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EXPERIMENTAL RESEARCHES REGARDING ADDED OF MICRO-COOLERS AT CONTINUOUS CASTING STEEL

Ana SOCALICI, Teodor HEPUT, Erika ARDELEAN,
Marius ARDELEAN, Daniela MILOSTEAN
University Politehnica Timisoara, Faculty Engineering of Hunedoara
socalici_a@fih.upt.ro, heput@fih.upt.ro, erika_a@fih.upt.ro , marius_a@fih.upt.ro,
daniela.milostean@fih.upt.ro

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ABSTRACT

The work presents the results obtained from industrial experimentations made for quality improvement of the semi-finished continuously cast product. The researches emphasize how the additions of micro-coolers in the steel continuous casting crystallizer are influence of the solidification phenomenon of the semi-finished product continuously cast, type (270x240mm) bloom. The application of steel continuously casting technology with addition of micro-coolers in the crystallizer, don't presupposes major investments, is easy to adapt for any installation of steel continuous casting equipment.

1. GENERAL CONSIDERATIONS

The major issue of continuous casting is steel solidification, i.e. the possibility of achieving the (direct and indirect) cooling conditions, in order to allow the dissipation of the heat from the molten metal. The theoretical basis of continuous casting resides in the research and knowledge related to the conditions of solidification, which determine the cooling conditions according to the cross section and the chemical structure of the material, as well as some of the technological and constructive parameters of the installations (casting rate, number of strands, height and curve radius of the installation, etc.).

The solidification process during the continuous casting of steel can be explained as follows: at a first stage, a thin crust is quickly formed at the upper side of the tundish, the thickness of this crust increasing abruptly as a result of the direct contact between steel and the tundish walls, which are water cooled. At a short distance from the liquid meniscus, the solidified crust is cold enough to shrink, which eliminates the contact between the metal and the tundish, and because of the air layer between the metal and the tundish, the conditions of heat exchange grow worse, and the solidification rate diminishes. The solidification of the core, under the effect of secondary water cooling, triggers a great difference of temperature between the surface and the centre of the continuous cast semi-finished part. Further on, temperature turns even in the cross section of the completely solidified semi-finished part, due to the air cooling after the secondary cooling area, the heat in the core being transmitted towards the exterior, which leads to the cooling of the entire section in contact with the air [1].

The main specific characteristics of the steel, which highly influence its continuous casting are: the high casting temperature, the large amount of heat contained in the molten steel, the low thermal conductibility and diffusibility, the high rate of heat transfer by radiation in the liquid state and the high solidification rate. The ideal solution would be for the metal to reach the tundish at a time-constant temperature, slightly superior to the solidification temperature of the respective steel. This cannot be entirely achieved in practice, as the thermal losses during casting reach significant values, which imposes an overheating of the steel when smelting, granting a proper temperature all along the continuous casting process. Considering the specificity of the technological process, the temperature of the metal at the end of its elaboration is higher than in the case of ingot casting. [2]

Steel temperature at various stages of the technological process depends on the following factors: steel quality (the liquidus and solidus temperatures), the size of the charge and the location of the casting shed within the technological flow (which determines the heat loss of the metal in the ladle, until it is positioned above the continuous casting machine).

The main method that can reduce steel overheating inside the tundish consists in introducing consumable coolers, which can be exterior (prepared outside the system and introduced into the tundish) and interior (made of steel crusts, formed in the very core of the semi-finished part, along water-cooled surfaces). The exterior coolers are introduced into the molten steel in different shapes: grits, grains or particles such as strips, rods, wires, and tubes filled with metallic powder. The use of micro-coolers leads to an increase of the zone of equi-axis crystals, a decrease of overheating and a reduction of axial porosity.

2. INDUSTRIAL EXPERIMENTS

In order to determine the quantity of micro-coolers to be added into the tundish of the casting machine, thereby to prevent the overheating of steel, we analyzed the results of the simulations on solidification of the semi-finished parts obtained by continuous casting, with addition of micro-coolers, for a 270x240mm bloom-type semi-finished part, by means of our own TURNCON program [3]. Thus, for example, we gave the results in the case of repeated random addition of micro-coolers into the tundish, as this is the variant that most closely emulates the industrial practice.

Within the industrial experiments, in order to reduce the overheating of the steel inside the tundish of the continuous cast machine, we established two work variants. Within each variant, we chose to add 3mm grain micro-coolers, in a quantity of 1% for variant P1 and 2% for variant P2.

