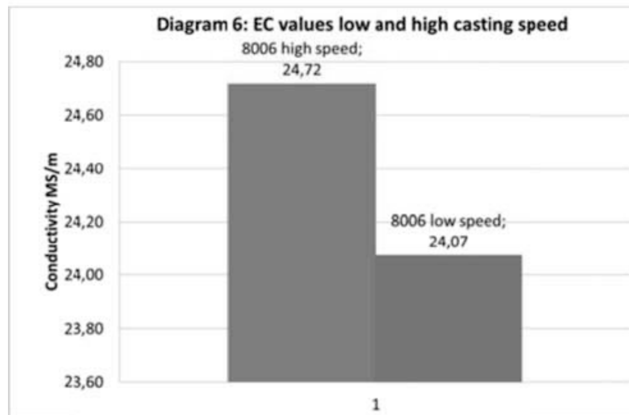


4. Electrical Conductivity data of low and high casting speed coils

Electrical conductivity (EC) measurements were carried out on both as-cast strips' rolling faces (Diagram 1-2). EC is a material property directly related with the amount of alloying elements in solid solution. In general, increasing the amount of alloying element in the solid solution reduces the metal's EC, but each element affects EC uniquely. It is well known in the industry that increasing Mn in solution significantly decreases EC.

In the case of the alloy 8079 that doesn't contain Mn, EC measurements did not show a significant difference between high and low casting speed coils. However, in the case of 8006 alloy, a significant difference in the EC measurement is observed with the high speed coil having higher conductivity relative to the low casting speed coil. This strongly suggests the low speed coil has a more Mn in solid solution relative to the high casting speed coil.





5. Metallography study of the as-cast strips

Cast strip cross sections parallel to the casting direction were metallographically prepared for grain structure study under the light optical microscope. A surface layer of recrystallized fine grains is observed in the highly sheared zone of the as-cast strip for both alloys and casting speeds (Fig 1-4).

The fraction of recrystallized grains near the surface is almost the same for each alloy and for the high and low casting speed.
The as-cast grains in the mid thickness of strip were similar between low and high casting speed coils due to the same quantity of grain refiner addition in all the castings trials (Fig 5-Fig 8).

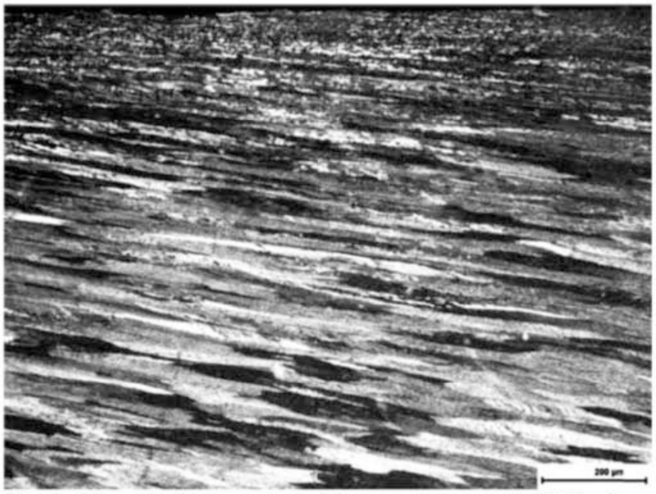


Fig 1: Near surface grains of low casting speed 8006 alloy strip. Barker's etch & cross polarizer illumination.

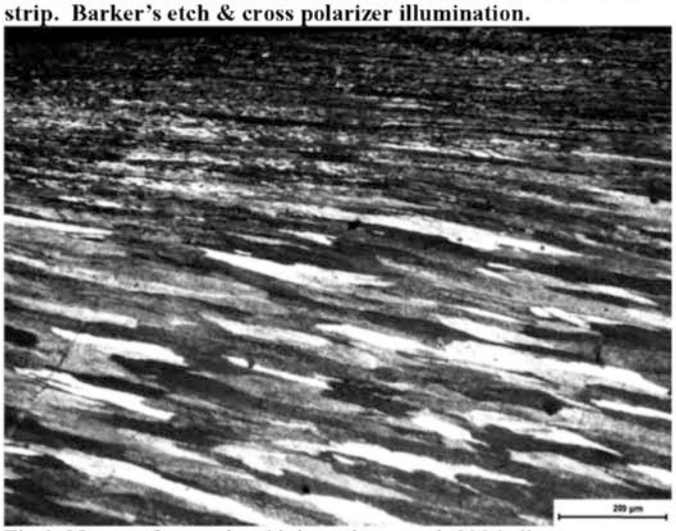


Fig 2: Near surface grains, high casting speed, 8006 alloy.

