(122) Comparison of the Laser-Flash Method and Hot-Wire Method for Measuring Thermal Conductivity from Metallurgical Slags

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1. Introduction

Blast furnace and converter slags represent the waste heat potential with the highest temperature level (1450–1650°C) in a steelworks. For carrying out thermal calculations on the heat recovery of slags, fundamental physical data – thermal diffusivity a, specific heat capacity c_p, thermal conductivity λ – are necessary (1).
Two non-steady-state methods for the determination of the thermal conductivity λ are introduced and compared.

2. Laser-flash method for measuring the thermal diffusivity a

Thermal diffusivities of actual BF- and converter slags and burden materials were measured using the laser-flash method (2,3). The measuring device of the laser-flash method is shown in Fig.1. The thermal diffusivity a is determined from the thickness of the sample (diameter d = 20 mm, thickness l=3 mm) and the time required for the back surface to reach half of the maximum temperature rise, which is detected by means of a thermocouple or fast pyrometer.
Blast furnace and converter slags have very low thermal diffusivity values – $4.0\text{–}7.0\times10^{-3}$ cm²/s – similar to refractories and BF-linings.

3. Thermoanalytical determination of the specific heat capacity c_p

The thermoanalyser allows simultaneous measurements of the weight (Thermogravimetry = TG) and the enthalpy (Differential Scanning Calometrie DSC = heat flux DSC) of materials. Measurements of the specific heat capacity c_p can be carried out from 20°C up to 1200°C.
The specific heat capacity for metallurgical slags is between 0.8 and 1.2 J/(g K) (4).

4. Thermal conductivity λ

By means of the specific heat capacity c_p, bulk density ρ_R and the thermal diffusivity a the thermal conductivity for solid materials can be calculated:

$$\lambda = a\, c_p\, \rho_R \qquad (1)$$

λ = thermal conductivity (W/(mK))
a = thermal diffusivity (cm²/s)
c_p = specific heat capacity (J/(g K))
ρ_R = bulk density (g/cm³)

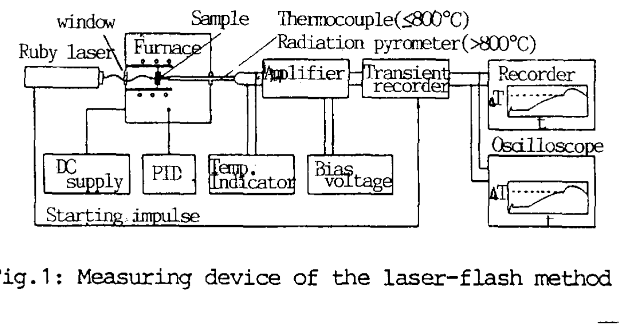

Fig.1: Measuring device of the laser-flash method

5. Direct measurement of the thermal conductivity λ by the transient hot-wire method

The construction of the cell of hot-wire method for measuring the thermal conductivity of slags from 20°C up to 1550°C is shown in Fig.2. A filament, consisting of a thin Mo-wire (Ø 0.17 mm) is immersed axially into a cylindrical graphite- or molybdenum crucible filled with sample liquid. The thermal conductivity λ of liquid or solid material is determined from the recorded temperature rise between two spot welded terminals of the Mo-wire, which acts both as an heating element and as a resistance thermometer (Fig.2) (5).
The thermal conductivity λ is calculated from the following equation:

$$\lambda = (q/4\pi) \,/\, (d\Delta T/d\ln t) \qquad (2)$$

q = Joule heat (W/ms); $d\Delta T/d\ln t$ = slope of the curve temperature increase of filament against the logarithm of time (K/s).

6. Conclusion

Data on thermal conductivity of actual metallurgical slags are not known from literature, but they are fundamental for thermal calculations. Therefore two non-steady state methods were used to measure the thermal conductivity of these materials.

References:

1) Lindner, K.-H.: Dr.-Ing. thesis, RWTH Aachen (1985), to be published. 2) Parker, W.J. et al: WAAD Technical Report 61-91 (1961). 3) Gudenau, H.W. et al: Fachber. Hüttenprax. Metallweiterv., Vol. 21, No. 6 (1983), 360-363. 4) Gudenau, H.W. et al: Fachber. Hüttenprax. Metallweiterv., Vol. 21, No. 10, (1983), 856-869. 5) Goto, K.S. et al: Stahl und Eisen (1985), to be published.

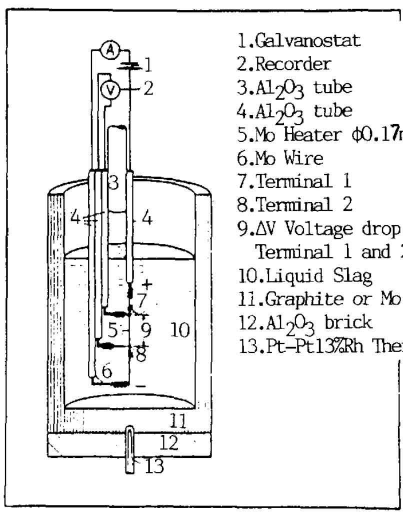

Fig.2: Construction of the cell of the hot-wire-method