THIN GAUGE TWIN-ROLL CASTING,
PROCESS CAPABILITIES AND PRODUCT QUALITY

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Abstract
Traditionally industrial twin roll casters have been operated at gauges 6 - 10 mm, depending on the type of caster and the final product requirements. Over the past few years it has become apparent that a significant increase in productivity can be achieved when the casting gauge is reduced. Hydro Aluminium embarked on an extensive research and development, thin gauge casting programme, in the beginning of the 1990's and this paper presents some results from a five year lasting project (joint programme between Hydro Aluminium a.s. and Lauener Engineering). Based on more than 400 casting trials the major benefits and limitations of casting at reduced gauge and increased speed are outlined. Important aspects related to process development and product quality are discussed including: productivity and limitations, surface defects, microstructural characteristics, cooling rates and dendrite structure, segregation behaviour and mechanical properties after thermo-mechanical processing. Results for casting of several alloys are given. Additionally, numerical modelling results of the strip casting process are included.

Introduction
As twin roll casting combines solidification and hot rolling into a single operation, the process in general requires low capital investments and low operational costs compared with the traditional DC ingot and hot rolling route. Both mathematical model calculations and tests on laboratory installation have shown that twin roll casters operated at gauges 6 - 10 mm, are far away from the theoretical limitations and the productivity can be increased by casting at thinner gauges. The results presented in this paper are based on the outcome of an extensive five year lasting research and development programme focusing on all relevant aspects of thin strip casting. The programme has been driven by the following expectations:

- Increased output
- Reduced operational cost (incl. less subsequent rolling passes)
- Property improvements, with respect to:
  - surface quality/level lines
  - centre line segregation
  - geometrical tolerances
- Wider alloy range (increased solidification rate)
- New products

Some preliminary results of the research programme have been published in a previous paper /1/.

Pilot caster line
Most of the results reported in this paper have been obtained by casting trials on a pilot caster line, designed and built by Lauener Engineering, but located at Hydro Aluminium, Karmøy - Norway. The pilot line allows tests under real production conditions. During a five year period over 400 full scale casting trials have been performed. The main features of the casting line are:

- 13 ton melting/holding furnace
- Filter unit; gas flotation and particle filtration
- Strip caster;
  - 800 mm wide caster stand
  - Separating force capability: max. 4000 kN
  - Hydraulic thickness regulation
  - Automatic process-control unit
- Pinch roll unit
- Shear and Coiler

Productivity and process-limitations
Thin strip casting - present status
Within the five year timeframe of the research and development programme, thin gauge strip casting technology has been developed for casting down to 3 mm strip thickness. For alloy AA3003, a qualification test including 3 x 6 hours stable casting and full strip width is accomplished at a productivity of 1.65 kgs/hours/mm. Maximum productivity, 2.0 kgs/hour/mm, is documented for 3 mm strip thickness with reduced casting width due to separating force limitation of the pilot caster. The results are illustrated in Figure 1.

Calculations using a finite difference, 2D thermal model (assuming plane strain condition according to classical rolling theory) indicate scale effects in the range of 15 - 20 %, by increasing roll diameter from 540 mm up to 900 mm, see Figure 2. This implicates a productivity performance in the range of 2.3 - 2.4 kgs/h/mm.
The results from the thin strip casting programme have shown that the process still has a potential for improvements, beyond the successful achievements in the finalised programme. Process developments related to the release agent system in particular, should increase the possible exit temperature of the strip and thereby increase the productivity during casting. Thermal model calculations are given together with the experimentally obtained results in Figure 3. The present limitation of strip exit temperature is assumed to be close to 350°C. A temperature increase of 50°C is predicted to give approximately 20% higher productivity at 3 mm strip thickness. This implies casting with a deeper solidification front and less hot deformation of the strip material. The productivity increase must be counterbalanced considering the specific product requirements. Improvements with respect to the release agent system should make it possible to utilise the remaining roll shell cooling potential in casting at gauges down to 2 mm. Comparing model calculations (Texit=350°C) with the experimental results, the lower productivity performance indicates process lay-out limitations beyond the roll cooling capacity.

**Process stability and surface defects**

Casting of thinner strips seems to give more possibilities in controlling different types of quality deviations in the process, compared with casting of thicker strips. However, the probability of unstable reactions in the roll gap increases. Several types of thin gauge defects have been observed and they need to be controlled in order to produce a high quality strip. The critical interaction between the cast rolls and liquid metal is assumed to be mainly linked to the behaviour of the meniscus. In case of unstable meniscus, a surface pattern would be generated which would imply a potential quality problem depending on alloy and application. Thinner gauges and higher productivity will significantly increase roll speed, which in turn will have a major influence on the stability of the meniscus. Therefore, based on the speed difference between roll and average aluminium bulk at actual setback position, a quality factor, Q(meniscus), is established in order to express the strong relationship between strip surface quality and casting conditions. Geometrical aspects will give the relevant correlation as indicated:

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Q(\text{meniscus}) = f(\text{roll speed}, \text{roll diameter}, \text{set-back}, \text{strip-thickness}, \text{forward slip}, \ldots)
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