

MICROSTRUCTURE AND FORMABILITY DEVELOPMENT IN AL STRIP CASTING FOR THIN GAUGE FOIL PRODUCTION

VARUŽAN KEVORKIJAN¹, ANTON SMOLEJ², MIRKO DOBERŠEK³,
MARJANA LAŽETA⁴, EDVARD SLAČEK⁴, LADISLAV KOSEC²,
BOŽIDAR ŠARLER⁵, MATJAŽ TORKAR³, ROBERT SKRBINEK⁴,
ALEKSANDRA ROBIČ⁴, ANDREJ KOLMANIČ⁴, MILICA PŠENIČNIK⁴,
LEONIDA KOČEVAR⁴, ALOJZ KEGL⁴ AND JOŽEF PLETERSKI⁴

¹Independent Reseracher, Maribor, Slovenia, varuzan.kevorkijan@siol.net,
²University of Ljubljana, Faculty of Natural Sciences and Technology, Department of
Materials and Metallurgy, Ljubljana, Slovenia, ³Institute of Metals and Technology,
Ljubljana, Slovenia, ⁴Impol d.d., Slovenska Bistrica, Slovenia, ⁵Nova Gorica
Polytechnic, Laboratory for Multiphase Processes, Nova Gorica, Slovenia

ABSTRACT

In this study, the optimal composition and the process parameters of continuous casting, which make it possible to use the strip as raw material for producing sheet and insulation, converter and household foils of standard quality are presented.

Key words: continuous casting of Al strips, production of foil stock and foils, tailoring of microstructure, composition and formability of strips

INTRODUCTION

One of the goals of Impol rolling modernization program is to focus production on making converting, household and insulation foils. Foil is a high added-value product if manufactured from in-house raw material^{1,2}. That is why Impol has opted for foil production based on 6 mm thin cast strips with broad widths (from 900 to 1700 mm) as raw material.

The basic challenges that IMPOL wishes to deal with in the proposed project are the mastering new technology, use of continuous cast strip for making high-quality foil and broadening its marketing possibilities with final products of new quality.

At this stage of the new technology implementation and restructuring of the roll casting programme it was realised that it would be absolutely essential (i) *to develop and master new knowledge in the field of developing cast strip properties* (roughness, oxide impurities and such); (ii) *to modified chemical composition of alloys for continuous casting and to unified various alloys into a few suitable for continuous casting, without affecting the properties of final products*, which is extremely challenging in terms of technology; (iii) *to develop the microstructure, phase composition and formability of cast strip as well as final products* (firstly 8-10 µm gauge insulating, converter and household foils); and (iv) *to continue development of new products/applications from cast strip*.

The introduction of continuous casting of thin aluminium strip based on AA 1050 and AA 8011 causes a fundamental change in the microstructure and therefore physical and chemical properties of the material when compared to conventional working of DC or semi-continuous cast slabs³⁻⁷.

During water-cooled rolling, due to the increased speed of crystallization, and simultaneous hot rolling in semi-solid state, the α solid solution is strongly supersaturated and non-equilibrium intermetallic phases Al_mFe and $Al_xFe_ySi_z$ are precipitated. The composition, distribution, size, shape and fraction of the microstructural constituents have a crucial effect on the formability of these alloys and the final quality of foil. The presence of fine-grain equi oxide in the metal at the strip surface, the size and orientation solidification grains and the central segregations all affect grain size and macroporosity^{3, 5}. Diffusion processes during crystallization and relaxation processes, i.e. the possibility of dislocation sliding during cold working, are much slower for continuous cast thin strip.

Understanding how the interrelationship between important alloying as well as trace elements (Si, Fe, Mn, Cr, Zn, Ti) in the based aluminium space lattice affects their solubility makes it possible to change and optimize the chemical composition of aluminium alloys 1050 and 8011, achieving in that way the standard and comparable quality of foil stock suitable for further downstream processing.

