

Solution of a theoretical model of convective drying of latex foils

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A system of differential equations describing convective drying of very thin layers (foils) and films of the coagulated latex consisting of solid latex particles and water was derived and numerically solved. The theoretical results were compared with some experimental data obtained by investigating convective drying of a chloroprene latex foil formed by freeze coagulation of chloroprene latex. In contrast to preceding models of drying of this material, the presented solution is independent of the time constant determined experimentally.

The developed method of numerical solution which was solved by means of a computer after algorithmization and transcription into language Fortran IV enables us to solve a system consisting of two partial differential equations of the parabolic type which form a mixed problem with mobile boundary and one ordinary differential equation. The agreement of the measured and calculated data is very good.

Были предложены и численно решены системы дифференциальных уравнений описывающие конвективную сушку очень тонких слоев (фольг) и пленок коагулированного латекса, состоящего по существу из частиц латекса и воды. Теоретические результаты были сравнены с экспериментальными данными, полученными при изучении конвективной сушки тонких фольг хлоропренового латекса, производимых путем вымораживающей коагуляции последнего. В отличие от ранее представленных моделей сушки этого материала, настоящее решение не связано с эмпирической константой (имеющей размерность времени).

Разработанный метод численного решения, который после алгоритмизации и перевода на язык Фортран IV был осуществлен на самодействующей вычислительной машине, решает систему, состоящую из двух дифференциальных уравнений в частных производных параболического вида, образующих задачу смешанного типа с подвижным краем, и одного обыкновенного дифференциального уравнения. Соответствие измеренных и рассчитанных данных более чем удовлетворительное.

Papers [1—4] contain a detailed description of the physical model of dried latex foil. It is based on the idea of a system of the parallel elastic capillaries filled to the border with water, the diameter, length, and number of which is a function of instantaneous moisture. It is assumed that this model system is an alternative of the dried material which, in reality, consists of spherical latex particles and water existing in the interspace among the particles. On drying, the latex particles form a continuous rubber material.

In conformity with this model image and a number of assumptions [4], the following equations were derived for the length, diameter, and a number of capillaries

$$H_u = kh_u \quad (1)$$

$$h_u = 2\delta_u = h_s(1 + Bu)^{\frac{1}{2}} \quad (2)$$

$$B = \frac{\rho_s}{\rho g_0} \quad (3)$$

$$d_u = \frac{2\rho_s d_p u}{3\rho g_0} \quad (4)$$

$$m_u = \frac{9\rho g_0^2}{2\pi\rho_s^2 d_p^2 k \delta_u u} \quad (5)$$

The above physical model of dried material is schematically represented in Fig. 1.

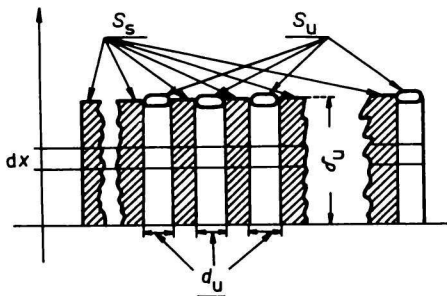


Fig. 1. Schematic representation of the model of dried material.

Hatched area is latex substance with the properties t, c, ρ, λ ; nonhatched area is water in capillaries with the properties $t, c, \rho, \lambda, w_e, \alpha_1, \mu$; area over the surface of material is drying medium with the properties $t, c, \rho, \lambda, w, \alpha_2, \mu$.

Let us consider such amount of material that contains just 1 kg of latex. The origin of the coordinate system is put in the centre of its width. Thus the border of capillaries is on the level δ_u and this quantity changes with moisture according to eqn (2). The surface of material which is in contact with drying medium comprises the sum of cross sections of the capillaries S_u (the surface of water or the surface of evaporation) and the surface consisting of dry latex mass S_s (this is identical with total surface of semispheres of the surface layer of latex particles). It is assumed that the surface of water is constantly pressed on the level of the border of capillaries by the effect of their contraction due to the decreasing content of water. The decrease in the cross section of capillaries is caused by the fact that the latex particles come near to each other during water evaporation due to the effect of the London—van der Waals forces and the space filled with water decreases. Thus the water continues to flow to the border of capillaries (to geometrical surface of material) and this phenomenon may be explained by the equilibrium of driving forces (London—van der Waals forces) and resistance forces.

