# Contribution to the improvement of the quality of continuous casting steels at Sider El-Hadjar-Annaba

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**ABSTRACT:**

Continuous casting is the process between steel making and rolling. It consists of turning liquid steel into slabs, blooms, or billets. The molten steel comes into contact with the mold, it will solidify and the first phases of the steel will form. This study confirms the need to check the steel quality and the continuous casting parameters such as; casting speed, extraction rate, oscillation of the mold and lubrication during primary cooling. The main objective is to build a thermal model that is an important task for predicting temperature profiles on different sides and edges of the product, in order to optimize the crust of steel.

**Keywords**: continuous casting - steel - mold - primary cooling – slab.

## 1. INTRODUCTION:

Continuous casting of slabs is a widespread steelmaking process. It occupies an important place in the production chain because of the advantages over the traditional ingot casting technique, such as: energy saving, labor, better performance and product quality. The trend of research today is oriented towards a generalized modeling of the process [1].

We have followed the most important parameters of mold solidification which are: heat transfer, oscillation and lubrication. Other parameters are also involved, including the steel composition the mold characteristics (geometry, construction).

The main objective of this work is the quality control of continuous cast steel slabs. For this purpose and during the production of the slab, at the outlet of the mold to the oxycutting zone, there appears a defect of creeks of banks which has adverse effects on the finished product. This problem requires the development of a thermal model of the strand contact and the mold during primary cooling.

## 2. Principle of continuous casting:

Continuous casting is a process of solidification of the molten metal. It consists of filling the liquid metal in a bottomless mold, then slowly extracting the product from the mold while the latter is, in some cases, still liquid at heart. The extraction of the solidified product is compensated by a supply of hot liquid metal: the liquid metal between one sides of the mold while the other side out a solid product (Fig.1) [2].

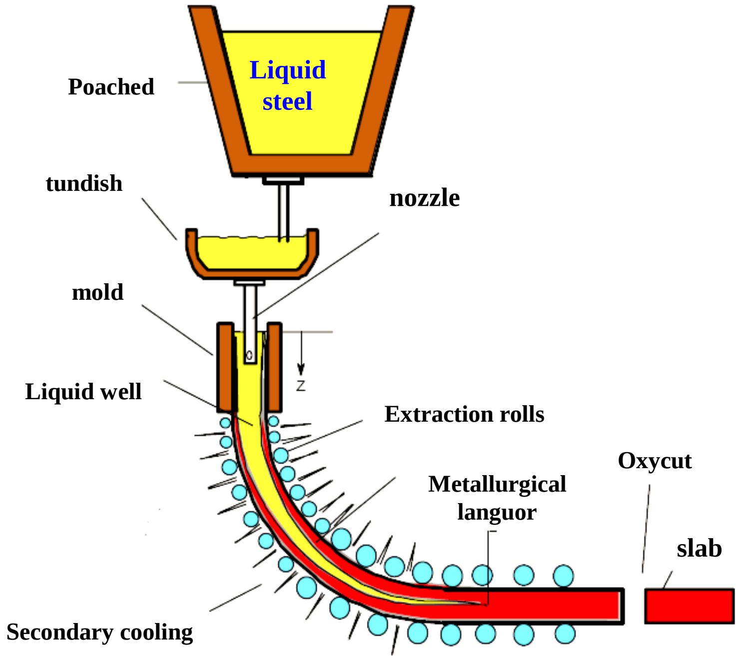


**Fig 1:** Principle of continuous casting. [2]

### 3. Solidification in the mold:

The main function of the mold is to form a solid crust of sufficient thickness to eliminate the risk of breakout; it is also important that the crust thus formed does not give rise to surface or subcutaneous defects. The most important parameters of mold solidification are heat transfer, oscillation and lubrication [3].

