FEATURES OF THE USE OF INDUCTION CRUCIBLE FURNACES FOR MELTING METALS

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Annotation. ***The article presents the classification of electrotechnological and electrothermal installations, in particular, induction crucible furnaces. A retrospective analysis of the development of electric power engineering is given. The principle of operation, design and purpose of induction crucible furnaces are considered.***

Keywords. ***crucible furnace, electrical technology, electrothermal installations, heating chamber, lamp generator.***

Today, in the field of electrothermy, the issues of automation and improvement of production technology are topical, as this leads to a reduction in the cost of metal smelting, a reduction in harmful emissions into the atmosphere and an improvement in product quality.

Installations in which the transformation of electrical energy into other forms with the simultaneous implementation of technological processes, as a result of which a change in substance occurs, are called electrotechnological.

Electrothermal installations are one of the most common groups and are used in various fields of industry, agriculture, medicine, food industry and everyday life. Electrothermal processes are associated with the conversion of electrical energy into thermal energy with the transfer of thermal energy inside the body (solid, liquid, gaseous) or from one volume to another according to the laws of heat transfer.

Heating of various bodies, materials, liquids, gases; their transfer from one state of aggregation to another can be carried out using electrothermal installations of various types.

The concept of "Electrothermal installations characterizes electrothermal equipment in combination with elements

structures, devices and communications (electric, gas, water, transport, etc.) that ensure its normal functioning. Electrothermal equipment is designed for the technological process of heat treatment using electricity as the main energy carrier.

A distinctive feature of an electric furnace (electric furnace) is the conversion of electrical energy into thermal energy and the presence of a heating chamber in which the heated body is placed. The concept

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of "electric furnace" can cover both the furnace itself and, in some cases, a furnace with special equipment included in the delivery set (transformers, control panels, etc.). The “heating chamber” is understood as a structure that forms a closed space and provides a given thermal regime in it.

Electrothermal devices designed for induction heating or melting of certain materials are called induction installations. Under the induction plant is understood the whole complex of devices that ensure the implementation of the electrothermal process. The main sources for obtaining high or increased frequency for powering electrothermal installations for frequencies up to 10,000 Hz are currently thyristor or machine frequency converters, and for high frequencies - lamp generators.

Of great interest is foreign experience in the field of designing installations and operation of induction furnaces, accumulated by one of the world's largest firms Brown Bovery und Cie Aktiengesellschaft and reflected in the book by K. Brockmeier "Induction Melting Furnaces". Electrothermal equipment (ETO) is designed for the technological process of heat treatment using electricity as the main energy carrier. Among the electrothermal equipment, an important place is occupied by the induction ETO group.

Criteria for high energy efficiency, product quality and environmental friendliness are fully met by induction crucible furnaces (ITF), which are used for smelting high-quality ferrous and non-ferrous metals and their alloys.

Induction crucible furnaces (ITF) are widely used in industry for melting ferrous and non-ferrous metals both in air and in vacuum and in protective atmospheres. Currently, such furnaces are used with a capacity from tens of grams to tens of tons. Crucible induction furnaces are mainly used for melting high-quality steels and other special alloys that require special purity, uniformity and accuracy of the chemical composition, which is unattainable when melting in flame and arc furnaces.

Advantages of crucible melting furnaces:

- Allocation of energy directly in loading, without intermediate heating elements.

- Intensive electrodynamic circulation of the melt in the crucible, which ensures rapid melting of fine charge and waste, rapid temperature equalization throughout the bath volume and the absence of local overheating and guarantees the production of multicomponent alloys, homogeneous in chemical composition.

- Fundamental possibility of creating any atmosphere in the furnace (oxidizing, reducing, neutral) at any pressure (vacuum or compression furnaces).

- High performance due to high power densities (especially at medium frequencies).

- Possibility of complete draining of metal from the crucible and relatively small mass of the furnace lining, which creates conditions for reducing the thermal inertia of the furnace due to the reduction of heat accumulated by the lining. Furnaces of this type are very convenient for intermittent operation with breaks between melts and provide an opportunity for a quick transition from one grade of alloy to another.