It holds for the flow rate of water through capillaries

$$w_c = - \left(\frac{du}{d\tau} \right) / S_u \rho \quad (6)$$

According to eqn (4), we may write for the loss of water in a unit of time

$$- \left(\frac{du}{d\tau} \right) = \frac{u\psi(p'' - p_t)}{\rho k \delta_u} \quad (7)$$

Equal flow of water comes to the edge of capillaries in interface. By inserting eqn (7) into eqn (6), we obtain

$$w_c = \frac{u\psi(p'' - p_t)}{S_u \rho^2 k \delta_u} \quad (8)$$

We may write for S_u

$$S_u = \frac{2m_u \pi d_u^2}{4} \quad (9)$$

or with respect to eqns (2—5)

$$S_u = \frac{u}{k \delta_u \rho} \quad (10)$$

The substitution of eqn (10) into eqn (8) gives

$$w_c = \frac{\psi(p'' - p_t)}{\rho} = \text{const} \quad (11)$$

Assuming the only source of heat is the drying medium, we may write the following balance for the differential width of the dried material dx (Fig. 1)

$$\rho_s c_s S_s \frac{\partial t_s}{\partial \tau} dx = -\lambda_s \frac{\partial t_s}{\partial x} S_s + \lambda_s \frac{\partial \left[t_s + \frac{\partial t_s}{\partial x} dx \right]}{\partial x} S_s - \alpha_1 m_u \pi d_u (t_s - t) dx \quad (12)$$

$$\rho_c S_u \frac{\partial t}{\partial \tau} dx = -\lambda \frac{\partial t}{\partial x} S_u + \lambda \frac{\partial \left[t + \frac{\partial t}{\partial x} dx \right]}{\partial x} S_u + \alpha_1 m_u \pi d_u (t_s - t) dx - w_c \rho_c S_u \frac{\partial t}{\partial x} dx \quad (13)$$

After rearrangement and respecting eqns (2), (4), (5), and (10), we obtain

$$\frac{\partial t_s}{\partial \tau} = a_s \frac{\partial^2 t_s}{\partial x^2} - \frac{3\alpha_1 g_0 (t_s - t)}{\rho_s^2 S_s c_s d_p k d_u} \quad (14)$$

$$\frac{\partial t}{\partial \tau} = a \frac{\partial^2 t}{\partial x^2} + \frac{3\alpha_1 g_0 (t_s - t)}{\rho_s c d_p u} - w_c \frac{\partial t}{\partial x} \quad (15)$$

This system of partial differential equations (PDE) is completed by eqn (2) and ordinary differential equation (ODE) (7) while the partial pressure of the saturated water vapour over interface is governed by a relationship of the type

$$p'' = p''(t) \quad (16)$$

which may be *e.g.* the Antoine equation [5] provided the capillary effects are neglected. If we take these effects into account, we obtain

$$p'' = p' \exp \left(\frac{-6\sigma_g M g_0 \cos \Theta}{RT \rho_s d_p u} \right) \quad (17)$$

where p' is the pressure of saturated vapour on the noncurved interfacial surface at a given temperature.

