SOLUTION OF THE PROBLEM IN THE DRYING OF FLAT INFRARED HEATING MATERIAL LAYER AT STATIONARY MOISTURE TRANSFER

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Abstract. *Nonlinear process when the moisture has a stationary position from the point of the analytical research is needed for theoretical and applied problems. In this paper we investigate the distribution of the heat provided stationary moisture where heat distribution has a pattern differs from the linear interaction between moisture and heat. Permanence moisture sampling is the result of a relatively steady drying mode. In the drying chamber we have a closed volume, it is particularly noticeable for the vacuum chambers, and therefore there is almost stationary process between stable heating and evaporation. Obtained linear problem of parabolic type to accomplish this task with the appropriate boundary conditions, we can apply for the interval (0, l), separation of variables. The solution for linear and non-linear interaction of moisture and temperature in the case of stationary moisture have a predetermined temperature field as a result of solution of the nonlinear system that is needed to assess the effect of non-linearity which clearly identifies with a solution.*

Keywords: *drying, infrared radiation, mathematical model, moisture transfer.*

One of the modern and increasingly used in industry promising processes is the heating of materials containing water, intense radiation [1].

The equation of drying A.V.Lykov [2], when the heat drying of the material takes place under the influence of the microwave field it has been investigated in the thesis Kazartsev D.A. [3]. In its task of heating is volumetric throughout the material as the physical nature of microwaves has the property.

The scientists of the Tashkent state technical university carried out a study of agricultural drying [4-6].

We write the well-known system of equations for our problem:

$$\begin{cases} c_s T_t - \varepsilon W_t = \lambda T_{xx} - c\left[\partial W_x + \partial_T T_\lambda\right] T_\lambda + Q \\ (1-\varepsilon) W_t = \left(ДW_x + Д_T T_x\right)_x \end{cases} . \qquad (1)$$

where, T- temperature of the material; c_s- the heat capacity of the environment; W- moisture material; ε- criterion phase transformation in vapor, defined as the ratio of the change in moisture content through evaporation and condensation to changes in moisture content due to fluid transfer; λ- local thermal conductivity; c- liquid heat capacity; ∂, ∂_T - this coefficient characterizing porous body and determined empirically.

A Q-function is a function of surface heating material decreases exponentially as the law of Bouguer-Lambert says that

$$Q = Q_0 e^{-\alpha(l-x)} \; . \tag{2}$$

where $x=0$, corresponds to the coordinates of the lower layer, a $x=l$, It corresponds to the upper surface of the material, where the infrared radiation waves. Q- the intensity of a plane wave at the inlet to the bed, α-linear absorption coefficient (also called the absorption coefficient). It is a function of the properties of the medium and the frequency of oscillation of infrared waves. If the medium is seeded centers, ie, a micro heterogeneity that is found in vegetables, fruits, have a law

$$Q = Q_0 \, e^{-(\alpha+\eta)(l-x)} \tag{3}$$

where η- it called extinction coefficient, and it characterizes the scattering loss.

Physical means that the diffraction of waves by inhomogeneities cause additional heating of the upper surface of the drying material.

Without loss of generality review research methods only formula (2), as both factors in this problem is the constant, and the drying medium is isotropic. This means that all coefficient $D, D_T, c_s, \lambda, c, \varepsilon$ - also permanent.

Permanence moisture sampling is the result of a relatively steady drying mode. In the drying chamber we have a closed volume, it is particularly noticeable for the vacuum chambers, and therefore stable between heating and evaporation there is almost stationary process, ie, $W_t = 0$.

From the system of equations of the second relation gives:

$$DW_x + D_T T_x = A, \; A=const, \text{ also } W_x(0)=const, \; T_x(0)=const \tag{4}$$

where A- constant integration of equation $\left(\partial D_x + \partial_T D_x\right)_x = 0$

But the condition of constancy of moisture selection, for the equation (4) provides that $T_x=0$. This does not mean that T and W are not a function of time and position, as shown in (4).

From (1), taking into account (4), we have after a following equation:

$$T_t - a^2 T_{xx} - в T_x = Q_0 e^{-\alpha(l-x)} \tag{5}$$

Received linear problem of parabolic type to accomplish this task with the appropriate boundary conditions, can apply for the interval $(0, l)$, method of separation of variables. To simplify the calculations, by substituting $T = Ve^{\beta x}$.

where, β- some constant, we get it from (5):

$$V_t - a^2 V_{xx} + \frac{в}{4a^2} V = Q_0 e^{-(\alpha+\beta)x} . \tag{6}$$

where $\beta = -\dfrac{в}{2a^2}$ $\quad в = \dfrac{cA}{c_s + \varepsilon \dfrac{Д_T}{Д}}$ $\quad \mu = \dfrac{Q_0}{c_s + \varepsilon \dfrac{Д_T}{Д}}$

where $a = \dfrac{\lambda}{c_s + \dfrac{Д_T}{Д}}$

The left side of this equation, written in a convenient way to search for their own functions and values. Now we write the boundary conditions. To have 3 surface-boundary value problem, ie

$$KT_x\big|_{x=l} = qT\big|_{x=l} \tag{7}$$

Finding relevant functions and eigenvalues for equation (6) to improve the known method of separation of variables, its homogeneous part under certain conditions, we have the solution $V = \sum в_n c_s \omega_n x$.

