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Control of the Process of Refining Silikomarganese in Metalurgical Production

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Abstract
In a given work there is presented a solution of the significant problem – the improvement of silikomarganse guality by means of release of metal in the ladie with slag placed into it, which is previously covered with limestone layer. In order to improve the guality control there was developed and applied in manufacturing by authors new method of avtomatically control oif limestone humidity in the drying camera that also together with a new refining method results in maximum decrease of the waste produchs and of the harmful impurities contents in silikomarganese.
Key words: METAL RELEASE, SILIKOMARGANESE, SLAG, HARMFUL IMPURITIES, QUALITU CONTROL, LIMESTONE LAYER, HUMIDITY CONTROL, DRYING, STATIG REGIME, THERMAL MATERIAL BALANCE.

I. Introduction

In metallurgical production, the tendency for a qualitative change in the structure of smelted steel due to the production of alloyed and high-alloy steel differs in all technically developed countries. The amount of smelting of ferroalloys with manganese is growing at a particularly rapid pace. This is due to the fact that manganese is considered a good oxidizing agent and alloying element. When smelting manganese ferroalloys, along with an increase in production, it becomes necessary to improve the quality of products by reducing the amount of harmful impurities. It is known that metallurgical production is characterized by processes harmful to human health. Therefore, the mechanization of technological processes and the provision of automation of control systems are considered as a solution to a social problem. The purpose of this work is to study the form and activity of harmful impurities in manganese alloys and, on this basis, to improve the control method during the refining process.

II. Prerequisites and means of solving the problem

The use of limestone in the ladle will have a significant impact on the technological process of silicomanganese smelting. In this case, [3]. limestone is used as a melting agent which is introduced into the blast furnace or into the sintering charge in order to reduce the melting temperature of unsuitable rocks existing in the charge materials, imparting the chemical composition and physical properties of the slag existing in the blast furnace, [1,4]. as well as the transition of lime and unsuitable rocks into slag breeds Limestone as a melting agent satisfies the following requirements: high basicity, low content of silicon, alumina and other harmful impurities, high hardness and certain size of the fragment. In simple limestone the phosphorus content is 0.01% and in low-phosphorus limestone -0. 005% To form slag with the desired chemical composition in electric furnaces, it is necessary to add limestone or freshly burnt lime to the charge. The limestone is fired in the mine kilns. [2,8]. Calcium carbonate undergoes thermal decomposition, resulting in calcium oxide and carbon dioxide:

$$CaCo_3 \rightarrow CaO + CO_2 \qquad (1)$$

Thermal dissociation of calcium carbonate occurs quite quickly at a temperature of 800-8500 C and the higher the temperature, the faster the process. [7]. In this case of refining silicomanganese, limestone should be poured into a ladle onto the surface of the slag. Experiments on refining silicomanganese liquefied slag were carried out in a problem laboratory for the preparation and processing of charge. In a lava ladle, a decrease in phosphorus and carbon occurs when the slag content is 30% of the processed metal. The process lasts 30 minutes at a temperature of 16000 ^{0}C.

III. Solution to the problem under consideration

Based on the results of laboratory experiments at the Zestafoni Ferroalloy Plant(Georgia), 18 pilot melts of commercial silicomanganese were carried out. The essence of smelting is that the metal is released in a ladle with liquefied slag, the amount of which does not exceed one third (approx. 33%) of the volume of the ladle being processed. [2.13]. The slag is covered with a layer of limestone 5...15mm thick. Then the released metal is poured out, which is kept in the ladle for 30 minutes. According to the current technology, metal is removed, the amount of lost metal is determined, and after the bucket cools down, the bottom is ejected.

