CERAMICS — Silikáty 34, s. 193—198 (1990)

Original papers

ELECTRIC RESISTANCE DRYING OF CERAMICS

Part II. experimental verification of the model

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Received 4. 5. 1989

Two types of electric resistance drying models were verified experimentally: (i) with constant material quantities, (ii) with material quantities depending on temperature and moisture content. It can be concluded that in the case of electric resistance drying it is possible to neglect the dependence of material functions on moisture content and temperature. The given model allows predictions to be made on the behaviour of bodies of saturated ceramic mix during the course of electric resistance drying.

INTRODUCTION

In Part I of the present paper, the authors developed models of electric resistance drying of ceramics (hereafter **ERD**), (1) with constant material quantities, and (2) with quantities depending on moisture content and temperature [1]. To verify suitability of the model and correctness of the simplifying assumptions introduced, it is necessary to compare both models with experimental data. For a correct comparison the experimental arrangement should correspond to the conditions under which the model was obtained, and vice versa. In addition to this, the models dictate a minimum number of experiments required for this comparison. The following demands have to be met in the present case:

— unidimensional flow of moisture and heat

— determination of the initial conditions (initial distribution of moisture and temperature)

— determination of the boundary conditions (time dependence of the surface flow of moisture and heat and of the source element)

— determination of the time development of moisture and temperature profiles in the body.

EXPERIMENTAL

The following experimental arrangement was chosen in order to meet the requirements mentioned above: All of the measurements were carried out on bodies of electroporcelain mixes with an elevated content of α-Al_2O_3 prepared by drawing the mix on a vacuum auger. The initial homogeneous distribution of moisture and temperature was achieved by waterproofing and insulating the body and placing it in a medium of 100 % relative humidity and at temperature T_0.

The unidimensionality of moisture and heat transfer was attained by means of the insulation system shown in Fig. 1. The hatched areas represent thermal insulation and the full areas moistureproofing. The two opposite surfaces are insulated, thus ensuring unidimensional flux of heat and moisture. The plates at the bases represent electrodes supplying electric current to the bodies. The system body-insulation, prepared in this way, was placed in a laboratory recycling drying oven with constant parameters of the drying environment ($T = 308.75$ K, $\mathbf{v} = 1.7$ m s^{-1}, $\varphi = 55$ %).

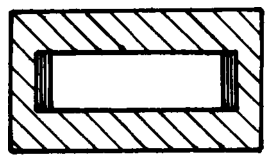

Fig. 1. Insulation and waterproofing of the body.

The time dependence of moisture surface flow was established from weight losses of the body; the time dependence of surface heat flow was calculated from experimental time development of temperature profiles, and the time dependence of the heat source was determined from the experimentally established dependence $I = I(t)$ at $U = 28.75$ V. The time development of the moisture profiles was found by cutting the body into slices at various time intervals. The time development of the temperature profiles was determined by means of copper-constantan thermocouples placed in the body.

