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# CONTINUOUS ROLL CASTING OF ALUMINIUM ALLOYS– CASTING PARAMETERS ANALYSIS

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Preliminary Note – Prethodno priopćenje

The main goal of the paper was to present the influence of casting parameters on casting conditions and interference of casting parameters on the final strip characteristics such as constant strip thickness, surface quality and roughness of aluminum alloys sheet 6,30 to 6,50 mm thick.
The study shows that casting speed, roll force and roll gap should have the greatest influence on the final strip thickness, and that the examined parameters agree well with the theoretical standpoints.

*Key words:* continuous roll casting, aluminum alloys, strip casting process, casting parameters

**Kontinuirano lijevanje aluminijskih slitina – analiza parametara lijevanja.** Temeljni cilj članka je prikazati utjecaj parametara lijevanja na uvjete lijevanja i njihov međusobni utjecaj na postizanje konstantne debljine trake, kvalitetu i ravnoću površine aluminijskih traka debljine 6,30 do 6,50 mm. Rezultati rada pokazuju da su glavne utjecajne veličine na debljinu trake brzina lijevanja, sila valjanja i razmak valjaka, što potvrđuju teorijske osnove.

*Ključne riječi:* kontinuirano lijevanje trake, aluminijske slitine, postupk lijevanja trake, parametri lijevanja

## INTRODUCTION

The continuous roll casting process (CRC), consisting of continuous strip casting between rolls, is now well known. It was introduced by the SCAL Company (Pechiney Ugine Kuhlmann Group) 60 years ago [1]. The process consists of solidifying aluminum or aluminum alloys between the water-cooled rolls of a duo rolling mill. From the moment when solidification is completed to the moment when the strip is no longer in contact with the rolls, aluminum is submitted to reduction leading to hot working which is essential for the final quality of the product [1, 2].

The cast strip is produced horizontally out of the caster and is directly coiled while it is still hot. The size of the coil is adapted to the cold rolling operation. The strip thickness ranges from 4 to 12 mm.

Figure 1 shows the principle of the CRC process [1-4].

In the aluminum continuous roll casting process (Figure 1), both solidification and deformation are completed in a narrow gap between a pair of opposite rotating rolls.

Therefore, the valid zone of this process is the solidification-deformation zone in the roll gap.

Conventional twin-roll casters for aluminum alloy have steel rolls, which have a separating force of

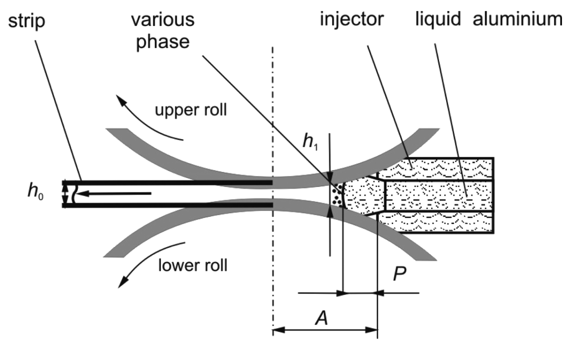


**Figure 1.** View details of solidification and rolling during the CRC procedure [1-4].

2,5-5·$10^3$ kN/mm. Lubricant is sprayed on the rolls to prevent the strip from sticking to the roll. The molten metal solidifies against the roll and is immediately hot-rolled into the solid strip [1, 2, 5, 6].

In order to produce flow disturbance in the aluminum melt at the solidification front, while keeping the stability of rheological interface, the configuration and parameters of this zone are determined through experiment and theoretical analysis.

The testing materials are Al99,2 (AA1235) and Al99,5 (AA8011) aluminum alloys. Their chemical composition measures up to the international deformation aluminum alloys standard. All these materials are able to form coarse crystals in the roll-casting process. The Al-Ti-B grain refiner in a form of wire was applied. This original process, attractive for its well-known operating simplicity was able to cast strips of about 1 to 2 m wide.

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## EXPERIMENTAL PROCEDURES

The present casting work was carried out using a horizontal twin roll caster designed and built by Pechiney, France [1,2]. Strip production in this facility was carried out by horizontal continuous casting process for aluminum casts between pairs of cooled and powered rolls. Working rolls affect rapid melt solidification (crystallization), as well as calibration solidified strip at the default strip thickness by means of hot rolling process.

Strip production process begins in melting furnace and ends at the strip coiler. For the purposes of cold rolling mills, this facility produces strip width from 1020 to 1520 mm, and thickness from 6,5 to 8 mm.

