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Laboratory grey cast iron continuous casting line with electromagnetic forced convection support

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Abstract

The article describes the construction of a 20 mm diameter grey cast iron ingots continuous casting laboratory line. This line is made of three main units: melting unit (induction furnace), casting unit and the pulling unit. In order to improve the homogeneity of the microstructure of ingots (by applying forced convection of liquid metal during the crystallization process) in this case a crystallizer system generating the forced movement of liquid metal based on a system of electrical power windings of the AC specific frequency. This solution allowed to obtain a homogeneous microstructure of the continuous casting of cast iron EN-GJL-200 species.

Keywords: continuous casting, electromagnetic field, grey cast iron

1. Introduction

Increasing demands of modern industry requirements for the quality of the produced castings, force the foundry equipment manufacturers, technologists, and foundry metallurgists to constantly seek ways to optimize the parameters of the production process.

One such process - constantly improving is the process of continuous casting, in which a number of factors (to a greater extent compared to other technologies for implementation) decide on the correct end result. Standard continuous casting lines are equipped with control and command systems, capable of producing continuous casting of different grades of steel, iron or non-ferrous metal alloys.

In the latest construction equipment for secondary ingot cooling beyond crystallizer, instead of spraying water a mist water - air cooling is applied. Another "novelty" is the introduction of alloying elements, in particular, readily oxidizable by means of core wire [1].

During the continuous casting process, the factors significantly affecting its performance are analyzed by measuring, monitoring, registration and control. The most important variable factors of production and casting processes are physical, and the measurement of these parameters are applicable mostly to:

- the temperature of molten metal, especially inside the crucible or the casting furnace interior,
- the level of molten metal in the intermediate tank and the crystallizer,
- the uniformity of the intensity of heat exchange in the crystallizer,
- speed of casting (Ingot extraction)
- the crystallizer oscillating motion parameters,
- parameters of the electromagnetic stirring of molten metal in the crystallizer as well as both inside and outside [1, 2].

Measurements of the chemical parameters such as oxygen, hydrogen, aluminum, titanium, calcium, boron and other alloying elements of cast materials.

Separate, modern and an important factor in shaping the properties of cast material is the electromagnetic stirring of the

liquid phase in the crystallizer and the lower parts of the solidifying ingot. The impact and effects of applied magnetic fields can be characterized as follows:
- minimize the gravity segregation of the different components of the iron mass density,
- minimize gas porosity,
- improving conditions for the exit of non-metallic inclusions and slagging in the lake of molten steel in the crystallizer,
- increasing the area of the occurrence of equiaxial crystals on the cross-sections of the ingot,
- improve the uniformity of heat removal during coagulation,
- improve the uniformity and intensity of secondary cooling.

Most often the systems supervising the correctness of the various elements of the COS (conceptual diagram process shown in Figure 1) are joined together to form an integrated system of automatic process control [1].

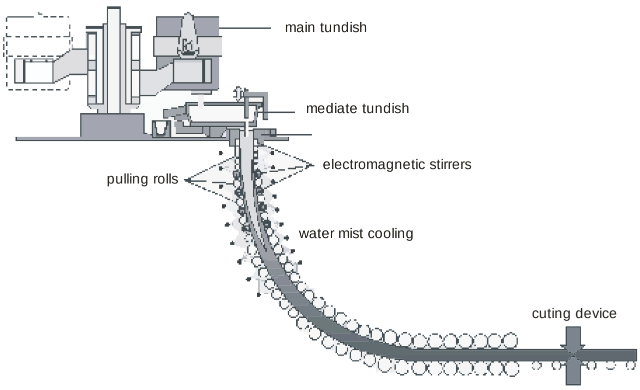

Fig. 1. Continuous casting process diagram [3]

One of the main difficulties during the process of continuous casting of cast iron is to obtain the cross-cast microstructure of uniformly distributed partial graphite [4] (Figure 2) and most importantly, without a partial cementite.

Fig. 2. "A" Graphite distribution model [5]

From a theoretical point of view, the manufacturing of such a casting, in which the graphite morphology is characterized by certain features, designed specifically for the working conditions of a particular casting seems simple. Unfortunately, practice shows that the receipt of such a cast is difficult. This happens for example in the case of the continuous casting lines, where the conditions of heat removal from the casting varies significantly depending on the distance between the location of the cross section of the casting and the crystallizer wall[6].

