Boundary conditions for the fluid-electrode interface

The thermal variable for electric arc simulation in Code_Saturne is enthalpy, while temperature is calculated for perception convenience, which involves continuity and integrability of enthalpy throughout the whole simulation domain. At the same time at the fluid-electrode interface we need to have continuous temperature and thermal flux, while Tungsten and Argon have different enthalpy dependencies of temperature, thermal and electrical conductivity. It means that for the same enthalpy the Tungsten and Argon temperatures are widely different. Hence, the requirements for enthalpy distribution function are violated at the fluid-electrode interface. The proposed solution of the described difficulty is to detach the electrodes from the fluid domain and get two coinciding boundary faces at both anode and cathode surfaces. In this case, we can sew together the temperature and electric potential fields for the electrodes and the fluid, while keeping separated the enthalpy calculation. At the same time we can take into account the significant difference in thermal and electrical conductivity of Tungsten and Argon.

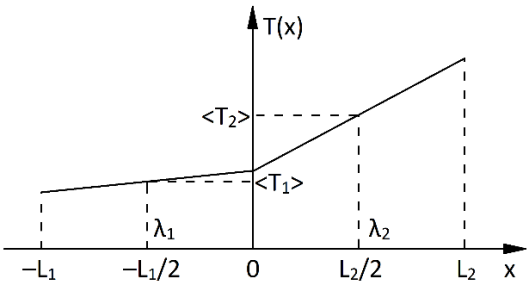

Fig. 1. Two cells case for the interface.

For every interface face between the electrode and fluid we consider two cells case (Fig 1) with linear approximation for temperature and electric potential inside the cells (1). At the interface face we have continuous temperature, thermal fluxes, electric potential and electric current, which implies (2).

$$\begin{cases} T_1(x) = < T_1 > + a_1\left(x + \frac{L_1}{2}\right) \\ T_2(x) = < T_2 > + a_2\left(x - \frac{L_2}{2}\right) \\ V_1(x) = < V_1 > + b_1\left(x + \frac{L_1}{2}\right) \\ V_2(x) = < V_2 > + b_2\left(x - \frac{L_2}{2}\right) \end{cases} \quad (1)$$

$$\begin{cases} T_1(0) = T_2(0) \\ \lambda_1 \frac{dT_1(x)}{dx}\Big|_{x=0} = \lambda_2 \frac{dT_2(x)}{dx}\Big|_{x=0} \\ V_1(0) = V_2(0) \\ \sigma_1 \frac{dV_1(x)}{dx}\Big|_{x=0} = \sigma_2 \frac{dV_2(x)}{dx}\Big|_{x=0} \end{cases} \quad (2)$$

Where λ_1, λ_2 are thermal conductivities of the cells and σ_1, σ_2 are electrical conductivities.

Inserting (1) to the equations set (2) we get the following values of temperature and electric potential for the interface between two cells:

$$T_1(0) = T_2(0) = \frac{\lambda_1 L_2 < T_1 > + \lambda_2 L_1 < T_2 >}{\lambda_1 L_2 + \lambda_2 L_1} \quad (3.1)$$

$$V_1(0) = V_2(0) = \frac{\sigma_1 L_2 < V_1 > + \sigma_2 L_1 < V_2 >}{\sigma_1 L_2 + \sigma_2 L_1} \quad (3.2)$$

$$\varphi_{therm\_diff}(0) = -\frac{2\lambda_1 \lambda_2}{\lambda_1 L_2 + \lambda_2 L_1}(< T_2 > - < T_1 >) \quad (3.3)$$

If the interacting cells have the same size, L_1 and L_2 can be neglected in (3.1) and (3.2).