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CONVECTIVE DRYING OF CERAMIC BODY, PART II — EXPERIMENTAL VERIFICATION OF THE MODEL

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A mathematical model of convective drying of a plate — shaped ceramic body in periods I and II of drying was verified experimentally. An electroporcelain mix with an elevated content of α-Al_2O_3 was used. The time development of moisture and temperature profile in the body and the time dependence of surface moisture and heat fluxes were determined. The time development of moisture and temperature profiles was compared with those calculated from both models, i.e. with the model involving thermodiffusion and with that neglecting it. A satisfactory agreement between the model and the experiment was established, and thermodiffusion was found to have a negligible effect on water transfer in the drying of ceramic paste.

INTRODUCTION

Part I was concerned with two models for convective drying of plate-shaped ceramic body in periods *I* and *II* of the drying process; one model considered thermodiffusion while the other neglected this phenomenon. Verification of the suitability of the models and determination of the effect of thermodiffusion on water transfer during the drying require a comparison of the models with experimental results. To provide a reliable comparison, the experimental arrangement must correspond to the conditions under which the model has been created, and vice versa. Moreover, the model should include the minimum number of quantities which must be determined experimentally for this comparison. In our instance, these were

— onedimensionality of heat and mass transfer,
— determination of initial conditions (initial moisture and temperature distribution),
— determination of boundary conditions (time dependence of surface moisture and heat fluxes),
— determination of the time development of moisture and temperature profiles.

EXPERIMENTAL

The experimental measurements were carried out on an electroporcelain mix with an elevated content of α-Al_2O_3. The bodies $30 \times 30 \times 60$ mm in size were prepared by drawing on a vacuum auger, insulated and allowed to equalize the moisture content throughout the body volume.

In the modelling of onedimensional moisture and heat transfer in the body, the insulation was removed from two opposite surfaces and the other surfaces were thermally insulated. This insulation is shown in Fig. 1. The hatched areas were coated with lacquer, and the boards at the body represent thermal insulation.

The temperature profiles were measured with copper-constantan thermocouples in differential arrangement. The measuring thermocouples were placed in Various body depths from its centre to its surface. The temperature was recorded as thermoelectric voltage on a digital millivoltmeter.

The bodies prepared in this way were placed in a laboratory recycling drying oven with their insulation-free surfaces parallel with the direction of the mowing air. The parameters of the drying medium were as follows: rate of flow $v = 1.7\ \mathrm{ms^{-1}}$, relative humidity 55 % and the dry thermometer temperature $t_s = 45\ °\mathrm{C}$.

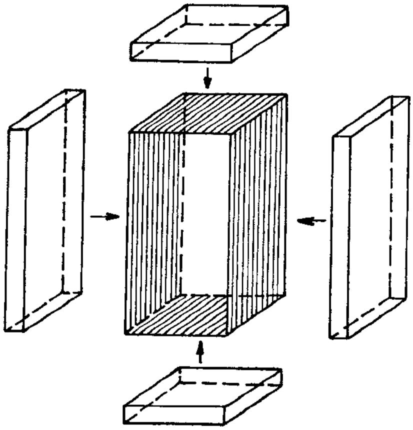

Fig. 1. Insulation of the ceramic body.