The micro-coolers used in the industrial experiments were made of rolled wire, having the chemical structure almost similar to that of the continuously cast steel. The wire with a diameter of 3mm was cut into pieces of 2-3mm. Before that, the wire was cleaned, in order to be oxide-free. After cutting, the grains were weighed, packed and shipped to the industrial unit where the experiments are being carried out.

The addition of micro-coolers was adjusted according to the work recipe, but it was done continuously during the casting of the steel, the micro-coolers having a random distribution. The experiments were done for a steel grade of the current production, i.e. S 235 JRG2 out of which a 270x240mm bloom was obtained. In figure 1 we show the way we added the micro-coolers used in the industrial experiments.

The sampling meant to determine the quality characteristics of the experimental semi-finished parts was done in accordance with the standards in force.

In order to point out to the influence of the micro-coolers on the quality of the continuous cast semi-finished part, a comparative analysis of the semi-finished parts cast with and without micro-coolers was done. To this effect, from the same strand of the installation, we also sampled the semi-finished part obtained without addition of micro-coolers, variant PM.

Figure 1. Used micro-coolers in cristallyze

3. RESULTS, DISCUSSIONS

With respect to the possibilities of improving the structure of the continuous cast semi-finished parts, we performed an analysis of the microscopic study of the structure of the experimental blooms, and for a comparison, we also analyzed a reference bloom, obtained without addition of micro-coolers.

The analysis of these samples brought into evidence an even crystalline structure from the point of view of grain size, in the case of the semi-finished parts continuous cast with addition of micro-coolers. These aspects are shown in figure 2 for the reference sample, and in figure 3 for a 2% addition of micro-coolers in the edge area of the experimental semi-finished parts.

Also, in figure 4, 5 and 6 we show the microstructures obtained for the median area of the experimental semi-finished parts for the reference sample, respectively for the ones with 1% and 2% addition of micro-coolers.

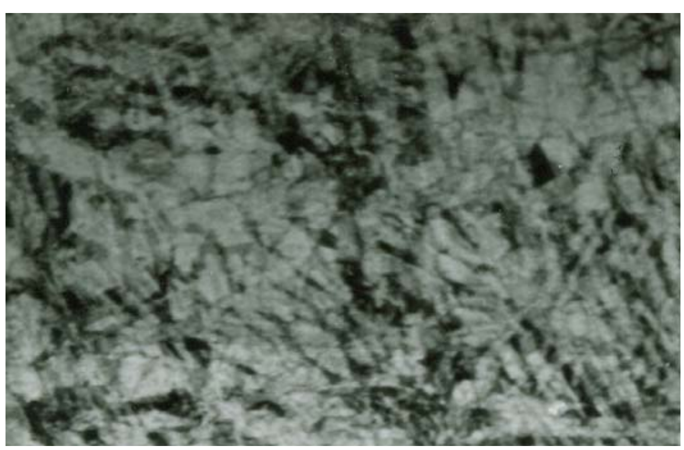

Figure 2. Microstructure, Nital 2%, x100
0% micro-coolers (the edge area).

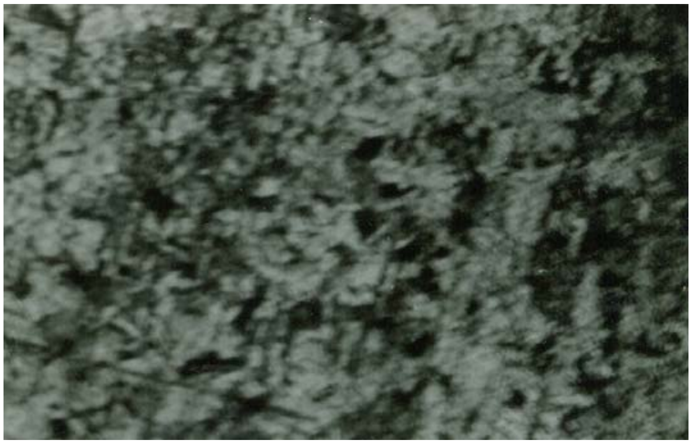

Figure 3. Microstructure, Nital 2%, x100
2% micro-coolers (the edge area).

Figure 4. Microstructure, Nital 2%, x100
0% micro-coolers (the median area).