The roll diameter is 690 mm at the start, and working width of the roll is about 1740 mm. The metal is fed into the rolls by pouring the liquid metal in refractory tip. A tip setback (*the distance from the end of the tip to minimum roll separation*), of 35-55 mm has been selected depending on the casting configuration. The tip is narrower than the roll face width and soft side dams are used to prevent sideways flow of the liquid metal. The gap between the bearing chocks is controlled; the size of which can be changed during the course of a run. Typically, strip cast is 1200-1600 mm wide, and this allows a total load of $5 \cdot 10^3$ kN/mm (*kilo Newton per millimeter in strip width*) to be applied. Strip can be cast at rates from 0,95 to 1,50 cm/min and gauges varying from 5,25 to 5,45 mm. Each casting regime has been carried out with two different alloys Al99,2 (AA1235) and Al99,5 (AA8011). Casting conditions, for mentioned alloys, and strip dimensions are shown in Table 1, [7].

Table 1. **Strip casting parameters for the CRC plant and casting alloys Al99,5 (AA8011) and Al99,2 (AA1235) [7]**

| Strip dimension | Aluminum alloy | |
|---|---|---|
| | Al99,5<br>6,3x1200(x1520) | Al99,2<br>6,3x1200(x1520) |
| Contact angle/mm | 50 | 47 |
| Roll gap/mm | 5,2 | 5,2 |
| Temperature/°C | 685 ± 5 | 685 ± 5 |
| Strip speed/cm/min | 1,30 | 1,25 |
| Graphite/l | 2 l on 75 l water | 2 l on l water |
| Modifier/cm/min | 35 | 28 |

The amount of sprayed lubricant has been carefully controlled during the CRC cast. The rate of applications depends on roll speed, strip thickness and alloy composition.

Keeping in mind that the final quality characteristics are the main objective to fulfill, the materials selected for this study had to be produced at casting regime recommended by the industrial set up, usually at low casting speed. Evaluated average productivity was approximately $2{,}86 \cdot 10^6$ t/(m·h) (*tones per meter in strip width per hour*) for roll shell quality I and per one roll pair, and $3{,}13 \cdot 10^6$ t/(m·h) for roll shell quality II and per one roll pair [1-11].

Expected finite strip quality refers to its thickness, profile and flatness. The research work was focused on achieving the listed quality characteristics by changing the casting parameters in respect to the alloy composition, and the casting regime and finally comparing these parameters with each other [1-9].

## THE CONTINUOUS ROLL CASTING PROCEDURE ANALYSIS - STRIP PRODUCTION ON TWIN ROLL CASTER

During the period of production monitoring, related to this research, four types of working rolls were used $\mathbf{A_I}$, $\mathbf{B_I}$, $\mathbf{C_I}$ and $\mathbf{D_I}$ for steel shell quality I, and $\mathbf{A_{II}}$, $\mathbf{B_{II}}$, $\mathbf{C_{II}}$ and $\mathbf{D_{II}}$ for steel shell quality II. Each of the four types listed was used with six roll pairs marked by numbers 2, 3, 4, 5, 6 and 7.

The rolls marked by numbers 2, 3 and 4 have a steel shell grade of rolls CMYV (*roll shell quality I*), and rolls marked by numbers 5, 6 and 7 have a steel shell grade of rolls MO22 (*roll shell quality II*). Chemical composition of these two roll shells are shown in Table 2, [7, 8, 12, 14].

Table 2. **General roll shell data [7, 8, 12, 14]**

| Roll shell grade | Roll shell chemical composition | | | | | |
|---|---|---|---|---|---|---|
| | C | Mn | Ni | Cr | Mo | V |
| Rolls 2, 3 and 4 Steel shell grade I (CMYV) | 0,1 – 0,3 | 0,6 – 0,8 | - | 1,0 – 2,0 | 1,0 – 2,0 | 0,1 – 0,3 |
| Rolls 5, 6 and 7 Steel shell grade II (MO22) | 02 – 0,4 | 0,4 – 0,6 | 0,2 – 0,4 | 2,0 – 4,0 | 0,8 – 1,2 | 0,1 – 0,3 |

The activities were divided into four phases, with each phase corresponding to one of the casting width of aluminum plant production program (1050, 1150, 1600 and 1700 mm). Each phase covers the following: defining the casting parameters, developing the casting operator's ability and autonomy to produce material under stable casting conditions, improving the cast strips 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 the cast strip surface quality, taking into account the feedback from the rolling mill regarding the end products (*foil production*).