Table 1. General data of experimental casting, taken on the chute (c%)

EXPERIMENTAL SAMPLES	Mn	Si	P	C	Fe
6602-23-220	74,9	17,5	0,27	1,43	5,9
6891-23-229	73,3	17,2	0,25	1, 58	7,4
7053-26-31517	76,4	14,6	0,24	2.76	6,0
7001-26-1	75,2	17,4	0,27	1,43	5,7
7003-26-3	74,7	17,7	0,26	1,54	5,8
7005-23-5	72,7	16,3	0,25	3,73	9,3
7229-23-250/15	73,3	15,3	0,27	1,94	7,4
7232-26-326/13	71.8	17,9	0,26	3,35	8,1
7292№19	77,2	13,1	0,25	2,43	6,1
7294№21	74,4	14,2	0,27	2,29	8,7
7341-21-29№25	73,2	14,3	0,21	1,64	10,0
7243-23-256№23	76,1	16,1	0,26	1,73	5,9
7390-№27	74,2	17,4	0,27	1,49	6,4
7393-№30	76,4	14,1	0,31	1,45	7,7
average	74,6	15,9	0,27	2,05	7,3

Then you should break the bucket, remove the metal and weigh it. The results of the experiments are given in tables. 1 No. 2.

Table 2. General data of experimental casting, taken on a casting machine (c%)

EXPERIMENTAL SAMPLES	Mn	Si	P	C	Fe
1	2	3	4	5	6
6804-23	74,7	18,3	0,23	1,37	5,4
6890-23-279	73,4	18,2	0,21	1,39	6,8
7052-26-315/8	80,0	14,2	0,18	1,22	4,4
7002-26-2	74,7	17,5	0,19	1,31	6,3
7004-26-4	74,9	18,7	0,12	1,18	5,1
7006-23-6	73,4	17,6	0,24	1,66	7,1
7230-23-250/16	76,6	17,9	0,16	1,14	4,2
7233-26-326/14	72,1	18,5	0,21	1,19	8.0
7293-№20	76,8	15,3	0,23	1,97	5,7
7295-№22	74,5	13,5	0,25	2,35	9,4
7342-21-29№26	72,9	15,9	0,23	2.37	8,6
7344-23-256№24	75,8	16,1	0,26	1,64	6,2
7391-№28	74,3	17,6	0,27	1,43	6,4
7392- №29	74,8	16,7	0,24	1,86	6,4
average	80,3	16,8	0,25	1,6	6,4
GENERAL DIFFERENCES	+ 5,7	+ 0,9	– 0,02	– 0,45	– 0,9

By adding burnt lime and limestone to the fused silicomanganese (in order to reduce the content of various impurities), both in free form and as a result of the decomposition of limestone[13,6]., the resulting product is combined in the fused silicomanganese with the oxides of the elements contained in it in the following equality:

$$CaO + AlO_2 \rightarrow Ca(AlO_2) \qquad (2)$$
$$CaO + Fe_2O_3 \rightarrow Ca(FeO_2)_2$$
$$CaO + P_2O_5 \rightarrow Ca(PO_4)_2$$

The mass of salts obtained in this way is lower than the mass of silicomanganese, which is why they adhere to the surface of the fused slag. After removing the slag in silicomanganese, while its total mass remains unchanged, the percentage of impurities of other elements decreases. Thus, an improvement in the quality of silicomanganese is achieved. Being on the surface of the slag, limestone undergoes partial thermal decomposition and it is possible that it gets into the slag. The quality of limestone fractionation and the total mass also depend on the amount of unburnt limestone. It should be noted that adding a large amount of limestone can cause a deterioration in the quality of silicomanganese[10].. When obtaining metal using this method, complications are possible - for example, if manganese is present in the metal as an impurity, then a decrease in the percentage of manganese is possible. But in most cases (based on laboratory tests), manganese enters the metal in its pure form and, as a result, the proportions of silicon and manganese content increase. As for the carbon content in the slag, it must be in a gaseous state. Therefore, the retention of liquefied silicomanganese is associated with a large amount of gas released and, accordingly, with a decrease in the percentage of carbon in the form of CO 2. For the process to proceed properly[22], the moisture content of the limestone must be certain. If the humidity does not meet the conditions of technological demand, it is necessary to regulate (listen) the limestone in the hopper using an automatic control system. To determine the moisture content of limestone, it is desirable to have a mathematical model of automatic control. When drawing up a mathematical model, it is necessary to pay attention to the following basic conditions: a) drying direction b) drying mode c) heat exchange between the surrounding medium and the buildings. Their choice depends mainly on the nature of the study. Therefore, the equations that make up the mathematical model are equations of heat and material balances.