The project objective was to understand the processes and determine the evolution of microstructure of rapidly solidifying aluminium alloys (1050 and 8011) cast in Impol's new caster, in order to enable faster development and implementation of new alloys with the aim of expanding the range of products made from continuous cast thin strip. By knowing the effect of continuous casting process parameters, by optimizing and unifying alloys and understanding thermomechanical processes we can expect to be able to change sufficiently the microstructure, chemical composition of the existing phases and thereby the technological properties and quality level of foil made from continuous cast strip in such a way as to get a favourable response in the market. The new knowledge gained about the material will furthermore serve as a basis for describing foil properties and their comparison with foil made from hot-rolled strip manufactured from conventional semi-continuously cast slabs.

EXPERIMENTAL PROCEDURES

The R&D activities are made of two main parts:

- *Strip production on caster, and*
- *Foil production from caster strip*

Strip production on twin roll caster. Activities were divided into four phases, each phase corresponding to one of the casting widths of IMPOL production program (1050, 1150, 1600 and 1700 mm). Each phase covers: casting parameter definition, developing casting operator ability and autonomy to produce under stable casting conditions, improving cast strip geometry (longitudinal gauge variations over the coil length below +/-2%, longitudinal gauge variations over one roll revolution below +/-1%, cross profile between 0 and 1%, tilting between two edges limited to 1%), and improving cast strip surface quality, taking into account the feedback from the rolling mill regarding the end products (foil production). Casting parameters were defined for various widths, alloys and roll cambers.

Foil production from caster strip. For the whole foil production program (final gauge from 0,006 to 0,100 mm), some representative final thickness and widths were chosen. The suitability of the technological procedures for all foils in the thickness range from 0,006 to 0,100 mm was assessed based on the approval of the technology and process for foil production and on the approval of quality by customers for the chosen

representative final thickness and width. Approval of cast strip quality and technology / process for foil production was also performed for all chosen widths using alloys AA 1050, AA 1200, AA 8011 and AA 8079.

RESULTS AND DISCUSSION

As-cast microstructure of strips. As-cast microstructure of strips was monitored in the longitudinal and the transverse cross section at the mid-width (Fig. 1) as well as at the mid-thickness (Fig.2) of the coils AA 1200. It has been shown that selected casting parameters result in the production of a cast strip of good quality, with especially: very fine microstructure, typical of strip casting at 6 mm with adequate grain refiner addition, small centerline segregation, similar to that in the cast strip of competitors, no hard phases (that could lead to porosity problems), and no surface segregations.

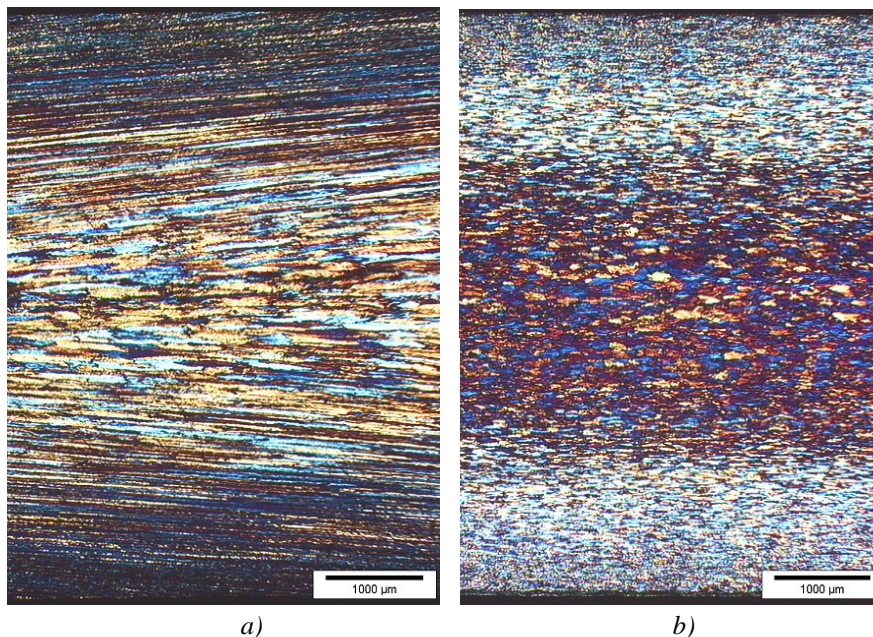


Fig.1. As-cast microstructure observation: (a) in the longitudinal and (b) in the transverse cross section at the mid-width of the AA 1200 coil.