The initial and boundary conditions for the system of PDE (14) and (15) and ODE (7) are as follows

$$\text{For } \tau=0 \text{ and } 0 \leq x \leq \delta_{w0}: u = u_0'; t_s = t = t_0 \quad (18)$$

$$\text{For } x = \delta_u \text{ and } 0 \leq \tau < \infty: -\lambda_s \frac{\partial t_s}{\partial x} = \alpha_2 (t_s - t) \quad (19)$$

$$\text{For } x = \delta_u \text{ and } 0 \leq \tau < \infty: -\lambda \frac{\partial t}{\partial x} = \alpha_2 (t - t_i) + \left(\frac{du}{d\tau} \right) \frac{r}{S_u} \quad (20)$$

$$\text{For } x=0 \text{ and } 0 \leq \tau < \infty: \frac{\partial t}{\partial x} = \frac{\partial t_s}{\partial x} = 0 \quad (21)$$

In addition, it holds

$$u'_0 = u_0 - \left(\frac{1}{B'} - \frac{1}{B} \right) \quad (22)$$

where

$$B' = \frac{\rho'_s}{g_0 \rho} \quad (23)$$

ρ'_s is the density of the porous nonhomogenized rubber mass arisen after the drying of latex.

Numerical solution of the model

Eqns (14) and (15) with initial and boundary conditions (18—21) represent a mixed problem for a system of two PDE of the parabolic type with one spacial coordinate. Eqn (7) with initial condition (18) is the Cauchy's problem for an ODE of the first order. The right side of eqn (7) depends on the variable t because of eqn (16) and it is the solution of the first problem. On the other hand, some coefficients of the PDE system are functions of solution of the ODE (are functions of moisture u). Thus we have a bound system of equations which must be solved simultaneously. Since eqn (16) is exponential, the problem is not linear and because of eqn (2) it has mobile boundary which is expressed by eqns (19) and (20).

An analytical solution of this problem is not known. The numerical solution is connected with the following partial problems: selection of the method of linearization of the PDE system, development of a proper method of solution of the mixed problem for the system of two linear PDE of the parabolic type, selection of the method of integration of eqn (7), solution of the problem with mobile boundary.

The method of networks [6—9] in which the values of unknown functions $t = t(x, \tau)$ and $t_s = t_s(x, \tau)$ are sought in discrete points — nodes of the network (x_i, τ_j) was chosen as a basis of numerical solution.

A method which may be characterized as extrapolation and iteration [6] was used for linearization of the problem. Its principle is as follows. We assume that the solution of the problem (the values of t, t_s, u, δ_s) is known in the time profiles from τ_0 to τ_j . Then the solution in the profile τ_{j+1} can be found in this way:

We estimate the temperature of water on the surface of material by extrapolating the known values of the quantity in preceding time profiles and denote this estimate by the symbol $t_{\delta, j+1}^0$.

We determine the corresponding value of p_δ^0 by means of eqn (16).

We integrate ODE (7) with $p'' = p_\delta^0$ between τ_j and τ_{j+1} and obtain the quantity u^0 corresponding to the used value of p_δ^0 .

By means of the values of p_δ^0 and u^0 we calculate the coefficients of PDE, boundary conditions, and the values of δ^0 according to eqn (2).

We solve the mixed problem for PDE (14) and (15) in the interval $x \in (0, \delta^0)$ as a linear problem by the method of network by using the values of parameters in the time profile τ_j for initial conditions. The result of this solution gives the values $t(x, \tau_{j+1})$ and $t_s(x, \tau_{j+1})$. We use the calculated value of $t(\delta^0, \tau_{j+1})$ as a new estimate of the temperature of water on the surface of material $t_{\delta, j+1}^0$ and repeat the whole procedure from the second step. We shall stop the cycle of iteration if the difference between the estimated and calculated value of $t_{\delta, j+1}$ is smaller than the precision of calculation fixed beforehand. Then we calculate the definitive values of u and p'' in a particular time profile and get on to subsequent profile.

This method enables us simultaneously to solve the problem of mobile boundary. The system of PDE is solved in a "fixed" interval for each time profile as well. Of course, the spacial step is different for each time profile because of the dependence of δ_u on u . The value of u , however, depends on time.