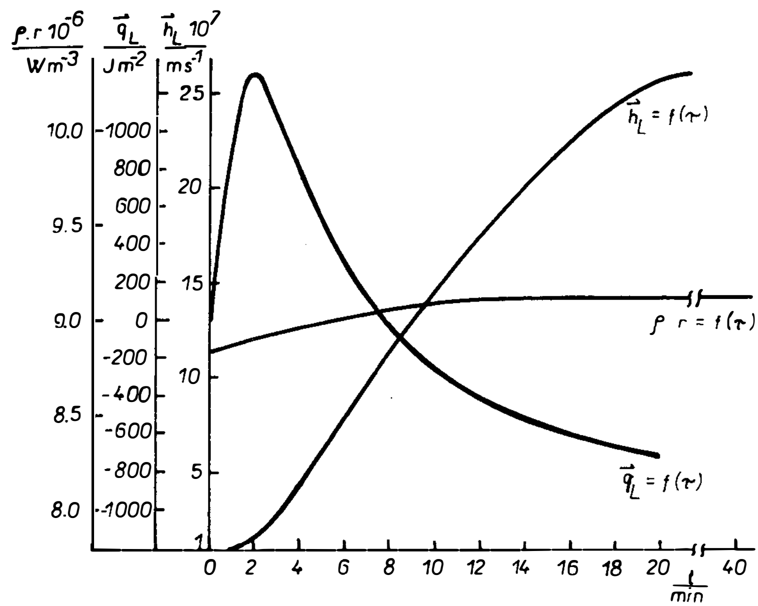

Fig. 2. Time dependence of surface mass, heat and heat source flux.

Typical relationships of the surface flow of moisture, temperature and the heat source are plotted in Fig. 2. The experimental time developments of temperature and moisture profiles are shown in Fig. 3.

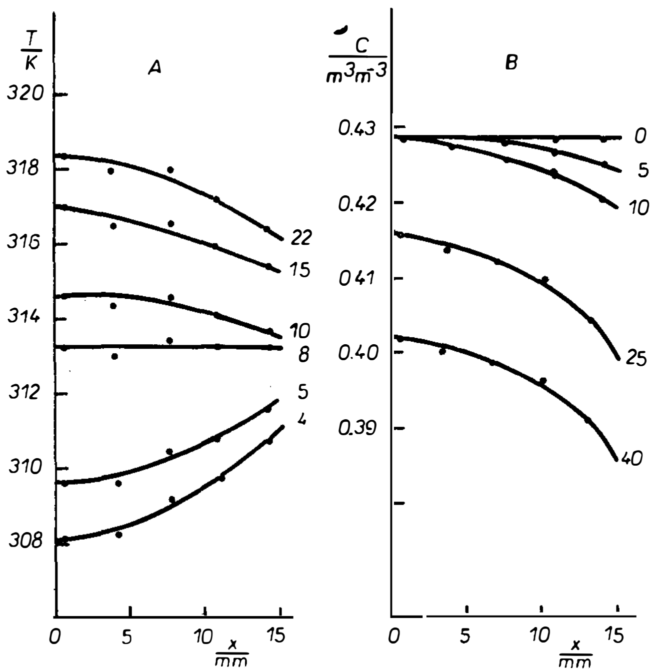

Fig. 3. Experimentally established time development of temperature and moisture profiles. The parameter at the curves signifies time in minutes.

DISCUSSION OF RESULTS AND CONCLUSION

The time development of moisture and temperature profiles can be calculated either for an arbitrary choice of initial and boundary conditions, or one can make use of values obtained from the given experimental arrangement. The latter procedure was employed in calculating the moisture and temperature profiles and the following values were chosen:

— initial homogeneous moisture content and temperature distribution $C_0 = 0.4281$ m^3m^{-3}, $T_0 = 293$ K

— the temperature dependence of the boundary conditions plotted in Fig. 2,

— the temperature dependence of the diffussion coefficient in the form [2]
$D = (2.46 \cdot 10^{-4} \exp(-2\,425/T))$ m^2s^{-1}

— the moisture content dependence of thermal diffusivity [3, 4]
$a = (1.988 \cdot 10^{-7} + 4.791 \cdot 10^{-8}\, w - 1.037 \cdot 10^{-9}\, w^2)$ m^2s^{-1}

— the moisture content dependence of specific heat [5]
$c_p = (-1\,107.1 + 34.73\, w)$ J $kg^{-1}K^{-1}$

— the moisture content dependence of thermal conductivity [5]

$\lambda = (-1.285 + 2.683 \,.\, 10^{-2}\, w - 5.325 \,.\, 10^{-3} w^2)\ \mathrm{Wm^{-1}K^{-1}}$

where w is the absolute moisture content.

The time developments of temperature and moisture profiles neglecting the dependence of material characteristics on moisture content and temperature were obtained by relating the above values to the temperature of 317.5 K and to the moisture content $C = 0.4200\ \mathrm{m^3m^{-3}}$ and by their substituting into equations (18) and (19) (cf. Part I). The calculated relationships are plotted in Fig. 4.

