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MOISTURE PROFILE IN A CERAMIC BODY DURING THERMODIFFUSION OF WATER

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The moisture profile in a ceramic body during thermodiffusion of water has been derived. This profile is compared with an experimentally determined one, which has been approximated by a linear relationship. The reliability of experimental determination of the tehrmodiffusion coefficient by the two thermal sources method was found to justify the use of a linear approximation of the moisture profile.

INTRODUCTION

A study of water transfer in a saturated ceramic mix in plastic state has shown that the gradients of concentration, temperature and pressure are the driving forces of the process. The effect of the temperature gradient on water transfer was dealt with in studies [1] and [2]. The two thermal sources method was worked out for the determination of the thermodiffusion coefficient. Using this method, the temperature dependence of the thermodiffusion coefficient was found to have the form

$$D_T = 3.19 \times 10^{10} \exp(-14\,397\ \mathrm{K}/T)\ \mathrm{m^2\,s^{-1}}. \tag{1}$$

The theoretical principle of the method and the evaluation proper were based on the following assumptions:

(i) A saturated ceramic mix is a binary mixture of two incompressible components, for which the moisture flow is described by the following equation for the one-dimensional problem:

$$\boldsymbol{h} = -D\partial C/\partial x - (D_T/T)(\partial T/\partial x), \tag{2}$$

where $\boldsymbol{h}$ is the volume moisture flow, D and D_T are the diffusion and thermodiffusion coefficients respectively, C is moisture content by volume and T is temperature.

(ii) In a steady state, when

$$\boldsymbol{h} = \mathbf{0},\ \partial C/\partial\tau = 0,\ \partial T/\partial\tau = 0, \tag{3}$$

equation (2) acquires the form

$$D\mathrm{d}C/\mathrm{d}x = -D_T\mathrm{d}T/T\mathrm{d}x. \tag{4}$$

(iii) The temperature profile, obtained by resolving Fourier-Kirchhoffer's equation for a body of planar symmetry, under the conditions sub (3), and

$$\begin{aligned} x &= 0, \qquad T = T_1 \\ x &= L, \qquad T = T_2 \end{aligned} \tag{5}$$

has the form

$$T = T_1 - (T_1 - T_2)\, x/L. \tag{6}$$

(iv) By neglecting the temperature dependence of D and D_T, by relating their values to mean temperature $\bar{T} = (T_1 + T_2)/2$ and by joint resolving of (4) and (6) for the conditions

$$\begin{aligned} x = O, \quad & C = C_1 \\ x = L, \quad & C = C_2 \end{aligned} \tag{7}$$

one obtains the following form of the moisture profile equation:

$$C = C_1 + (C_2 - C_1)\, x/L. \tag{8}$$

The present study had the purpose to determine the error introduced into the expression of the moisture profile by the use of assumption (iv).

ANALYTICAL EXPRESSION OF THE MOISTURE PROFILE

The moisture profile is expressed on the basis of assumptions (i) through (iii), equations (4) and (6) and the temperature dependences of the diffusion coefficient and of the thermodiffusion coefficient having the forms

$$D = D_0 \exp(-B/T), \tag{9}$$

$$D_T = D_{0T} \exp(-B_1/T), \tag{10}$$

where D_0, D_{0T}, B and B_1 are constants. By substituting (6), (9) and (10) into (4), one obtains

$$\begin{aligned} \mathrm{d}C/\mathrm{d}x = (D_{0T}/D_0)\, (\exp(-(B_1 - B)\, L/(T_1L - (T_1 - T_2)\, x))) \,. \\ .\, (T_1 - T_2)/(T_1L - (T_1 - T_2)\, x). \end{aligned} \tag{11}$$

Introduction of the variable

$$y = (T_1L - (T_1 - T_2)\, x)^{-1} \tag{12}$$

and solution of equation (11) for the conditions

$$\begin{aligned} x = 0, \quad & y_0 = (T_1L)^{-1}, \quad & C = C_1, \\ x = L, \quad & y_L = (T_2L)^{-1}, \quad & C = C_2 \end{aligned} \tag{13}$$

yields the moisture profile equation in the following form:

$$C = D_{0T}/D_0(\ln(y/y_0) + \sum_{n=1}^{\infty} a^n\, (y^n - y_0^n)/n\,.\,n!) + C_1, \tag{14}$$

where $a = -(B_1 - B)\, L$. Equation (14) shows that the moisture profile in the body is not linear.

A COMPARISON OF THE RELATIONSHIPS (14) AND (8)

The error introduced by approximating the equation $C = f(x)$ by the linear equation (8) then can be assessed by comparing mutually the courses of both profiles, (8) and (14). The following experimental and calculated values are employed for this comparison: $T_1 = 322.8$ K, $T_2 = 296.7$ K, $L = 1.2 \times 10^{-2}$ m

$C_1 = 0.4069$, $n = 3$ [2], the temperature dependence of the diffusion coefficient according to (9) where the constants have the following values [3]:

$$D_0 = 5.52 \times 10^{11} \text{ m}^2 \text{ s}^{-1}$$

$$B = 14\,484 \text{ K},$$

and the temperature dependence of the thermodiffusion coefficient according to (10), using the following values of the constants [2]:

$$D_{0T} = 3.19 \times 10^{10} \text{ m}^2 \text{ s}^{-1}$$

$$B_1 = 14\,397 \text{ K}.$$

Substitution of these values into equation (14) then yields the temperature profile listed in Table I under the designation C_{14}. The moisture profile determined experimentally and approximated by equation (8), is designated C_8.

