UDC 661.666:66.096.5

Research of the influence of the sub electrode section on the work of electro-thermal fluidized bed furnaces

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Abstract
The influence of the working space profile of high-temperature electro-thermal fluidized bed furnaces for carbon materials processing on their electrical resistance and power distribution in the volume was studied. The conditions for minimum heat release section under the central electrode were determined. The recommendations on the choice of the furnace's working space size (height of active zone and sub electrode area) were offered, which are provide the stability of the electro-thermal regime.
Keywords: CARBON MATERIALS PROCESSING, HIGH-TEMPERATURE ELECTRO- THERMAL FURNACE, FLUIDIZED BED, DESIGN PARAMETERS DETERMINING

The general condition of the matter

Electro-thermal fluidized bed furnaces (ETFBF, Fig. 1) make it possible to solve a number of technological problems associated with the graphitization of carbon materials, due to removing from them chemical impurities and produce ultrahigh temperatures (2000-3000 °C) when heat treatment. [1] This explains the special interest in such units from the leading companies in the production of graphite for mechanical engineering, power engineering and metallurgy.

Choice of rational designs ETFBF is associated with the need to account the complex of interconnected physical processes: heat and mass exchange, electrical conductivity, hydrodynamics of fluidized bed [2-5], which, in turn, depend on the operating temperature, the performance of the unit, the nature and the fractional composition of raw materials. Performed in [1] parametric analysis of operational modes connections with the design of the working space of the furnace allowed us to formulate the basic principles for calculating the size of the active heating zone and central electrode. However, this task does not take into account the influence of sub electrode area conductivity (Fig. 1).

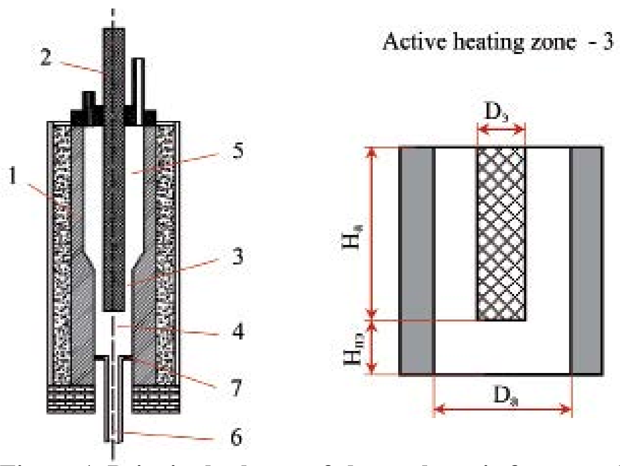

Figure 1. Principal scheme of electrothermic furnace of boiling bed [1]:
1-graphite lining; 2- central graphitized electrode; 3- active zone of heating; 4 – space under electrode; 5- freeboard; 6 – pass of finished product; 7- graphite distributing lattice: H_a, D_a – height and diameter of active zone; H_{ue} – height of zone under electrode; D_{el}- diameter of central electrode

Purposes and objectives of research

Due to the increase cross-section of the mine ETFBF under the gas electrode (Fig. 1), the rate of the inert gas takes smaller values as compared to the interelecrode space. Thus, layer under the central electrode is in a state of “minimum” fluidisation at a lower intensity of material mixing. This can lead to bypass of the active zone, exceeding the limits of the allowable current density at the electrode end and emission of the substantial heat output in a relatively small volume, which negatively influence on the operation of the furnace as a whole. This problem can be avoided by selecting the appropriate configuration of the working space and rational aerodynamic regimes.

Work objective

Determination of the conditions corresponding to minimal heat evolution outside active zone of the electro-thermal fluidized bed furnace.

Methodology of the researches

To solve this problem a numerical modeling of current spreading in the active zone and sub electrode section were carried out. The isotropic properties of the conducting medium and fluidized bed and perfect contact with the central electrode, the lining and the distribution grid were made as the main assumptions (Fig. 2).