Foil production. Fabrication schedules through to the 8-9 μm gauge have been developed for the downstream processing of strips of AA 1050, AA 1200, AA 8011, AA 8079 and AA 8006. These schedules were field tested during industrial trials at Impol Rolling Mill, where foils are produced from both hot rolled foil stock and as cast strips.

Trials with AA 1050 alloy for insulation foil products (final gauge 70 μm). The main results are:

- 1st trial: non proper strip surface aspect with longitudinal lines,
- 2nd trial: acceptable strip surface aspect, similar to hot rolled material,
- 3rd trial: acceptable strip surface aspect, similar to hot rolled material.

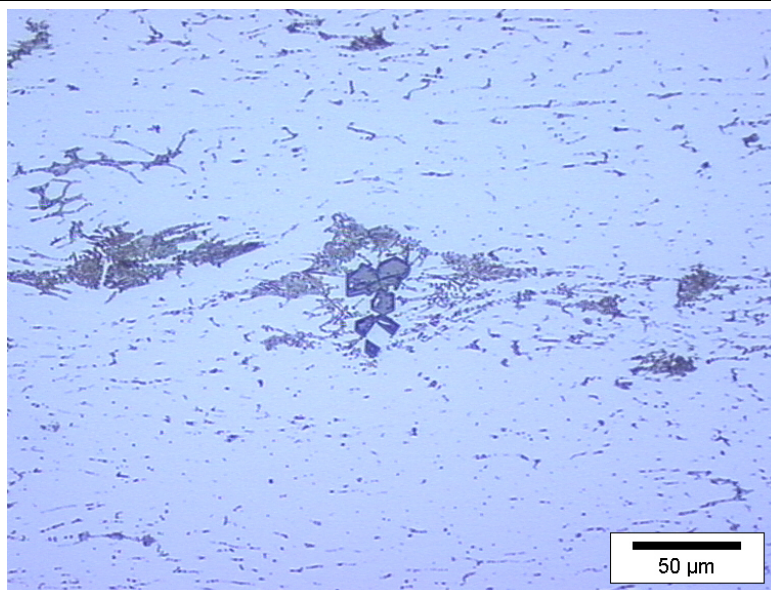


Fig. 2. As-cast microstructure at the mid-thickness of the coil AA 1200.

It has been identified that the poor surface aspect obtained with the coils of 1st trial was mainly due to a large as-cast grain size as-cast due to the insufficient addition of grain refiner (large feathery grains were observed at the strip mid-thickness). This has been solved during the 2nd and especially the 3rd trial by increasing the grain refiner addition from 1 to 1.6 kg/t-3 kg/t.

Trials with AA 1200 and AA 8011 alloys for foil products (final gauge 8 μm).

Surface quality of the mat side at the final gauge was the most important parameter to be controlled.

A correlation between the surface aspect of the mat side and the grain size of the foil was found. This quality evaluation was also done at 0.6 mm OH after intermediate annealing and the correlation has been found to be the same.

The results obtained could be summarized as follows:

- The foil from reference caster material has the finest grain size at the final gauge and after intermediate annealing
- Regarding AA 1200 alloy, the foil with Fe/Si ratio 1:1 from the 2nd trial the grain size was small both, at the final gauge and after intermediate annealing (without any large surface grains). The grain size was however, slightly larger than in the foil from reference caster material. The foil with Fe/Si ratio 2:1 from the 2nd trial has larger grains at the final gauge and large surface grains are observed after intermediate annealing. The foil with Fe/Si ratio 2:1 from the 1st trial has numerous large grains both at the final gauge and after intermediate annealing.
- In case of AA 8011 alloy, the foil from the 2nd trial has a slightly larger grain size at the final gauge than the foil from the 1st trial. The material from the 2nd trial also has a few large surface grains after intermediate annealing

It was found that the Fe/Si ratio 1:1 (the same ratio as in the reference caster material) for foils made from AA 1200 alloy is giving better surface quality of the final product. In addition, the increased grain-refining rate was the key of the improved mat side surface aspect in the 2nd and 3rd trials.