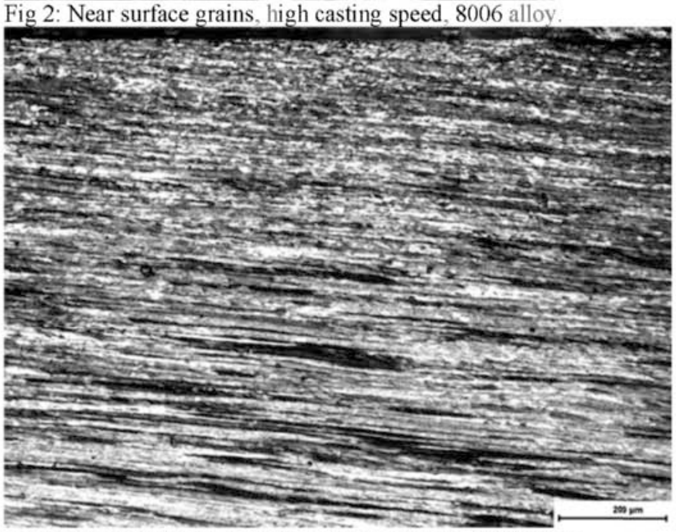


Fig 3: Near surface grains, low casting speed, 8079 alloy.

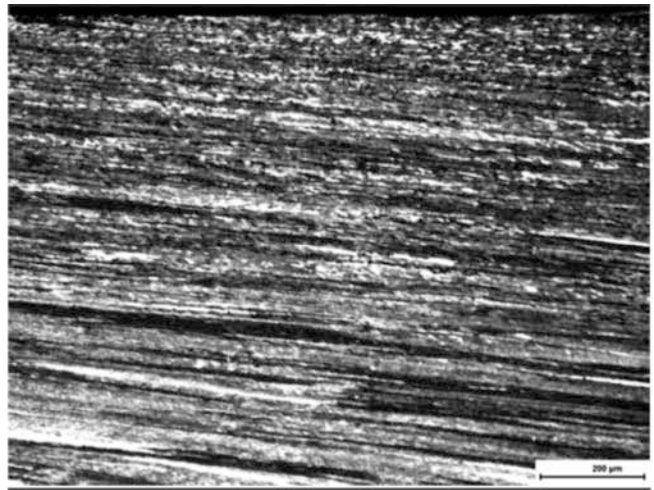


Fig 4: Near surface grains, high casting speed, 8079 alloy.

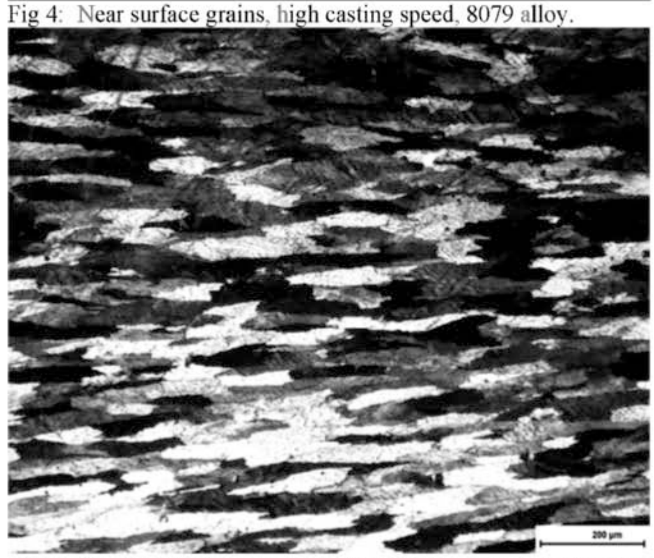


Figure 5: Mid thickness grains, low casting speed, 8079 alloy.

