STUDIES AND RESEARCHES CONCERNING THE MICROCOOLERS UTILISATION AT COOLING STEEL IN INGOTS

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Abstract

The casting and solidification processes belong, in most cases, to non-stationary thermal conductivity processes, namely: cooling solidified crusts, ingot cooling, melting of the micro-coolers and inoculums in the liquid metal during the directed solidification.

The necessity to approach the theme results from the importance of through knowledge of phenomena and processes taking place in casting and solidification of steel ingots, continuously improvement of technology, understanding of the complex phenomena of the mass transfer and energy and the ways of action for continuously improvement of quality and cast and forged products. Study goal was to determine the dynamic parameters' variation and transfer believed representatively, depending on the specific technological parameters of the casting and solidification processes, to determine ways of influencing them in order to obtain steel products of high quality, in terms of maximum technoeconomical efficiency and reproducibility.

1. INTRODUCTION

Using of the micro-coolers produces decreasing of the thermal gradient and also allows increasing of the dispersion grade and increasing of the homogeneity for the dendritic structure and, at the same time, decreasing of the chemical inhomogenities zone, decreasing of the blows located at the edge of the primary grains and reduction of segregation and gases. Improvement of the equi-axial homogenous structures is obtained, by addition of the micro-coolers into the liquid steel entering the ingot mould. Crystals' germination determines melt undercooling and the superficially active impurities increase the superficial tension at the melt-crystal interface, reduce the consumed energy for its formation and also reduce the undercooling tendency.

The ingot solidification process mechanism is influenced, in a decisive manner, by the thermal phenomena that take place in the steel casting and solidification processes and also by the heat transmission to the exterior ambient. Usually, the ordinary solidification image is that of a solidification front moving through the ingot and breaking-up the liquid zone from the completely solidified one.

The solidification front movement is exclusively related to the thermal phenomena and it is realized in inverse sense with respect to the heat flux. In reality, the thermal phenomena represent just the exterior aspect of the ingot solidification process, solidification being, in fact, the complex result of the different physical phenomena's conditioning crystals' formation [2].

This paper presents the essence of some researches regarding the cooling speed modification of the liquid steel by using of some micro-coolers, modifiers and other crystallization centers that contribute to rapid increase of the equi-axial crystals in front of the crystallization front and stop the columnar dendritic increasing.
2. CONSIDERATIONS REGARDING MICRO-COOLERS UTILISATION

Activated solid particles, having an increased value of the free enthalpy and introduced into the liquid steel, do have a significant role in acceleration of the crystallization grains’ appearance. The active state, from the surface of these particles, appears as a result of an important development of its surface, high concentration of the traps and atomic defects appearing in the atomic net deformation, and, in this way, the active impurities will have a higher free enthalpy and an increased tendency with respect to chemical reactions. The particles' activation can be made by a variety of proceedings: mechanic working (grinding, spraying, rolling), compounds’ reduction (as an example, in a pre-alloys form which grinded to dimensions of some microns are put into jet in the steel casting, the compounds having the low casting temperature and carbides and nitrides, obtained by its reduction, having high melting temperatures), thermal treatment, condensation from the vapors state (based on the substance evaporation into the vacuum or cathode spraying and a rapid condensation of the vaporized atoms having as a result a disorderly deposit of the crystals which produces a high increasing of their surface activity).

The experiments’ target was to improve the steel ingots’ quality by knowing and correct directing of the solidification process [1].

![Fig. 1. The introduction of thermocouples into ingot](image)

By these methods, an increase of active surface is obtained, but grinding being made until to a critical dimension at which the grains receive the agglutination capacity, as well as a trap formation and other net defects, the trap density could not get over a certain determined level after which their tension field could get to high values, this resulting to total destruction of the particles. By introducing of the micro-coolers, in powder form, into the steel, there is acting efficiently against the crystallization process.

On the experimental information basis obtained by measuring of the temperature field in one tone ingots cast in steel, with thermocouples (fig.1), there was established that the disperse powder addition has determined overheating reduction of the liquid steel by 30-40°C, increasing of the solidification speed until to 25%, reduction of the thermal gradient in the crystallization interval by 1.5-2 times and a faster uniformization of it in the ingot section. Using of this method has allowed significant increase of homogeneity and dispersion grade of the dendritic structure, decreasing of chemical inhomogeneities in the development zone and blows’ quantities located at the edge of the primary grains, reduction of segregation and gases.

Simultaneous addition of iron powder and ferroalloys allows increasing of density, mechanical and metal working properties and feeder mass reduction. Input of inoculums, modifiers and other crystallization centers, contributes to rapid increase of the equi-axial crystals and stops the columnar dendritic increasing even at high speeds of steel crystallization.
3. DIRECTING OF EXPERIMENTS REGARDING MICRO-COOLERS' INFLUENCE AGAINST SOLIDIFICATION

Charges' elaboration was made in air induction kilns having 160 and 1000 kg capacity. In the induction kiln, time for this process was determined, firstly by the melting duration (50-110 minutes, with respect to kiln refractory mass temperature, so that a cold kiln determines a higher melting time), steel alloying duration (20-30 minutes with respect to liquid steel temperature in the kiln, so that, a too accentuated cooling of the metal bath could not take place in order to avoid chromium losses by oxidation).