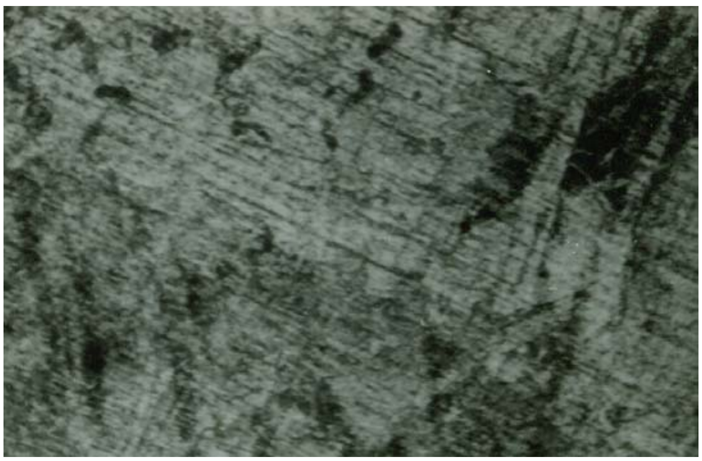

Figure 5. Microstructure, Nital 2%, x100
1% micro-coolers (the median area).

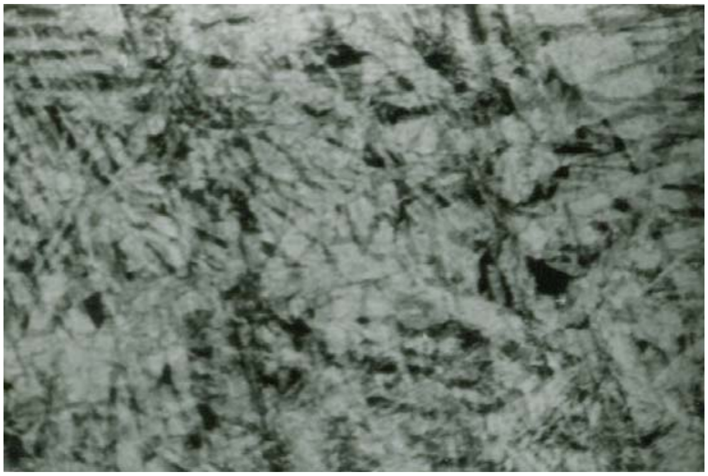

Figure 6. Microstructure, Nital 2%, x100
2% micro-coolers (the median area).

4. CONCLUSIONS

From the analysis of the results obtained for the experimental semi-finished parts with addition of micro-coolers, it is obvious that there is a good finishing of the structure.

The analysis of the graphic dependencies leads to the following conclusions:

- the appearance of a large number of evenly distributed crystallization centers;
- a great difference of temperature between the molten steel and the steel next to the micro-coolers;
- as solidification advances, one can notice a leveling of the temperatures in the first minute after the micro-coolers have been added;
- the addition of micro-coolers leads to a correction of temperature inside the tundish, depending on the quality and quantity of micro-coolers added;
- by modifying a number of parameters (the number of discretization points, the quantity of micro-coolers added, the heat dissipated in the tundish and the secondary cooling, which are strictly related to the steel grade), one can obtain, by means of the simulation program, correct values for other steel grades, too;
- the thickness of the crust depends on the solidification time and on the cooling conditions;

The determinations we have made have lead to the conclusion that for a continuous casting machine, the length of solidification cone of a 240x270mm semi-finished part can be up to 19 cm and the overall solidification time reaches 21 minutes (at a mean casting rate of 0,92m/min);

From the analysis of the samples taken during the industrial experiments, one can notice the way micro-coolers influence the structure of the continuous cast semi-finished parts, namely, for the semi-finished parts obtained with an addition of 2% micro-coolers, we obtained a finer granulation and the metallographic constituents are more evenly distributed.

Processing the experimental data collected and analyzing the diagrams obtained helps in establishing the casting parameters, the optimal quantity of micro-coolers to be added to the tundish in order to adjust the temperatures within the limits desired by the technological engineer, in order to improve the casting structure of the continuously cast semi-finished parts.

REFERENCES

1. E. Ardelean, Semi-finished product cast, Ed. Mirton, Timisoara, Romania, 2004, pp. 56-57.
2. E. Ardelean, M. Ardelean, A. Socalici, T. Heput, Revista de Metalurgia, Madrid, Spania, vol.43 (3), 2007, p.183
3. *** Research project nr.3196/13.10.2005 with title: Researches and Experiments Regarding the Improvement of Semi Manufactured Good Structure Continuous Casting, Excellence Research Projects – Young Researchers 2005.