Eqns (14) and (15) with pertinent boundary conditions are after linearization a special case of the general problem given by the following system of equations

$$\bar{v}_\tau = a_1 \bar{v}_{xx} + b_1 \bar{v}_x + c_1 \bar{w}_x + d_1 \bar{v} + e_1 \bar{w} + f_1 \quad (24)$$

$$\bar{w}_\tau = a_2 \bar{w}_{xx} + b_2 \bar{v}_x + c_2 \bar{w}_x + d_2 \bar{v} + e_2 \bar{w} + f_2 \quad (25)$$

$$\bar{v}(x, 0) = \varphi_1(x) \quad (26)$$

$$\bar{w}(x, 0) = \varphi_2(x) \quad (27)$$

$$a_{10}(\bar{v}_x)_{x=a} = a_{11} \bar{v} + a_{12} \quad (28)$$

$$a_{20}(\bar{w}_x)_{x=a} = a_{21} \bar{w} + a_{22} \quad (29)$$

$$b_{10}(\bar{v}_x)_{x=b} = b_{11} \bar{v} + b_{12} \quad (30)$$

$$b_{20}(\bar{w}_x)_{x=b} = b_{21} \bar{w} + b_{22} \quad (31)$$

where the functions \bar{v} and \bar{w} are, in our case, t and t_s and the indices τ , x , xx denote the derivative with respect to time, the spacial first-order derivative, and the spacial second-order derivative (with respect to single coordinate). The solution is sought in the rectangular region $x \in (\bar{a}, \bar{b})$, $\tau \in (\tau_0, \tau_k)$. The coefficients $a_1, b_1 \dots b_{22}$ are constants or functions of x , τ . The functions $\varphi_1(x)$ and $\varphi_2(x)$ are known and in our case $a = 0$ and $\tau_0 = 0$.

An approach to solution of the system of eqns (24), (25) by using the implicate difference substitution is suggested in paper [6]. It may be shown that the matrix of the resulting system of linear algebraic equations is five-diagonal in our case

because $c_1 = b_2 = 0$. This system can be solved by the "labour-saving" algorithm which is analogous to the method of solution of the three-diagonal matrix [7].

ODE (7) was integrated in the interval $\tau_j - \tau_{j+1}$ by the use of the Runge—Kutta method of the fourth order.

Results and discussion

The calculations were performed for 6 temperatures of the drying medium: 75, 85, 100, 110, 120, and 135°C which corresponded to the experiments carried out earlier [1]. The range of values of the transfer coefficients α_1 , α_2 , and φ was determined from relationships of the type

$$StPr^{\frac{2}{3}} = f_1(Re) \quad (32)$$

$$Sh' Pe^{-1} Sc^{\frac{2}{3}} = f_2(Re) \quad (33)$$

As the value of α_1 has no significant influence on solution, it was considered to be constant and equal to $5.8 \text{ w m}^{-2} \text{ K}^{-1}$. The physical properties of water and latex were always assumed to be constant, their values being

$$\begin{array}{ll} \rho = 1000 \text{ kg m}^{-3} & c = 4200 \text{ J kg}^{-1} \text{ K}^{-1} \\ \rho_s = 1230 \text{ kg m}^{-3} & c_s = 2200 \text{ J kg}^{-1} \text{ K}^{-1} \\ \rho'_s = 850 \text{ kg m}^{-3} & S_s = 0.54 \text{ m}^2 \\ r = 2.5 \times 10^6 \text{ J kg}^{-1} & h_s = 10^{-3} \text{ m} \\ \lambda = 0.7 \text{ w m}^{-1} \text{ K}^{-1} & d_p = 0.12 \times 10^{-6} \text{ m (according to [10])} \\ \lambda_s = 0.2 \text{ w m}^{-1} \text{ K}^{-1} & \end{array}$$

The value of overall pressure P and partial pressure of water vapour in the flow of medium p_t was also constant in all calculations

$$P = 10^5 \text{ Pa}$$

$$p_t = 1200 \text{ Pa}$$

The Antoine equation [11] in the form

$$\log \frac{p''}{133.322} = 8.07 - \frac{1730.6}{t + 233.4} \quad (34)$$

was applied to calculation of the pressure of saturated vapour in the interface.

