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# USE OF THE HANCOCK-SHARP TECHNIQUE IN TOPOKINETIC ANALYSIS OF METAL PHASE NUCLEATION DURING CARBOTHERMIC SELF-REDUCTION OF DISPERSED IRON-GRAPHITE METALLURGICAL WASTE

Previous studies have shown that dispersed iron-graphite wastes (IGW) of metallurgical production are inexpensive and promising raw materials for obtaining radio shielding and radio-absorbing compositions [1]. Iron oxides and carbon contained simultaneously in dispersed IGW at temperatures higher than 960 $^{o}$C make it possible to carry out self-reduction carbothermic reactions to metallic iron. In this case, the specific saturation magnetization, $\sigma_s$, increases from ~30 to 180 A·m$^2$/kg [1]. Therefore, the study of the kinetic dependences describing the course of the process is of both theoretical and practical interest**.**

The experiments were carried out on dispersed IGW with a fraction of less than 160 μm, while the iron oxide particles themselves had an average size of less than 75 μm. Analysis of the course of carbothermic self-reduction (CSR) of dispersed IGW showed that the kinetic curves of the process have an S-shaped form [1]. This testifies to its two-stage character. The first stage is the reduction of higher oxides to wustite, and then its reduction to metallic iron.

The first stage proceeds very quickly, so its duration in the kinetic analysis of the CSR process can be neglected. The main time of the process is occupied by the reaction FeO →Fe.

It is known that the solid-phase reduction of iron oxides proceeds with the participation of the gas phase [2], i.e., the process is topokinetic in nature. At the initial stage metallic phase nuclei are formed, which have a catalytic effect on the reaction. Due to this, the process is accelerated. After the entire surface of the particle is covered by a thin layer of metallic iron, the process enters the second stage with the reaction front moving deeper into the particle. The second stage proceeds under reaction inhibition conditions. Analysis of the literature shows that it is advisable to describe each stage separately [3].

It is generally accepted that the nucleation of a new phase on the particle surface is most accurately described by the Avrami-Erofeev equation (equation 1) [3], and the analysis of the process itself is performed using the Hancock-Sharp procedure [4]:

$$\alpha = 1 - \exp(-\beta\tau^n), \quad (1)$$

where α is the degree of transformation;

β - a constant indirectly depending on the temperature;

τ – the time from the beginning of the process;

n - a power index indicating the geometric peculiarities of germ growth. At n from 1 to 2, there is nuclei growth is one-dimensional; from 2 to 3 - two-dimensional; from 3 to 4 - three-dimensional [4].

In the first stage of the Hancock-Sharp analysis, we plotted linear plots in the coordinates ln(-ln(1-α)) - lnτ for all process temperatures. Based on these plots, we calculated the average values of lnβ = -4.8342 and n = 1.48 with an average correlation coefficient R = 0.993.

Comparison of the experimental values of α and the calculated values obtained using equation (1), with the found values of β and n showed a good agreement $\alpha_{exp.}$ and $\alpha_{calc.}$ in the range 0<α<0.2, which fully corresponds to the literature data given for the transformation $Fe_3O_4 \rightarrow FeO$ [4].

For the convenience of subsequent calculations, equation (1) was transformed to the form (2) [4]:

$$[-\ln(1-\alpha)]^{1/n} = k\tau . \quad (2)$$

Using the graphs built in accordance with equation (2) for different temperatures and n we calculated the value of the coefficients k. Then, using the graph constructed in Arrhenius coordinates, we found the value of apparent activation energy, $E_a$ = 250 kJ/mol. According to the value of $E_a$, we can conclude that the wustite reduction process at the first stage of the CSR is limited by the carbon gasification reaction.

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## PREDICTING THE PROPERTIES OF CAST NICKEL-BASED SUPERALLOYS

Details of modern thermally stressed gas turbine engines are made from multicomponent heat-resistant alloys based on nickel, cobalt and iron using equiaxial, directional or single-crystal casting methods. The most critical parts of gas turbine engines are the gas turbine blades, which determine the maximum temperature of the working gas at the turbine inlet. One of the ways to solve the problem of increasing the working temperature of the gas before the turbine is to increase the ratio of the parameters of the crystal lattice of the matrix and $\gamma'$-phase [1-7].

For experimental and theoretical studies of temperature performance, a working sample of industrial superalloys was formed. The selection of alloys was made from the standpoint of a variety of chemical compositions (alloying systems). According to the content of chemical elements, they have a wide doping range. The value of the properties of alloys were taken from open sources in articles, books and Internet resources. On their basis, correlation dependences of the "parameter-property" type were established in the form of mathematical models. The resulting equations have sufficiently high coefficients of the correlation criterion $R^2>0.85$ and can be used for predictive calculations of these characteristics with a relative error of about 4%.

The phase composition was determined by XRD method using Bragg-Brentano focusing on a RIGAKU MINIFLEX 600 diffractometer (CoKα-radiation). The samples were