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DETERMINATION OF THERMAL DIFFUSIVITY IN POROUS MATERIALS

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ABSTRACT

A method of measuring the thermal diffusivity in porous materials, above all in refractories and sand mixtures, was proposed. This method is based on measuring the temperature field in a material sample by a jump-change of its surface temperature. The thermal diffusivity is evaluated from the measured temperature differencies on the surface and in the centre of the sample by an analytical relation, which was derived by the integration of the differential equation of heat conductivity.

INTRODUCTION

One of the demands of the experimental and theoretical research in the field of heat engineering is gaining the possibly most accurate data from the temperature field in the heated or cooled material. The physical parameter on which the changes of the temperature field in the material depend is the thermal diffusivity:

$$a = \frac{k}{c.\rho} \qquad / \ m^2.s^{-1} \ / \qquad (1)$$

where

k....thermal conductivity, $W.m^{-1}.K^{-1}$

c....specific heat, $J.kg^{-1}.K^{-1}$

ρ....density, with porous materials the bulk density, $kg.m^{-3}$

The necessity to determine the thermal diffusivity appeared in connection with kinetics research of the temperature field during the solidification of steel. By controling the solidification of steel in sand forms a homogenous structure of the castings can be reached and the casting properties can be influenced.

Because of the above mentioned reasons there was at the Heat Engineering Department of the Mining University at Ostrava proposed an equipment to determine the thermal diffusivity.

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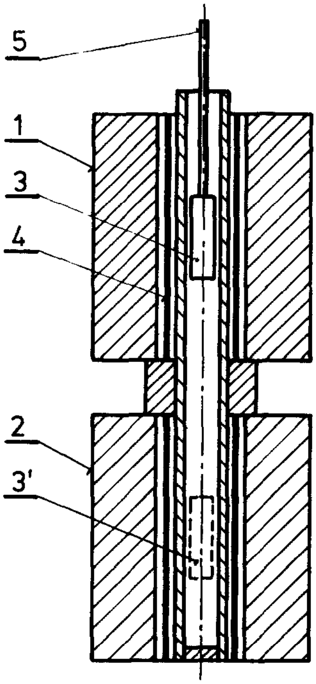

Fig. 1 Equipment for measuring the thermal diffusivity

1 - Furnace 1 for heating the sample to temperature t_1
2 - Furnace 2 for heating the sample to temperature t_2
3 - Sample of examined material
3' - Position of the sample after its transfer to furnace 2
4 - Kanthal heating elements
5 - Fixing of the sample

MEASURING METHOD AND RESULTS

The method of determining the thermal diffusivity is based on the evaluation of the temperature field measured in a cylindrically shaped sample changing the surface temperature of the sample by a jump from temperature t_1 to temperature t_2.The diagram of the measuring equipment is in fig.1.The apparatus consist of two furnaces,that are heated by kanthal heating elements.The material sample is heated in furnace 1 up to the temperature t_1,after reaching a uniform temperature in its cross-section it is transferred into the furnace 2.The temperature course is measured by thermoelements installed in a sample.The thermal capacity of the furnace 2 must ensure a change in the temperature of the sample surface by a jump from temperature t_1 to t_2.Fig.2 shows the measured temperatures on the surface and in the centre of the sample.

The temperature area in material is described by the Fourier field equation.The solution of the Fourier's equation is performed for thermal conditions equal to those of the measurement:

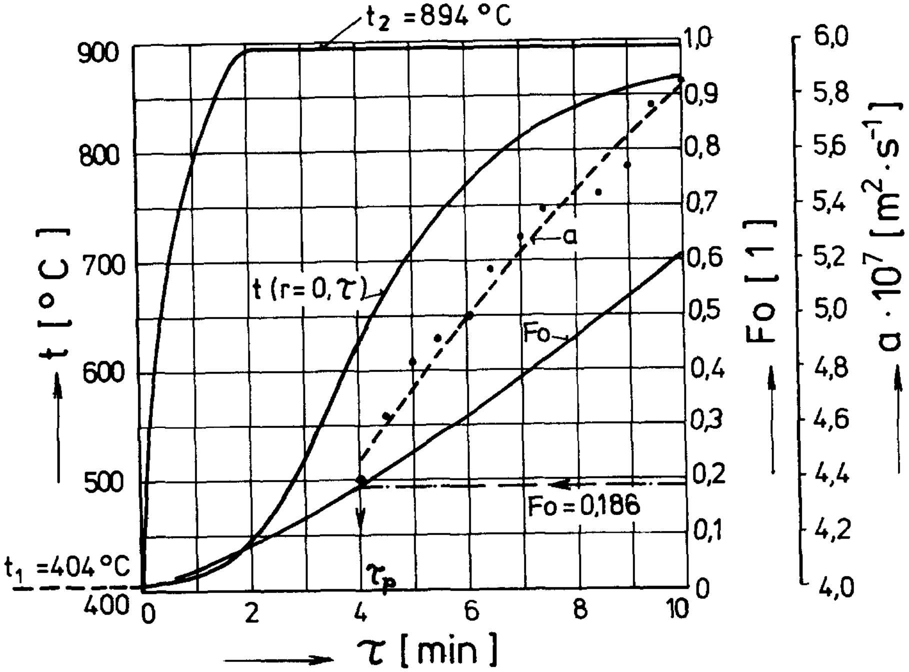

Fig.2 Courses of the measured and calculated values
$t(r=r_0;\tau)$.....temperature of the sample surface
$t(r=0;\tau)$......temperature in the sample centre
Fo.............Fourier s number
a..............thermal diffusivity
t..............temperature
τ..............time

1) initial condition:

$t(r;\tau=0) = t_1 = \text{const.}$ ....for $r \langle 0;r_0 \rangle$ (2)

2) surface condition:

$t(r=r_0;\tau) = t_2 = \text{const.}$ ....for $\tau > 0$ (3)

Further it is necessary to meet this conditions:

$$\frac{\partial^2 t}{\partial \varphi^2} = 0 \quad \text{and} \quad \frac{\partial^2 t}{\partial z^2} = 0 \qquad (4),(5)$$

After the initial section of heating, i.e. after meeting the condition:

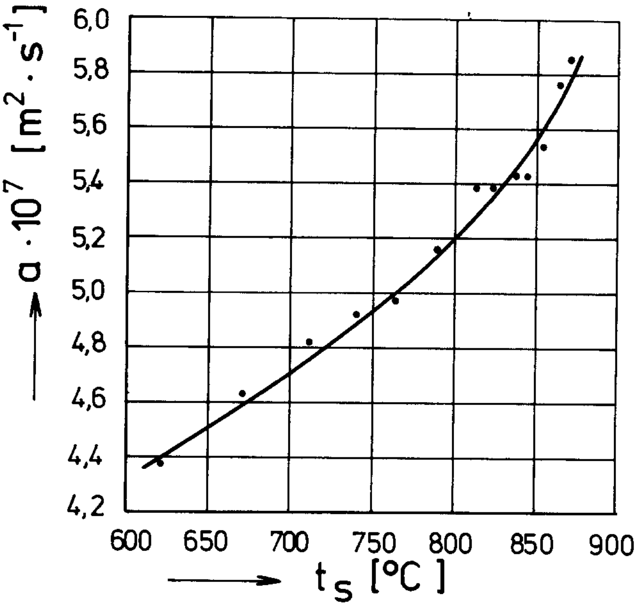

Fig. 3 Dependence of thermal diffusivity of the CT form mixture on temperature

a......thermal diffusivity

t_s.....temperature in the sample centre

$$Fo = \frac{a.\tau}{r_o^2} > 0,186 \quad \text{or} \quad \tau_p > 0,186 \frac{r_o^2}{a} \qquad (6),(7)$$

it is possible to use to determine the thermal diffusivity:

$$a = \frac{r_o^2}{5,783.\tau} \left(\ln 1,602 - \ln \frac{t_2 - t(r=0;\tau)}{t_2 - t_1} \right) \qquad (8)$$

The values of thermal diffusivity calculated according to equation 8 are given in fig.3.The measuring was performed with a sample of the CT foundry form mixture produced of quartz sand with a 5% addition of water glass.

REFERENCES

Current report of the research task:Study of the kinetics of temperature areas in the course of steel solidification. Mining University Ostrava,1982 and 1984.