## RESULT AND DISCUSSION – PARAMETERS ANALYSIS

The analysis of parameters was conducted in a steady state casting process, but for better understanding of the procedure it was necessary to specify the start of rolling. Based on different rolls quality (*steel shell grades of rolls*), and respect for roll-generation technology needs, the influence of the following mutually dependent parameters was examined:

- The influence of the strip width both on the contact angle and rolling force (*for the default alloy, an appropriate roll shell quality and roll diameter*),
- The influence of the strip thickness on the mechanical roll camber, rolling force, roll gap, contact angle, casting speed (*comparison of two alloys observed -each with its strip thickness, for the appropriate roll shell quality, strip width and roll diameter*).

The analysis shows that the rolled strips produced with the individual roll pairs are grouped according to the diversity of their widths in classes up to 1000 mm, up to 1200 mm, up to 1400 mm and up to 1600 mm. Data for each of the analyzed alloys and used roll pairs were different. The mean values of the roll diameter, contact angle, rolling force at the entrance and at the exit from the roll were taken into account. Due to insufficient number of data for all used rolls, the analysis does not cover the results for the strip width of 1000 mm.

## INFLUENCE OF THE STRIP WIDTH ON THE CONTACT ANGLE

The influence of the strip width on the contact angle for both alloys was analysed on data according to the strip width and steel shell grades for all rolls. This summarized influence is graphically shown in Figure 2 [7].

It can be concluded that roll-casting process undergoes certain number of casting cycles. These cycles imply a new start of the process at smaller roll diameter from the previous one. Analyzing data and diagram on Figure 2, it can be concluded that every casting cycle is carried out from the greater width to the narrower. Every casting width decrease is followed by increase of contact angle. Besides, while casting with rolls with steel shell grade II (MO22) it is noticed that some lower average value of contact angle is achieved. Average value of contact angle was about 50 mm.

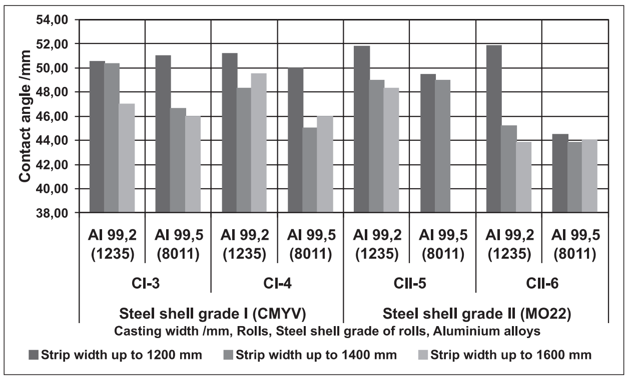


**Figure 2.** Influence of the strip width on the contact angle for the default alloys Al99,2 (AA1235) and Al99,5 (AA8011), and appropriate rolls with steel shell grade I (CMYV): $C_{I-3}$ and $C_{I-4}$ , and steel shell grade II (MO22): $C_{II-5}$ and $C_{II-6}$ [7]

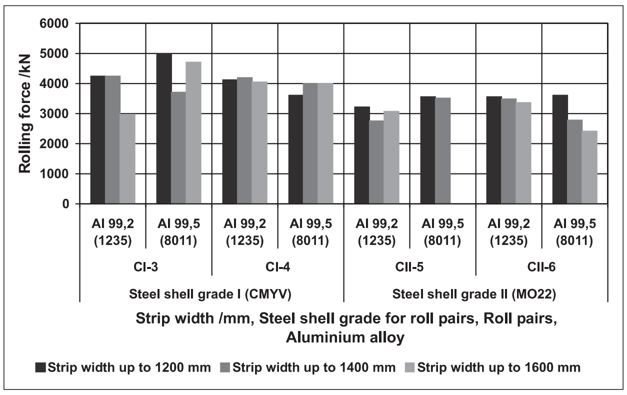


**Figure 3.** Influence of the strip width on the rolling force for the default alloys Al99,2 (AA1235) and Al99,5 (AA8011), and the corresponding roll pairs with steel shell grade I (CMYV): $C_{I-3}$ and $C_{I-4}$, and steel shell grade II (MO22): $C_{II-5}$ and $C_{II-6}$ [7]

## INFLUENCE OF THE STRIP WIDTH ON THE ROLLING FORCE

Figure 3, [7], shows a rolling force – strip width arithmetic means diagram with correlation to steel shell grade at the same roll-casting cycle and casting speed. The reduction in casting width is followed by rolling force increase. While casting with steel shell grade II (MO22) some lower rolling force values were noted. According to cast strip widths no significant differences in average rolling force values were noted.

