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TEMPERATURE INFLUENCE ON THE TECHNOLOGICAL PARAMETERS IN STEEL CONTINUOUS CASTING PROCESS

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Abstract: One of the main factors which influence quality of semi-finish product is temperature of liquid steel. The casting temperature is function of steel chemical composition and is fixed in function of casting method. Also, it is in compressed correlation with casting speed, this one will be regulate in function of casting temperature. Regarding temperature of steel casting, ideal will be the steel to arrive at crystallizer at a constant temperature.

The paper presents a few correlations between steel temperature and the main technological factors that influence steel continuous casting process: speed and time casting, and also the parameters on primary and secondary cooling.

1. INTRODUCTION

To obtain an adequate quality of the semi-finished products continuously casted, it is not enough a good quality of the casted steel. Analyzing the faults obtained at the semi-finished products, it can be seen that a small part of these faults is generated by same errors consequence the design of the plant and the greatest part is generated by the noncorrelation of the main technological parameters which have an influence on the casting process: the casting speed, respectively the extraction speed of the cooling conditions either in the primary cooling area, respectively in the mould or in the secondary cooling area (flow, pressure, temperature), temperature of the liquid steel, time casting.

2. EXPERIMENTAL RESULTS

The studied charges were elaborate into an electric arc furnaces (EBT) by 100 t capacity and continuous casting. So, the investigation was made on 51 charges, mark S 235 JRG1 – SR EN10025 casting like a Ø 150mm billets section.

A very important factor in what concerns the continuous casting and the quality of the obtained semi-finished products is the casting temperature of the steel.

The ideal solution would be that the steel to arrive in the crystallizing apparatus at a constant temperature in time, a little bit higher that the solidification temperature of the respective steel. This thing can’t be completely done because the thermal losses during the casting reach important values, which imposes an overheating of the steel at melting, ensuring a sufficient temperature of the period of continuous casting. Taking into consideration the special features of the technological process, the temperature of the steel at the end of the elaboration is higher than in the case of casting into ingots.

In most of the cases in which the secondary treatment is realized in an installation where a supplementary heat contribution is possible for the heating of the steel, the anterior condition is not necessary to be fulfilled.

The temperature of the steel in different phases of the technological process of continuous casting depends on the following elements: the quality of the steel, (the liquids and solids temperature), the size of the charge and the conditions of emplacement of the continuous cast hall in the technological flux (which determines the heat losses of the metal from the melting ladle, up to positioning this above the continuous casting installation). [1,2]

The temperature of the steel at the beginning of the evacuation from the evacuation furnace or from the secondary treatment unit may vary in large limits (1600 – 1700^{0}C), depending on the above-mentioned elements; at the majority of the modern installations, this temperature is situated between 1620 – 1650^{0}C. [3]

The temperature in the casting ladle of the steel during the continuous casting must be all along the process 30–60^{0}C higher than the melting temperature, generally speaking being between 1570 and 1620^{0}C, and the temperature from the distributor must be 15–40^{0}C over the melting temperature, generally speaking being between 1550–1580^{0}C (the cooling speed in the distributor varying in the high capacity installations between 2 and 5^{0}C/min, the stationary time being of some minutes and the lowering of the temperature in the distributor is small: 10–20^{0}C). For the carbon un-allied steels, the temperature of the steel in the distributor is set as low as possible. The reasons are the higher functional safety and the quality of the profiles (the elimination of the perforations, improving the internal structure and preventing the internal cleaving).

Also, for the correct functioning of the continuous casting installation, a severe control must be assured on the steel temperature and forward, in the technological flux. Thus, the necessary precision regarding the prescribed temperature at the crystallizer entrance must be of ±5-10^{0}C. [2,4]

For the studied cases we distinguishes an increase of temperature gradient with about 100^{o}C over the recommended temperatures - figure 1. An explanation of this fact should be a noncorrelation suitable of all processes to continuous casting machine, fact that tended necessity to increase steel temperature still from the secondary treatment unit. The issues of this increases temperature influence the other technological parameters: cast speed, primary and secondary cooling conditions (generally for increase values of these parameters).

