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Increasing the level of control and management of arc steel-smelting furnaces

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Abstract. The urgent problems of modern steel-making devices are considered on the example of ASSF-90 arc steel-smelting furnace. The analysis of modern methods for controlling the parameters of arc steel-smelting furnaces is performed, the main shortcomings of the methods used are diagnosed. Laboratory studies of the parameters of arc steel-smelting furnaces were carried out, as a result of which the dependences of the temperature parameters of the furnace during different periods of melting were revealed. Based on the data obtained, an algorithm for controlling an electric steel-arc furnace has been developed and a computer program has been written. A project has been proposed for introducing the program into an existing SCADA system at one of the modern Russian electrometallurgical facilities.

1. Introduction

Today, one of the most common ways of steel production in both Russian and foreign industries is electric smelting in an arc steel-smelting furnace (ASSF) [1].

ASSFs are widely used as aggregates for steel production due to their high productivity and the ability to smelt steels of almost any composition with desired physicochemical properties. However, when using this method, there are drawbacks and problems of sustainable operation of the units, and this is primarily due to the limitedness of controlled and controlled parameters [2].

The main source of heat in an electric arc furnace is an open electric arc [3]. When burning, it is in the arc column that large power is released, which leads to problems of uneven heating of the components of the electric arc furnace and the charge materials loaded into it. When this occurs, the mismatch between the electrical and thermal parameters [4] of the furnace.

The uniformity of the heating of the furnace and the material (melting temperature) depends mainly on the quality of control of the arc, and is often measured indirectly. To stabilize the temperature within the specified limits, depending on the grade of steel produced, it is necessary to maintain a certain electric mode of operation of the furnace with the given values of current, voltage and power. At the same time, it is important that these values are as consistent as possible. During smelting in an electric arc furnace, the length of the electric arc is constantly changing, therefore, the power of this arc and the temperature regime also change [5]. This directly affects the temperature jumps, which change the thermal state of the furnace shaft and its elements and structures when the charge materials are heated to melt. Abrupt heating or insufficient melting temperature, in addition to the destruction of the electrodes and the furnace lining, directly affects the quality of the steel itself [6, 7].

Mostly, the control methods of arc furnaces and the level of automation at enterprises do not correspond to current trends and the requirements of the development of technology, as well as the physicochemical conditions of melting processes of multicomponent alloys. For this reason, the electrodes and the hearth and side lining of the furnaces prematurely fail, and a large number of defects (porosity, nonmetallic inclusions, segregation, etc.) appear with a low yield of suitable products [8.9].

2. Experimental part

Based on the foregoing, it is important to constantly monitor the thermal state during smelting and effectively control the arc size in the smelting process of the initial metallurgical raw materials. This problem today is not fully resolved and remains one of the urgent problems in the production of steel in ASSF.

To study the heating process and the thermal state of an electric steel-arc furnace, an experimental setup was assembled. The purpose of the experimental studies was to determine the dependence of the temperature change of the lining and the electrodes on the temperature change of the metal and exhaust gases during smelting. Experimental studies were carried out in a laboratory setup, the scheme of which is shown in figure 1.

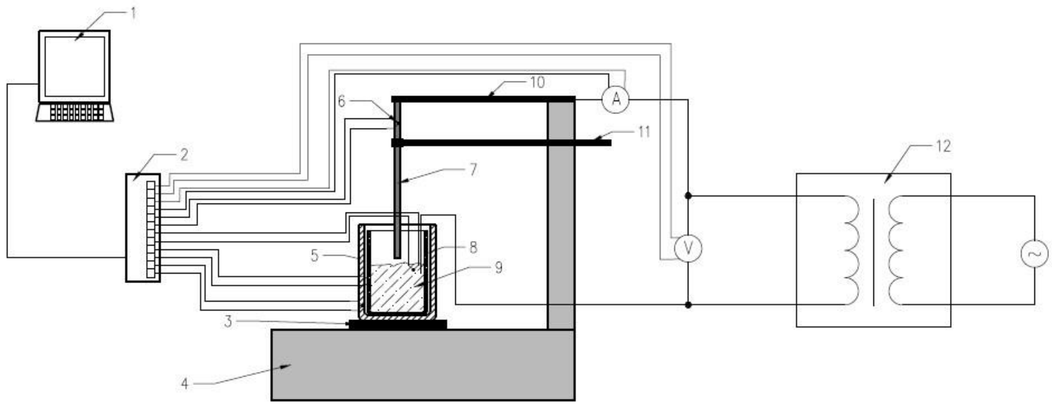

Figure 1. The scheme of the experimental setup: 1 - personal computer; 2 - analogue-to-digital converter; 3 - stand; 4 - tripod; 5 - chamotte crucible; 6 - thermocouple; 7 - graphite electrode; 8 - graphite crucible; 9 - melt (metal); 10 - current lead; 11 - electric holder; 12 - welding transformer.

During the study, a series of experiments was conducted, showing the change in temperature of the metal, lining, and electrodes during smelting. As a result of processing the obtained data, the following dependencies were obtained (figure 2).