2. The stand building concept

The Foundry Department of the Silesian University of Technology in Gliwice carried out the work on the use of forced convection of liquid metal in the crystallizer installed on a continuous casting line. Effect of external factors (in particular the electromagnetic field) in the solidifying cast are presented among others in the work [2, 6 ÷ 10].

For the purposes of the research a laboratory stand (shown in Figure 3) for the continuous casting of cast iron ingots of a 20 mm diameter was designed and built, the stand consists of three components:

- melting part (Fig. 3) consisting of a crucible induction furnace with the following parameters: maximum capacity of the furnace. 80kg, water inductor cooling in a closed circuit, continuously adjustable power,
- casting part (Fig. 3, 4) consisting of a 20 mm diameter graphite crystallizer and water cooling radiator operating in a closed circuit, equipped with water flow controls and temperature measurement system and a electromagnetic field inducer of the induction up to 100MT placed in the chamber of crystallizer water cooling. The radiator is made of stainless 1H18H9T.
- manual and automatic pulling of continuous ingot part (Fig. 3) with the following technical parameters: the average speed of pulling the ingot 150-1500 mm/min, the possibility of regulating the speed of pulling in a series of manual and automatic traffic characteristics of the ingot pulling algorithm in automatic cycle: forward movement 5 - 15 sec, stop, backward movement 0.5 - 2 s, the ingot pulling roller drive with a double set - pulling roll and an overdraft roller moved to and from the ingot by a pneumatic or hydraulic actuator (Figure 3 pos. 4).

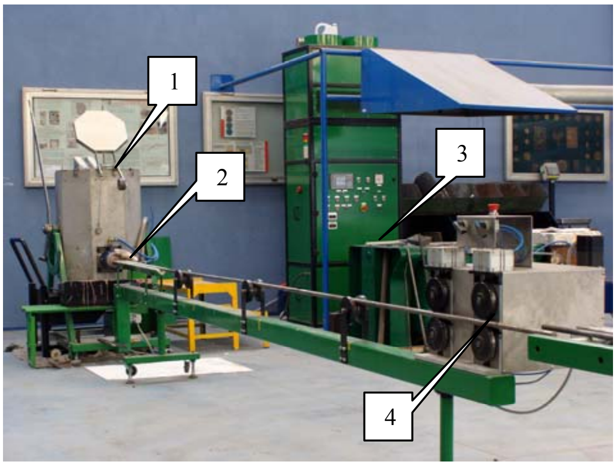

Fig. 3. Continuous casting line in the Foundry Department of the Silesian University of Technology: 1 - induction furnace, 2 - crystallizer, 3 - steering, 4 - pulling machine

Fig. 4. Casting part with the electromagnetic field inducer

The proper conduct of the continuous casting process is affected by a number of factors such as temperature of metal in the furnace, the temperature of crystallizer water cooling, ingot pulling speed and specification (depending on the pulling algorithm), the temperature at the outlet of the continuous casting crystallizer, the chemical composition of metal furnace, etc.

The above-mentioned parameters can be classified into a group of necessary variables, but insufficient to obtain a grey cast iron ingot with a uniform microstructure of the cross-section. For this reason, the process of continuous casting of cast iron has been "enriched" with another group of parameters controling the work of the inducer, which is an integral part of the casting part (with the crystallizer and the cooling system).

The basic parameters include the intensity of the supply current I. The increase in the value of inductor current causes an increases in the value of the magnetic induction B inside the crystallizer, which intensifies the mixing of the liquid metal in a crystallizer. Another parameter is the inducer voltage frequency f , which allows maintaining a constant value of electrical current while regulating its power and force that enforces the movement of liquid metal F (Fig. 5) and consequently the speed of its rotation in the crystallizer.

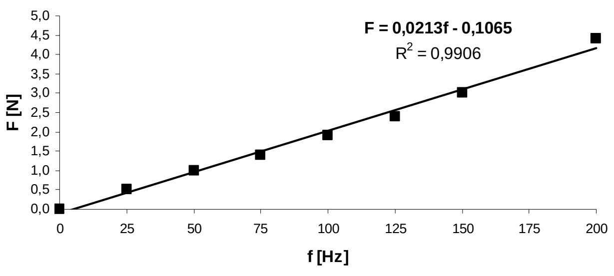

Fig. 5. Effect of frequency f of the supply voltage to the inductor value of force F which enforces movement of liquid iron at the inner diameter of 20mm graphite crystallizer

However it should be noticed that with increasing force that enforces the movement of liquid metal (by increasing the frequency of voltage inducer) adverse events occur. These phenomena are illustrated in Figure 6, where the current density distributions are presented. It may be noted that despite the summary increase in the mixing strength of liquid metal with increasing the frequency, while too large values of frequency intensifies the skin phenomenon effect, which reduces the surface impact of current, and current distributions go asymmetric as a result of excessive speed of rotation of the magnetic field.

