Steel smelting in induction crucible furnaces with industrial frequency

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Abstract. Induction crucible furnaces with industrial frequency (IChT) have been used since the 50s of the last century. The performance of the furnaces guarantees temperature that is lower than 1450°C for constructors and developers. That is why the lining of these furnaces is made of quartzite, which gives its high resistance (300-350 smelts) for melting alloys at this temperature. However, the developers have provided a power reserve that allows raising the temperature to 1550°C for performing such technological melting operations as the carbonization process with steel scrap, alloying while the smelting of special cast iron, the use of a large amount of light scrap and recovery. Market conditions began to dictate their requirements to the casting manufacturers (the demand for castings from cast iron decreased, and steel increased) and this especially affected the foundries that were equipped with the IChT furnaces only. For this reason, there was a need to develop a technology that allows the steel smelting in an IChT furnace.

1. Introduction

Induction crucible furnaces with industrial frequency (IChT) have been used since the 50s of the last century. An important feature of induction furnaces is the intensive circulation of liquid metal, caused by the interaction of electromagnetic fields, excited on the one hand by currents passing through the inductor and, on the other hand, by eddy currents in metal. [1 - 3]

The nature of the circulation flows is shown in Fig. 1.
The positive side of it is, due to mixing, smelting accelerates and metal’s composition and temperature are aligned. The negative side is the surface of the metal can become bare and convex as the slag flows down to the walls of the furnace crucible. Indeed, when the induction crucible furnace is supplied from an industrial frequency source, the depth of penetration is relatively high, the electrodynamic forces push out a large amount of metal, causing unfavorable mixing, which can lead to the spillage of the melt from the furnace. [4, 5]

Therefore, these furnaces, due to its structural features, are designed for cast iron smelting at operating temperature of 1450°C, short-term overheating up to 1550°C is permitted [6].

Even furnaces with high frequency, with much higher power and melting temperature, do not have that effect. For this reason, it is generally accepted that it is impossible to produce steel in induction crucibles of industrial frequency.

2. Relevance
At the end of the 90s of the last century, the existing market for the consumption of black alloys castings had a detrimental effect on foundries, equipped with IChT induction furnaces only.

In this situation, there was also a foundry named "Krasnoyarskenergo", because it was equipped with the ICHT-10 smelters only. The lining of these furnaces was made with Pervouralsky quartzite and boric acid [7]. The melting temperature of quartzite, depending on its purity, is not more than 1710°C, but since the composition of the lining there has also boric acid with the melting point of 171°C, the lining itself begins to melt is within the temperature range of 1690°C-1700°C. The foundry was equipped with automatic molding lines, and the metal was delivered to them with the help of a TML truck. According to practical data, the temperature of the metal, while it is transported in a barrel-type ladle before it reaches the melting section, falls by 60-80°C, and during the casting, it drops by another 10-20°C. To perform profitable orders for steel or shaped casting, it is necessary to deliver the metal to the place of pouring with a temperature of not less than 1560-1680°C.

3. Practical significance
In order to solve the problem of steel smelting in IChT furnaces, which is vitally important to the team, it is necessary to solve two things. Firstly, is it possible to raise the melting temperature to 1670-1680°C? Secondly, what lining can be used to melt steel?

At that time, smelters had already learned how to smelt cast iron from a charge consisting only of steel scrap, recarburizing agent, and ferroalloys, and freely raised the furnace operating temperature to
1550°C and sometimes up to 1600°C [8]. A more careful study of the documentation for induction crucible furnaces with industrial frequency has shown that these creators selected a power system that ensures the possible fuller release of power in the heated metal under various operating conditions. That is why transformers with the constant power in the first four-five voltage levels were used as a power source. In fact, the transformer has a certain power reserve, and while operating at low voltage levels, the transformer current will be greater at rated power than at the rated voltage. The graph of the dependence of the active resistance and the value of filling the crucible with a metal by its height is shown in Fig. 2.

Since the final operation of refining requires high temperature and can be carried out with a fully filled crucible only, the equivalent of the active resistance of the "inductor-charge" system (Rₐ = U² / Pₐ) is significantly reduced, which leads to an increase in the total furnace power. Furnace with the capacity of 40 tons, with a fully filled crucible, Rₐ = 0.4, and with a filling of height by 0.2, Rₐ increases to 1.2. For this reason, the power reserve is 15-20%. It inspires confidence in solving the first problem.

The solution of the second problem began with the elaboration of the issue of the production of the main lining since manganese steels were more in demand.

| Grain composition                  | %, within the range |
|-----------------------------------|---------------------|
| The remainder on the grid №3,2    | 5 – 10              |
| The remainder on the grid №1      | 20 – 30             |
| Pass through the grid №05         | 50 – 60             |
| Pass through the grid №006        | 22 – 27             |

In that time, the North Angarsk Mining and Metallurgical Combine produced it, but he practically sent all product to the Urals, and we could not get all necessary things. Due to this reason, the lining made from the obtained periclase powder did not pass tests. It was necessary to develop the technology of making acid lining based on traditional materials, which would allow the smelting of steel.
4. Conclusion
As a result, the work that was done to change the sintering regime and the technology for the first
meltings, which made possible to obtain a fairly strong melted layer with thickness of 3-5mm, allowed
to master the smelting of carbon steels with a carbon content of 0.3-0.35% and higher, and steels
doped with chromium and nickel. The strength of lining for steel smelting was 14-16 smelts, but after
transferring the furnace for futher smelting of cast iron, it could handle 40-50 smelts more. The
difficulty of steel smelting was in the temperature. If the temperature of the melt was higher to 1600°C,
the process of slag formation increased rapidly [9, 10]. The temperature began to rise very quickly,
and it was impossible to analyze it by the color of the surface. The first time it was necessary to
control the temperature with a thermocouple just after 1-2 minutes (there were cases when the
temperature reached 1700°C, which led to an irreversible process of the lining destruction).
Despite all the difficulties, the task was solved, and foundry carried out orders for cast iron and
steel casting. In 2005, this technology was reproduced in another factory on the IChT-1 furnace.

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