## INFLUENCE OF THE STRIP THICKNESS ON THE CONTACT ANGLE AND ROLLING FORCE

The dependence of casting parameters on as cast strip thickness was analyzed. Figure 4, Š7Ć, shows the dependence of casting parameters for chosen roll pairs. The influence of strip thickness upon dependence of casting parameters on as cast alloy and steel shell grade shows the following:

Each strip thickness is associated with appropriate alloy, Al99,2 (AA1235) with strip 6,3 mm thick and Al99,5 (AA8011) with strip 6,5 mm thick. While casting strip thickness 6,3 mm and 6,5 mm with equal type of working rolls and equal steel shell grade, it can be noted that contact angle is greater while casting strip 6,3 mm thick. The same relation is valid while comparing steel shell grades, that is, greater contact angle can be noted while casting with steel shell grade I (CMYV) than with steel shell grade II (MO22).

Figure 5, [7], shows the influence of strip thickness on rolling force and roll shell quality for both alloys.

While casting strip 6,3 mm and 6,5 mm thick, with equal type of working rolls and the same steel shell grade, it is noted that rolling force is greater while casting strip 6,3 mm thick. The same relation is valid while comparing steel shell grades, that is, greater rolling force can be noted while casting with steel shell grade I (CMYV) than with steel shell grade II (MO22).

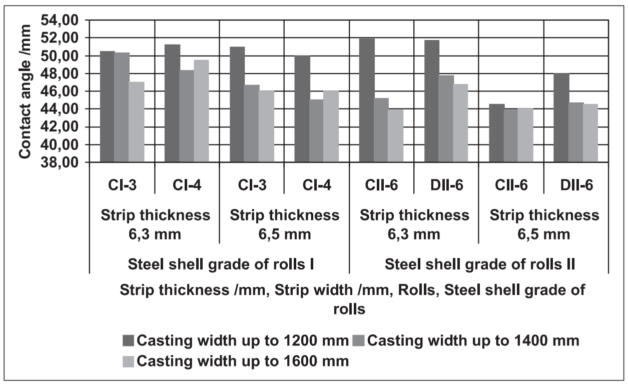


**Figure 4.** Influence of strip thickness and roll shell quality on contact angle for both alloys [7]

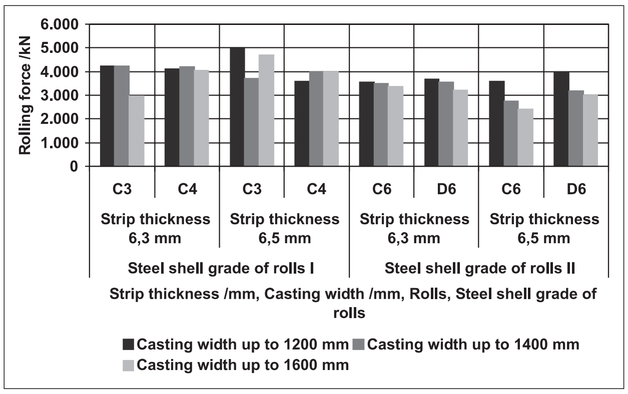


**Figure 5.** Influence of strip thickness and roll shell quality on rolling force for both alloys [7]

## CONCLUSION

The roll casting producers include such rolling and cast conditions which depend on a large number of parameters. These parameters may be divided into two broad classes, those that depend on the material and those that are determined by the process. When roll casting is considered, the letter includes the temperature, the rolling speed, the lubrication conditions, the rolling force, the roll diameter, the roll gap, the contact angle, etc. Some of these parameters were the concern of the present study.

The analysis of casting parameters proves the complexity of the problems of CRC procedure. Resolution of this issue involves melt quality preparation using the following:

- quality charge assurance in melting furnace;
- ensuring melt homogeneity by chemical composition and the entry temperature;
- microstructures insurance;
- ensuring melt purity.

As a result, quality cast includes:

- casting insurance at temperatures as close to liquidus line;
- ensuring high levels of melt in storage tank;
- lower casting speed insurance;
- nozzle geometry insurance control;
- providing good heat conduction between the melt and roll shell and toward the cooling media.

Optimal choice of each parameter individually and of all together to achieve maximum productivity is not possible without knowledge of the manufacturers' references and of equipment users experiences.

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**Note**: This paper was proofread by Jasmin Eleonor Vukelja, Professor of English and Italian language Zagreb, Croatia