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A STUDY OF STEEL THERMAL REGIME IN THE CONTINUOUS CASTING TUNDISH

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Abstract: Steel thermal regime is an important factor relative to the quality of continuously cast blanks. The thermal analysis must be performed on all the technological flux, given the influence of the correct preparation, secondary treatment and finally, semi-finished products continuous casting. Should also take into account the interdependence with other factors: the chemical composition of the steel grade, type of furnace and secondary treatment equipment, type of semi-finished profile continuous casted, casting speed and casting time, etc. This paper presents an analysis of thermal regime at continuous casting tundish, last equipment used before continuous casting of steel, but also some technological solutions that enable control of temperature.
Keywords: thermal regime, tundish, steel, continuous casting, micro-coolers

1. INTRODUCTION

Steel casting temperature is one of the technological factors which must be considered in order to achieve a good quality of semi-finished casted products. This parameter depends on the following factors: steel quality (liquidus and solidus temperature), charge size and placement conditions of continuous casting hall in the technological flux (which causes heat losses of the liquid metal from the ladle, until positioning it above the continuous casting machine). The ideal solution would be that the steel reach at the crystallizer with a constant temperature over time, higher than the solidification temperature of the steel grade. This cannot be achieved fully, because heat losses during casting reach important values which require an overheating of molten steel, thus ensuring a sufficient temperature during the entire casting process.

In addition, the casting temperature must be correlated to the casting speed and casting time; in industrial condition, maximum casting speed is chosen according to the steel grade, semi-finished product section, solidification time and the distance between the crystallizer and cutting device (i.e. the cutting cone length). The casting time depends in the first place on the maximum admissible temperature decrease because of metallurgical considerations require keeping the casting temperature between specific limits, in order to achieve the required product quality and reliable operation of the system.

For the reasons stated above, the steel temperature at the beginning of the evacuation of the steel-making furnace or the secondary treatment unit may vary within a wide range (1600 - 1700°C). The temperature in the ladle during the continuous casting of steel must be, during the entire period, of 30-60°C above the melting temperature and is generally comprised between 1570 and 1620°C. Also, the steel temperature in the tundish should be 15-40°C above the melting temperature and is generally comprised between 1550-1580°C [1,4].

2. STUDY OF THE PROBLEM

To analyze the thermal regime of steel continuous casting, were analyzed 12 charges of steel S235JR grade, charges that after making in an electric arc furnace EBT type of 100t capacity, were treated in a secondary treatment LF facility and continuously cast in billet form with Φ 310mm section. Is mentioned that this section was casted for a short period of time, crystallizers Φ 310mm section being mounted only on 2 wires (1 and 2), and the rest of the billet was casted with section Φ 270mm (wires 3,4 and 5). Also, because the wire 2, at the first 7 charges is missed oscillating table, casting of Φ310mm profile was achieved only wires 1. In Table 1 is presented the main technological parameters of continuous casting for wires F1 (Φ310mm) and F5 (Φ270mm).

Table 1. Technological parameters on steel continuous casting

No.	Steel temperature at the end of treatment in LF [° C]	Steel temperature in tundish [° C]	Steel liquidus temperature, [° C]	Casting speed, [m / min]	
				F1	F5
1	1604	1547	1512	0.75	0.75
2	1614	1543	1513	0.75	0.75
3	1602	1540	1512	0.75	0.75
4	1600	1552	1513	0.75	0.75
5	1603	1552	1512	0.8	0.8
6	1602	1544	1513	0.75	0.75
7	1600	1547	1515	0.8	0.8
8	1614	1562	1515	0.55	0.55
9	1611	1552	1514	0.7	0.65
10	1596	1541	1515	0.9	0.85
11	1609	1557	1514	0.6	0.65
12	1608	1558	1516	0.6	0.65

Also, the Table 2 are presented the main data from the primary and secondary cooling zone for the wires F1 (Φ310mm) and F5 (Φ270mm).