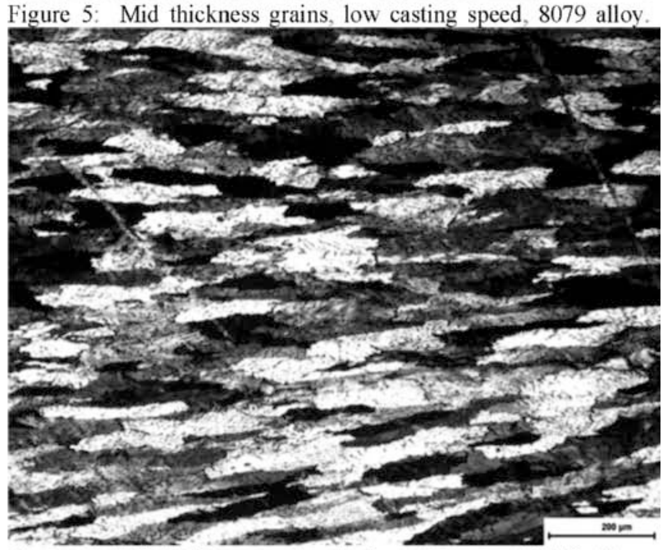


Figure 6: Mid thickness grains, high casting speed, 8079 alloy.

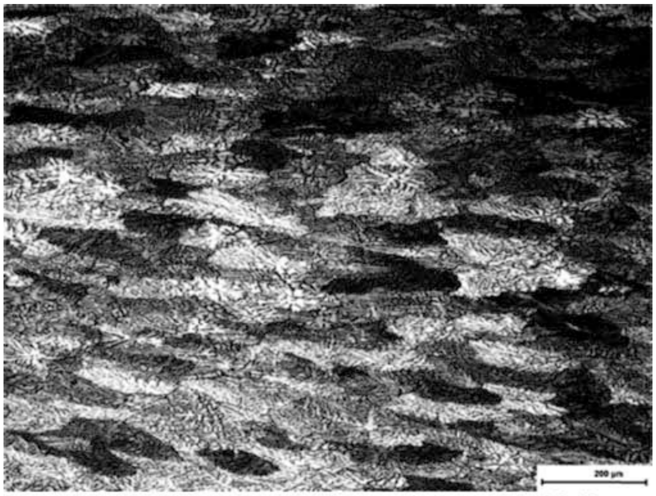


Figure 7: Mid thickness grains, low casting speed, 8006 alloy.

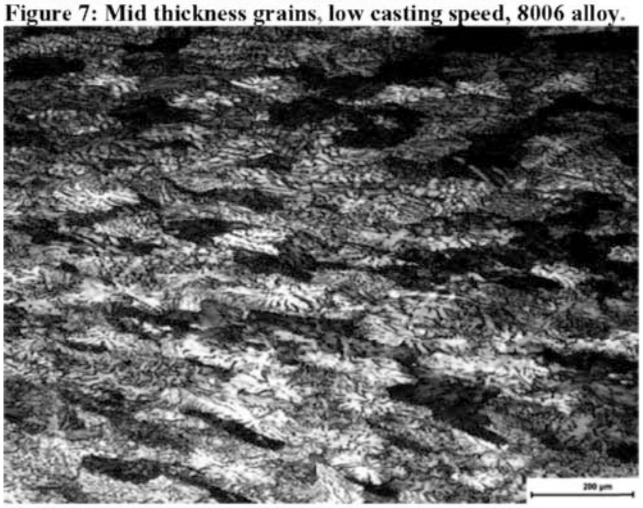


Figure 8: Mid thickness grains, high casting speed, 8006 alloy.

6. Summary and Conclusions

Both alloys 8079 and 8006 exhibits higher hardness and higher yield strength of the as cast gauge strip when the casting speed is reduced.

Diagram 7 data [2] shows the correlation of slab (strip) exit temperature and the casting speed for several alloys.
Caster's speed reduction results in a lower exit temperature of the strip.
At the same time, the caster strip speed reduction cause an increase of the surface shearing forces and the induced deformation in the hot rolling zone of the caster as it is illustrated in diagram 8 [3].