These effects also limit the scope of the beneficial changes to the frequency of the electromagnetic stirring, to about 500 Hz.

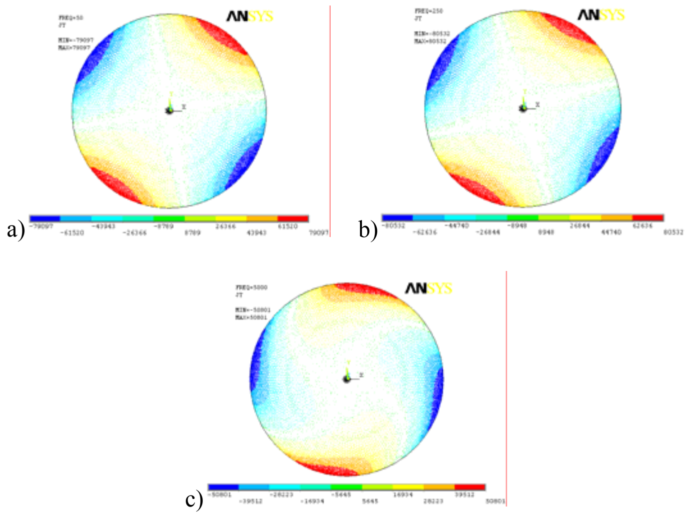

Fig. 6. Current density distribution in the field of cast metal in a frequency power inductor:
a) – 50 Hz, b – 250 Hz, c – 5 kHz

3. Summary

Verification of the correctness of a devices set was carried out in a series of studies on the described above, continuous casting line. As a result of tests carried out to test the material obtained in the form of cast iron ingots (grade EN-GJL-200) produced in strictly defined circumstances wich were tested, among others metallographic test for determining microstructure of cast on its cross-section.

The figure below shows some of the microstructure, on which the improvement of the morphology of graphite - especially in the outer part of the cast for the samples made with rotating magnetic field is clearly visible (Figure 7d).

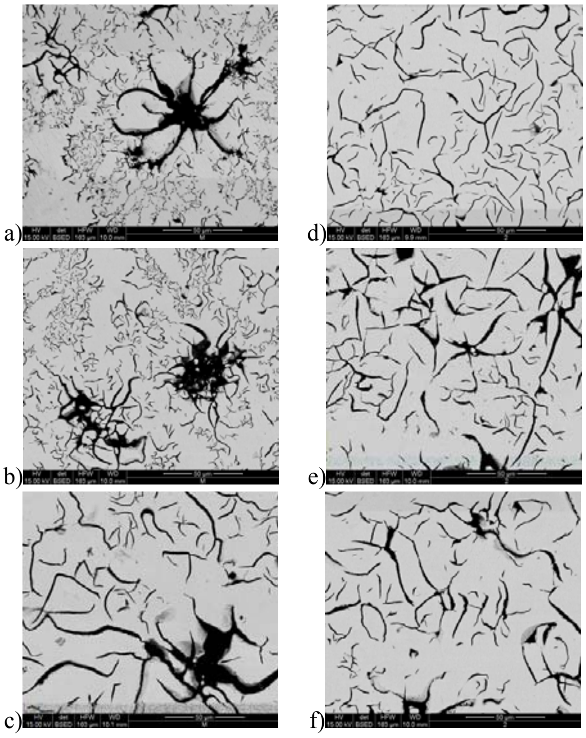

Fig. 7. Microstructure obtained by tests carried out on the continuous casting line (a ÷ c) model casting without the participation of an electromagnetic field, (d ÷ f) the cast made with the parameters of rotating electromagnetic field (WPM): 5A, 50Hz, and casting pulling speed 700mm/min. Microstructure presented in the following order: a, d - edge of the sample, b, e - half radius, c, f - a measure of the sample

The Foundry Department of the Silesian University of Technology is continuouing the efforts to generate a detailed knowledge of the impact of external factors (mainly the electromagnetic field) on the quality of castings produced on continuous casting lines.

Developed design solutions (described in this article), the construction of the casting stand (crystallizer) were covered by the patent [11].

Acknowledgements

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