To the Issue of Choosing the Criteria of Dynamics of Complex Physico-Chemikal Processes

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Abstract— **On the basis of experimental studies, it was determined the capability to evaluate qualitatively and quantitatively the degree of arrhythmia of the carbon oxidation process, which determines the dynamics of the oxygen-converter metallurgical process.**

Keywords— process, dynamics, analysis, converter, autocorrelation function, spectral density.

I. INTRODUCTION

Lack of methods for an objective assessment of the nature of the dynamics of complex technological processes does not allow to classify clearly individual implementation of the process, depending on the peculiarities of its flow in time, and quantitatively assess the impact of changes in individual technological factors on the dynamics of the process in total.

The dynamics of many technological processes cannot be attributed to defined ones.

This is particularly true of the complex physical and chemical processes of the metallurgical, chemical and other sectors of the economy. Most implementations of such processes can be described by stochastic dependencies, which, as practice [I] shows, have the properties of ergodicity, which greatly simplifies the use of mathematical statistics for their study.

The development of the oxidation rate of carbon is one of the most important factors that determine the dynamics of the oxygen-converter process [2-4].

In order to obtain objective estimates of the nature and characteristics of the dynamics of the carbon oxidation process, in the second purge period, the following approach was proposed. In the second period, the rate of oxidation of carbon can be conventionally represented by two components: constant (which corresponds to the average value of Vc for this period) and variable. The dependence of the average rate of carbon oxidation on the technological parameters has already been studied sufficiently completely [2,3]. The performance of the component variable, depending on the technological parameters, has not been reflected by this time, namely, it characterizes the dynamics of carbon oxidation.

Experimental data to estimate the rate of carbon oxidation during the purge were obtained on converters of several metallurgical combines (Temirtau in Kazakhstan and Kryvyi Rih, Ukraine). The rate of oxidation of carbon was determined by analyzing waste gases for CO and CO2 and their utilization. These parameters were registered by the automatic information gathering system.

The rate of oxidation of carbon (Vc) in the second period was calculated by the formula:

$$Vc = 8,93 \cdot 10^5 \cdot F_i^{w.g.} (CO_i^{w.g.} + CO_{2i}^{w.g.}) \kappa g / \sec \qquad (1)$$

where, $F_i^{w.g.}$ represents exhaust gas utilization in the i-th time of purging m^3/h, $CO_i^{w.g.}, CO_{2i}^{w.g.}$ represent the composition of oxide and carbon dioxide in the waste gases at the time of purging, %.

A preliminary analysis of the realizations of the rate of carbon oxidation showed that according to the variable component of the oxidation rate of carbon (ΔVc) all the melting can be divided into 2 groups. An indication of such a distribution can be an estimate of the degree of uneven carbon oxidation in the second period. The first group includes smelting, in which minor oscillation amplitudes (deviation from the mean value of less than 15-20%) were observed, and no acceleration of the carbon oxidation process was observed, more than $0.12 \text{ kg} / \sec^2$, at constant values of the position of the lance (Hl) and oxygen consumption (FO 2). In the second group - the smelting, in which significant amplitudes of oscillations (the deviation from the average exceeds 20%), and the value of accelerating the process of oxidation of carbon more than $0.18 \text{ kg} / \sec^2$ with constant Hl and FO 2 .

The analysis of a large number of implementations of Vc in time has also revealed the common features for both classification groups that correspond to the dynamics of carbon oxidation velocity - implementation graphs are within certain limits and during the period of implementation they retain the general nature of the fluctuations and do not intend to deviate from any direction (see Figure 1). This gave rise to the assumption [4] that the character of the rate of carbon oxidation in the second purge period, in the first approximation, can be regarded as a stationary, ergodic, random process. With this assumption it became possible to

apply for the analysis of the behavior of the variable component of the rate of carbon oxidation (Vc) apparatus of mathematical statistics [1], namely, the correlation and spectral analysis of stationary random processes.
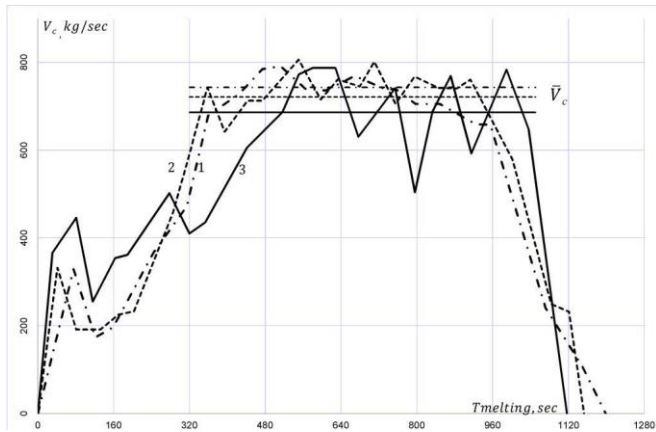

Figure 1. Implementation of the rate of carbon oxidation on heavy-duty converters: 1 - melting of the first group; 2, 3 – melting of the second group;

$\bar{V}_C$ - average carbon oxidation velocity in the second purge period

Initially, for the estimation of autocorrelation functions, the centering of experimentally obtained realizations of the oxidation rate of carbon was carried out, that is:

$$\overset{*}{X}(t)=X(t)-\bar{X}(t) , \qquad (2)$$

where $\bar{X}(t)=\dfrac{1}{n}\sum_{i=1}^{n} X_i(t)$

And then the autocorrelation functions were calculated in the form [4-7]:

$$\hat{R}_X(\tau)=\frac{1}{N-n}\sum_{i-1}^{N-n} \dot{X}_i \dot{X}_{i+n} , \; n=0,1,2,\dots,m \qquad (3)$$

where n denotes a step number; m represents maximum step numbers;

$\dot{X}_i$ - denotes the value ΔVc in the i-th time interval;

$\dot{X}_{i+n}$ - represents the value ΔVc with shifting motion n;

$\hat{R}(\tau)-$ is estimation of the value of autocorrelation function with shifting motion $\tau=n\Delta t$;

N is a number of discrete ordinates ΔVc .