The equations for drying materials when operating in static mode have the form:

$$\begin{cases} f_1^0 = G_m^0 \frac{d\omega}{dx} + N^0 g_m^0 = 0 \\ f_1^0 = G_m^0 (\omega_m^0 - \omega_m^0) N^0 g_m^0 = 0 \end{cases} \qquad (3)$$

and when working in dynamic mode they have the form:

$$\begin{cases} f_1 + \frac{\delta(g_m \omega_1)}{\delta_r} \\ f_1 = \frac{\delta(g_m \omega_1)}{\delta_r} \end{cases} \qquad (4)$$

The equation of thermal material balance in the static drying mode has the form:

$$f_1^0 = \frac{G_m^0 d(c_m^0 + \omega^0 G_B)\, t_m^0}{dx} + ɑ_m^0 F_m^0 (t_m^0 + t_r^0) + N^0 g_m^0 + ɑ_m^0 F_m^0 (t_m^0 + t_r^0) = 0 \qquad (5)$$

and for dynamic drying mode:

$$\frac{\delta(C_m + C_{B\,\varpi}) t_M g_M}{\delta_x} + f = 0 \qquad (6)$$

The equation of thermal material balance of the drying agent has the form:

$$f_4^0 = G_r^0 \frac{dI_r^0}{dx} + \alpha_{M/\Gamma} F_{M/t} (t_r^0 - t_m^0) - N^0 g_m^0 \Gamma + \alpha_{T/\Gamma}^0 + F_{T/\tau} (t_\Gamma^0 - t_T^0) + \alpha_{k/\tau}^0 (t_\sigma^0 - t_r^0) = 0$$

$$f_5^0 = G_\tau^0 \; I_{1\Gamma}^0 \; -G_\Gamma^0 - \alpha_{M/\Gamma}^0 F_{M/\Gamma}^0 (t_\Gamma^0 - t_M^0) + N^0 g_m^0 \Gamma - \alpha_{T/\Gamma}^0 + F_{T/\tau} (t_\Gamma^0 - t_T^0) - \alpha_{k/\tau}^0 (t_\sigma^0 - t_r^0) = 0 \qquad (7)$$

and when the dryer operates in dynamic mode, they have the form :

$$\begin{cases} f_4 + \frac{\sigma(g_r I_r)}{\sigma_r} \\ f_5 = \frac{\sigma(g_r I_r)}{\sigma_r} \end{cases} \qquad (8)$$

The thermal material balance equation for humidity for the static mode is written in the following form:

$$\begin{cases} f_6^0 = G_\Gamma^0 \frac{dd^0}{dx} - N^0 g_m^0 = 0 \\ f_7^0 = G_\Gamma^0 (d_1^0 - d_2^0) + N^0 g_m^0 = 0 \end{cases} \quad (9)$$

The following GM notation is used in the equations. G_R G_T…. G_{CT} – heat capacity of the transporting device and wall, respectively, of the material (j/kg cal) d_1 d_2 – moisture content of the drying agent along the length, at the entrance and exit of the device: $F_{M/G}$, $F_{M/T}$, $F_{\Gamma/T}$, $F_{K/\Gamma}$ - heat exchange areas between the surfaces of the material, drying agent, transport device and dryer body: G_M, G_T- costs of materials and drying agent, respectively (kg/s), g_M g_Γ---- mass of materials and dried axite, respectively (kg), I_G, I_{1G}, I_{2G} - entalypya of the drying agent according to the length, . to the entrance and exit of the apparatus (j.kg), N-drying speed (1.s), $t_{M...}$ t_G.,.. t_T, $t_{K....}$ – temperatures respectively between the material, the drying agent, the transporting device and the dryer body; - ω_1 , ω_2 moisture content of the material along the length to the entrance and exit of the apparatus, respectively; $\alpha_{T/\Gamma}$, $\alpha_{M/\Gamma}$, $\alpha_{K/T}$, $\alpha_{\Gamma/\tau}$, $\alpha_{K/\Gamma}$ - heat exchange coefficients, respectively, between the material and the drying agent, between the drying agent and the transporting device, between the transporting device and the dryer body (W/μ); τ- time (s) Inductive /zero/ indicates static mode[6,20].