According to eqn (32), the values of the coefficient of heat transfer by convection from the drying medium to the surface of material α_2 vary in the range 5—50 $\text{w m}^{-2} \text{ K}^{-1}$ [12, 13]. A similar estimate of the range of values of the

coefficient of mass transfer ψ by using analogous eqn (33) is problematic because the value of p'' affects the magnitude of ψ through p_{Bs} which is comprised in Sh'

$$Sh' = \frac{\psi L p_{Bs}}{D Q_t} \quad (35)$$

while

$$p_{Bs} = \frac{p'' - p_t}{\ln \frac{P - p_t}{P - p''}} \quad (36)$$

The calculation of p'' from eqn (34) is not possible for temperatures above 100°C even if eqn (17) and the values $\Theta \in (0, \pi/4)$ and $u \geq 0.1$ are applied because the values of $p'' > P$ would be obtained. In this case, eqn (36) loses sense and the drying of material is not a diffusion process but it proceeds owing to the difference between total pressures. The behaviour of material during drying [1, 10, 14] contradicts this opinion. At the same time, it has been ascertained experimentally that the temperature of the dried material (measured in the centre of its width) approaches very rapidly the temperature of the drying medium so that the difference is less than 5°C even if the temperature of the drying medium is 110–130°C (Fig. 2). These facts lead to the assumption that a greater decrease in

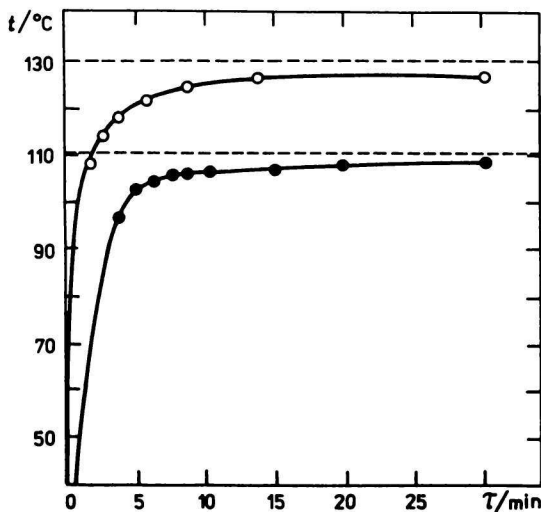


Fig. 2. Temperature of material measured in the centre of its width during drying.

- Temperature of drying medium
- Temperature of material at $t = 130^\circ\text{C}$
- Temperature of material at $t = 110^\circ\text{C}$

pressure of the saturated vapour of water than required by eqn (17) appears in capillaries of the considered model of material. But the character of the relationship (17) remains preserved. This assumption is justified. It is alleged in literature [14, 15] that a ten times and even eighty times greater decrease in pressure of the saturated vapour than required by eqn (17) appears in the capillaries of the 3–10 μm diameter if the angles of wetting are smaller than $\pi/4$. Of course, the problem is open how the value of p'' should be estimated in a given case. For this reason, eqn (34) was applied to the numerical calculation of p'' . This equation gave the values $p'' > P$ at $t_t > 100^\circ\text{C}$, but that was “compensated” by the choice of intentionally “low” values of the coefficient of mass transfer ψ . In this relation, the “low” value of this coefficient is a value which is approximately by two decimal orders smaller than the value calculated from eqn (33) for temperatures under 100°C . While this relationship gives values of ψ varying in the range 4×10^{-7} – $7 \times 10^{-7} \text{ s m}^{-1}$, we used the values 4×10^{-9} – $7 \times 10^{-9} \text{ s m}^{-1}$ for numerical calculations.