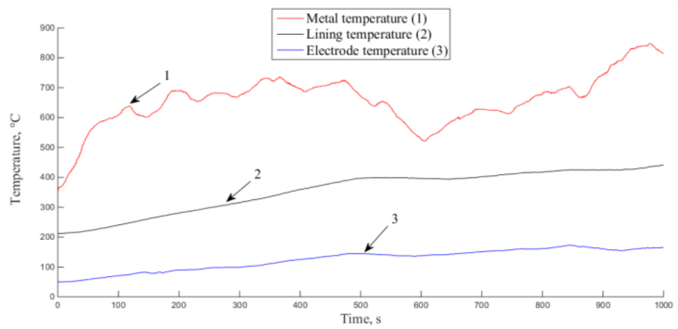

Figure 2. The dependence of the temperature parameters of the furnace from time.

The graphs show that when the metal is heated and melted, the lining temperature changes with a delay (fault = 1.35) compared with the metal temperature. The temperature of the electrode also changes with a lag factor of 0.55 in contrast to the temperature of the metal. This is due to the direct influence of the location of structural elements from the maximum heating. It can be seen that the lining warms up much faster than the electrodes. However, alternating heating and cooling of the electrodes due to their alternating movement up or down while regulating the arc leads to uneven heating of these elements and jumps. It is also important to find the most stable place to install the thermocouple on the electrode. Experiments have shown that in practice such an area is the upper part of the electrode in the zone of contact with the current-carrying elements.

3. Practical application of software for controlling ASSF electrodes

The obtained results and dependencies allowed us to develop an algorithm for controlling an electric arc furnace and propose its implementation directly at the enterprise of the metallurgical complex.

Arc steel-smelting furnaces are batch furnaces. This mode of operation has a significant impact on the lining materials of the furnace shaft. For example, a typical ASSF-90 arc steel-smelting furnace is operated at the electrometallurgical enterprises of the country. The steelmaking cycle in this arc furnace is 52 minutes, while the temperature of the melt reaches 1620-1630 ºC. After pouring the metal, the lining temperature decreases to 700-800ºC, which leads to a change in the thermal field in some parts of the furnace. Such temperature drops adversely affect the condition of the furnace lining: microcracks occur, a change in the thickness of the seams occurs, chips and fractures are formed). At the same time, the features of ASSF operation affect the thermophysical properties of the lining elements themselves (metallization and slagging). All this changes the heat balance of the unit. There is a need to continuously adjust the arc power, since the efficiency of the furnace and the amount of energy consumed are directly dependent on heat loss through the furnace lining [10,11,12].

To control the temperature regime and its thermal state throughout the entire volume of the metallurgical device (ASSF), a software algorithm has been developed as part of the Schneider Electric package. This algorithm for controlling the thermal state of particleboard, which controls the temperature conditions throughout the entire volume of the metallurgical unit, can be applied at electrometallurgical plants. On the basis of the above algorithm, a computer program was written. This program takes into account the following factors: the initial values of the temperature of the furnace bath, the temperature in the wall of the furnace, the temperature under the electrodes, the temperature of the metal (melt). The program “Control of the thermal state of an arc steel-smelting furnace” provides the following functions: temperature control over the entire volume of the metallurgical unit; calculation of the temperature of the top layer of slag; calculation of the temperature field of the metal under the electrode; calculation of the thermal field of the entire metal; calculation of the wall temperature [13,14].

The result of the program is presented in figure 3, which shows that the temperature field has a uniform distribution if the arc size changes with minimal current jumps [14].

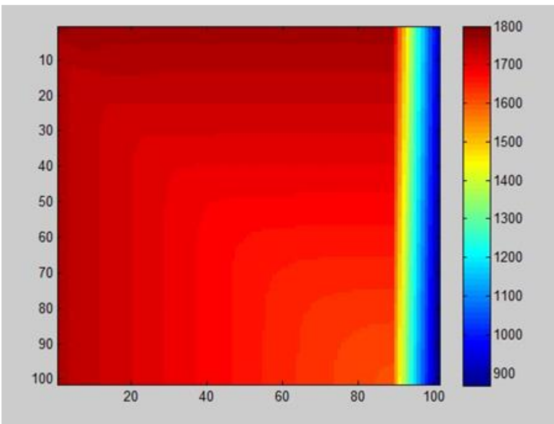

Figure 3. Thermal field furnace.

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To implement this algorithm, it was proposed to add the following parameters to the existing SCADA system at the enterprise: initial values of the furnace bath temperature, temperature in the furnace wall, temperature under the electrodes, metal (melt) temperature. This will improve the management of the thermal state of the particle board and, by expanding the information flow, optimize the existing parameters to narrower values. The project of entering new parameters into the existing SCADA system is shown in figure 4. The project of entering new parameters into the existing SCADA system (into the electrode controller) is presented in figure 5.