- Simplicity and ease of maintenance of the furnace, control and regulation of the melting process, ample opportunities for mechanization and automation of the process.

- High hygiene of the melting process and low air pollution.

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Along with the advantages of their use, ITPs have the following disadvantages:

• Relatively low temperature of slag brought to the surface of the melt for the purpose of its technological processing. Relatively cold slags hinder the reactions between metal and slag and, therefore, hinder refining processes. The slag in the ITP, which is indifferent to the electric current, is heated only by the melted metal, so its temperature is always lower.

• Relatively low durability of the lining at high operating temperatures of the melt and in the presence of thermal cycles (sharp fluctuations in the temperature of the lining when the metal is completely drained).

• High cost of electrical equipment, especially at frequencies above 50 Hz.

• Lower efficiency of the entire installation due to the need to have a source of high or high frequency in the installation, as well as capacitors, as well as when melting materials with low resistivity.

The paper considers induction crucible furnaces (ITF) designed for melting non-ferrous metals and alloys, steel, as well as for melting and holding cast iron.

The first attempts to melt metals in induction crucible furnaces with high-frequency currents date back to the beginning of the 20th century. Due to the rapid development of radio engineering, various high-frequency current generators appeared - arc, spark, machine and with electronic tubes. As a result, by the beginning of the 1930s, the cost of high-frequency current energy decreased to 2-4 times the cost of industrial frequency current energy (according to G.I. Babat). This was one of the reasons for the widespread introduction of high and high frequency furnaces into industry. ITP are widely used in industry for melting ferrous and non-ferrous metals, both in air and in vacuum and in protective atmospheres. Currently, such furnaces are used with a capacity from tens of grams to tens of tons. Crucible induction furnaces are mainly used for melting high-quality steels and other special alloys that require special purity, uniformity and accuracy of the chemical composition, which is unattainable when melting in flame and arc furnaces.

The melting of conventional steels in coreless furnaces is less economical than in arc furnaces, as well as conventional non-ferrous metals and alloys, compared with induction channel furnaces. However, at present, crucible induction furnaces of increased and industrial frequency are widely used abroad and in Uzbekistan for melting conventional heavy and light non-ferrous metals and their alloys in industries with a periodic operating mode and a wide range of alloys to be smelted, as well as for melting heavily contaminated charge with high content of chips or alloys requiring modification. Since the presence of channels in channel furnaces makes it difficult to transfer furnaces from melting one alloy to another, and at the same time, fluxes and modifying salts, as well as dirty fine charge, contribute to the overgrowth of channels.

The scope of these furnaces is limited not by technical, but by economic factors, as the production of electricity increases, it is constantly expanding, capturing ever cheaper metals and alloys. The main trend in the development of induction crucible furnaces is the growth of both the unit capacity and the total capacity of the furnace fleet, associated primarily with the need for large quantities of high-quality metal. In addition, with an increase in capacity, the efficiency of the furnace increases, and the unit costs for its manufacture and operation decrease. The operation of the crucible furnace is based on the transformer principle of energy transfer by induction from the primary circuit to the secondary. The alternating current electrical energy supplied to the primary circuit is converted into electromagnetic energy, which in the secondary circuit is converted again into electrical and then into

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heat. High-frequency current, passing through the furnace inductor, provides induction EMF induction in the cage, which in planes parallel to the plane of the winding turns will cause eddy currents. In order to provide ample opportunities for the operation of an induction crucible furnace, it is necessary to be able to supply energy to the furnace also in an inclined position (there are no difficulties in maintaining the melt in a heated state at any inclination).

Electric current is supplied through a water-cooled cable, which therefore also performs the functions of a water supply. The general water supply may also include the use of separate hoses. The installation of the oven must be carried out in such a way as to ensure good supervision and control of the oven. Reliable from the point of view of metal breakthroughs, the constructive implementation of the furnace basement is carried out by making a special receiving pit, as well as by protected laying of water and oil supply lines and ceramic lining of all the most important structural elements.