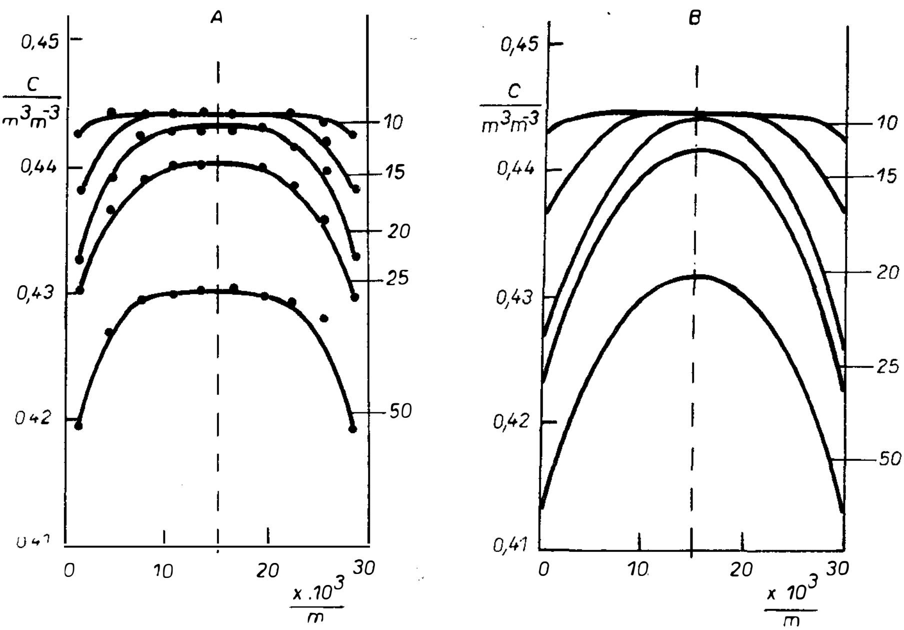

Fig. 2. Time dependence of moisture profiles in the body.
A — experimental profiles, B — calculated profiles. The parameter at the curves has the significance of time in minutes.

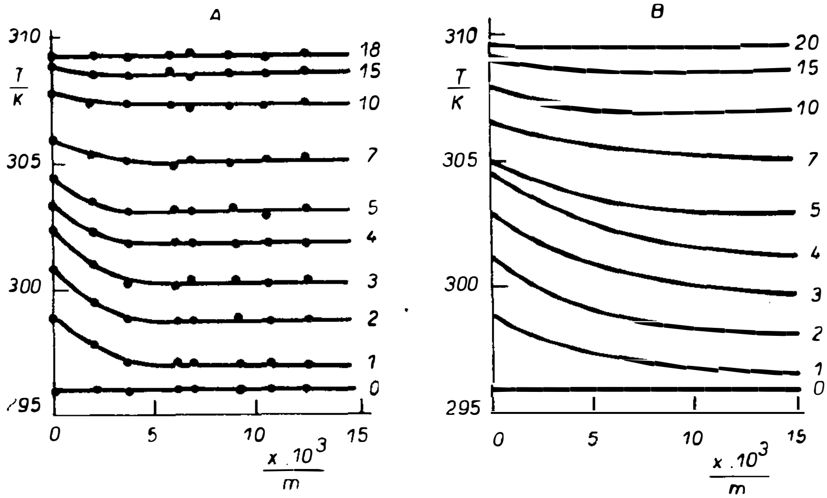

Fig. 3. ***Time development of temperature profiles in the body.***
A — experimental profiles, B — calculated profiles. The parameter at the curves has the significance of time in minutes.

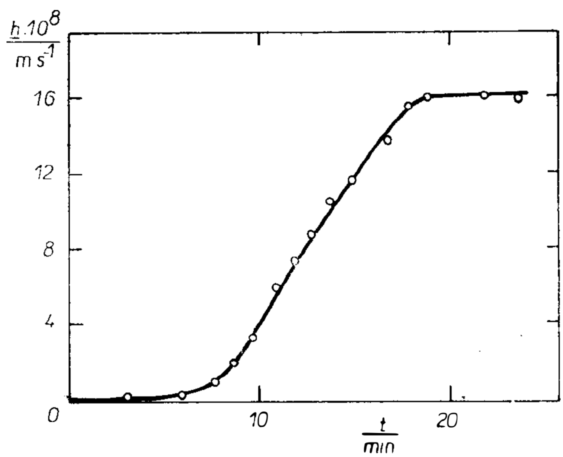

Fig. 4. Time dependence of the surface moisture flux.

Losses in the body weight, the time development of the temperature profiles and the time development of the moisture profiles in the body, determined by cutting the body to pieces, were then measured at regular intervals of time. The time dependence of the surface moisture fluxes were then calculated from the body weight losses, and the time dependence of surface heat fluxes from the time development of temperature profiles. Typical experimental time developments of moisture and temperature profiles are shown in Figs. 2 and 3, designation A. Figs. 4 and 5 show the time dependences of surface moisture and heat fluxes.

