LTE Modelling of a DC Arc Ignition on Cold Electrodes

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Abstract : The assumption of plasma in local thermal equilibrium (LTE) is commonly used to perform electric arc simulations for industrial applications. This assumption allows to model the arc using a set of magneto-hydromagnetic equations that can be solved with a computational fluid dynamic code. However, the LTE description is only valid in the arc column, whereas in the regions close to the electrodes the plasma deviates from the LTE state. The importance of these near-electrode regions is non-trivial since they define the energy and current transfer between the arc and the electrodes. Therefore, any accurate modelling of the arc must include a good description of the arc-electrode phenomena. Due to the modelling complexity and computational cost of solving the near-electrode layers, a simplified description of the arc-electrode interaction was developed in a previous work to study a steady high-pressure arc discharge, where the near-electrode regions are introduced at the interface between arc and electrode as boundary conditions. The present work proposes a similar approach to simulate the arc ignition in a free-burning arc configuration following an LTE description of the plasma. To obtain the transient evolution of the arc characteristics, appropriate boundary conditions for both the near-cathode and the near-anode regions are used based on recent publications. The arc-cathode interaction is modeled using a non-linear surface heating approach considering the secondary electron emission. On the other hand, the interaction between the arc and the anode is taken into account by means of the heating voltage approach. From the numerical modelling, three main stages can be identified during the arc ignition. Initially, a glow discharge is observed, where the cold non-thermionic cathode is uniformly heated at its surface and the near-cathode voltage drop is in the order of a few hundred volts. Next, a spot with high temperature is formed at the cathode tip followed by a sudden decrease of the near-cathode voltage drop, marking the glow-to-arc discharge transition. During this stage, the LTE plasma also presents an important increase of the temperature in the region adjacent to the hot spot. Finally, the near-cathode voltage drop stabilizes at a few volts and both the electrode and plasma temperatures reach the steady solution. The results after some seconds are similar to those presented for thermionic cathodes.

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