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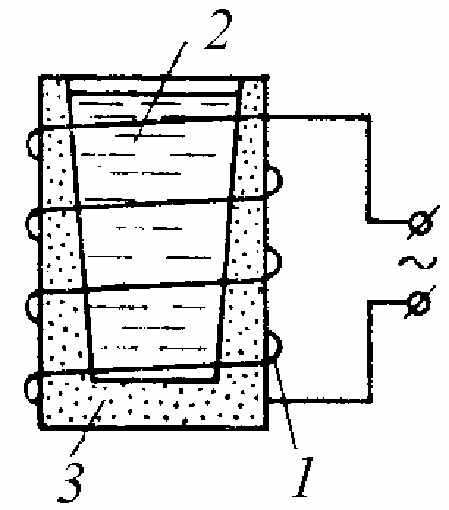
Induction crucible furnaces are also called coreless induction furnaces. The furnace is a melting crucible, usually cylindrical, made of refractory material and placed in the cavity of an inductor connected to an alternating current source (Fig. 1).



Rice. 1. Induction melting of metals in a crucible furnace:
1 - inductor; 2 – melt; 3 - refractory crucible

The metal mixture (the material to be melted) is loaded into the crucible and, absorbing electrical energy, melts. In a crucible furnace (Fig. 1), the primary winding is an inductor flowed around with alternating current, and the secondary winding and at the same time the load is the molten metal itself, loaded into the crucible and placed inside the inductor.

The magnetic flux in the crucible furnace passes to some extent through the charge itself. Therefore, magnetic properties, as well as the size and shape of the batch pieces, are of great importance for the operation of a coreless furnace.

When ferromagnetic metals are used as a charge, then until their temperature has not yet reached the Curie point, i.e. ~770740÷C, their magnetic permeability retains its value. In this case, the charge will play the role not only of the secondary winding and load, but also of an open core. In other words,

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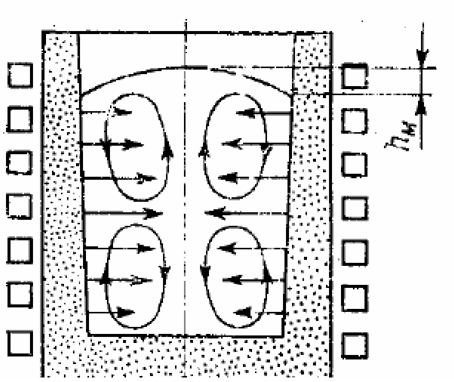
when melting ferromagnetic metals in a crucible furnace, the heating of the charge in the first period (up to the Curie point) will occur not only due to the heat released from the circulation of eddy currents in it, but also due to losses due to its remagnetization, which during this period observed in the mixture. After the Curie point, ferromagnetic bodies lose their magnetic properties and the operation of an induction furnace becomes similar to that of an air transformer, i.e. coreless transformer.

Molten metal in an induction crucible furnace is compressed by an electromagnetic field. In the middle part of the cylindrical crucible, where the edge effect does not affect, the forces of the electrodynamic interaction of the induced current and the magnetic field of the inductor are directed radially to the axis of the cylinder and decrease from the maximum value on the surface to zero on the axis. The compressive pressure created by these forces increases from the surface to the axis.

The crucible furnace is a relatively short electromagnetic system (the ratio of loading height to diameter rarely exceeds 1.5), so the electrodynamic forces are directed strictly radially only in the middle part of the crucible. Closer to the upper and lower edges of the crucible, where the magnetic field is distorted and its lines do not run parallel to the axis, the radial component of the electrodynamic forces decreases, as shown by the horizontal arrows in Fig. 2.



Rice. 2. Double-circuit metal circulation in the induction crucible furnace

Under the action of such a system of forces, the metal in the middle part of the crucible flows from the periphery to the axis, then along the axis of the crucible it is squeezed up to the bath mirror and down to the bottom of the crucible. At the top and bottom, it flows to the walls and returns along the walls to the middle part of the crucible, making the so-called two-circuit circulation.

The very fact of the electrodynamic circulation of the metal, which can be very intense, is an advantage of the induction crucible furnace, which distinguishes it favorably from the arc furnace. Circulation accelerates melting, equalizes the temperature and chemical composition of the bath, promotes the interaction of metal with slag.