Synthetic slag was added for protecting the metal bath. Melting slag was completely evacuated, after which chemical analyze samples in melting were took, especially for determining the carbon content.

The steel alloying was made with respect to these samples' results. The metal bath temperature was between 1475-1490°C. Until the chemical analyze result arrival, the metal bath heating was continued so that, at the start of alloying, this should be 1560-1580°C.

All the ferroalloys introduced in kiln, were calcined at 600-700°C temperature. Alloying was made after pre-deoxidation. Alloying elements' assimilation was determined by temperatures' regimen in the time of alloying, pre-deoxidation mechanism, alloying period duration and total duration of charge.

The best values, for ferroalloys' assimilation, were obtained by using deoxidation process (pre-deoxidation realized in the kiln, before chromium introduction, by 2 kg/to silico-manganese and 0.4 kg/to Al) with new slag formation, followed by chromium alloying and deoxidation in aluminum powder slag and silico-calcium.

3.1. Experimental methodology

There were used, as micro-coolers, metallic powders with iron (96-99% Fe) and metallic powders obtained in the steel small shots' fabrication process. Micro-coolers' quantity has varied between 0.5 and 3% in cast alloy mass, having granulation between 0.1 and 1.5 mm. Experiments were made by correlating micro-coolers' quantity to casting temperature, time of casting and micro-coolers input mode.

Micro-coolers’ quantity and granulation were established depending upon technological parameters of the process: input mode, casting temperature, ingot thickness, time of casting.

Micro-coolers, used for directing steels’ solidification process, shall fulfill the following conditions:
- it should have high purity with respect to oxide inclusions’ content (oxygen < 0.5%);
- not to have oxidized surfaces;
- it should have a certain granulometric composition that influences micro-coolers' melting duration;
- humidity should be limited (< 0.25%).

3.2. Obtained results

Micro-coolers, introduced in liquid steel, produce the following phenomena:
- an intense change of heat between steel and micro-coolers, due to large contact surface, takes place;
- micro-coolers take the overheating heat and a part from solidification heat resulting to contraction decrease that implies decreasing of the concentrated shrinkage;
- produce crystallization sprouts, creating high local undercoolings which take to crystallization conditions modification;
- increase the solidification speed which take to chemical inhomogeneities' decrease (zonal segregation) and finishes the structure.

The directing method of steel ingots' solidification process, by micro-coolers' input, is determined by a characteristics' series:
- physical properties and micro-coolers' chemical composition;
- micro-coolers' input methods;
- particularities of heat changing between micro-coolers and steel;
- particularities of physico-chemical processes.

Fig. 2. The temperature curves obtained on three samples

In these experiments, micro-coolers were introduced in the steel ingots with a spear, after casting in the ingot mould. Three ingots were cast, one ingot blank and two experimental ingots, having 160kg each and designated to forging. In the fig.2 are presented the temperatures curves for three samples.

Steel temperature, measured by Pt-PtRh 18 thermocouples, was 1620°C. Time of fill the ingot mould and the feeder was about 55 seconds. After ingot filling, three tracers were introduced with a spear, at 1 minute time periods. Tracer mass was 400 grams.

4. CONCLUSIONS

- Optimization of geometrical parameters, shrink head casing conditions, casting parameters and influence modalities of steel solidification after casting in ingots present importance for steel removal increasing.
- In order to obtain a corresponding material, from metallurgic point of view, the followings are required:
  - raw materials should be selected;
  - elaboration should ensure low contents of P and S, in order to reduce mechanic properties' anisotropy;
- casting device preparation and casting should be done in accordance with purity steels' prescriptions.

- Experiments have shown an increase of the metal removal level, depending on segregation level reduction. Macrostructure determination did not present any defects as: shrinkage traces, porosities, blows, flakes, inclusions.

- Requirements, for obtaining a feeder capable to ensure a positive temperature gradient in the entire period of solidification, have standup. Thermal result improvement of shrink head casing on account of thermal conductivity decrease in thermo-insulating plates, decrease of heat stored by these as result of density diminution and supplementary heat contribution brought by the external dusts and, also, casting temperature soft increases allow sensitive diminutions of positive segregation level inside the ingot, transfer of it to feeder respectively. Experiments have shown real possibilities in feeder volume reduction in similar level segregation conditions and these allow to foresee segregation diminutions in the product, after shooting, in case of a feeder variable volume.

- In order to prevent ingots' welding, the following measures are applied:
  - raw materials should be selected;
  - device preparation for casting and casting should be done in accordance with purity steels' prescriptions;
  - reasonable cast regimen setting in the lower ingot zone;
  - location of metallic insertions that protect the lower part of the ingot moulds against overheatings;
  - use of special casting bridges;
  - use of protection paints which shall prevent metals welding;
  - analyze of informations, in speciality literature, shows that ingots and casting bridges protection problem could be successfully solved by using of some efficiently protection films that are, in fact, concentrated refractory materials' suspensions being in disperse form in non-organic binders' solutions which have sticking properties and films' formation capacity;
  - these materials are applied by mechanical spraying on the surfaces that are protected, creating, in these places, insulating films, which are capable to oppose to liquid steel jet action and to afferent thermal flux implicitly. Films are made from purverulent melted silica and aqueous colloidal solutions of silica.
  - almost total elimination of ingot welding may be obtained by using of graphite chamotte insertions which ensure a minimum contact between ingot and casting bridge.

REFERENCES