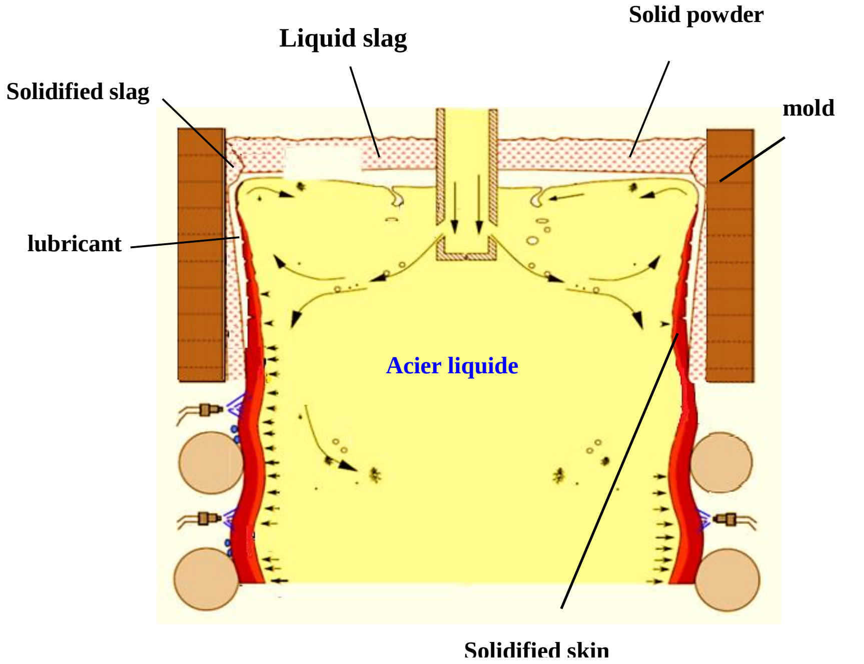


**Fig 2:** Formation of the solid skin in the primary cooling [4].

## 4. Crystallization of powder from the casting:


**Fig 3**: Crystallization of the powder in continuous casting [5].

## 5. Experimental data of continuous slab casting:

**Tab1:** Physical properties of continuous casting of the slab.

| **Caractéristiques** | **Données** |
|---|---|
| Density ρ in the liquid state (g/cm$^{3)}$ | 7 |
| Tf melting temperature (°C) | 1536,6 |
| Temperature of the casting (°C) | 1520 |
| Speed of the casting (m/min) | 1 and 0,8 |
| Extraction speed (m/min.) | 1,5 |
| Primary cooling rate (m$^3$/ h) | 360 |
| Depth of meniscus (mm) | 200 |

## 6. Thermal model:

### 6.1. Hypotheses:

- The heat transfer between the solid skin and the liquid phase is done by convection.
- No contact between the walls of the mold and the solid skin so friction is low.
- One-dimensional heat exchange is assumed along axis OX and in casting direction OY is neglected = 0.

### 6.2. Basic equations:

- The transfer is done by convection so calculation formula is given as follows [6]:

$$\phi_{conv} = h_{conv}(T_{moul} - T_{fluid}) \quad (1)$$

- The transfer coefficient depends on the nature of the wall between the two media, $T_{moul}$ and $T_{fluid}$ temperatures of the media that exchange [6] :

$$h = \frac{\phi}{T_{moul} - T_{fluid}} \tag{2}$$

where,
T: The temperature [° c].
h: Coefficient of heat exchange [w / $m^2$. k].
Ø: Heat flow density [W.m-$^2$].

- The heat of fusion [6] :

$$\Delta H = \begin{cases} 0 & \text{si } T < T_{sol} \\ Lf_{liq} & \text{si } T_{sol} \leq T \leq T_{liq} \\ L & \text{si } T > T_{liq} \end{cases} \tag{3}$$

In the pasty state, we have $T_{sol} \leq T \leq T_{liq}$ so $\Delta H = Lf_{liq}$
where,
ΔH: The heat of fusion [j / kg].
liq: Liquid.
Sol: Solid.

- Liquid fraction [6] :

$$f_{liq} = \frac{T - T_{sol}}{T_{liq} - T_{sol}} \tag{4}$$

where $T_{sol}$ and $T_{liq}$ are the solidus and liquidus temperatures of the material.

## 7. Results and interpretations :

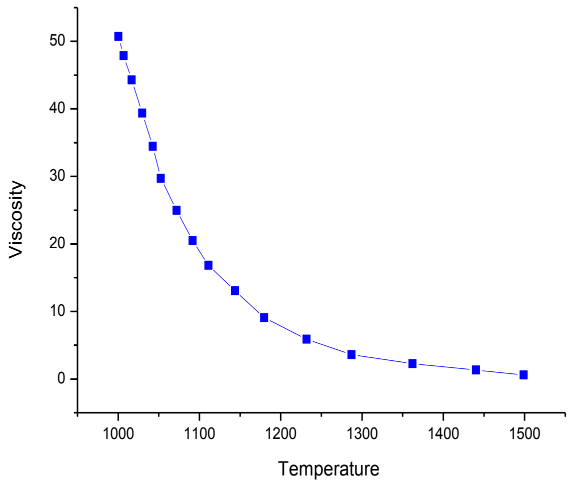


**Fig 4:** Powder viscosity

The powder of the continuous casting used in sider-Elhadjar varies homogeneously because of its low viscosity (Fig4). The casting temperature is optimal, which explains a good fluidity of the liquid steel in the mold as well as the absence of impurities in this powder.