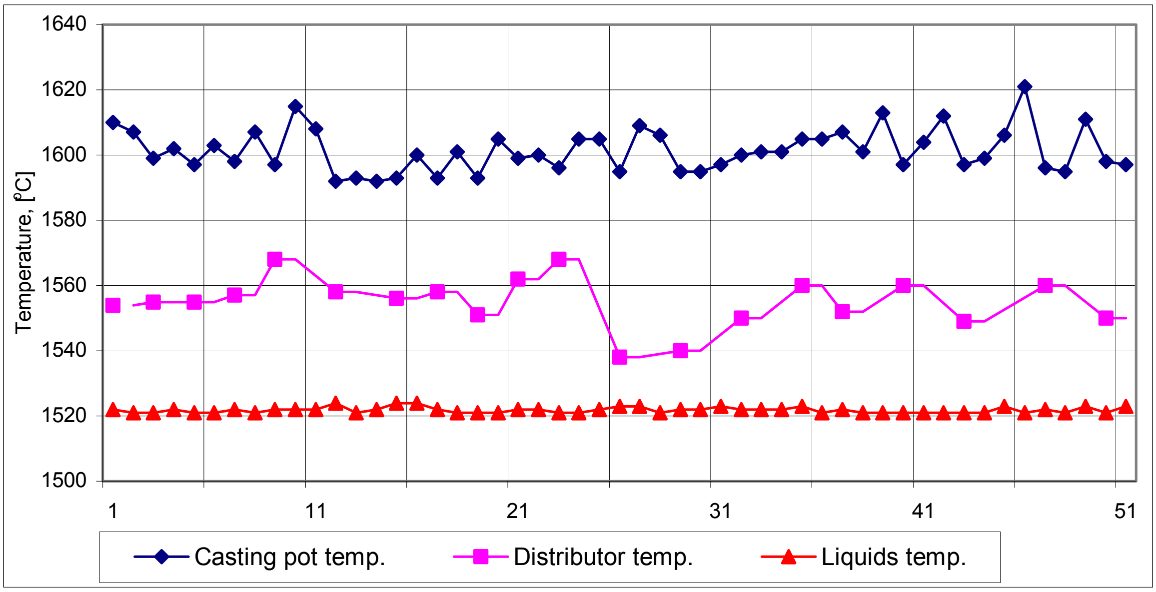

Figure 1. Steel temperature variation

Speed casting is the governing factor for the installation dimensioning of continuous cast because it influences the sensible productivity, the needed number of wares and the minimum section of semi-finished products.

To billet with the section Ø 150mm, speed cast has varied between 1,5-2,7m/min in ordinary working behaviors conditions, considering as original casting speed is much smaller (of 1,2m/min). In this case, casting speed average speed is also described of this time under a polynomial function of III degree – figure 2, resulting a global correlation coefficient of 0,89.

