Analysis of Heating Condition of Copper Crucible in Vacuum Suspension Furnace Melting Process

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Abstract: The copper crucible is one of the most important parts in the process of vacuum suspension furnace melting, which must work at a certain temperature to ensure its stable physical and chemical properties. The study of its temperature is crucial because it directly affects the quality of the smelting process.
Keywords: Copper Crucible, Suspension smelting,Crucible temperature, The crucible cools

1 Introduction

The temperature of copper crucible is changed by the Heat absorbed and released by the Crucible. The heat absorbed by the crucible mainly includes the heat transfer of burden to it and the induction of melting magnetic field to it. It releases heat in the way that it conducts heat to cooling water.

2 Heat transfer of charge to crucible

At the initial stage of smelting, the charge is not melted, and the heat is transferred from the charge to the crucible in the form of heat transfer, the contact area between liquid metal and crucible will increase gradually, and the heat transfer mode will become convective conduction.

(1) Heat transfer from solid charge tocrucible

The initial stage of smelting. According to Fourier's law, it can be calculated using the following formula:

$$Q_1 = \lambda F(t_1 - t_2)$$

Explain:

Q_1—Heat conduction of charge to crucible (Unit W);

λ —Thermal conductivity between charge and crucible （W/m²*℃）;

F —The contact area between solid charge and crucible is different due to the different particle size of charge;

t_1—Contact side charge temperature;

t_2—Crucible temperature;

3 Heat transfer of liquid metal to crucible

After the metal has melted， Under the action of gravity and levitation， It rolled in the Crucible， But only the bottom touches the crucible

The heat transfer can be calculated using the following formula:

$$Q_2 = \alpha F_2(t_3 - t_2)$$

Explain:

Q_2—Convection heat transfer of liquid charge to crucible;

α — Convective heat transfer coefficient between furnace charge and crucible;

F_2—The contact area between the liquid charge and the crucible;

t_3—Melting charge temperature;

t_2—Crucible temperature;

4 The work of electromagnetic field on the input of Copper Crucible

According to the principle of electromagnetic induction, the work entered can be calculated using the following formula:

$$P = KH^2 q_f \sqrt{\rho \mu f}$$

Explain:

P—The power absorbed by a copper crucible(kW/m²);

K—Constant;

H—Magnetic field strength（A/m);

q_f — The ratio of crucible cross-section diameter to penetration depth;

ρ—The resistivity of copper（1.75*10-5Ω*cm）;

μ—The relative permeability of copper;

f—Electromagnetic frequency;

5 Heat transfer between the crucible and the cooling water

The heat transfer between cooling water and crucible is convective heat transfer.it can be calculated using the following formula:

$$Q_3 = hA\Delta t$$

Explain:

Q_3 —Heat transfer between crucible and cooling water;

h—Convective thermal conductivity between water and copper;

Δt—Temperature difference between crucible and cooling water;

A—Contact area between cooling water and crucible;

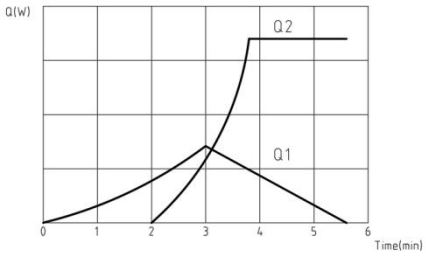
From the formula,The larger the contact area A, the larger the temperature difference between crucible and cooling water, and the higher the heat transfer efficiency.

6 For example

The process of titanium suspension melting in vacuum was recorded.

Materials	Weight（kg)	Power supply power（kW)
Titanium	5	200

At the beginning of smelting, the power supply is 50kW, the charge begins to heat up, and when the power is raised to 100kW by 2 minutes, part of the titanium metal begins to melt. As the power increases, the melting speed increases, 3 minutes and 50 seconds, titanium liquid has filled the bottom of the crucible, increase the power to 150 kW, 5 minutes 30 seconds, titanium all melting, into suspension.



Q1-heat conduction
Q2-convection

Figure.1 Heat transfer of crucibles

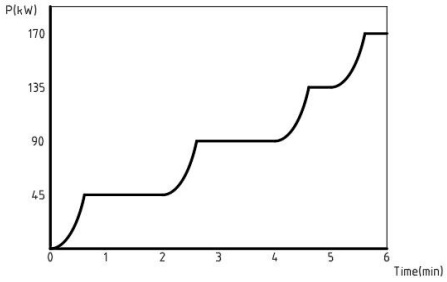


Figure. 2 The heat of the crucible

7 Result and discussion

According to the heating condition of the copper crucible, the section of the water channel of the Crucible and the requirement of the cooling water flow are designed to improve the production efficiency, reduce production costs while ensuring product quality and safe production.

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