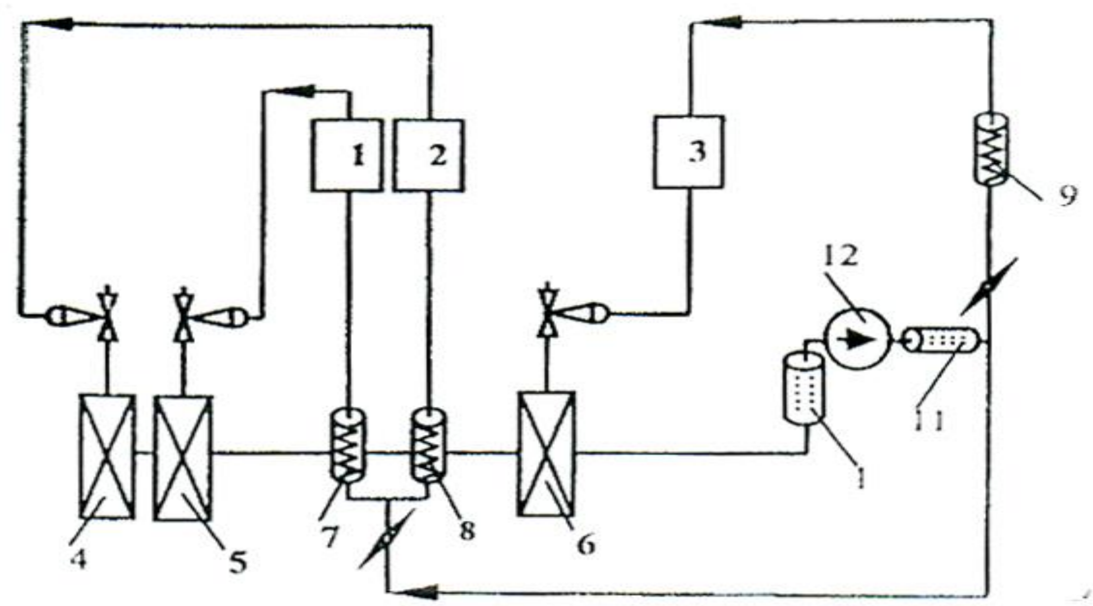

Fig. 1. Automatic air humidity control system

Air temperature regulation (see figure) is carried out by regulators 1.2.and 3, and after passing through drying chambers 4.5.and 6, the air through the bag filter 10 enters the compressor 12, which ensures air circulation. From compressor 12, air is passed through a rotary dispersion analyzer 11 and then branches into two streams, enters heater 9 connected to drying chamber 6 and (or) heaters 7 and 8, connected in parallel to two drying chambers 4 and 5. Simultaneous or separate connections to single-chamber or two-chamber circuits 4 and 5 depend on the required amount of dried limestone.

Control of the process of cleaning the surface of a metal cast in slag from slag is an important point in the automatic cycle, since the separation of metal and slag is quite conditional. The design of the universal metal separation control device is as follows (Fig2.). [2,6].The tool consists of a stand (5); from the light source (1); from the measuring surface (2); from the reflected beam recording device (3); which is informationally connected to the computing device (4). The light source and the recording device are located vertically in the plane of the direction of the surface being measured with the possibility of simultaneous rotation.