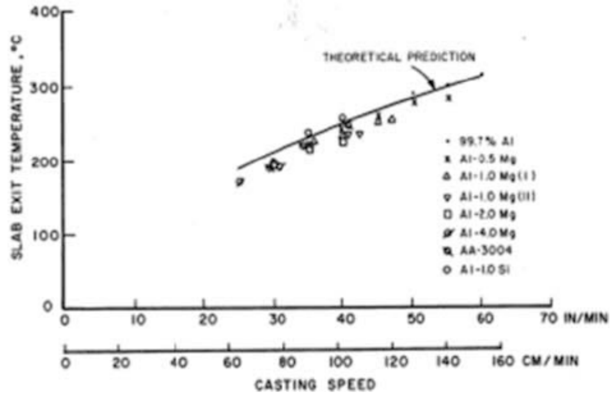


Diagram 7: strip exit temperature (slab) versus casting speed for several aluminum alloys [2]

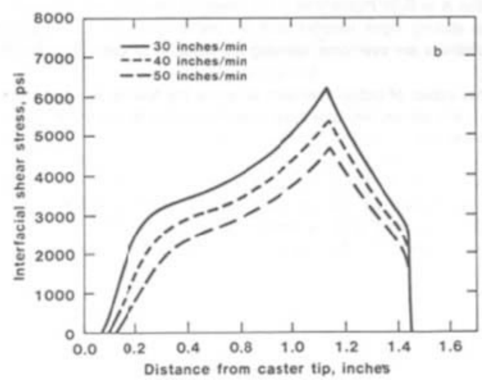


Diagram 8: Interfacial shear force for different casting speeds [3]

The hardness and mechanical properties of the as cast strip is the outcome of the balance between the hardening and the softening mechanisms occurred in twin roll casting [4].

The recovery or recrystallization softening mechanism is activated when the strip exit temperature is increased. The major metal hardening mechanisms in twin roll casting can be a combination of solid solution hardening and deformation hardening of the material in the caster rolling zone.

The metallography grain structure study of the as cast strips lead to the conclusion that recrystallization softening mechanism has no significant contribution in the differences of hardness and mechanical properties between low and high casting speed coils for both alloys.

In the case of 8006 alloy, the electrical conductivity values shows that the low casting speed results in higher amount of Mn dissolve in solid solution. So the increased hardness and yield strength of the low casting speed 8006 coil could be caused by a combination of solid solution hardening, reduced recovery due to the low exit temperature and increased shearing deformation hardening due to the lower speed.

In the case of 8079 alloy, there is no significant difference in Electrical Conductivity measurements between low and high speed 8079 coils. Iron solid solubility in aluminum alloys is very small and therefore even a significant change in casting speed did

not change significantly the amount of iron trapped in solid solution and the corresponding EC values.
Also, iron is not a potent solid solution strengthener for the aluminum alloys due to its very low solid solubility. Increase of yield strength has a linear relationship with $C^{2/3}$, where C is the solid solute concentration [5].

Therefore, solid solution strengthening is not the mechanism which contributes to the mechanical properties variation of 8079 alloy. We believe the low exit temperature of the low casting speed 8079 coils reduce recovery softening of the coiled material and the low strip speed increase the shearing hot/warm deformation hardening of the metal

Acknowledgments.

The authors would like to express their acknowledgment to Mr. Andreas Mavroudis ELVAL SA Technology Director and Mr. Bogos Giakoupian ELVAL SA Depute General Director for their approval to present the paper's data. In addition, the authors would like to thank Steven W. Ping for reviewing the manuscript.

References

[1]. ASTM E 384. Standard test method for micro indentation Hardness of materials

[2]. Rolling aspect of twin roll casting. B.Iricibar and I. Jin. Alcan international Limited. Kingston Laboratories Light metal TMS 1984

[3]. Continuous Casting of aluminium alloys. TMS 1988. T. Kattamis and others

[4]. Microstructure and texture assessment of Al-Mn-Si (3003) aluminium alloy produced by continuous and semicontinious casting process.J.PMartins. A.I.M Carvalho,A.F.Padiha. Journal of material science 2009.

[5] Physical Metallurgy. Robert Kahn. Peter Hassen. 1996. Elsevier. Science