Induction Melting-Casting Systems With Controlled Movement Of Metal For High-Quality Cast Iron Production

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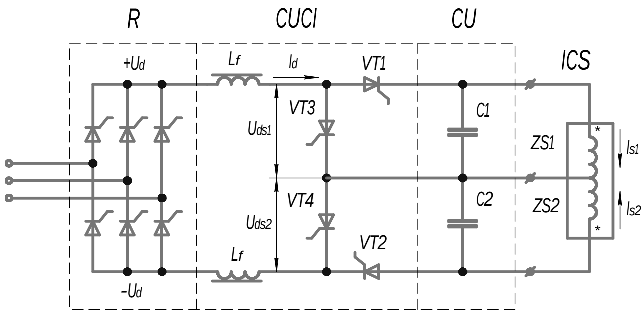
Abstract. The system of two-part power inductor crucible furnace with converter of frequency, that creates a controlled movement of the liquid metal in the working volume of the furnace. Described the functioning of the power system and shows the effects of its actions. Rate of carbonation of the iron in both natural and controlled circulation is compared.

I. Extended Abstract

Induction melting has received widespread occurence on a number of working systems and on a great number of technologic applications in different technical areas. One-phase induction crucible furnaces of medium frequency (250-2500 Hz), that operate in the batchwise melting regime (melting with complete tapping) at the power of up to 1000kV, are widely used in foundry production. High efficiency of melting and overheat with low power consumption per a ton of metal (500-560 kW·hour/ton during melting of cast iron) are achieved. Besides this, natural two-circuit mixing occurs. However, during one-phase electric supply the circulation of liquid metal occurs in two poorly mixing toroid contours. So the circulation does not provide the required uniformity of chemical composition and homothermal temperature of the metal.

The control of liquid metal movement and the formation of one-circuit smelt circulation in the system's effective volume are the methods that enable to activate metallurgic processes and to increase the quality of derived smelt in induction crucible systems. The metal direction and spinning speed in the toroidal circuit must change depending on the requirements of technological process of smelt treatment. These requirements can be fulfilled in the induction crucible system (ICS) with a multisection inductor and multiple-circuit energy supply. The control of value and phase shift of medium-frequency currents formed by multi-energy-channel frequency converter are performed in the multisection inductor.

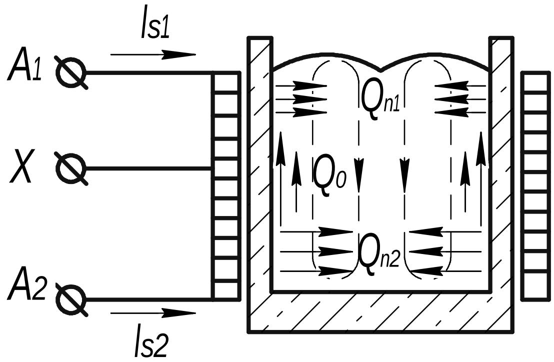


Picture 1. Basic diagram of induction melting system

The authors suggest considering the system of two-circuit energy supply of two-section inductor with frequency converter that is assembled on the base of cascaded unsymmetrical current inverter (CUCI, the scheme is in picture 1). The converter is assembled according to the two-tier block scheme. The first tier is three-phase bridge-circuit rectifier (R), the second one is two-stage unsymmetrical inverter with filtered throttle in direct-current circuit. Energetic output buses of the inverter are connected with two circuits of ICS energy supply that are created with connected inductor sections and capacitor unit (Z_{S1}-C_1; Z_{S2}-C_2).

At the different stages of melting the various control algorithms are realized. At the stage of heating and melting of a charge two cascades (VT_1-VT_3 и VT_2-VT_4) operate in common mode and the inverters' currents (i_1, i_2) of rectangular shape run through load circuit where alternating differential-mode voltages (u_{C1} and u_{C2}) appear. The inductor's sections have right and left windings so the differential-mode currents in sections $I_{S1}$and I_{S2} create alternating electromagnetic field in effective volume of the system and this promote more efficient electrothermal transformation in the charge [2].

Induction crucible systems with reverse-controlled metal movement can be identified as the furnaces of special class – the induction systems with controlled movement (ISCM). Reverse one-circuit mixing of metal enables to widen technological possibilities of ISCM to realize difficult metallurgic processes.



Picture 2. One-circuit circulation with riser metal flow

Induction melting systems with controlled metal movement assume competitive advantages in comparison with furnaces of other types, increase efficiency of metallurgical production and improve the quality of the products.

Carbonization of melted metal is one of the most important processes in synthetic iron melting and a lot of experimental studies are devoted to this process.

Carbonization rate depends on mixing intensity, temperature and chemical composition of liquid metal, type of carbonizer and its properties, and technological carbonization mode.

Rapid mixing of liquid metal grades various conditions of carbonization. The percent of recovery of carbon by liquid metal increases with the increase of mixing intensity. The higher metal temperature is, the faster the carbonization occurs. The larger the contact surface is, the more efficient mixing is. Impregnation with carbon with high mixing intensity is two times faster than with low mixing intensity.

Electromagnetic mixing of liquid metal in the furnaces of commercial frequency promotes convective mass transfer at the liquid-solid interface and creates heavy gradient of carbon concentration during the whole process. Carbon diffusion enhances as it is proportional to concentration gradient. As the result the recovery of carbon from any reagents in induction furnaces of commercial frequency is higher than in medium-frequency furnaces where the mixing intensity is much lower. At the same time recovery of carbon with low mixing intensity depends a lot on carbon concentration in chemical reagent and the lower carbon density is, the lower the percent of recovery is. This can be explained as a result of the increasing of carbonization time in the furnaces of medium frequency and oxidation of carbons on the surface of liquid metal. The effect of rapid and full recovery of carbon by liquid metal is achieved in the induction systems with controlled movement. In such systems the technological possibilities are liberalized and the efficiency of high-quality cast iron production increases.

[1] Russian patent № 2394400. Converter installation for induction heating and its variants. / Luzgin V.I., Petrov A.Y., Chernyh I.V. Publication date: 10.07.2010. Bulletin 19.

[2] Vainberg A.M. Induction and melting systems. M., Energiya. 1967. 415 p.