Table 2. Data on primary and secondary cooling of continuously cast billets

No.	Primary cooling crystallizer			Secondary cooling						
	Water pressure [bar]	Water flow [l / min]		Water pressure [bar]	Ø 310			Ø 270		
		F1	F5		DM1	DM2	Dz3	DM1	DM2	Dz3
1	8.8	2090	908/900	9.8	170	117	117	86	86	60
2	8.8	2075	908/900	9.9	162	119	119	86	86	60
3	8.8	2084	906/879	9.8	166	126	114	94	94	60
4	8.8	2057	906/879	9.8	158	122	108	60	80	60
5	6.8	2090	906/879	9.8	166	125	118	93	93	60
6	8.8	2066	906/878	9.8	159	110	110	82	82	60
7	8.8	2070	906/878	9.8	162	111	111	101	101	65
8	10.1	2030	1115/1118	9.5	144	110	102	86	86	62
9	10.1	2044	1110/1120	9.5	166	120	114	94	86	62
10	10.1	2100	1120/948	9.5	180	130	124	95	90	60
11	10.1	2000	1180/948	9.5	157	111	111	92	92	62
12	10.2	2000	1160/980	9.5	151	116	115	86	86	62

3. ANALYSIS, DISCUSSION, APPROACHES, INTERPRETATIONS

For a more accurate assessment of the data presented in table 1, in figure 1 is shown in comparison, the variation of the casting speed for this two sections simultaneous casted. Because sections are similar, there are not substantial differences for casting speed (possibly slightly increased values for higher section), taking into account that the temperature is the same (they are not different charges).

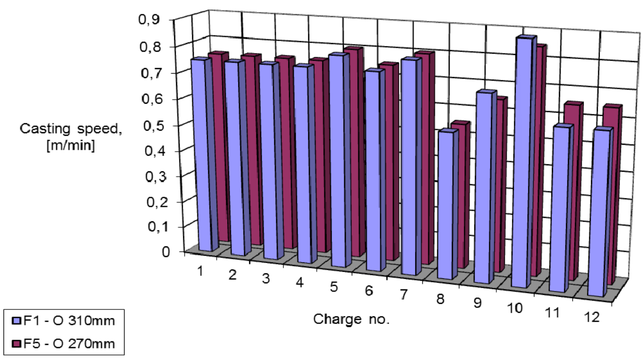

Figure 1. Changes in the casting speed for the two profiles

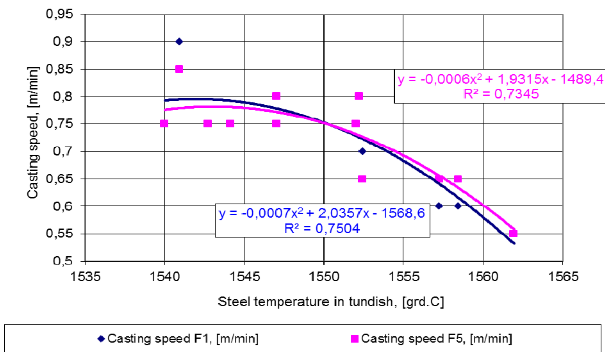

Figure 2. Dependence of casting speed with steel temperature in tundish

The same dependency is found in figure 2: casting speed depending on steel temperature. It is noted that increasing the temperature, the casting speed decreases, in order to ensure proper casting regime parameters and an appropriate casting structure.

Also, it can be seen that with increasing of casting speed (and thus reducing the temperature of casting), it is necessary to increase the cooling water flow rate in the crystallizer (figure 3) and the secondary cooling water flow rate (figure 4).

