Temperature Distribution in a Grain-Dryer with Induction Heaters

H. Isembergenov, and A. Sagyndikova

***Abstract*—The method of drying of grain and removal of moisture which is based on receiving and processing of arising thermal processes described by the thermodynamics equation is developed. This way was a little studied and was less often applied because of considerable imperfection of the production technology of the converter of frequency of big power (to some hundred kilowatts) and frequencies (to some hundred kHz).**

***Keywords*—grain-dryer, temperature, induction heaters, energy balance.**

I. Introduction

Installation of various types of technology design and other examples of operating principles are used for grain crop drying in agricultural production, grain drying plants and grain enterprises.

At each stage the main attention is paid to the economy of the thermal energy making 90% of all power expenses when developing technological designs of grain-dryers. [1].

Peasants and farmers unlike large producers mainly apply low-speed installations of drum type which implement an induction way of grain drying.

In this regard, development of the technical solutions directed at the intensification and energy saving of technological process of grain drying is an actual scientific and technical task of agriculture industry in the Republic of Kazakhstan.

Now possibility of effective application of electric heating for grain drying has been proved. [2]. Grain dryers of high-frequency were designed, tested and even applied into practice.

II. Procedure for Paper Submission

The grain subjected to the drying in such installations conforms to all production requirements and in some cases this type of grain exceeded the grain dried in the traditional, convective way in quality.

The economic changes in our country revealed the demand for miniaturization of installations and there were created the mini grain dryers which have rather low power consumption and they are energy efficient , easy to apply and maintain and above all they are rather cheap.

However, the situation is changed at creation of mini grain dryers. With a small productivity of the dryer, especially in a case when grain is located in installation in one layer, the nature of moisture removal process is changed a little. As the small volume of grain is exposed to thermal influence, there are more opportunities for a gradient humidity creation which is sufficient for moisture removal from a small thickness grain layer. Therefore, in this case efficiency of drying process can be provided by optimization of the corresponding constructive technological scheme of the dryer.

Productivity improving technologies were created throughout all history of mechanization means of grain drying development and limited distribution of the contact method of heat transfer was connected with it but that way didn't provide the demanded economic indicators. However, an experience shows that the creation of a mini dryer is possible on the basis of the contact method of heat transfer to grain from the electric heating device [3].

In Figure 1 the authors suggest an installation with induction heaters to increase the efficiency of grain thermal treatment processes, to improve the installation capacity, to provide more uniform grain distribution on the heating surface (increasing in filling coefficient), and for more uniform warming up of the processed grain layer.

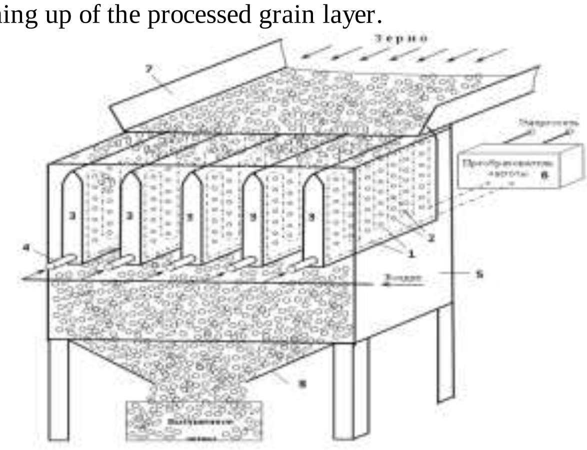

Fig. 1. Installation for grain drying with induction heaters

Heating elements are executed with possibility of distance regulation between them. The heating plate is made of two tin plates where the electric wire is located. An electric current passing through the electric wire heats two tin plates and these tins transfer the received heat to grain. At a current transmission through an electric wire which in turn heats tin

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plates, they transfer the received heat to grain.

Developed installation is universal, since the use of a closed magnetic circuit in the heating plates and grains that located between two parallel plates, all of this allows heat treatment of grain and for the majority of crops of various size and weight characteristics.

III. Math

On example of developed installation, the heat balance equation is derived. In the steady state heat flux density between the two parallel surfaces of the body depends on the temperature vim, wall thickness and thermal constant which calls thermal conductivity λ [3]:

The change in heat flow is characterized by the amount of heat, which considerate in a given volume of the processed grain.

$$\left[\frac{\partial}{\partial x}\left(\lambda\frac{\partial t}{\partial x}\right)+\frac{\partial}{\partial y}\left(\lambda\frac{\partial t}{\partial y}\right)+\frac{\partial}{\partial z}\left(\lambda\frac{\partial t}{\partial z}\right)\right]dv, \qquad (1)$$

where - λ grain material thermal conductivity [W/(m·^{0}C)];

$$dv = dxdydz.$$

The energy balance for the elementary volume of grain subjected to heat exposure in the installation for induction heating the grain can be represented as:

$$c\rho\frac{\partial t_{гп}}{\partial \tau}=\frac{\partial}{\partial x}\left(\lambda\frac{\partial t_{гп}}{\partial x}\right)+\frac{\partial}{\partial y}\left(\lambda\frac{\partial t_{гп}}{\partial y}\right)+\frac{\partial}{\partial z}\left(\lambda\frac{\partial t_{гп}}{\partial z}\right)+q, \qquad (2)$$

where c - the specific heat of the material of the heating surface [kJ/ (kg·^{0}C)]; ρ – bulk density of grain [kg/m^3]; $t_{гп}$- the temperature of the heating surface [^{0}C]; τ – exposure thermal effects [s]; q = cρdv $\frac{\partial t}{\partial \tau}$ - quantity of heat transmitted from the heating surface to a unit volume of grain material [kJ].

