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(142) Temperature Control of Metal-Slag Droplet in The Levitation Melting

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I. Introduction

To investigate slag-metal equilibria with the levitation melting technique, the temperature behavior of the levitated droplet was clarified quantitatively, and the temperature control technique of the specimen was developed in this study.

II. Experimental method

Fig.1 shows the levitation apparatus. A 3-turn levitation coil was powered by a 600 kHz, 40 kW HF generator. A transparent silica glass tube inserted through the coil allowed the use of controlled atmospheres during levitation melting. Specimens were prepared by pressing 0.19g of premelted slag powder into a cavity drilled in 3.14g of cylindrical iron(Fig. 2). Two two-ratio pyrometers were used to measure the metal top and slag bottom temperatures independently. Quenching was performed by a copper mold, and the sample was mechanically separated into slag and metal portions and analysed entirely.

III. Temperature control

Temperature was controlled from 1,550°C to 2,095 °C by changing not only the coil current and the cooling gas flow rate, but also the coil distance,x between the direct loops and the reverse loop. The coil distance was variable during melting.

To achieve an accurate control of temperature, thermal balance was calculated by Eq.1 for metal drop. By increasing the coil distance,x, a larger thermal absorption was gained and a higher temperature was achieved. Such a large heat input was also necessary for the slag melting at the very first stage of the levitation melting of the slag-metal specimen.

The condition to achieve a homogeneous surface temperature of the metal droplet can be calculated by Eq.2 considering the mass flow and the heat flow in the droplet during melting. Fig.3 shows the observed temperature difference in a levitated metal droplet. By balancing the coil distance and the cooling gas flow rate, the temperature difference in the metal droplet was minimized.

IV. Conclusion

By controlling the coil distance, the cooling gas flow rate and the coil current, a homogeneous metal temperature at 1,550 - 2,095°C was achieved in the levitation melting.

Symbols

a :radius of droplet [m]	p :penetration ratio [-]
D :diameter of droplet [m]	Re:Reynolds number [-]
d :inner diameter of cylindrical glass tube [m]	T :temperatures [°C]
I :coil current [A]	z :height from top direct loop [m]
k_f:thermal conductivity of gas at film temp. [J/m·s·deg]	ε_M:hemispherical total emmisivity of metal [-]
m_M:mass of metal [kg]	ρ :electrical resistivity of metal [m]
Pr:Prandtl number [-]	

As for dimensionless heat and force functions, $H(p)$, $h_m(z)$, $h_B(z)$, $h_T(z)$ and $f(z)$, refer to Fromm et al:Brit.J.Apply.Phys.,16(1965)p653-662.

L(x) is a parameter which should be experimentally determined for each coil.

$$\underbrace{\frac{3}{4}\pi a I^2 \rho H(p)\{h_m(z)\}^2}_{\text{(Thermal absorbtion)}} = \underbrace{4\pi a^2\{\sigma \varepsilon_M T_M^4}_{\text{(Radiation)}} + \underbrace{\frac{k_f Nu}{D}(T_M - T_f)\}}_{\text{(conduction)}} \qquad \text{(Eq.1)}$$

$$\frac{3}{4}\pi a I^2 \rho H(p)[\{h_B(z)\}^2 - \{h_T(z)\}^2] = L(x) + 0.60(2\pi a^2)\frac{k_f}{D}(Pr)^{1/3}(Re_B)^{1/2}[1-\{2-(\frac{D}{d})^2\}^{-1/2}]\frac{T_M - T_\infty}{2} \qquad \text{(Eq.2)}$$

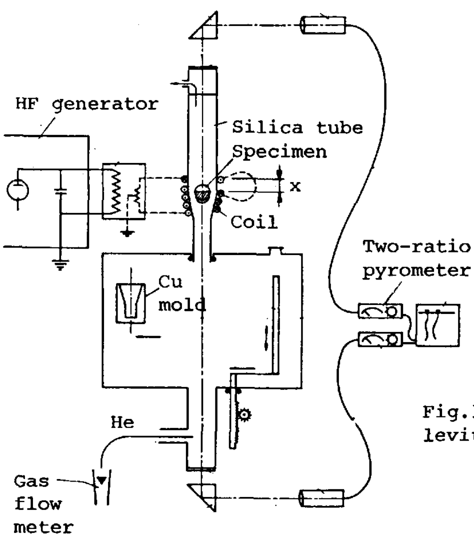

Fig.1 Schematic view of levitation apparatus

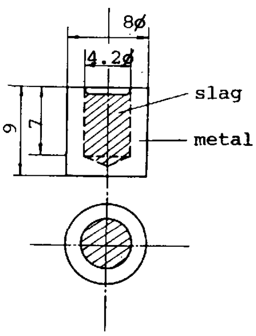

Fig.2 Slag-metal specimen

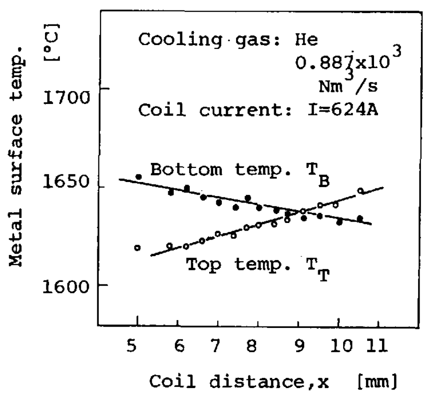

Fig.3 Effect of the coil distance,x on the temperature difference between top and bottom of the metal sphere