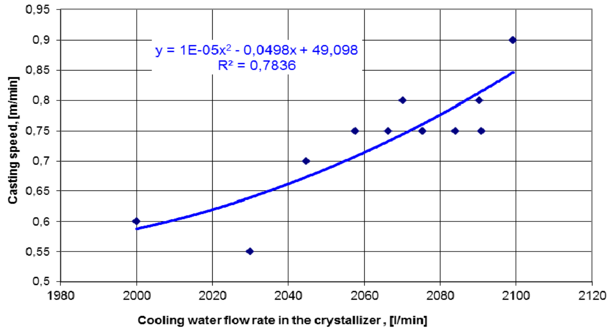

Figure 3. Changes in the casting speed, according to the cooling flow rate of water in the crystallizer

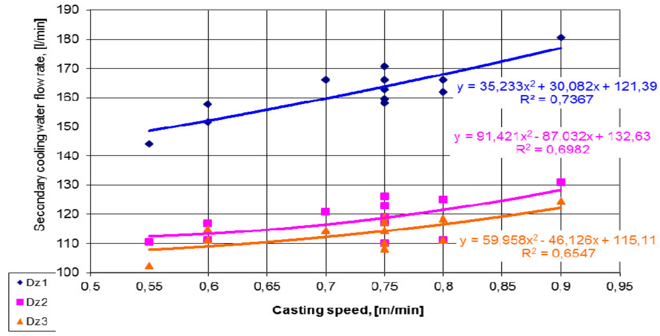

Figure 4. Changes in the casting speed, according to the secondary cooling water flow rate, for all sections

For comparison, in figure 5 have achieved the comparison between the secondary cooling water flow rate variations for these two profiles, on the three sections.

It appears different flow rates correlated also with the section to be solidified (cone length is similar, it is normal to higher section to intensify cooling - solidifying of wire).

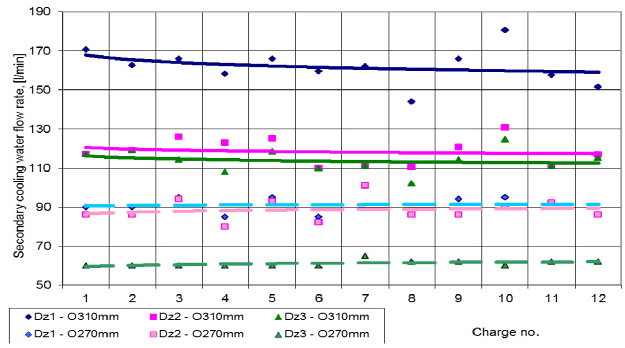

Figure 5. Variation of secondary cooling water flow rate for Φ270mm and Φ310mm profiles

To maintain constant parameters during continuous casting, steel temperature in tundish should not suffer too much change. Therefore, there have been developed technologies to adjust steel temperature in tundish (by the addition of coatings compound, application of cap to distributor for prevent heat losses to the outside, adding of microcoolers, etc.) so that it is within the limits imposed by technology: 15 – 40^{o}C above the liquidus temperature (TL).

At starting of casting, steel temperature decreases (heat is transferred to refractory of tundish) after which occurs equalize of thermal losses (temperature remains almost constant), followed by a further decrease in temperature at the end of casting. Are distinguished two cases of temperature control: heating or maintaining (if temperature permitted values at the lower limit of technology) or cooling it.

For steel heating in tundish can use induction currents (with a channel induction type), where the steel temperature drops 0-5^{o}C (compared to 10-20^{o}C when not use other heating system) [2].

Another method for temperature control (company Krupp Stahl-Germany-Italy Centro Sperimentale Metallurgico) is to use AC or DC plasma, the main advantage being to achieve higher temperatures for slag and thus better conditions to conduct metallurgical reactions [2].

If the steel temperature in tundish is close to the lower limit, often using the addition of coating powder and exothermic powder. In this context, some important factors are:

- ✓ the material must not react with the steel;
- ✓ not release hydrogen, oxygen, nitrogen or other gases;
- ✓ not contaminated with oxide inclusions and other inclusion metal bath;
- ✓ the layer of liquid slag formed on the metal bath surface must be reducing as much heat released to the outside, thus reducing the temperature of the steel;
- ✓ the coating must be able to absorb all the impurities which arise in the liquid steel, but it should not become so fluid that it is absorbed into the holes of the tundish, as this would result in crystallizer, when the level of the metal bath drops from the tundish;

- ✓ coating compound should not form a hard crust that could block the monoblock and make it difficult to measure the steel temperature.

One such coating which has proven successful, it has the following chemical composition: 37% SiO_2, 20% Al_2O_3, 7% Fe_2O_3, 19% C.