IV. Units

Therefore, the task can be regarded as one-dimensional, and set the following boundary conditions for the case:

$$t(0,\tau) = f(z), \qquad (3)$$

$$\left.\begin{array}{l} t|_{z=0}=t|_{z=l}=t_{гп}=const \\ \dfrac{\partial t}{\partial z}=0 \end{array}\right\} \qquad (4)$$

V. Helpful Hints

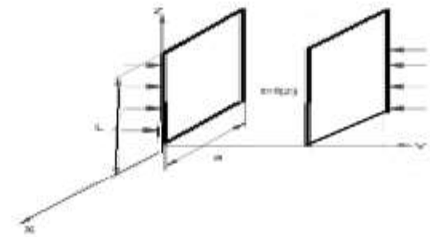

Fig. 2. Heat transmission from the grain flat heating surface

Figure-1 shows two heat tracing plates C and D, where a, l, b - width, length and thickness of the heating surfaces, respectively [m]. The resulting dependence characterizes the distribution of temperature conditions in the drying chamber at any time for the thermal conductivity of the case.

$$\theta(z,\tau)=\sum_{n=1}^{\infty}D_n\cos(2n-1)\frac{\pi}{2}\frac{z}{l}\exp\left[-(2n-1)^2\frac{\pi^2}{4}a\right]\tau \qquad (5)$$

Constant D_n in each particular solution will have its own values, since the sum of partial distributions of temperature for any given time is the actual temperature distribution. Then, after the transformations, we obtain equation (6) in the case where the outer surface of the heating plate has a high quality heat insulation ($\frac{\partial t(0,\tau)}{\partial z}$= 0):

$$t(z,\tau)=\sum_{n=1}^{\infty}\mu_n\frac{z}{l}e^{-\mu_n^2\frac{a\tau}{b^2}}\cdot\frac{2}{l}\int_0^b f(z)\cos\mu_n\frac{z}{l}dz \qquad (6)$$

где, $\mu_n = k_n b = (2n-1)\frac{\pi}{2}$,

A. Experimental studies of grain drying systems

For confirmation of correctness of the complited theoretical calculations it is necessary to conduct pilot studies and to establish a temperature gradient of heating of grain at the existing system and in the presence of the heated plates, and also to determine the maximum productivity. Table 1. Definition of gradient grain drying when the heating plates

№ measurement	Time, min	The values of temperature, °C		
		sensor №1	sensor №2	sensor №3
1	0	16	15	16
2	3	28	26	24
3	6	36	33	36
4	9	46	44	47
6	12	48	48	50
7	15	52	50	52
8	18	55	54	56

The error of measurement of temperature of grain in a place of connection of the sensor No. 3 is experimentally established it makes 3-4 °C towards increase. Temperature of external air is -18 °C, indoors +16 °C.

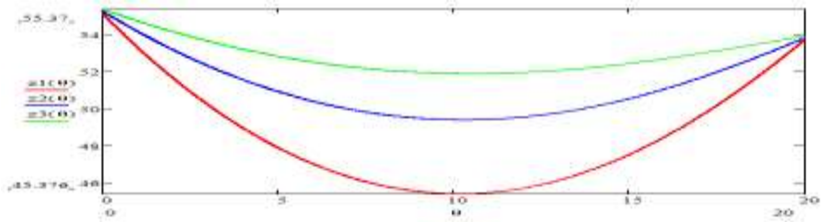

Fig. 3. The schedule of temperature of heating from various distance plates

The obtained dependence allows to prove grain moisture on the duration of heating of the heating surface.

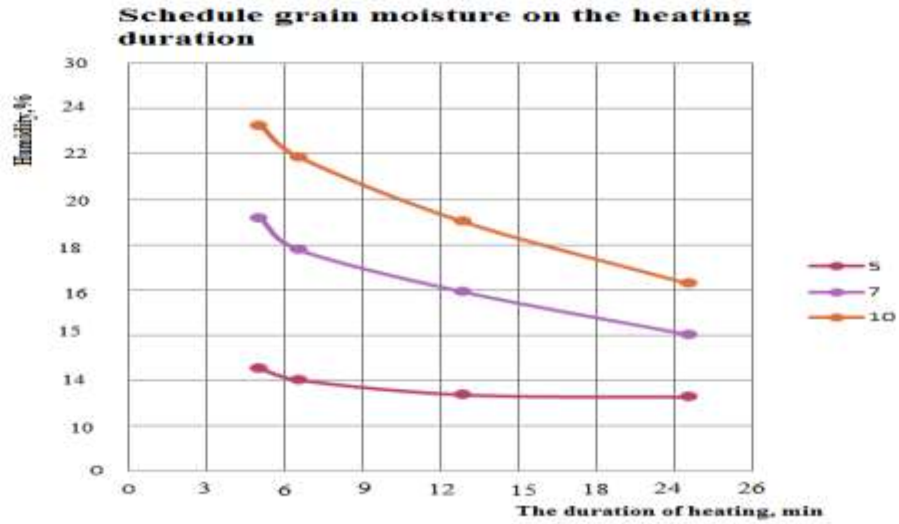

Fig. 3 The schedule of humidity from heating duration

VI. Conclusion

Thus temperature gradient on length and width of a plate is equal to zero (a case of a one-dimensional task). Then temperature in any point of a plate will depend on b and τ.

Thus, the amount of heat necessary for heating of grain and removal of moisture from it at a contact way of transfer of warmth depends on heat diffusivity of material of the heating surface, differences of temperatures of the heating surface of the processed grain (a temperature gradient) and an exposition of thermal influence.

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