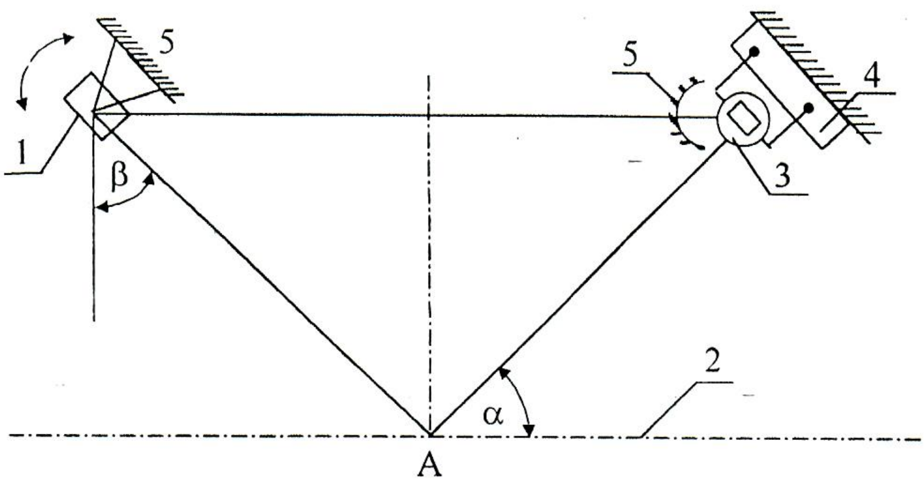

Fig. 2. Universal measuring tool

At an equal distance from point A of the beam reflection, the operation of the device is based on the use of the laws of interaction between mechanical and electromagnetic phenomena. When interacting with the surface of an object, coherent waves arise, the phases of the waves change; if we intersect these waves with the waves of a coherent diffraction source in the recording medium, we will obtain an interference image. Then we reconstruct the wave in the recording environment, by the diffraction of waves coming from the source on the recorded interference image and by the relative intensity of the reconstructed waves we judge the degree of roughness of the surface of the slag and metal. . The significant difference between the slag and the metal roughness allows the monitoring device to give a signal after the cleaning process is completed, indicating the end of the process by which the metal roughness has already been detected. The essence of the process is as follows: Fig. (2) the first and third rays fall on the uneven surface at a certain angle \alpha_0, then, after reflection, a phase difference between the waves from different points of the unevenness arises. Let us assume that (2) the ray is reflected from the plane z=0. The phase difference between rays (2) and (3) after their reflection is equal to 0. Determine the phase difference between rays (1) and (2) along the path traversed by these rays:

$$\Delta R = BC + CD = 2CD - AB \tag{10}$$

from the drawing, CD=h(x)/sin α_0 და AB= ADcos α_0 = 2h(x)cot α_0 cos α_0
where h(x) - is the height of surface irregularities, respectively

$$\Delta R = h(x)/\sin\alpha_0 - 2h(x)\cot\alpha_0 \cos\alpha_0 = 2\, h(x)\sin\alpha_0 \tag{11}$$

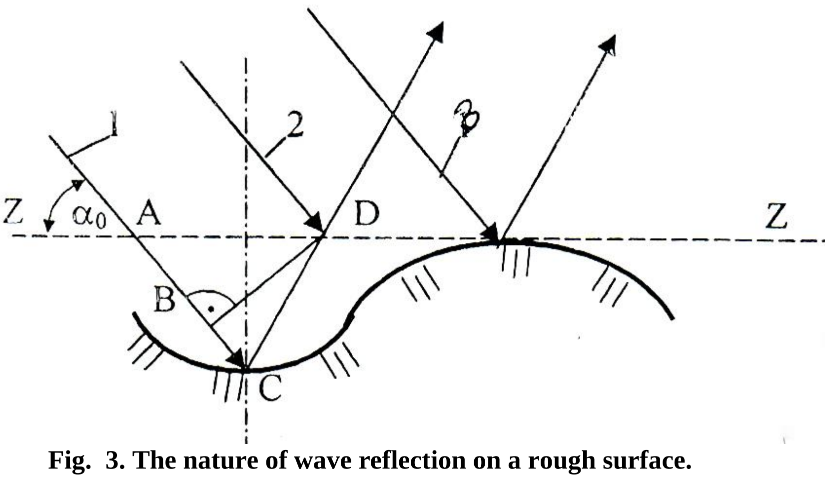

Fig. 3. The nature of wave reflection on a rough surface.

And the phase difference is determined by the following relationship:

$$\Delta\varphi = k\Delta R = 2kh(x)\sin\alpha_0/\lambda \qquad (12)$$

Where $k=2\boldsymbol{\pi}/\lambda$ wave number, λ - is the transmitted wavelength. otherwise:

$$\Delta\boldsymbol{\varphi} = 2\boldsymbol{\pi}\frac{\mathbf{2}\boldsymbol{Vt}}{\lambda} \qquad (13)$$

where V and t - are the beam speed and travel time.