The maximum number of steps is associated with the maximum shift ratio $\tau_{\max}=m\Delta t$.

When using the formula for calculations (3) it is necessary to satisfy the following conditions [4]:

$$10\tau_{\max}\leq T \; ,$$

where T denotes time of the process $\dot{X}(t)$, and the interval of discreteness;

$$\Delta t=1/2 F_c \leq 1/2 F_d ,$$

where Fc is Nyquist frequency,

$Fd<=Fc$ - is the largest frequency that is being researched in the analyzed process.

From the technological point of view, the information content is only low-frequency components with a period of oscillation of 10 seconds and more, that is, with frequency 0.1 Hz and below - so the value for the Fc was considered 0.05 Hz. In the numerical evaluation of the spectral density, the Blackman and Tuke methods [1-5] were used, respectively, which is determined by the Fourier transformation of the autocorrelation function.

In this case, the estimation of spectral density is determined the following way:

$$S_R(\omega)=S_R(n\Delta\omega)=R_X(0)+2\sum_{i=1}^{m} R_i(\tau)\cos i\Delta\omega , \qquad (4)$$

where, $R_i(\tau)$ - is evaluation of the i-th autocorrelation function; m - is a maximum number of steps; $\Delta\omega = \pi/10m$ represents a step of discreteness in frequency [5], n is a step number

Calculations were made taking into account the recommendations [5] to the frequency $\omega_{mp}=\pi/\Delta t$,

where, ω_{mp} denotes transposition frequency, and Δt represents an interval of discreteness between adjacent values of autocorrelation function.

Performed calculations of autocorrelation functions and spectral densities of the variable component of the oxidation rate of carbon finally confirmed the appropriateness of the distribution of all melts in two groups.

Fig. 2 and fig. 3 gives characteristic estimates of autocorrelation functions and spectral densities for two groups of melts. For the melts of the first group (Fig. 2, curve 1), slowly damped autocorrelation functions are typical, which indicates a rather slow change in the random component ΔVc . For the second group, fast-decreasing autocorrelation functions are typical (Fig. 2, curves 2,3), which, in turn, shows the weak link of neighboring values in 20-30 seconds interval (that is, its sharp changes).
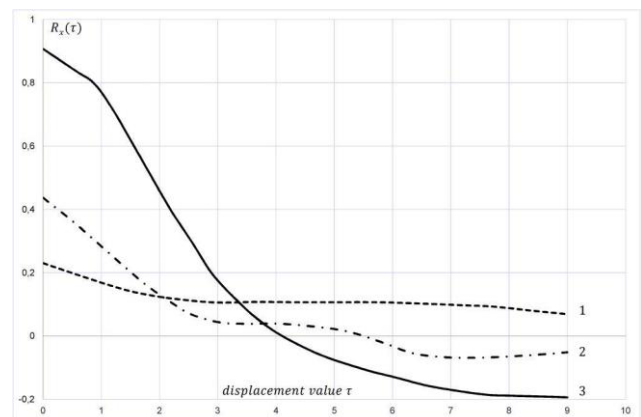

Figure 2. Characteristic estimates of autocorrelation functions and spectral densities for two groups of melts
(symbols, as in Fig. 1)

Frequency analysis of the components of random processes that were considered for two groups of melts, showed the following. In the implementations of the first group of melts, the low-frequency components- (0,005-0,02 Hz) are preferred, that is, with a period of variation of 200 - 50 seconds (Fig. 3, curve 1). The second group is characterized by higher components $0,07-0,1\pi c^{-1}$ (0,035 - 0,05 Hz), that is, with a period of fluctuations of 20-30 seconds (Fig. 3, curves 2.3).
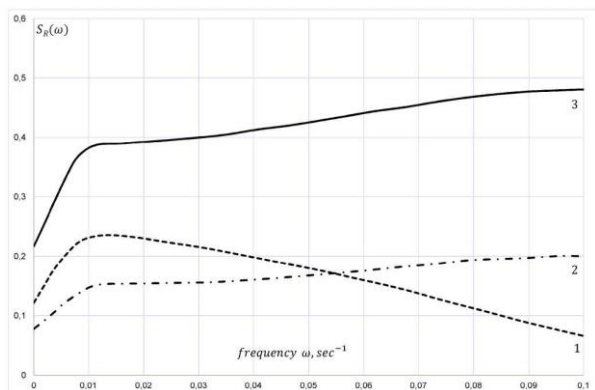
Thus, the autocorrelation function and the spectral density qualitatively characterize the behavior of the variable component of the carbon oxidation rate in the second purge period, and can be considered as objective criteria for the dynamics of this physicochemical process.

Figure 3. Characteristic estimates of spectral densities for two groups of melts (symbols, as in Fig. 1)

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