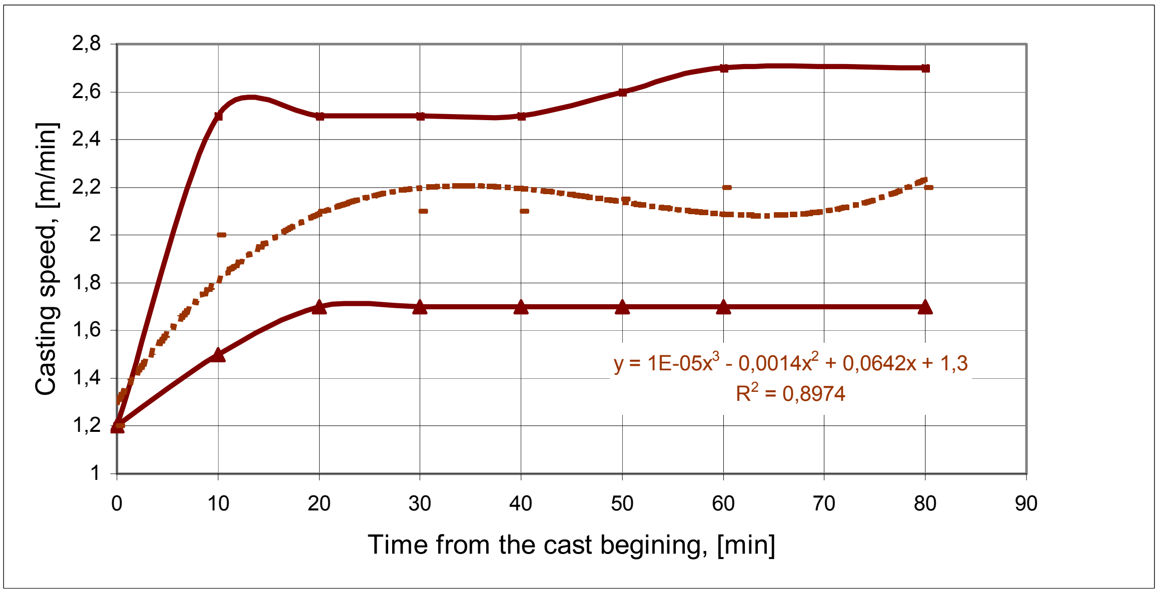

Figure 2. Casting speed variation

The casting time of one charge results from the ladle capacity and speed cast. The maximum cast time depends uttermost of the admitted temperature decrease, because, metallurgical considerations impose framing casting temperature between precise limits, for obtaining a suitable qualities of products and of a sure operation of installation. So, in figure 3 it is presented casting time variation dependent on steel temperature from distributor (for 2 charges formats sequences). [2]

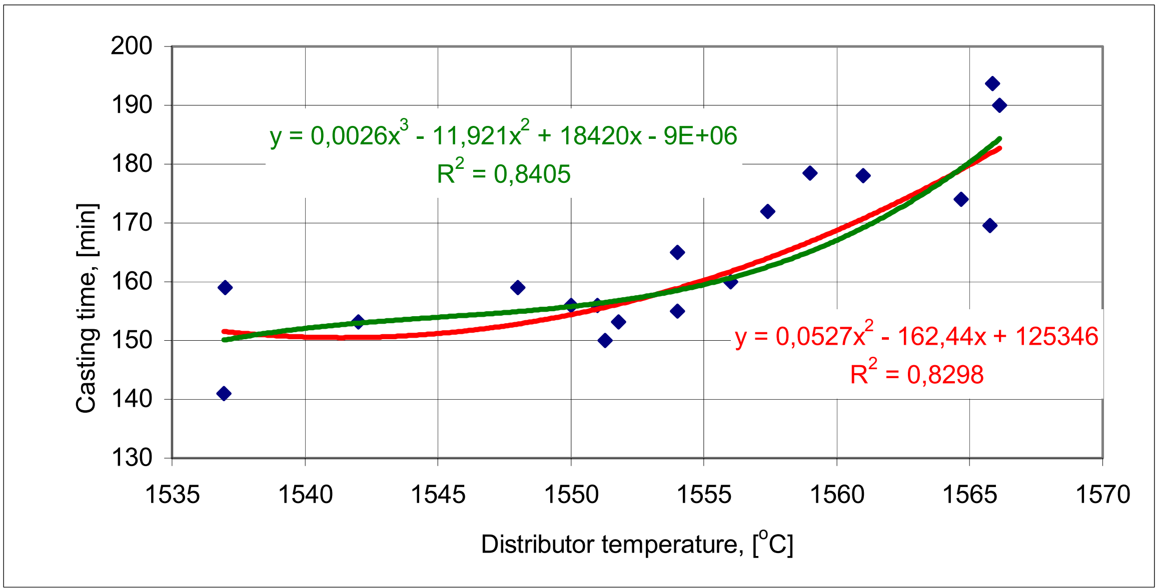

Figure 3. Distributor temperature variations depending on the casting time

With reference to primary cooling, for this profile, the flow of the cooling water does not vary on the section, the values being adapted to the types of semi-finish products. Therefore, if for a billet with a 150mm diameter, the surface obtained admits a minimum outside the technological field (figure 4) and the casting speed increases with the cooling parameters of the crystallizing vessel.