Accordingly, the amplitude of a wave scattered from a stationary object:

$$U_0 = \alpha_0\exp(i\boldsymbol{\varphi}_0) \qquad (14)$$

The amplitude of the scattered wave from a moving object will have the form:

$$U0(t) = \alpha_0\exp[i(\boldsymbol{\varphi_0} + \Delta\boldsymbol{\varphi}] = \alpha_0\exp\left[i(\boldsymbol{\varphi_0} + \mathbf{4}\boldsymbol{\pi}\frac{\boldsymbol{Vt}}{\lambda}\right] \qquad (15)$$

In the recording environment we will obtain an interference image, the intensity of which will be recorded as follows:

$$\mathbf{I_{int}} = \mathbf{sin}\,\boldsymbol{c}^{\mathbf{2}}\left(\mathbf{2}\boldsymbol{\pi}\frac{\boldsymbol{h(x)}}{\lambda}\right) \qquad (16)$$

where, $\mathbf{sin}\boldsymbol{c}\,\boldsymbol{x} = \frac{\sin x}{x}$; λ =0.63 mk.m - coherent wavelength, T-registration time, that VT=h(x)

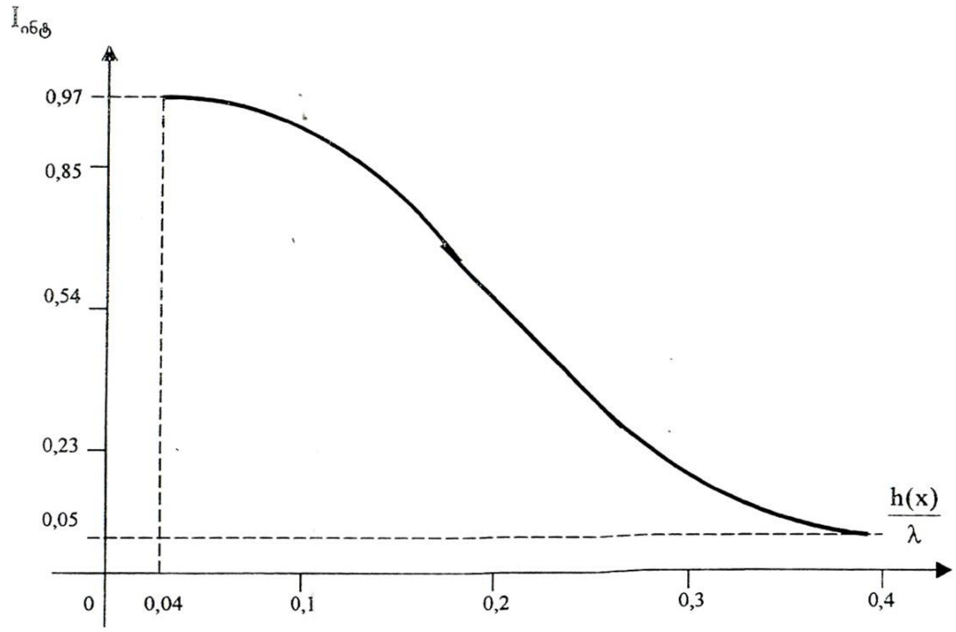

Fig. 4. Graph of the dependence of the intensity of reconstruction waves on the surface roughness values

Thus, according to the formula, a connection was established between a surface displaced in its plane and the intensity of the returning wave. Determining the intensity of the reconstruction wave leads to the determination of roughness, and the reconstruction image contains information about the spatial distribution of irregularities on the surface of the object. About the completion of the process as a structural diagram of technological process control. It can be seen that an audible warning occurs: “Metal cleaning is completed.”.

IV. Results and discussion

This work examines the activity of the presence of harmful impurities in a manganese alloy, and on the basis of this, the improvement of the method of controlling the refining process using the latest physico-chemical methods of experimental research. The reliability of the research results was confirmed by the act of implementation of the Zestafoni ferroalloy plant (Georgia).

V. Conclusion

Adding burnt lime or limestone to fused sycomanganese in order to reduce the percentage of impurities has the meaning that limestone joins the oxides found in fused sycomanganese, which causes them to fall on the surface of the slag, after removing which (slag) the percentage of sycomanganese naturally decreases, but increases percentage content of manganese and silicon, which causes an increase in the quality of sycomanganese. Using a mathematical model, the optimal option for regulating the moisture content of limestone is achieved.

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