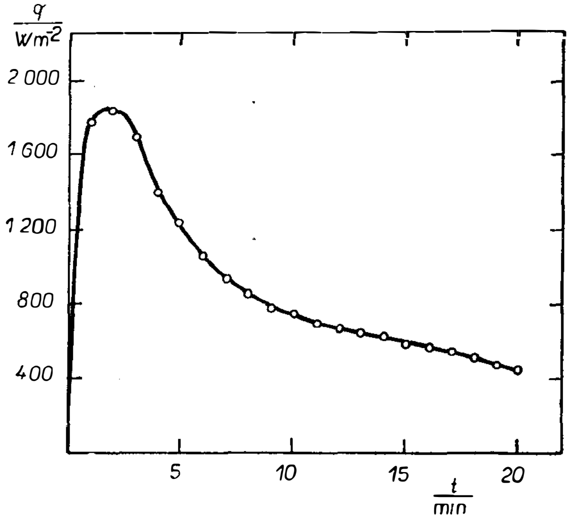

Fig. 5. Time dependence of the surface heat flux.

DISCUSSION

The time development of moisture and temperature profiles can be calculated and compared for any arbitrary choice of boundary conditions, or it is possible to substitute directly their realistically attainable relationships. The latter method was chosen for the comparison. The calculations were carried for the following input data:

— initial homogeneous moisture and temperature distribution

$$C_0 = 0.4450 \text{ m}^3\text{m}^{-3} \qquad T_0 = 296 \text{ K},$$

— time dependence of surface moisture and heat fluxes according to Figs. 4 an 5,

— temperature dependence of the diffusion coefficient [1]

$$D = 3.93 \exp(-5645/T) \qquad \text{m}^2\text{s}^{-1},$$

— temperature dependence of the thermal diffusion coefficient [2]

$$D_T = 3.9 \times 10^3 \exp(-14095/T) \qquad \text{m}^2\text{s}^{-1}\text{K}^{-1},$$

— moisture dependence of thermal diffusivity [3]

$$a = (1.998 \times 10^{-7} + 4.791 \times 10^{-8} W - 1.037 \times 10^{-9} W^2) \qquad \text{m}^2\text{s}^{-1},$$

— moisture dependence of thermal conductivity in the form [4]

$$\lambda = (-1.285 + 2.683 \times 10^{-1} W - 5.325 \times 10^{-3} W^2) \qquad \text{Wm}^{-1}\text{K}^{-1},$$

— moisture dependence of specific heat in the form [4]

$$c_p = (-1107.1 + 34.73 W) \qquad \text{J kg}^{-1}\text{K}^{-1},$$

where W is the absolute moisture content.

Substitution of these relationships into equations (42 and 43) (cf. Part I) yielded the time development of moisture and temperature profiles shown in Figs. 2 and 3, designation *B*. The procedure provided the time development of moisture and temperature profiles in the case of the model considering the effect of thermodiffusion.

The effect of thermodiffusion on water transfer during drying can be determined by substituting the above relationships into the model not considering thermodiffusion, i.e. equations (57) and (58). As the time dependence of the moisture and temperature profiles are identical, they are not specified here.

The effect of thermodiffusion was evaluated by comparing the computed moisture profiles from both models. This comparison was carried out on the basis of expressing the mean quadratic error. The comparison shows that the mean quadratic error $\sigma = 0$. This means that thermodiffusion, which in the given instance concerns the heating period only, has no effect on water transfer during the drying of a saturated ceramic mix if the temperature gradient is 600 K m^{-1}.

The comparison of the time development of moisture and temperature profiles implies that the assumptions taken in the formulation of the problem are satisfactory for a mathematical description of the convective drying operation. The model therefore allows the time development of moisture and temperature profiles to be calculated with a satisfactory accuracy.

CONCLUSION

The agreement between the model and the experiment justifies the approach to the resolving of the convective drying of ceramic bodies and shows that the choice of symplifying assumptions introduced in the formulation of the problem were correct. The model allows the time development of moisture and temperature profiles in ceramic body to be calculated with a satisfactory accuracy. This means that with any arbitrary drying curve (the time dependence of surface =45°C. moisture flux) it is possible to predict the corresponding moisture profile in the body and determine whether the drying schedule employed will leadto damaging the green ware or not.