The course of theoretical relationships $u/u_0 = f(\tau)$ in confrontation with experimental course of these relationships is represented in Fig. 3 which shows that the

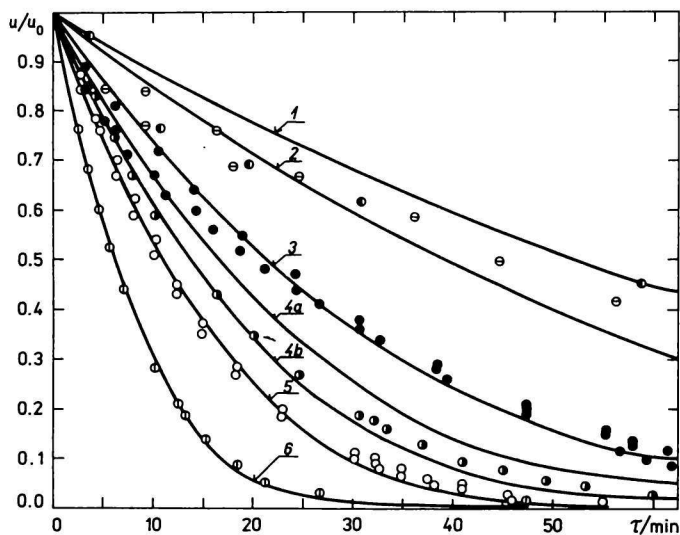


Fig. 3. Theoretical and experimental relationships $u/u_0 = f(\tau)$.

Theoretical curves: 1. $t_t = 75^\circ\text{C}$; $\alpha_2 = 300 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 4 \times 10^{-9} \text{ s m}^{-1}$;

2. $t_t = 85^\circ\text{C}$; $\alpha_2 = 300 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 4 \times 10^{-9} \text{ s m}^{-1}$;

3. $t_t = 100^\circ\text{C}$; $\alpha_2 = 120 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 4.7 \times 10^{-9} \text{ s m}^{-1}$;

4a. $t_t = 110^\circ\text{C}$; $\alpha_2 = 120 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 4.7 \times 10^{-9} \text{ s m}^{-1}$;

4b. $t_t = 110^\circ\text{C}$; $\alpha_2 = 120 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 5.7 \times 10^{-9} \text{ s m}^{-1}$;

5. $t_t = 120^\circ\text{C}$; $\alpha_2 = 110 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 5.7 \times 10^{-9} \text{ s m}^{-1}$;

6. $t_t = 135^\circ\text{C}$; $\alpha_2 = 110 \text{ w m}^{-2} \text{ K}^{-1}$; $\psi = 6.0 \times 10^{-9} \text{ s m}^{-1}$.

Experimental values: ● $t_t = 75^\circ\text{C}$; ○ $t_t = 85^\circ\text{C}$; ● $t_t = 100^\circ\text{C}$; ● $t_t = 110^\circ\text{C}$;

○ $t_t = 120^\circ\text{C}$; ◊ $t_t = 135^\circ\text{C}$.

model is in a very good harmony with reality. This statement is also valid if the temperatures of the drying medium are 75 and 85°C irrespective of apparent disagreement between theory and reality under these conditions. As a matter of fact, the graph describes only the initial stage of process for these temperatures of the medium. The material is dried after 200—250 min and the time axis is drawn only up to about 60 min. In the more advanced stage (not included in graphical representation), the consistence of theoretical and real course is much better.

It is characteristic of all temperatures of the drying medium that the theoretical values of u_0/u'_0 are in the initial stage of the process higher than the real ones and on the contrary, the theoretical course is somewhat more rapid than the experimental in the advanced stage of the process. The explanation of these facts ensues from the relation of the physical model to the real dried material. In the real material there are also larger "pores" which contain the "fully nonbound" moisture (water) which easily and rapidly escapes in the early stage of the process. On the other hand, other portions of moisture can be bound in material more tightly than it should correspond to the interaction between moisture and surface of the latex particles. This fact manifests itself by retardation of the process in comparison with the theoretical course.