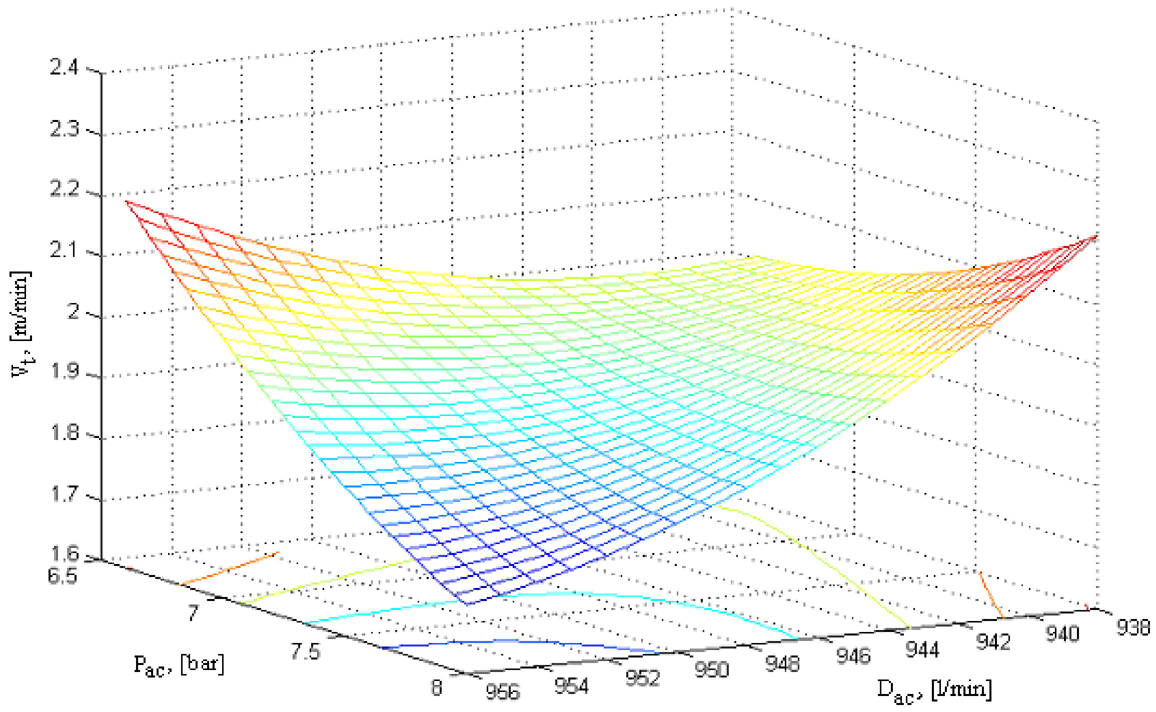

Figure 4.The variation of the casting speed depending on the pressure and the flow of the cooling water in the crystallizing vessel for section Ø 150mm

The equation of the regression surface from figure 4 is:

$$v_t = 2{,}23\cdot10^3 - 4{,}9\cdot D_{ac} + 23{,}7\cdot p_{ac} - 0{,}5\cdot p_{ac}^2 \qquad (1)$$

and the correlation coefficient is: r_{yx1x2}=0,8430

For a more systematic examination of the processes that take place in the primary cooling, we considered as a necessary thing to study the temperature of the cooling water from the crystallizing vessel and the way in which this influences the parameters of continuous casting (the casting speed respectively) and inevitably the conditions in which the formation of the crust in the crystallizing vessel takes place.

The increase in the cooling water temperature on its way out from the crystallizing vessel was taken into consideration, this being one of the parameters considered in the investigation.

As far as it concerns the with a section of Ø150 mm, the income temperature of water was lower than in the first case and, due to the high casting speed, the quantity of heat that must be removal increased in a very short time, and respectively the outcome temperature of the water in the crystallizing vessel with 4-5^{o}C at 10 minutes from the beginning of the casting (figure 5) and with 7-9^{o}C at 40 min from the beginning of the casting.

The regression surface admits an inflexion point type saddle at the limit of the technological fields, most of the points being situated in the growing part of the surface, where, with the increase of the casting speed increases both the income temperature of water (all along the casting process) and the outcome temperature.

The equation of the regression surface for this case is:

$$v_t = 1 + 0{,}13\cdot T_{ia} - 0{,}396\cdot\Delta T - 6{,}5\cdot10^{-3}\cdot T_{ia}\cdot\Delta T - 1{,}5\cdot10^{-3}\cdot T_{ia}^2 - 51{,}7\cdot10^{-3}\cdot\Delta T^2 \qquad (2)$$

and the total correlation coefficient is 0,9059.

When the continuous casting went into a stationary regime, the variation mode of the three parameters changed, resulting a direct proportional dependence among them.