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[4] Havrda J., Gregorová E., Oujiří F., Pešek F.: Silikáty (1985) in press.

KONVEKČNÍ SUŠENÍ KERAMICKÉHO TĚSTA, ČÁST II. — EXPERIMENTÁLNÍ OVĚŘENÍ MODELU

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V části I byly odvozeny modely konvekčního sušení keramického těsta 1. s termodifúzí a 2. bez termodifúze. Ověření vhodnosti přijatých předpokladů zavedených při formulaci úlohy, počátečních a okrajových podmínek a vlivu termodifúze na přenos vody při sušení lze provést

na základě porovnání modelu s experimentálním měřením. Z uvedených porovnání vyplynula vhodnost přístupu k řešení považující přenos vlhkosti za difúzi a přenos tepla za vedení, správnost volby počátečních a okrajových podmínek uvažované operace a zanedbatelný vliv termodifúze na přenos vody při sušení keramického tělesa.

Obr. 1. Způsob izolace tělesa.
Obr. 2. Časové vývoje vlhkostních profilů v tělese.
A — profily naměřené, B — profily vypočtené. Parametr u křivek má význam času v minutách.
Obr. 3. Časové vývoje teplotních profilů v tělese.
A — profily naměřené, B — profily vypočtené. Parametr u křivek má význam času v minutách.
Obr. 4. Časová závislost povrchového toku vlhkosti.
Obr. 5. Časová závislost povrchového toku tepla.

КОНВЕКТИВНАЯ СУШКА КЕРАМИЧЕСКОГО ТЕЛА, ЧАСТЬ II — ЭКСПЕРИМЕНТАЛЬНАЯ ПРОВЕРКА МОДЕЛИ

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В части I выводили модели конвективной сушки керамического тела, во-первых с термодиффузией и во-вторых без термодиффузии. Проверку пригодности принятых предложений, введенных при формулировке задания, начальных и контурных условий и влияния термодиффузии на передачу влажности при сушке, можно проводить на основании сопоставления модели с экспериментальным измерением. Из приводимых сопоставлений следует пригодность подхода к решению, при котором передача влажности считается диффузией и передача тепла теплопроводностью, оправданность подбора начальных и контурных условий рассматриваемой операции и пренебрегательное влияние термодиффузии на передачу влажности при сушке керамического тела.

Рис. 1. Способ изоляции тела.
Рис. 2. Временное развитие профилей влажности в теле; A — измеряемые профили, B — расчитанные профили. Параметр у кривых имеет значение времени в минутах.
Рис. 3. Временное развитие температурных профилей в теле; A — измеряемые профили, B — расчитанные профили. Параметр у кривых имеет значение времени в минутах.
Рис. 4. Временная зависимость поверхностной передачи влажности.
Рис. 5. Временная зависимость поверхностной передачи тепла.

ED. R. E. FISHER: ADVANCES IN CERAMICS, VOL. 13., NEW DEVELOPMENTS IN MONOLITHIC REFRACTORIES (Pokroky v keramice, sv. 13, Nové vývojové trendy v monolitických žárovzdorných materiálech), 424 str. The American Ceramic Society, Inc. Columbus, Ohio, 1985. Cena neuvedena.

Kniha je sborníkem mezinárodního sympozia o nových směrech vývoje v monolitických žárovzdorných materiálech, pořádaného jako 86. výroční schůze Americké keramické společnosti 29. 4.—3. 5. 1984 v Pittsburghu. Obsahuje 32 článků předních odborníků, zachycujících nové vědecké a technologické poznatky a ukazující rostoucí použití monolitických žárovzdorných materiálů v USA, Evropě a Japonsku. Jsou rozděleny do šesti tematických celků, a to: světový vývoj v použití žáromonolitů, zařízení pro zkoušení vlastností, zařízení a směsi pro aplikaci, směsi s nízkým obsahem cementu, použití ve vysokých pecích a aplikace pro specifické účely.

Publikace představuje vynikající příspěvek do knihovny vědeckých pracovníků stejně jako inženýrů z praxe, zabývajících se problematikou žáromonolitů.

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