The mathematical formulation of the problem includes the dimensionless Laplace differential equation in cylindrical coordinates:

$$\frac{1}{\overline{R}} \bullet \frac{\partial}{\partial \overline{R}}\left(\overline{R} \bullet \frac{\partial \overline{\varphi}}{\partial \overline{R}}\right) + \frac{\partial^2 \overline{\varphi}}{\partial \overline{H}^2} = 0; \quad (1)$$

where $\overline{\varphi}$ – relative potential; $\overline{R}$, $\overline{H}$ – relative radius and height of the workspace.

And we take the following boundary conditions:

– On the surface of the central electrode

$\overline{H} \in [H_{se} / (H_{se} + H_a); 1]$, $\overline{R} = D_e / D_a$

and $\overline{H} = H_{se} / (H_{se} + H_a)$, $\overline{R} \in [0; D_e / D_a]$):

$$\overline{\varphi} = 1; \quad (2)$$

– On the surface of lining and distribution grid

$\overline{H} \in [0; 1]$, $\overline{R} = 1$ and $\overline{H} = 0$, $\overline{R} \in [0; 1]$:

$$\overline{\varphi} = 0; \quad (3)$$

– On the axis of symmetry of the furnace (when $\overline{R} = 0$):

$$\frac{\partial \overline{\varphi}}{\partial \overline{R}} = 0; \quad (4)$$

– On the free surface of the fluidized bed

$\overline{H} = 1$, $\in [D_e / D_a; 1]$:

$$\frac{\partial \overline{\varphi}}{\partial \overline{R}} = 0. \quad (5)$$

The problem (1.5) has been solved by the method of finite differences in the dimensionless step of unit cell $\Delta \sim 0.01$. The range of the relative size variation of the furnace in accordance with the results of [1] for the height is up to $H_a / D_e = 0.5$-5 and the diameter of the active zone, $D_a / D_e = 1.4$-2.3. The relative height of the sub electrode section H_{se} / D_e has been changed in the range of 0.25-2. As a result of the potential problem solution (1-5) the value of a conditional current is determined between the nodes calculation grid and sources power of Joule heat for each elementary volume in the vicinity of the

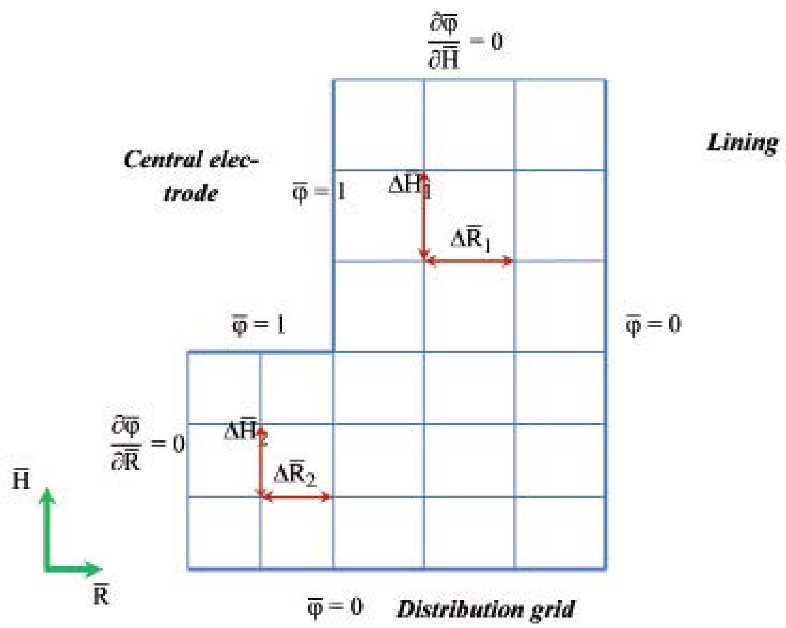

Figure 2. The design scheme of the potential problem of spreading the electric current in a fluidized bed

nodal points in the electrical resistivity (ER) of the medium - 1 ohm • m.

The obtained results and their analysis

Generalized results for the power of the sub electrode section in relation to the total capacity of the furnace Q_{se} / Q_S are shown in Fig. 3 and 4. As seen in the studied range the degree of influence of the height H_{se} / D_e on the relative power Q_{se} / Q_S of sub electrode section depends largely on the size of the active zone of the furnace and the electrode. In certain combinations H_{se} / D_e и D_a / D_e is possible to increase Q_{se}/Q_S to 50 %. Increasing of the distance from the electrode to the lattice does not solve the problem of power limitation. When $H_{se} / D_e > 1$ changing Q_{se} / Q_S does not exceed 1%. Thus, the condition $H_{se} / D_e > 1$ can be recommended when choosing a height of sub electrode section.