The good agreement of theoretical and experimental relations $u/u'_0(\tau)$ was achieved after several preceding "numerical experiments" in which different variants of the numerical values ψ and α_2 were examined. The influence of the value of ψ on the course of the theoretical relationship $u/u'_0(\tau)$ is illustrated in Fig. 3 where curves 4a and 4b, both for $t_f = 110^\circ\text{C}$ and $\alpha_2 = 120 \text{ w m}^{-2} \text{ K}^{-1}$, are represented. Curve 4a corresponds to $\psi = 4.7 \times 10^{-9} \text{ s m}^{-1}$ and curve 4b to $\psi = 5.7 \times 10^{-9} \text{ s m}^{-1}$. The sensitivity of the above courses to the value of α_2 is also observable, which is in harmony with the physical essence of this quantity.

As obvious from Fig. 3, the illustrated good agreement of theory and experiment was achieved for the values of ψ and α_2 which were different from the values resulting from relationships (32) and (33). The values of ψ used for calculation are smaller and the values of α_2 are two times and even four times greater than the values resulting from the above relationships. The choice of smaller values of ψ has been discussed. The problem of suitability of higher values of α_2 requires a special analysis which has not yet been performed. Anyway, because of these facts, we must regard the quantities ψ and α_2 as parameters of solution and not as coefficients of transfer.

At first sight, a comparison of the results of solution based on this model with the model image according to [4] may make the impression that the presented model and the method of solution are too complicated and tedious and that there are no substantial differences in the agreement of theoretical and experimental results. But the solution according to paper [4] implies the knowledge of the experimental constant K , the model idea does not adequately enough depict the simultaneous

transfer of heat and mass in the process and it is assumed that the product $\psi(p'' - p_t)$ is constant during drying. On the other hand, the presented model is a result of more consequent elaboration of the ideas on which the solution according to [4] is based and is a more convenient approximation to the real mechanism of the process. Moreover, the parameters of solution of the model ψ and α_2 have a certain relation to the coefficients of heat and mass transfer. For this reason, it is justifiable to consider the presented model and its solution to be more realistic than the preceding stage of development in the command of this problem as described in paper [4].

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Symbols

a	coefficients of thermal conductivity of water	$L^2\tau^{-1}$
\bar{a}	limit of the interval of solution for the problem given by the system of eqns (24—31)	
a_s	coefficient of thermal conductivity of latex	$L^2\tau^{-1}$
$a_1, a_2, a_{10} \dots a_{22}$	coefficients in the system of eqns (24—31)	
\bar{b}	limit of the interval of solution for the problem given by the system of eqns (24—31)	
$b_1, b_2, b_{10} \dots b_{22}$	coefficients in the system of eqns (24—31)	
B	quantity defined by eqn (3)	M^{-1}
B'	quantity defined by eqn (23)	M^{-1}
c	specific heat capacity of water	$L^2\tau^{-2}T^{-1}$
c_t	specific heat capacity of drying medium	$L^2\tau^{-2}T^{-1}$
c_s	specific heat capacity of latex	$L^2\tau^{-2}T^{-1}$
c_1	coefficient in eqn (24)	
c_2	coefficient in eqn (25)	
d_1	coefficient in eqn (24)	
d_2	coefficient in eqn (25)	
d_p	mean diameter of a latex particle	L
d_u	diameter of model capillary	L
D	coefficient of diffusion of water vapour in drying medium	$L^2\tau^{-1}$
e_1	coefficient in eqn (24)	
e_2	coefficient in eqn (25)	
f_1	coefficient in eqn (24)	
f_2	coefficient in eqn (25)	
g	acceleration of gravity	$L\tau^{-2}$
g_0	weight of dry substance in considered amount of dried material	M
h_s	width of dry latex foil	L