That is heat flow at the surface is proportional to its temperature.

Physically, this solution corresponds to the cooling of the drying material in the off radiation that occur in a discrete drying modes. Now consider the equation (6) with the right side for this function can be represented as

$$V = \sum_{n=0}^{\infty} T_n(t) B_n \cos \omega_n x \tag{8}$$

and from (6) have:

$$\sum \left[+ a^2 T_n \omega^2 + T_n + \frac{в}{4a^2} T_n \right] B_n \cos \omega_n x = Q_0 e^{-(\alpha+\beta)x} \tag{9}$$

Multiplying the left and right on the part of, integrate over the interval [*0, l*] have ended up

$$\left[T_n + \left(\frac{в}{4a^2} + \omega^2 a^2 \right) T_n \right] \int_0^l \cos^2 \omega_n x dx = Q_0 \int_0^l e^{-(\alpha+\beta)x} \cos \omega_n x dx \tag{10}$$

where

$$\int_0^l \cos^2 \omega_n x dx = \int_0^l \left(\frac{1 - \cos 2\omega_n x}{2} \right) dx = \frac{l}{2}$$

$$\int_0^l e^{-(\alpha+\beta)x} \cos \omega_n x dx = \frac{e^{(\alpha+\beta)l} [\cos \omega_n l + \sin \omega_n l] - 1}{\alpha + \beta}$$

So we have from (10)

$$T_n + \left(\frac{в}{4a^2} + \omega^2 a^2 \right) T_n = \frac{Q_0}{2l} \frac{e^{(\alpha+\beta)l}}{\alpha+\beta} [(\cos \omega_n l - \sin \omega_n l)] = f_n . \tag{11}$$

here $$T_n = e^{-\left(\frac{в}{4a^2} + \omega^2 a^2\right)t} \left[T_0 - Q_0 \frac{fn}{\frac{в^2}{4a^2} + \omega^2 a^2} \right] + \frac{Q_0 fn}{\frac{в^2}{4a^2} + \omega^2 a^2} \tag{12}$$

From the boundary conditions for the function *V=V(x, t)*, have

$$\begin{cases} K\left[x^{|} + \beta X\right]_{x=l} = qX\big|_{x=l} \\ x^{|}(0) = 0 \end{cases} \tag{13}$$

$$\begin{cases} Kx^{|}(l) = (q - \beta) x(l) \\ x^{|}(0) = 0 \end{cases} \tag{14}$$

Decision of the second equation (11) is

$$X(x) = B\cos\omega x + D\sin\omega x \tag{15}$$

where $\omega^2 = \gamma^2 - \frac{в}{4a^2}$

From (14) and (15) that received $\partial = 0$ it is a condition of when $x=0$, and from the condition $x=l$, have

$$\frac{\gamma}{\omega n} = tg\,\omega l \tag{16}$$

Received a transcendental equation for determining the eigenvalues of the problem. Since the $tg\omega l$, affect periodic functions of the roots of the equation (16) are discrete ie $\omega = \omega\left(n, l, \frac{\gamma}{k}\right)$

Thus obtained solution of the homogeneous equation (6) with $Q_0=0$.\

$$V = \sum_{n=0}^{\infty} B_n e^{-\gamma^2 t}\cos\omega_n t \tag{17}$$

Obtain finally solution for $T=T(x, t)$, ie.

$$T = \sum e^{-\frac{в}{a^2}x} T_n(t)\cos\omega_n x \qquad \text{or}$$

$$\begin{cases} T = e^{-\frac{в}{a^2}x}\sum_{n=0}^{\infty}\left\{ e^{-\left(\frac{в^2}{4a^2}+\omega^2\right)t}\left[T_0 - \frac{Q_0^* f_n}{\frac{в^2}{4a^2}+\omega^2 a^2}\right]\right\}. \\ Q_0^x = \frac{Q_0}{\cos + \varepsilon\frac{\partial_г}{\partial}} \end{cases} \tag{18}$$

Conclusions. Received solution for linear and non-linear interaction of moisture and temperature in the case of stationary moisture have a predetermined temperature field as a result of solution of the nonlinear system that is needed to assess the effect of non-linearity which clearly identifies with a solution (18).

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