

Application of valve action of alternating current electric arc



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Abstract

The nature of existence of alternating current electric arc valve action and possibility of its use for the control of the technological processes, which are carried out in the rod ovens, are considered on the example of the industrial electric furnace for normal electrocorundum production. It is noted that the valve effect of alternating current arc in the rod oven is caused by the different nature of electrodes, between which the arc burns, i.e. finally, by electronic work function of a cathode spot and conditions of their contact with reaction zone materials.

The direct component in the electric arc voltage results from the existence of valve effect. Its dependence on arcing conditions, namely melt composition, on which the arch burns, and its temperatures, can be used for the characteristic of technological process behavior in the rod oven, that is shown on the example of the electric furnace for normal electrocorundum production.

Key words: MINE HEAT-TREATMENT FURNACE, ELECTRIC ARC, ELECTROLYSIS, VALVE ACTION, VOLTAGE DIRECT COMPONENT

Fourier theorem is used for studying of processes in electric circuits with nonsinusoidal currents and voltage. According to this theorem, any nonsinusoidal periodic variable can be expand into a trigonometric series. This series can be considered as the sum of a constant value and the number of sinusoidal (harmonious) values with frequencies multiple of the fundamental value [1].

In this regard, the use of zero harmonic voltage component, or in other words, a constant component, is of special interest. This results are explained by the fact that, first of all, its measurement is quite simple (Fig. 1) and, secondly, the inductive component of furnace installation resistance and also various hindrances from the equipment operating in the neighborhood do not influence the obtained results.

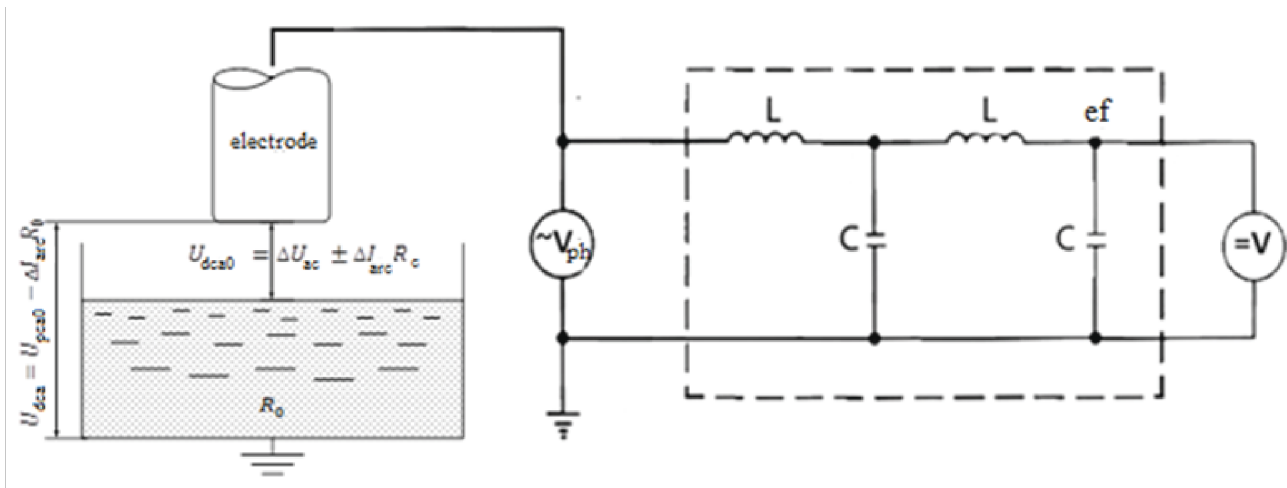


Figure 1. The diagram of measurement of phase voltage direct component: L - coefficient of induction; C – capacitor; V_{ph} – the phase voltmeter; =V – the voltmeter of a direct current

The electric arc of alternating current, burning between the dissimilar or being in different conditions materials, can be presented as two different arcs of a direct current burning alternately. The current density and voltage gradient in these arcs (in an arc column) differ, at that, the drops in arc voltage also differ, being constant in each half-period, as it is necessary for a direct current.

The direct component U_{dca0} (Fig. 2), which is first of all equal to the difference of sums of cathode and anode voltages in half-periods (U_{ac1} and U_{ac2}), will be present in voltage of alternating current arc burning between the dissimilar or being in different thermal conditions electrodes.