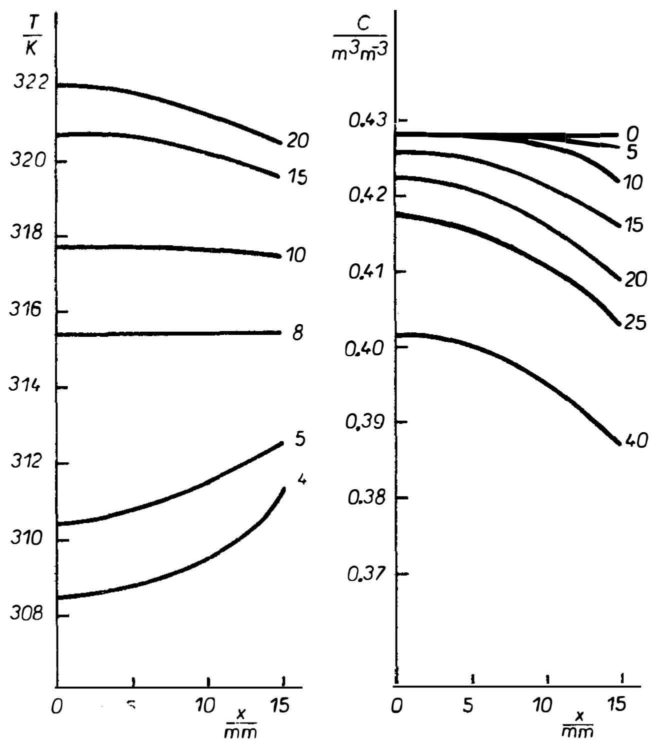

Fig. 4. Time development of temperature and moisture profiles calculated for the case of constant material characteristics. The parameter at the curves signifies time in minutes.

Substitution of the above relationships into equations (20) — (25) yielded the time development of moisture and temperature profiles on the assumption of relationships between the material characteristics and moisture content and temperature. These relationships are shown in Fig. 5.

A comparison of the calculated profiles with the experimental ones indicates a satisfactory agreement. The comparison of temperature profiles showed a maximum deviation of 2 K from the experimental value. The deviation is above all due to the inaccuracy of the method employed, and in part to the way the material characteristics were derived from the experimental data. The difference is not surprising when one takes into account that the time dependence of surface flux of heat must be determined from experimentally obtained temperature profiles. A good agreement was likewise attained in the case of moisture profiles. The comparison of moisture profiles yielded by the two methods indicates that in view of the experimental errors involved, it is possible to neglect the dependence of the material characteristics on moisture content and temperature.

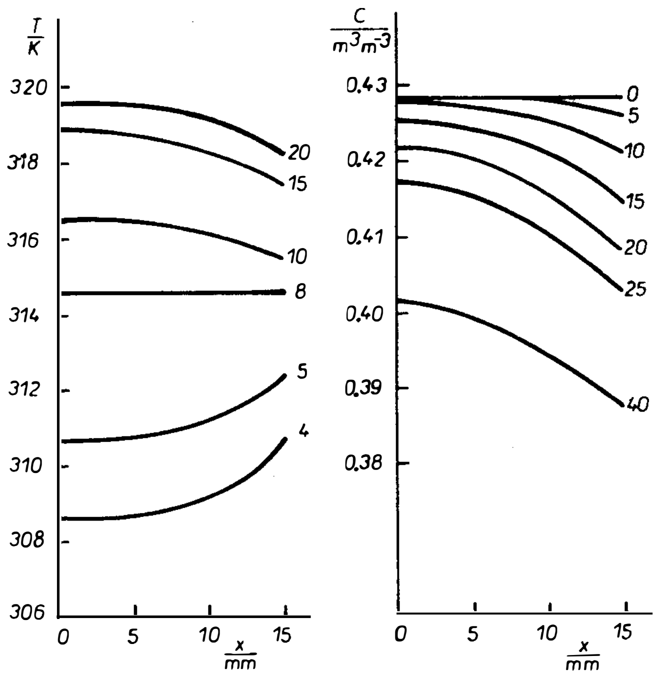

Fig. 5. Time development of temperature and moisture profiles calculated for the case of material characteristics dependent on temperature and moisture content. The parameter at the curves signifies time in minutes.

