Investigation of the induction heating spherical bodies dispersed in the continuous load inductor stove

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Abstract—*The article presents a drying unit in which it is possible to provide an unlimited amount of energy to a process medium containing metal balls-heaters, which can be implemented using induction heating. The dependences of the electrical parameters of the steel load in a general view are considered taking into account the mutual influence. A model for calculating the maximum effective power of a dispersed steel charge with a dielectric component has been developed*

Keywords—*bulk load, energy parameters, high temperature furnaces, induction heating, iron shot*

I. Introduction

In the processes of production of powder materials, often the original is obtained in the form of a suspension, and moisture removal is required to prepare the product for further processing. During the process of removing excess moisture, both gas furnaces and resistance furnaces with a ventilated chamber can be used [1-4].

In this case, the heating of the material goes from the surface into the interior of the medium, and in order to ensure sufficient process performance, it is necessary to provide a large surface area of the material onto which the radiation of the heaters falls, or which is washed by convective flows from heat sources. In such installations with a developed surface of the medium to be treated, in the presence of a powerful ventilation system of the heating chamber, a significant part of the material is carried out through the ventilation, and therefore the drying installation requires the installation of complex multi-stage filters to catch the product removed from the heating chamber. Such a system requires frequent and costly maintenance. In addition, the product removed from the heating chamber is often under-processed, since chemically bound moisture does not have time to be removed from it, and in some cases such a product needs to be processed again.

Suspension drying systems have been developed that use indirect heating of the processed material using preheated steel balls [5-8]. Since the transfer of heat from the balls to the heated medium occurs in direct contact with the processed material, the volume of the heating chamber can be reduced. Product loss through the ventilation system is also reduced. However, in such a system, the energy transferred to the material during the drying process is limited by the energy accumulated by the steel balls during preheating.

A drying unit, in which it is possible to provide an unlimited amount of energy to a process medium containing metal balls-heaters, can be implemented using induction heating [9]. To ensure maximum performance of such an installation, it is required to determine the number and size of ball heaters loaded into the installation.

II. Ease of Use

One of the possible designs of an induction drying plant that transfers energy to the processed material through metal balls-heaters is shown in fig. 1. The heating chamber is a ceramic crucible - 1, located in the opening of the inductor – solenoid - 2. The processed material is loaded into the crucible with steel balls previously mixed into it - 3, a heat insulator, kaolin wool - 4.

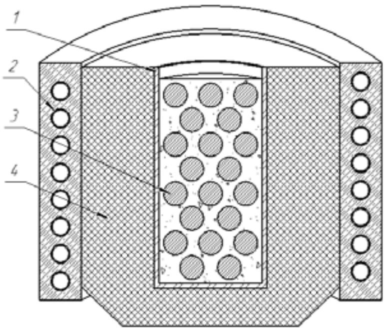

Fig. 1. The design of the induction dryer

When determining the maximum efficiency of the system, the following assumptions were made: the efficiency of the heating system will be the higher, the greater the total surface of the ball-heaters; energy costs for the drying process will increase with increasing mass of balls loaded with the processed material; efficiency increases with increasing electrical efficiency of the inductor with the load.

The assumptions made do not change their significance for all operating modes of the drying installation. For simplicity of analysis, it is more convenient to consider the removal of chemically unbound moisture contained in the treated suspension as the basic mode. In this mode, the temperature in the chamber stabilizes at 100 ° C under normal pressure.

Each of the assumptions can be expressed mathematically in the form of corresponding coefficients, the product of which will give the desired expression of the objective function.

The first coefficient shows the ratio of power supplied to the load and heat loss from the crucible walls.

The second coefficient shows the ratio of the energy accumulated by the balls and transferred to the charge.

The third coefficient is determined by the ratio of the heat dissipation power in the balls-heaters and losses in the inductor.

The electrical parameters of the inductor-loading system are calculated according to the "classical" method using a T-shaped equivalent circuit [10-11]. When calculating the reduction coefficient C, both the active and reactive resistance of the load are taken into account, as well as the scattering in the gap, inside and outside the inductor. In this case, the coefficient is calculated for the actual arrangement of the balls in the load, and when determining the scattering inductance inside the inductor's opening, we consider that the calculated arrangement of the balls along the axis of the inductor is close to each other in order to take into account the magnetic resistance of the sections of the magnetic circuit between the layers during loose laying (Table 1).

TABLE I. THE PARAMETERS OF THE BALL IN THE LOAD ARRAY WITH A UNIFORM ARRANGEMENT

b/d	$H_{пов}$	P	r	x	K_r	K_x
	A·m	W	mOhm	mOhm		
5	14600	-	0,0108	0,0167	1,00	1,00
1,01	23965	0,00942	0,072	0,0120	0,66	0,72
1,06	17952	0,00787	0,091	0,0145	0,84	0,87
1,11	13246	0,00705	0,0120	0,0186	1,10	1,12
1,15	11411	0,00670	0,0137	0,0211	1,26	1,26
1,18	10964	0,00656	0,0142	0,0217	1,311	1,30
1,19	10871	0,00653	0,0143	0,0219	1,321	1,310
1,20	10850	0,00648	0,0143	0,0218	1,312	1,308
1,21	10898	0,00647	0,0142	0,0217	1,314	1,301
1,30	11741	0,00631	0,0132	0,0199	1,22	1,20
1,40	12491	0,00663	0,0124	0,0187	1,15	1,12
2	13922	0,00633	0,0113	0,0169	1,04	1,01

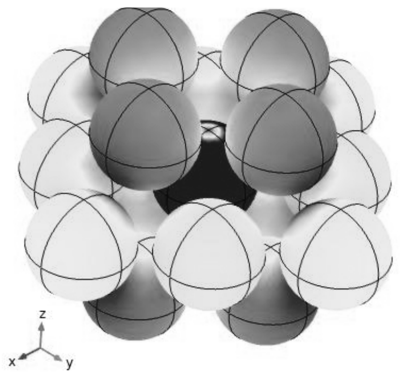

Fig. 2. Arrangement of spheres in an array with a field strength gradient over a surface

The electrical parameters of a single ball are determined using the expressions [12]. The objective function, which is a product of the three above-described coefficients, must have an extremum when changing the number and diameter of the loaded balls, since the first and third coefficients will monotonously decrease with decreasing mass of the ball-heaters, and the second when the same changes will grow (fig. 3).

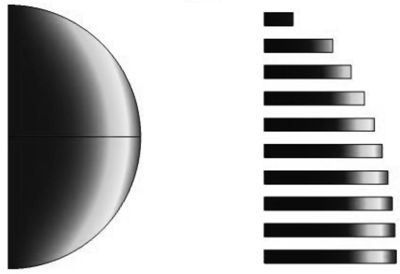

Fig. 3. Decomposition of a sphere into disks with a level of heat transfer on a body surface

The maximum number of balls in a layer, as well as the maximum number of layers during tight packing to calculate bulk density (fig. 2), can be determined using the methodology [13].

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