Taking into account the foils from AA 8011 alloy, the slightly lower mat side quality of the 2nd and 3rd trials compared to the 1st trial may be due to the higher casting speed. A possible explanation is that casting speed is affecting the solidification front, the segregation regime of the alloying elements, and therefore the distribution of the recrystallization nuclei.

Suitability of IMPOL caster material for foil downstream processing.

- **Isolation foil (70 µm):** Alloy 1050 is suitable for the production of isolation foil, using IMPOL standard processing route (no homogenizing). The quality obtained (especially surface aspect) is comparable to that of the hot rolled material.
- **Technical foil:** Alloy 1050 is suitable for the production of technical foil, using IMPOL standard processing route.
- **Household foil (10 µm):** Alloy 8011 processed through IMPOL standard route is suitable for the production of household foil
- **Converter foil (8 to 10 µm):** Alloys 1200 and 8011 processed through a route with homogenizing are suitable for the production of converter foil.
- **Blister foil (about 20 µm):** For this specific case, thermostability is a key property. For alloys 1200 and 8011 processed through IMPOL standard route, the thermostability is within the specifications. Depending on the surface quality requirements, a specific processing route will probably have to be defined for this foil product
- **Porosity (general comment for all foils):** Porosity from IMPOL caster material is usually of low level, well within the specifications, except in some cases. A sufficient proportion of ingots must always be used in the furnace charge (at least 50 to 70%) for coils production and filtration of a molten metal could be increased.

CONCLUSION

- Complete casting parameters for strip production on Jumbo 3CM Impol caster were defined and approved for alloys: AA 1050, AA 1200, AA 8011, AA 8079.
- Various strip downstream processing routes for foil stock and foils production were tested on the level of industrial trials.
- Based on this, several process modifications were introduced resulting in significant quality improvements of as-cast strip, foil stock and foils.
- Insulation, converter and household foils of standard quality in gauge between 8-70 µm were produced and foil production technology for these target products was successfully implemented.
- An ambitious program of thin gauge 6,35 µm foil production development is planned for the months to come, which will allow Impol to meet even more closely the customers needs.

REFERENCES

- [1] CRU Aluminium Research Group, Continuous casting of aluminium sheet, CRU International Ltd., London, 2000
- [2] B. Taraglio and C. Romanowski, *Thin gauge/high-speed roll casting technology for foil production*, in J. Evans (ed.), Light Metals 1995, TMS (1995) 1165
- [3] O. Daaland, A. B. Espedal, M. L. Nedreberg, I. Alvestad, *Thin gauge twin-roll casting, process capabilities and product quality*, in R. Huglen (ed.), Light Metals 1997, TMS (1997) 745
- [4] M. Gupta, D. P. Cook, J. Sahai, *Strip casting of aluminium using twin roll casters*, in C. E. Eckert (ed.), Light Metals 1999, TMS (1999) 925
- [5] S. Ertan, M. Dundar, Y. Birol, K. Sariogly, E. Ozden, A. S. Akkurt, G. Yildizbayrak, S. Hamer, C. Romanowski, *The effect of casting parameters on twin roll cast strip microstructure*, in R. D. Peterson (ed.), Light Metals 2000, TMS (2000) 667
- [6] C. A. Santos, J. A. Spim Jr., A. Garcia, J. Mater.Process. Technol., 102 (2000) 33
- [7] D. S. Kim, W. S. Kim, A. V. Kuznetsov, A, 41 (2002) 1