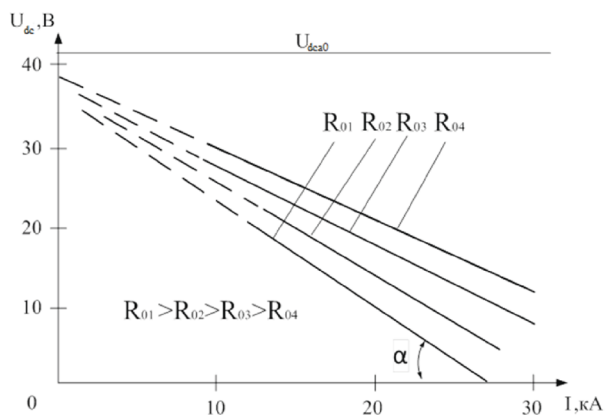


Figure 2. Dependence of a voltage direct component on electrodes current

$$U_{ac1} - U_{ac2} = \Delta U_{ac} \quad (1)$$

where U_{ac1} and U_{ac2} – the sums of cathode and anode voltage drops in the neighbor half-periods.

The value ΔU_{ac} can be presented as voltage source. The size of this source voltage does not de-

pend on resistance of loading and current intensity. It is determined only by electrodes material and temperature on cathode spots in the neighbor half-periods.

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There will be a difference of voltage gradients, and correspondingly, voltage drops in an arc column in half-periods as a result of various densities of emission currents from cathodes in the neighbor half-periods in an electric circuit.

$$\Delta U_{col} = L \cdot \Delta I_{arc} = L \cdot (I_{arc1} - I_{arc2}) \quad (2)$$

where I_{arc1} and I_{arc2} - arc currents in the neighbor half-periods;

L – arc column length.

The voltage drop in the furnace contour caused by difference in an arc column voltage, will be

$$\Delta U_{col} = R_c \cdot \Delta I_{arc}, \quad (3)$$

where R_c – electrical resistance of furnace contour.

Thus, the total size of a direct component will be

$$\Delta U_{dca0} = \Delta U_{ac} \pm \Delta U_{col} = \Delta U_{ac} \pm R_c \cdot \Delta I_{arc}$$

From the equation (3), it follows that the direct component at constant phase voltage does not depend on electrode current and is a constant value, i.e. in this case, there is also a voltage source.

However, when the arch burns on some resistance of the charge or melt R_0 (Fig. 1), the voltage drop of

a direct current caused by the arc valve action and measured between the electrode and "earth" (ΔU_{dca}), will be equal to

$$\Delta U_{dca} = \Delta U_{ac} + (R_c \cdot \Delta I_{arc} - R_o \cdot \Delta I_{arc})$$

and

$$\Delta U_{dca} = \Delta U_{dca0} \pm R_o \cdot \alpha \Delta I_{arc} \quad (4)$$

where α – the ratio of currents difference of an arc in the neighbor half-periods to the average arc current for both half- periods.

Thus, in this case, the current source, i.e. a source of electromagnetic energy, which current intensity does not depend on load resistance, takes place.

The dependence of a direct component value on the current according to the equation (4) is presented in Fig. 2 graphically.

The tilt angle of straight lines α is defined by resistance of material, on which the arc burns. The value ΔU_{dca0} depends on the differences of the sums of cathode and anode drops in voltage and on difference of current densities in the neighbor half-periods. The direction of a direct component also depends on the same values.

The fact that the tilt angle of straight lines is defined by the melt resistance, on which the arc burns, can be used for the estimation of the melt composition and its temperature connected with composition [2]. Periodic process of normal electrocorundum production [3] may serve as an example.

For the normal electrocorundum production, the bauxite (agglomerate) undergoes melting with a carbonaceous reducing agent. The process cycling is caused by discrepancy between temperatures of initial charge melting (1677 °C) and the final product (2077 °C).

The high-aluminous melt can be obtain in the fluid state only after melting of all the charge in the furnace mouth. The arc appears at the end of a melting stage and reaches the maximum development when corundum melt tapping. Existence of an arc is caused by the fact that although iron and silicon oxides reduction is finished until the time of mouth opening, the electrocorundum is tapped only after a considerable melt overheat.

The molten aluminum oxide is the good conductor of electric current. The melt overheating (finishing) is conducted if there is an electric arc for the preservation of power, which is fed into a furnace.