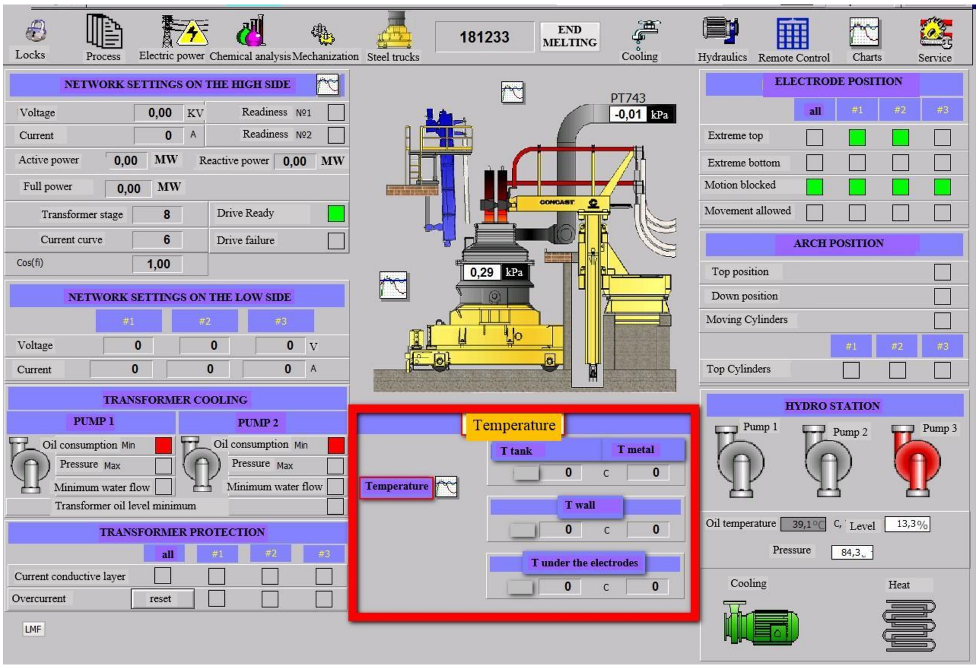

Figure 4. The project of entering new parameters into the existing SCADA system.

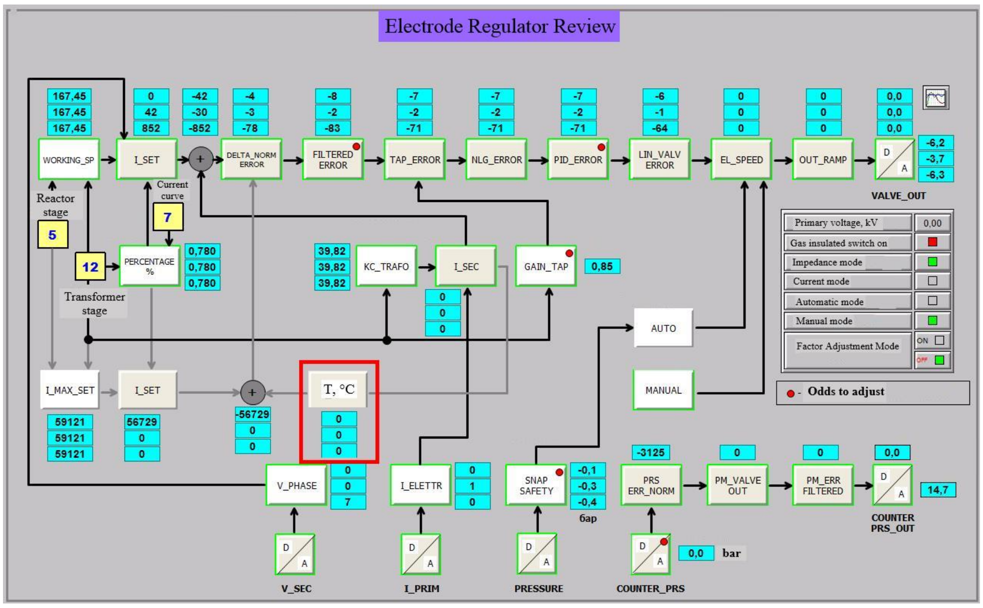

Figure 5. The project of entering new parameters into the existing SCADA system (into the electrode controller).

4. Conclusion

The main problems of the existing steel production in arc steel-smelting furnaces are identified and analysed, the scale of their impact on the production facilities is assessed. The experiments were conducted in the laboratory to study the thermal state of the furnace bath. On the basis of the experimental data obtained, the dependences of the temperature of the metal, lining and electrodes on time are determined, that is, the thermal state of the furnace is described. An algorithm for controlling the thermal state of an electrometallurgical furnace has been developed. On its basis, a control program for a programmable logic controller is written. A draft of amending the existing SCADA system at the existing production was proposed. The implementation of this project will allow to optimize the management of the thermal state of the steel-arc furnace bath by more accurately determining the length of the arc, and, therefore, minimizing current surges. As a result, the metal charge and lining materials will warm up evenly, which will make it possible to significantly reduce their wear.

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