The temperature of leucoxene melted zone under DC plasma arc anode spot

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Leucoxene concentrate is a perspective titanium source. Leucoxene concentrate consists of TiO_2 and SiO_2 with similar mass quantities. Plasma-arc heating of concentrate with carbon allows to separate titanium from silicon. The reaction $SiO_2 + C = SiO + CO$ takes place and volatile SiO evaporates. Experimental results of DC plasma arc melting of leucoxene concentrate in graphite and copper water-cooled crucibles are compared. It was established that melting in the graphite crucible leads the less overheat of leucoxene pool under the anode spot of DC plasma arc then in the copper water-cooled crucible. The calculation method of the temperature field of melting pool is considered.

1. Introduction

Copper water-cooled crucible and graphite crucible were used [1]. The enrichment of TiO_2 was worse in graphite crucible then in cooper water-cooled. The both crucibles had a similar geometry and arc power. The anode spot in graphite crucible was disperse ($\approx$ 10 A/cm^2) and the anode spot in copper crucible was constricted ($\approx$ 100 A/cm^2). Thus the material was not overheated enough in the graphite crucible. The purpose of this work was to calculate the temperature field of the pool surface under the anode spot in both cases.

2. Calculation model

The calculation model is presented on fig.1.

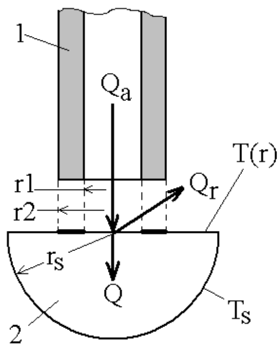

Figure 1. Calculation model scheme.
1 – electrode (graphite hollow cathode); 2 – melted pool (anode); $Q = Q_a - Q_r$ – heat flow into melted pool; Q_a – heat transfer via electrical physical processes in anode spot of DC plasma arc; Q_r – heat radiation of melted surface.

The quantity of Q_a was determined experimentaly on cold anode. It equaled approximately 50 % from arc power [2].

The quantity of Q_r was detemined as:

$$Q_r = 2\pi\varepsilon\sigma\left[\int_0^{r1} r(T(r))^4 dr + \int_{r2}^{rs} r(T(r))^4 dr - 0{,}5T_k^4(r1^2 + rs^2 - r2^2)\right]$$

here r_s – pool radius; r_1, r_2 – inside and outside radiuses of non-radiated area under hot hollow cathode; T_s – periphery temperature of melted pool; T(r) – temperature of the pool surface in dependance of radius.

The temperature field of the pool surface is calculated as:

$$T(r) = 0{,}282\frac{Q}{\lambda r_o}\left[\varphi(r) - \varphi(r_S)\right] + T_S\,, \qquad (1)$$

here r_o – plasma arc anode spot radius; λ– thermal conductivity of the material; $\varphi(r) = \exp\left(-\frac{r^2}{2r_o^2}\right)\cdot I_o\left(\frac{r^2}{2r_o^2}\right)$, Io – Bessel's function of imaginary argument.

Calculation results are presented in the figure 2.

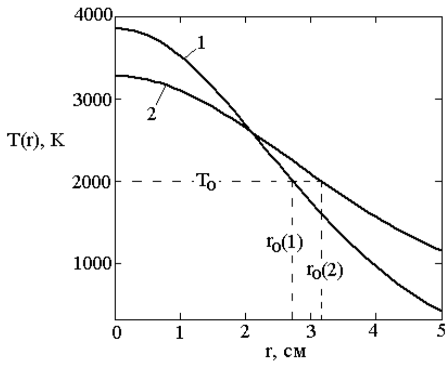

Figure 2. Calculated temperature field of the pool surface. r – radial distance from the center; 1 – copper crucible; 2 – graphite crucible; T_o – anode spot edge isotherm; $r_o(1)$, $r_o(2)$ – anode spot radiuses in cupper and graphite crucibles.

3. Conclusions

The temperature of melted zone under DC plasma arc anode spot is less in hot (graphite) crucible than in cold copper crucible due to less current density.

4. References

[1] A. A. Nikolaev, D. E. Kirpichev, A. V. Samokhin, A. V. Nikolaev. Russian Metallurgy (Metally), Vol. 2016, No. 12, pp. 40–43.

[2] Erohin A.A. Plazmenno-dugovaia plavka metallov i splavov [Plasma-arc melting of metals and alloys]. Moscow, Nauka, 1975, 188 p. (In Russ.).