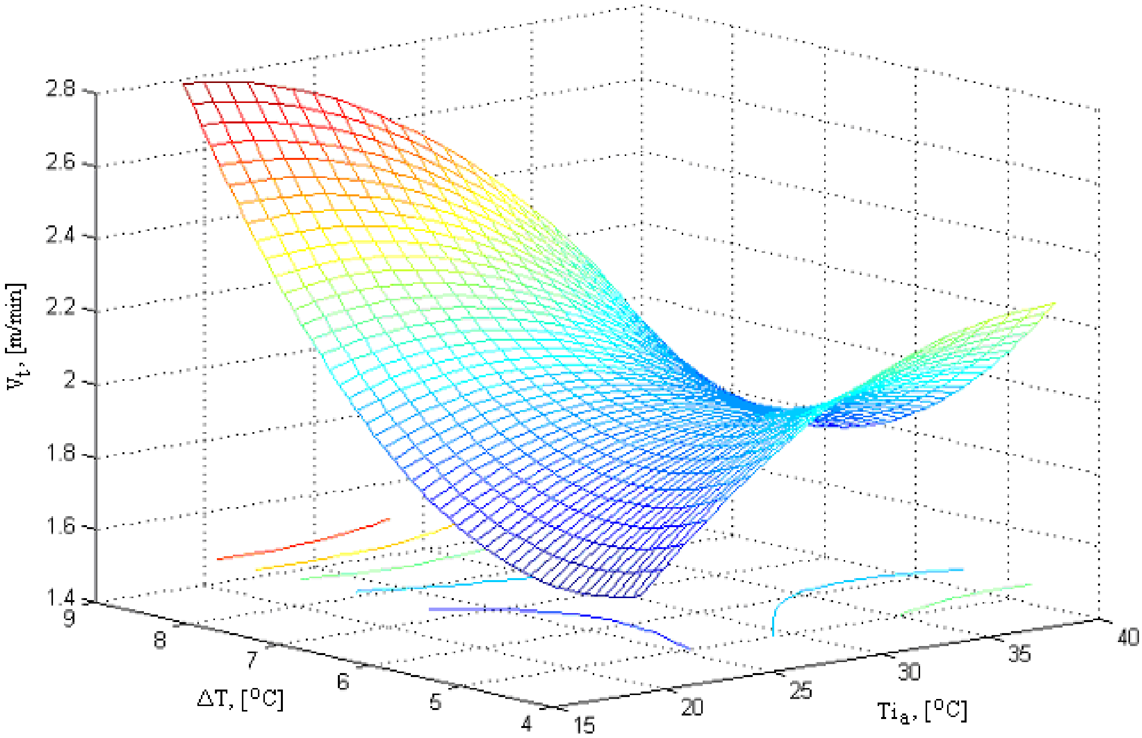

Figure 5. Variation of the casting speed depending of the water temperature and its variation on its way out from the crystallizing vessel

When cooling the semi-finished products in the crystallizing vessel, the secondary cooling takes place. During this, the solidification has to be performed on entire cross section of the strand. In order to achieve this, beside a proper primary cooling, the factors that influence the secondary cooling have to be also correlated: the water flow on three areas on the installation, the water pressure in the secondary line, etc.

All these have in view a proper solidification length; an intense cooling can generate cracks due to the thermal stresses, while a too slow cooling can generate a partial solidification of the strand up to the cutting machine area.

For the billet with cross section Φ150mm, the directly proportional dependency between the parameters is kept, the work magnitudes of parameters being: pressure 8.2-8.8bar, and the flow rates 39-60 l/min for z_1, 53-84 l/min for z_2 and 43-73 l/m for zone z_3 (figure 6, 7, 8).

The equations of the regression surface and the total correlation coefficients are:

$$v_t=111{,}34-1{,}31\cdot D_{ar\,1}-17{,}29\cdot p_{ar}+0{,}21\cdot D_{ar\,1}\cdot p_{ar}-4\cdot 10^{-3}\cdot D_{ar\,1}^{2}+0{,}35\cdot p_{ar}^{2}\ ;\ r_{yx1x2}=0{,}8224 \qquad (3)$$

$$v_t=82{,}09-0{,}12\cdot D_{ar\,2}-17{,}35\cdot p_{ar}+0{,}049\cdot D_{ar\,2}\cdot p_{ar}-2{,}1\cdot 10^{-3}\cdot D_{ar\,2}^{2}+0{,}788\cdot p_{ar}^{2}\ ;\ r_{yx1x2}=0{,}8127 \qquad (4)$$

$$v_t=194{,}17-1{,}27\cdot D_{ar\,3}-35{,}28\cdot p_{ar}+0{,}18\cdot D_{ar\,3}\cdot p_{ar}-2{,}6\cdot 10^{-3}\cdot D_{ar\,3}^{2}+1{,}36\cdot p_{ar}^{2}\ ;\ r_{yx1x2}=0{,}8786 \qquad (5)$$