h_u	width of moist latex foil	L
H_u	length of model capillary	L
k	constant of proportionality in eqn (1)	
L	characteristic dimension of material	L
m_u	number of model capillaries	
p'	pressure of saturated water vapour over noncurved level	$ML^{-1}\tau^{-2}$
p''	pressure of saturated water vapour in interface	$ML^{-1}\tau^{-2}$
p_t	partial pressure of water vapour in the flow of drying medium	$ML^{-1}\tau^{-2}$
p_{Bs}	logarithmic mean of partial pressures of inert in interface and in the main flow of drying medium	$ML^{-1}\tau^{-2}$
P	overall pressure of medium	$ML^{-1}\tau^{-2}$
Pe	Peclet number for drying medium	
Pr	Prandtl number for drying medium	
r	heat of evaporation of water	$L^2\tau^{-2}$
R	universal gas constant	$L^2M\tau^{-2}n^{-1}T^{-1}$
Re	Reynolds number for drying medium	
Sh'	Sherwood number for drying medium	
S_s	portion of the surface of material formed by latex substance	L^2
Sc	Schmidt number for drying medium	
St	Stanton number for drying medium	
S_u	surface of evaporation equal to overall cross section of model capillaries	L^2
t	temperature of water	T
t_f	temperature of drying medium	T
t_0	initial temperature of material	T
t_s	temperature of latex substance	T
T	absolute temperature of saturated vapour in interface	T
u	weight of water in dried material	M
u_0	initial weight of water in dried material	M
u'_0	initial weight of water in dried material modified according to eqn (22)	M
\bar{v}	generalized function of time and coordinate	
$\bar{v}(x,0)$	function \bar{v} in the time moment $\tau=0$	
\bar{v}_x	first derivation of \bar{v} with respect to coordinate	
$(\bar{v}_x)_{x=a}$	value of \bar{v}_x for $x=a$	
$(\bar{v}_x)_{x=b}$	value of \bar{v}_x for $x=b$	
\bar{v}_{xx}	second derivation of \bar{v} with respect to coordinate	
\bar{v}_τ	derivation of \bar{v} with respect to time	
w	mean velocity of drying medium	$L\tau^{-1}$
\bar{w}	generalized function of time and coordinate	
w_c	mean rate of water flow in model capillary	$L\tau^{-1}$
$\bar{w}(x,0)$	function \bar{w} in the time moment $\tau=0$	

\bar{w}_x	first derivation of \bar{w} with respect to coordinate	
$(\bar{w}_x)_{x=a}$	value of \bar{w}_x for $x=a$	
$(\bar{w}_x)_{x=b}$	value of \bar{w}_x for $x=b$	
w_{xx}	second derivation of \bar{w} with respect to coordinate	
w_t	derivation of \bar{w} with respect to time	
α_1	coefficient of heat transfer of water in capillaries	$M\tau^{-3}T^{-1}$
α_2	coefficient of heat transfer of drying medium	$M\tau^{-3}T^{-1}$
δ_s	half-width of dry foil	L
δ_u	half-width of moist foil	L
δ_{u0}	initial half-width of foil	L
Θ	angle of wetting	
λ	thermal conductivity of water	$ML\tau^{-3}T^{-1}$
λ_t	thermal conductivity of medium	$ML\tau^{-3}T^{-1}$
λ_s	thermal conductivity of latex	$ML\tau^{-3}T^{-1}$
μ	dynamic viscosity of water	$ML^{-1}\tau^{-1}$
μ_t	dynamic viscosity of medium	$ML^{-1}\tau^{-1}$
ρ	density of water	ML^{-3}
ρ_t	density of medium	ML^{-3}
ρ_s	density of latex	ML^{-3}
ρ'_s	density of nonhomogenized latex substance in the state after drying	ML^{-3}
τ	time	
φ_1	function of coordinate	
φ_2	function of coordinate	
ψ	coefficient of mass transfer	L^{-1}
σ_{gl}	surface tension of water in the interface water—saturated vapour	$M\tau^{-2}$

Dimensionless quantities

$$Pe = \frac{Lw}{D}; \quad Pr = \frac{c_t \mu_t}{\lambda_t}; \quad Re = \frac{LwQ_t}{\mu_t}; \quad Sc = \frac{\lambda_t}{c_t D Q_t}$$

$$Sh' = \frac{\psi L p_{Bs}}{D Q_t}; \quad St = \frac{\alpha_2}{c_t w Q_t}$$

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