With the electric arc occurrence in the phase voltage, the constant component appears (Fig. 3, 4) due to the valve action. In this case, this action is caused by higher electrons emission from electrode in comparison with the melt. The cathode spot temperature on the electrode is higher than on the free-running melt [4].

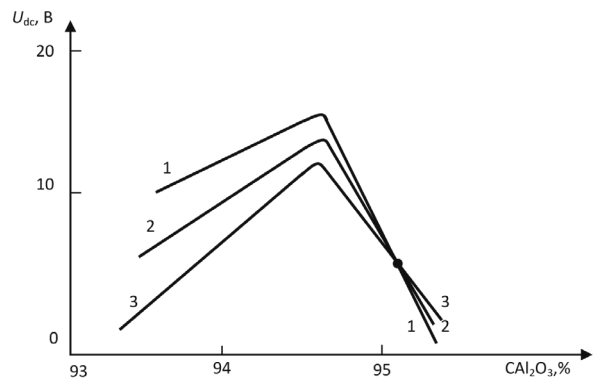


Figure 3. Dependence of value of a direct component (U_{dc}) on Al_2O_3 content in the melt in the furnace for normal electrocorundum production. Electrode current, kA: 1-26,6; 2-29,9; 3-33,2.

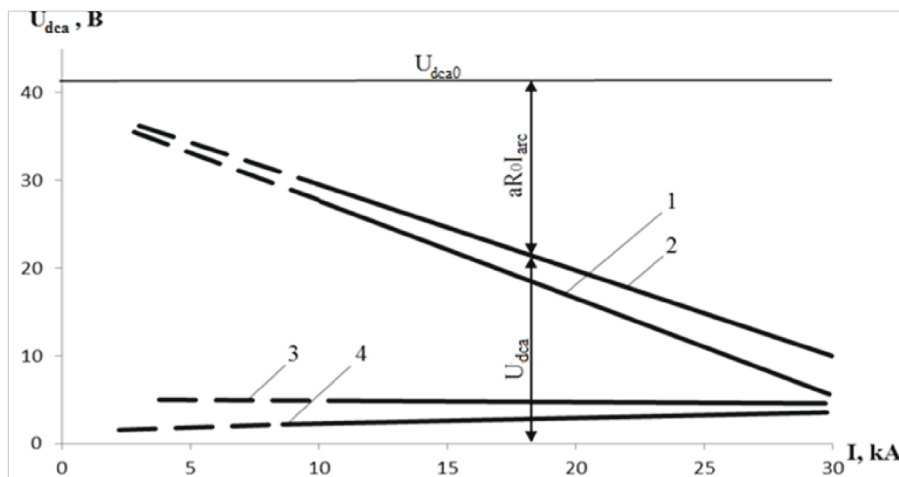


Figure 4. Dependence of a voltage direct component on current of the PKO-10,5 furnace for melting of normal electrocorundum at various AL_2O_3 contents, %: 1-93,5; 2 – 94,5; 3 – 95,5; 4 – 96.

When melt heating and increasing in its Al_2O_3 content, its resistance (R_o) drops, as is followed by growth of voltage dropping of a direct current (ΔU_{dca}) in a furnace bath according to the equation (4).

At achievement of Al_2O_3 content in fusion up to 95.5%, as a result of boiling, the emission from it increases sharply and comes to the emission from an electrode, i.e. the difference of currents ΔI_{el} in half-periods decreases and the size U_{dca} decreases according to the equation (4). If the emissions from an electrode and melt become equal, i.e. $\Delta I_{arc} = 0$, the value U_{dca} will be determined by a difference of cathode and anode voltage drops only ($U_{dca} = U_{ac}$) and will not depend on the current (the straight line 3, which is parallel to abscissa axis, in Fig. 4).

When further melt heating, the emission from it will be higher than emission from an electrode. This will lead to that the value U_{dca} will become directly proportional to electrode current (straight line 4).

As is seen from Fig. 3, the dependence of the phase voltage direct component on the Al_2O_3 content in operating limits of Al_2O_3 content in melt of 92.5 – 94.5% is of the linear character, and therefore can be used for the estimation of melt composition and determination of the moment of its tapping from the furnace beginning [5].

Such method of determination of the melt tapping beginning was introduced into all the industrial furnaces for normal electrocorundum production [6].

As it appears from examples, the continuous control of operation parameters of the ore-thermal furnace on the basis of the electrophysical and electro-

chemical phenomena following the current flow in it can become the new direction in creation of control systems of the technological process, which is carried out in it.

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