At dust cover addition in the tundish it must be rapidly and uniformly spread on the steel surface, thus covering the entire metal mirror. In this way forms an insulating layer that reduces heat loss by radiation. The covering powder must not melt and burn too quickly on the steel surface, so as not to make a too thick layer of slag, but in due course, have to form a relatively thin layer of liquid slag, capable of absorbing non-metallic inclusions from steel. In general the following criteria apply to determination of the powders characteristics (Table 3).

Table 3. The covering powders characteristics

Criteria	Characteristics
Steel brand or liquidus temperature	A high speed of fusion and low melting temperature.
Melting rate	At high speed casting, powder must melt quickly.

If the steel temperature at the casting (in the ladle and then the tundish) is too high, cooling may be carried out by introducing in the liquid steel of the steel powder (micro-coolers). In this case, in order to prevent steel solidification in the tundish critical points, it's required a high degree of overheating at the beginning of steel casting. In theory it was determined that a 1% quantity of metal powder causes a decrease of steel temperature about 18^{o}C.

The micro-coolers introduced into the liquid steel during the casting made several effects, namely: cooling by overheating heat accumulation of the steel, and partially of the crystallization heat, resulting a changing character of the solidification, crystallization by the formation of additional crystallization seed.

From this point of view, micro-coolers may be used in the form of powder, granules, briquettes, etc. *The powder* can be obtained either as a result of different machining operations of ferrous materials (metal filings) or directly from the granulation of melt. However, certain conditions need to obtain adequate quality for micro-coolers:

- ✓ metallic material used must be clean, without dirt or rust;
- ✓ granulation of liquid phase should be made controlled, in order to not obtain a lot of tiny fraction (micron);
- ✓ granulation must be carried out in an inert atmosphere [1].

However, in terms of particle size, the powder is very fine. At addition of powder due to grain size, it remains in the slag layer and does not penetrate into the metal bath. In addition, the powder requires great effort to obtain. For these reasons, the option of using iron powder as micro-coolers is not viable.

Micro-coolers in the form of *granules c*an be obtained by cutting the wire rod with a chemical composition closest of the cast steel. Previously, the wire is subjected to purification of oxides. After cutting, the resulting granules are weighed and packaged for transport to the industrial unit [1]. Also, micro-coolers may be used in the form of *briquettes* by briquetting fresh unoxidised swarf, without moisture and oils, obtained from other manufacturing processes [1]. In this version, swarf need not be contaminated with oil or grease from the lathe, requiring a degreasing previously briquetting is made. Also, in order to achieve small briquettes, workmanship would be much higher. However, obtaining the larger lighters Φ 30mm and 20mm of height) is easy but will melt much harder.

Micro-coolers injection is carried out, for the most part by using argon, the consumption of argon is ranging from 200-300 l/min. Micro-coolers are placed under the tundish cap, forming a neutral atmosphere.

From the theoretical data and the previous studies it has been concluded that a satisfactory metallurgical result they have micro-coolers granules or briquettes with sizes of 2-3mm in diameter and 5-6mm in length.

4. CONCLUSIONS

Form analysis of presented data results several conclusions:

- ✓ At studied charges, the degree of superheat is higher than is recommended, and the steel is slightly superheated in the LF treatment facility. Cooling conditions are so related and applied that to supplement this overheating.
- ✓ Although the global trend is to increase as much as possible the casting speed, for the studied sections were used the following casting speed: for Φ 310mm section, normal operating speed range was 0.55 to 0.9 m/min; for Φ 270mm section, normal operation speed varies between 0.55 and 0.85 m/min;
- ✓ Is required a correlation of primary and secondary cooling parameters, so that the frequency of faults is much reduced;
- ✓ There are technological possibilities for adjusting the temperature of the liquid steel in the tundish, or by an increase temperature (heating in the tundish), or by reduction the temperature loss (using the exothermic powder covering). If there is a casting temperature too high, the micro-coolers can be added (the purpose is not to change the parameters of casting, respectively, to obtain a more homogeneous solidification structure).

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