The calculation programs in use at this moment do not allow us to obtain the dependency of water flow rates for the three zones on the casting rate (4 parameters in all), and this is why we have used a specialized software used in statistic processing of data (STATISTICA 5.5). By means of this data processing application we obtained the ternary diagrams of the type given below (one parameter depending on other three parameters). [2]

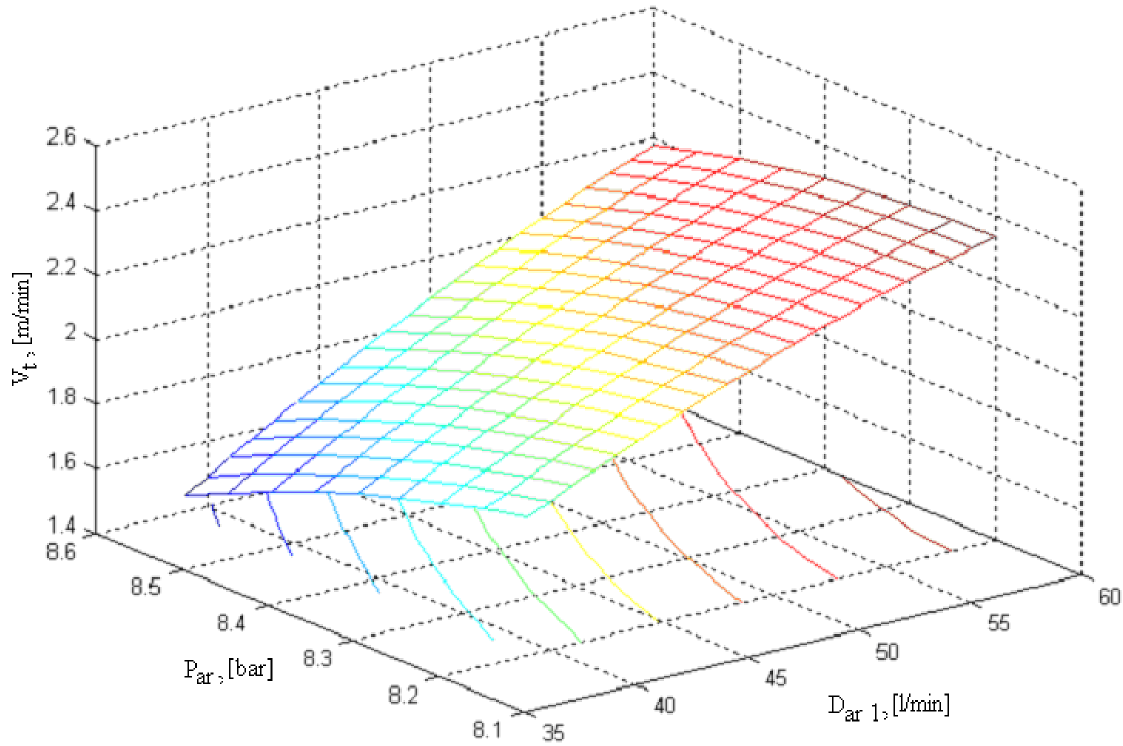

Figure 6. The variation of casting rate with pressure and water flow rate for zone 1 of secondary cooling, for the semi-finished products