An induction melting crucible furnace (Fig. 3) is a cylindrical electromagnetic system with a multi-turn inductor 1. Since load 2 is heated to a temperature exceeding the melting temperature, a crucible is an essential element of the furnace design - a vessel into which the melted charge is placed. Depending on the electrical properties of the crucible material, induction furnaces are distinguished with non-conductive (Fig. 3, a) and conductive (Fig. 3, b) crucible.

The first group includes furnaces with a dielectric ceramic crucible 3, designed for melting metals. In such furnaces, the load (charge) is heated by the current induced in it, while the crucible is equivalent to an air gap.

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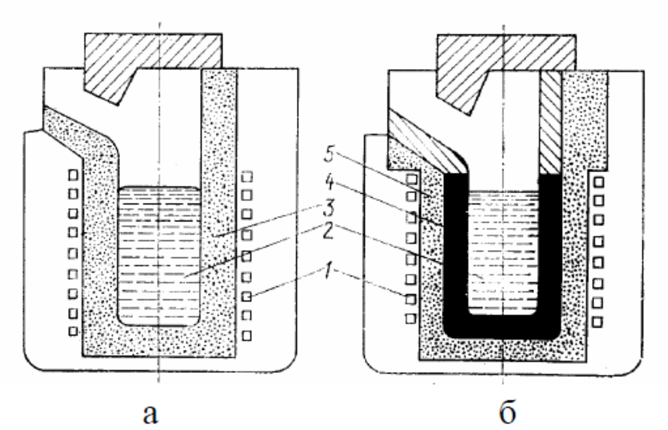
The second group includes furnaces with a steel, graphite or graphite-chamotte crucible 4, which has a greater or lesser electrical conductivity. If the thickness of the crucible wall is more than twice the depth of current penetration into the crucible material, then we can assume that the induced current is concentrated in the crucible wall, while the load is heated only by heat transfer and may not have electrical conductivity. With a smaller thickness of the crucible wall, the electromagnetic field penetrates into the load and energy is released both in the crucible wall and in the load itself, if it is electrically conductive. Conductive crucible furnaces are thermally insulated 5.



Rice. 3. The device of the induction crucible furnace

According to the nature of the working environment, induction crucible furnaces can be divided into open, working in the atmosphere, and vacuum. The design of vacuum furnaces provides both melting and pouring of metal in vacuum, due to which the content of gases dissolved in the metal is very low. The inductor and lining, the main part of which is the crucible, are fixed in the furnace body. The structural parts of the case are located outside the inductor at a small distance from it, i.e., in the area penetrated by the magnetic flux of the inductor on the path of its reverse circuit. Therefore, eddy currents can occur in the metal parts of the housing, causing heating.

In order to reduce losses in the casing for small capacity furnaces, the main casing parts are made of non-conductive materials. It is also possible to remove the metal components of the case to a greater distance from the inductor, to the region of a weaker field.

However, such a constructive solution leads to a sharp increase in the dimensions of the furnace and, therefore, is acceptable only for furnaces of the smallest capacity. In furnaces of significant capacity, it is necessary to protect the nodes of the supporting structure from the external field of the inductor. For protection, a magnetic circuit is used in the form of vertical packages of transformer steel located around the inductor, or an electromagnetic screen between the inductor and the housing in the form of a continuous casing made of sheet material with low resistivity; losses in such a screen are small.

The combination of such qualities in crucible furnaces as a fairly high cost of electrical equipment and low efficiency determines the scope of induction crucible furnaces - melting of alloyed steels and cast iron, non-ferrous heavy and light alloys, rare and noble metals. Since the scope of these furnaces is limited not by technical, but by economic factors, as the production of electricity increases, it will continuously expand, spreading to ever cheaper metals and alloys.

The main trend in the development of induction crucible furnaces is the growth of both the unit and total capacity of the furnace fleet, associated primarily with the need for large quantities of high-

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quality metal. In addition, with an increase in capacity, the efficiency of the furnace increases and the unit costs for its manufacture and operation decrease.

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