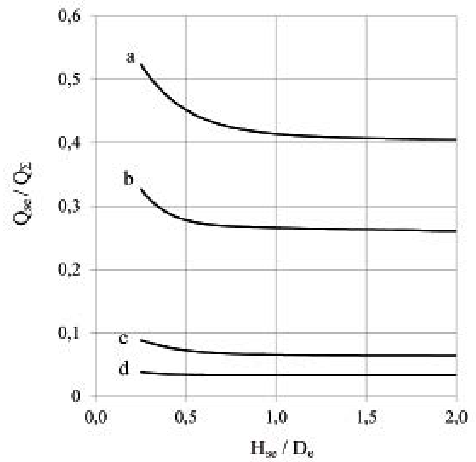

Figure 3. Influence of dimensionless height on the relative heat release at the sub electrode section when $D_{se} / D_e > 1{,}0$: a – $H_a / D_e = 0.5$; $D_a / D_e = 2.3$; b – $H_a / D_e = 0.5$; $D_a / D_e = 1.4$; c – $H_a / D_e = 5.0$; $D_a / D_e = 2.3$; d – $H_a / D_e = 5.0$; $D_a / D_e = 1.4$

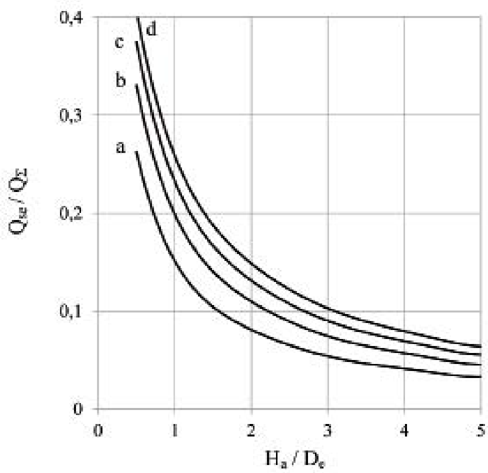

Figure 4. Influence of dimensionless height of the active zone on the relative strength of sub electrode section when $D_{se} / D_e > 1.0$: a – $D_a / D_e = 1.4$; b – $D_a / D_e = 1.7$; c – $D_a / D_e = 2{,}0$; d – $D_a / D_e = 2.3$

The main factor determining the distribution of heat release between the characteristic zones of the furnace is the ratio of the height of the active zone and the diameter of the electrode H_a / D_e (Fig. 4). When values $H_a / D_e \geq 2$ the sub electrode section contribute to the overall capacity of the furnace does not exceed 15%. For furnaces with developed height $H_a / D_e \rightarrow 5$ the proportion of Joule heat under the electrode is 3.3-8.8%. This interconnection is due to the developed of side surface of the central electrode and the lining, which leads to reduction of electrical resistance of the active zone.

Similar is an influence of the relative internal diameter of the furnace D_a / D_e (Fig. 4), an increasing of which in the range of 1.4-2.3 is accompanied by an growth of the radial resistance of the electrode space correspondingly by greater amount of current, and power under the electrode. However, compared with the height the active zone, this factor is less significant.

Conclusion

Thus, the results of numerical modeling of the potential problem of electrical current spreading in the working space of electro-thermal fluidized bed furnace with the influence of sub electrode section in the size range of the active zone height $H_a / D_e = 0.5$-5, diameter of active zone $D_a / D_e = 1.4$-2.3, height of sub electrode section $H_{se} / D_e = 0.25$-2 the height of the active zone was found as the main factor determining the distribution of power between the zones of the furnace. When values $H_a / D_e \geq 2$ the sub electrode section contribute to the overall capacity of the furnace does not exceed 15%. Increasing the height of the sub electrode section in the range of $H_{se} / D_e > 1$ does not influence on its relative thermal power.

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