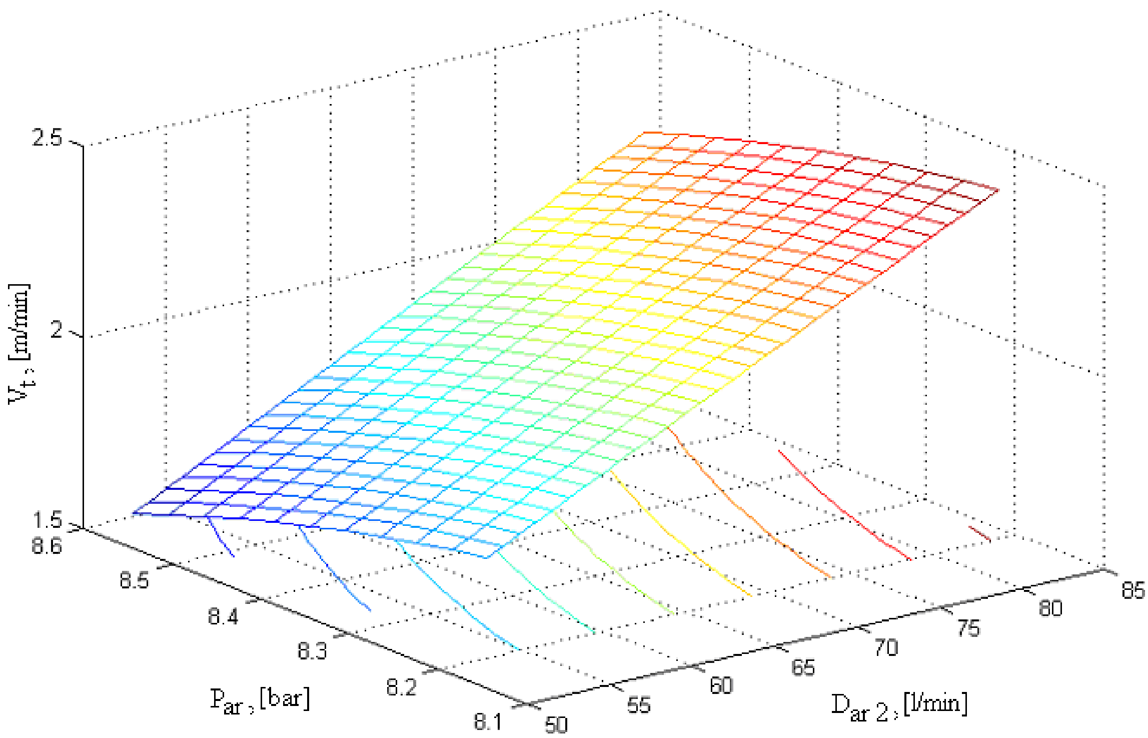

Figure 7. The variation of casting rate with pressure and water flow rate for zone 2 of secondary cooling, for the semi-finished products

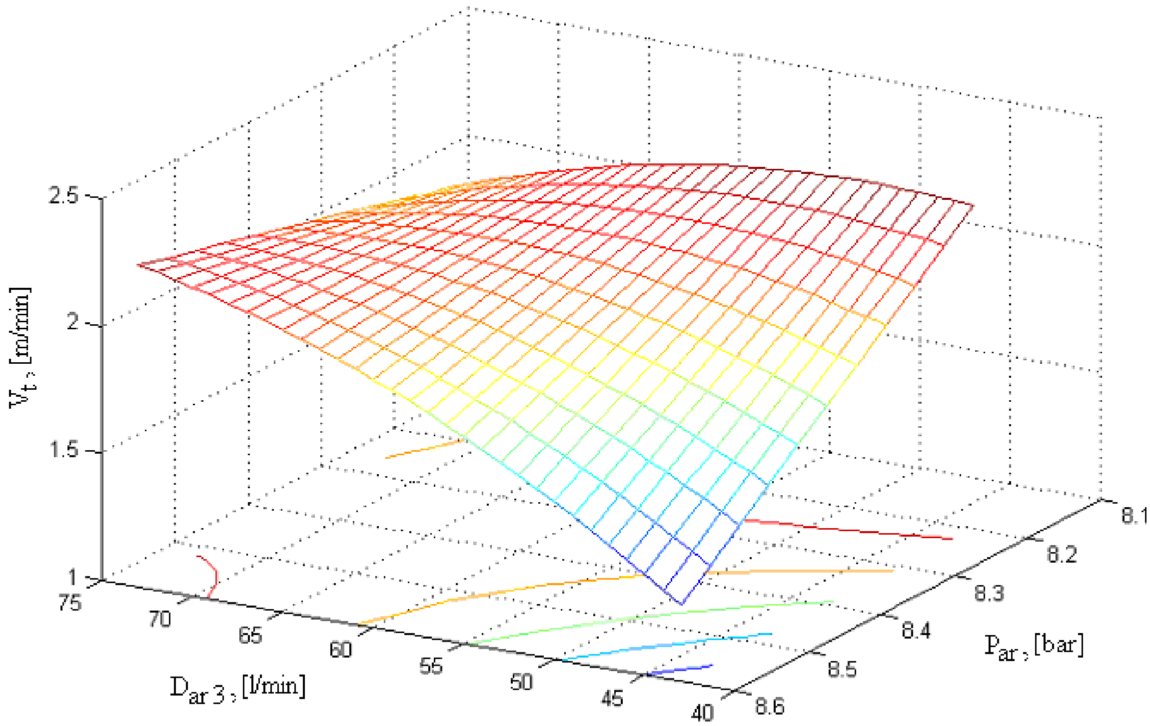

Figure 8. The variation of casting rate with pressure and water flow rate for zone 3 of secondary cooling, for the semi-finished products

For the cross section with the diameter Φ150mm, we have taking in consideration the different variation of flow rates along the casting flow and we obtained a variation curve, respectively a ternary diagram of the type given in figure 9.