The results obtained lead to the conclusion that the ERD model, regarding the transfer of water as diffusion in a binary mixture of incompressible components and the heat transfer as heat transmission with a bulk heat source, allows the behaviour of a body in the course of electric resistance drying to be predicted with a satisfactory accuracy.

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ELEKTROODPOROVÉ SUŠENÍ KERAMIKY — ČÁST II. EXPERIMENTÁLNÍ OVĚŘENÍ MODELU

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Pro dva typy matematických modelů elektroodporového sušení (i) s konstantními materiálovými veličinami a (ii) s materiálovými veličinami závislými na vlhkosti a teplotě je provedeno ověření vhodnosti modelu a volby počátečních a okrajových podmínek porovnáním s experimentálními výsledky. Při zachování podmínek, pro které byl odvozen matematický model (jednorozměrný tok tepla vlhkosti, počáteční a okrajové podmínky), ukázalo srovnání časových vývojů profilů teploty a vlhkosti v tělese, že matematický model (i), založený na materiálových konstantách (D, a, λ a c_p) nezávislých na koncentraci a teplotě, vystihuje uspokojivě chování těles z nasycené keramické směsi v průběhu první a druhé etapy elektroodporového sušení

Obr. 1. ***Způsob izolace tělesa.***

Obr. 2. ***Časové závislosti povrchového toku hmotnosti, tepla a zdroje tepla.***

Obr. 3. ***Experimentálně stanovené časové vývoje teplotních a vlhkostních profilů. Parametr u křivek má význam času v minutách.***

Obr. 4. ***Časové vývoje teplotních a vlhkostních profilů vypočtené pro případ konstantních materiálových veličin. Parametr u křivek má význam času v minutách.***

Obr. 5. ***Časové vývoje teplotních a vlhkostních profilů vypočtené pro případ teplotně a vlhkostně závislých materiálových veličin. Parametr u křivek má význam času v minutách.***

ЭЛЕКТРОСОПРОТИВИТЕЛЬНАЯ СУШКА КЕРАМИКИ II. ЭКСПЕРИМЕНТАЛЬНАЯ ПРОВЕРКА МОДЕЛИ

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Для двух типов математических моделей электросопротивительной сушки (i) с постоянными величинами материала и (ii) с величинами материала, зависимыми от влажности и температуры проводили проверку пригодности модели и подбора исходных и краевых условий путем сопоставления с экспериментальными результатами. При соблюдении условий, для которых была выведена математическая модель (одноразмерное течение тепла и влажности, исходные и краевые условия) сопоставление временных развитий профилей температуры и влажности в теле показало, что математическая модель (i), основывающаяся на постоянных материала (D, a, λ и c_p), независящих от концентрации и температуры, надежно отражает поведение тел, приготовленных из насыщенной керамической смеси, во время первого и второго этапа электросопротивительной сушки.

Рис. 1. ***Способ изоляции тела.***

Рис. 2. ***Временные зависимости поверхностного течения массы, тепла и источника тепла.***

Рис. 3. ***Временные развития температурных и влажностных профилей, установленные экспериментальным путем. Параметр у кривых обозначает время в минутах.***

Рис. 4. ***Временные развития температурных и влажностных профилей, рассчитанные в случае постоянных материальных величин. Параметр у кривых обозначает время в минутах.***

Рис. 5. ***Временные развития температурных и влажностных профилей, рассчитанные в случае материальных величин, зависимых от температуры и влажноти. Параметр у кривых обозначает время в минутах.***