Table I

Calculated moisture profiles

$x \times 10^3$ (m)	C_{14} ($m^3 m^{-3}$)	C_8 ($m^3 m^{-3}$)	C'_{14} ($m^3 m^{-3}$)
0	0.4069	0.4069	0.4069
1	0.4074	0.4076	0.4076
2	0.4080	0.4082	0.4083
3	0.4086	0.4089	0.4089
4	0.4090	0.4096	0.4096
5	0.4096	0.4103	0.4103
6	0.4101	0.4110	0.4110
7	0.4107	0.4117	0.4118
8	0.4113	0.4124	0.4125
9	0.4118	0.4131	0.4132
10	0.4124	0.4137	0.4139
11	0.4130	0.4144	0.4147
12	0.4136	0.4152	0.4154

DISCUSSION AND CONCLUSION

Study [2] shows that the relative error of the determination of D_T amounts to about 28 %. On replacing the D_{0T} in the initial problem with the value D'_{0T} (which includes the determination error) and when carrying out the calculation according to equation (14), one obtains the moisture profile designated C'_{14} in Table I. A satisfactory mutual agreement follows from a comparison of this moisture profile with moisture profile C_8. This means that the experimental error in the equation $D_T = f(T)$ and possibly also $D = f(T)$ determines the accuracy of the moisture profile calculation.

It can therefore be concluded that during thermodiffusion of water through a saturated ceramic mix, the moisture profile developed in a body of planar symmetry is described by equation (14). The error involved in the determination of D_T or D results in an insignificant difference between moisture profiles (14) and (8), which proves that the assumptions employed have been fully justified.

References

[1] Havrda J., Oujiří F., Macháček J.: Silikáty *26*, 299 (1982),
[2] Havrda J., Oujiří F., Kofroňová B.: Silikáty *27*, 107 (1983).
[3] Havrda J., Oujiří F.: Silikáty *26*, 203 (1982).

VLHKOSTNÍ PROFIL V KERAMICKÉM TĚLESE PŘI TERMODIFÚZI VODY

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Tato práce doplňuje předchozí dva články, zabývající se termodifúzí vody v keramické směsi (viz. literatura [1], [2]). Je zde analyticky odvozen tvar vlhkostního profilu v keramickém tělese tvaru desky v ustáleném stavu pro difúzní a termodifúzní koeficient závislý na teplotě. Tento profil je porovnán s experimentálně stanoveným, který je aproximován lineární závislostí. Výsledkem je zjištění, že spolehlivost experimentálního stanovení termodifúzního koeficientu metodou dvou tepelných zdrojů opravňuje použití lineární aproximace vlhkostního profilu.

ПРОФИЛЬ ВЛАГИ В КЕРАМИЧЕСКОМ ТЕЛЕ ПРИ ТЕРМОДИФФУЗИИ ВОДЫ

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Приводимая работа является дополнением двух предходящих публикаций, посвященных термодиффузии воды в керамической смеси (см. литература [1], [2]). В ней аналитически выводится вид профиля влажности в керамическом теле формы пластины в устойчивом состоянии для коэффициента диффузии и термодиффузии, зависящего от температуры. Данный профиль сопоставляется с профилем, установленным экспериментальным путем, который апроксимируется линейной зависимостью. Результатом является установление, что надежность экспериментального установления коэффициента термодиффузии с помощью метода двух термических источников предоставляет оправданное применение линейной апроксимации профиля влажности.

J. VOLDÁN, V. DUŠÁNEK: ELEKTRICKÉ VLASTNOSTI SKEL. Knižnice Hutní sklářské příručky, SNTL, Praha 1983, 140 stran, cena 16 Kčs.

Dalším svazkem HSP o elektrických vlastnostech skel se blíží ukončení tato i ve světovém měřítku ojedinělá řada publikací, pojednávajících o všech aspektech sklářské výroby.

Již výběr autorů, z nichž první se zabývá touto problematikou více než 30 let, je zárukou kvalitního zpracování látky. Úplnost dokládá soupis 172 citací, zasahujících až do dnešní doby. Po definici základních pojmů a jednotek následují kapitoly: Měření elektrických vlastností skel, Elektrická vodivost skel, Elektronová vodivost skel, Dielektrické vlastnosti skel, Elektrická pevnost skel a Použití skla v elektrotechnice a elektronice.

V souladu s posláním knižnice je výklad založen na přiměřené teoretické bázi, avšak orientován prakticky a podán tak, aby byl srozumitelný široké obci čtenářů. Vzhledem k rostoucímu významu skla jako materiálu v moderní elektronice a elektrotechnice bude kniha zajímat nejen odborníky z oblasti výroby skla, ale také pracovníky z aplikačních oborů. Pedagogické podání látky činí knihu vhodnou pomůckou pro specializované studium na středních a vysokých školách.

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