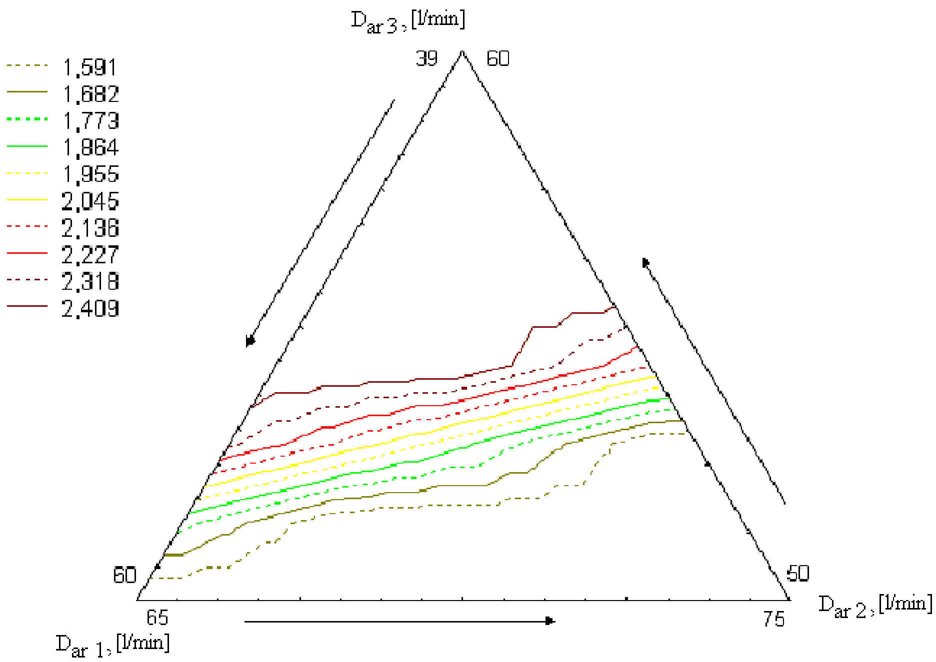

Figure 9. The ternary diagram for the cross section Φ150mm

The high values of the partial correlation coefficients in the case of this cross section entitle us to successfully use the diagram (especially the projection of the contour lines, respectively of the ternary diagram) in production. Actually the high quality of the

Φ 150mm billets produces on the continuous casting machine at S.C. Arcelor Mittal Steel Hunedoara prove the correctness of the secondary cooling procedures.

3. CONCLUSIONS

From the researches made based on the data from the specialty literature and those of our own experiments their result the following conclusions:

- if the casting temperature is too high, is necessary to diminish the casting speed and a secondary cooling very intense, the results are intern deficiency, because are thermic tension; also a temperature too high of steel growth the danger of thread break through under the crystallizer;

- a low casting temperature can go to plug up the casting orifice of tundish, in special in thin semi-manufactured good case or of a little section pipe billet, as well as surface defects;- a highest value of casting speed conduct to obtain an small thickness for steel crust in crystallizer, without an enough resistance to the fero-static pressure of liquid core, which may be conduct to the dangerous breaking effect;

- a smallest value of casting speed are negative influences to metallographic structure of the semi-finished product; it turns out cold welds and other surface faults; it can tend steel over cooling in cast ladle and diminish the installation productivity;

- for the primary cooling, the parameters that come into the process were analysed so that the casting should go on without problems and the influence of the parameters variation to have no negative effect on the quality of the semi-manufactured products. It is known the fact that in the crystallizing vessel the steel crust is formed, steel crust whose thickness can be influenced, first by the parameters of primary cooling. For the round sections there wasn't a certain optimum field for the studied parameters, being recommended such values so as the quality of the semi-finish product should not be affected (preferably a medium speed of 2,1m/min not to create favourable conditions for surface cracks and internal cracks).

- the variation of the outcome temperature of water from the crystallizing vessel was in the limits of 6-8^{o}C. It could be said that a more intense cooling was done to the round billet than to bloom, with consequences on the quality.

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