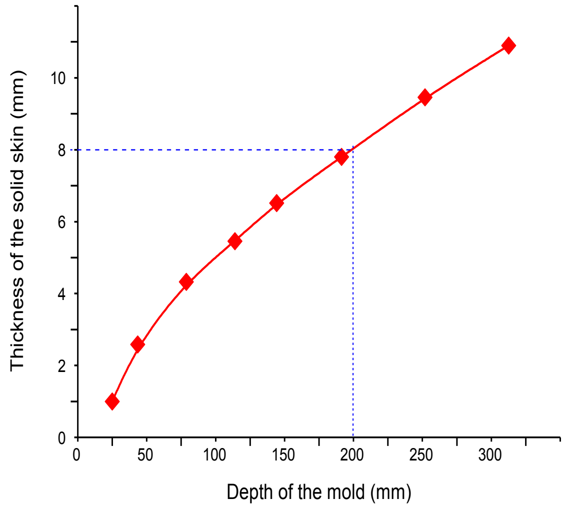


**Fig 5:** Thickness of the solidified skin

Fig. 5 illustrates the evolution of thickness of the solidified skin according to the depth of the slab. The obtained result determines the value of the thickness of the solidified skin which is 8 mm.

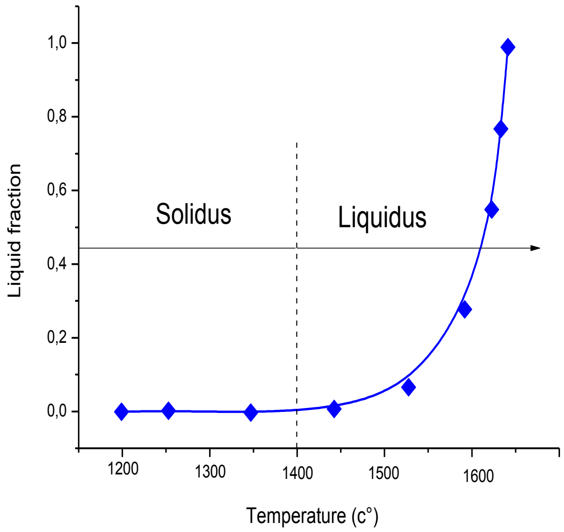


**Fig 6:** Liquid fraction.

Fig. 6 represents the curve of the liquid fraction according to the temperature. The observed deference is due to the difference between the liquidus and solidus temperatures of the steel.

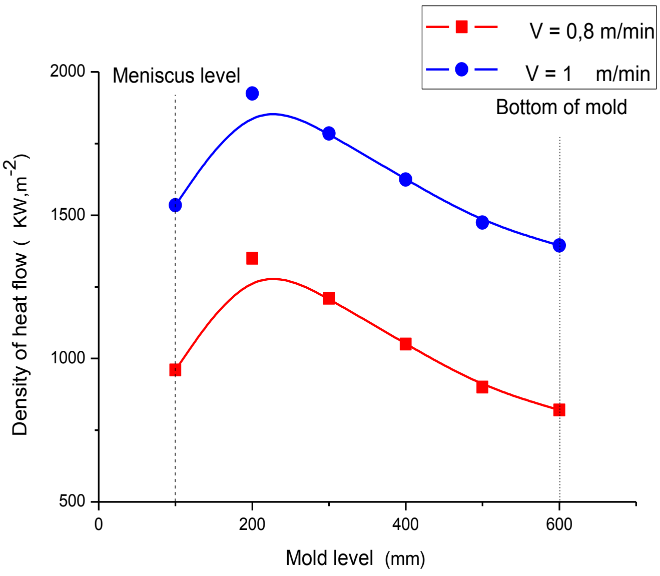


**Fig7:** Heat flow density versus distance to meniscus.

Fig. 7 shows the heat flow density versus distance to meniscus for casting speeds given in the table (1). From this figure, the thermal extraction in the mold is favored by a casting speed given in Table 1 higher; this curve further shows that the maximum heat flow (and therefore the highest temperature rise of the wall) is about 50 mm below the meniscus.

## 8. CONCLUSION:

During solidification, the solid skin in contact with the mold creates a release of heat and the appearance of friction forces. These forces can be large because of the lack of lubrication and very small to its presence.

To manage the heat transfer and the steel flow in the mold we propose the thermal model during the primary cooling of the mold.

Lubrication, which consists of a continuous casting powder, plays a very important role in the heat exchange in the mold and avoids the sticking of the steel on the walls of the mold. This study deals with the evolution of the powder viscosity according to the temperature during primary cooling and first phase formation of steel (solid skin), which explains why the lubrication has a good friction between the skin solid and the walls of the mold.

The lubricant used in the mold can have a significant influence on the thermal extraction. In the case of using powders, it may happen that the optimum conditions of lubrication (melting temperature and powder viscosity) do not coincide with the highest thermal extraction rates.

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