Modelling of plasma-species mixing in argon-steam arc discharge for broad range of currents and argon mass flow rates

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The paper focuses on numerical simulation of mixing of plasma chemical species under extreme temperature and density gradients in the arc discharge with combined stabilization of an electric arc by axial argon flow and tangential water vortex. This arc has been used at present for plasma spraying and for investigation of production of syngas ($CO + H_2$) from municipal waste and biomass.

In the present study we assume one-fluid, two-dimensional, axisymmetric, unsteady, compressible, quasi-laminar and generally turbulent plasma flow, with mixing of steam and argon plasma species considered by the so called combined diffusion coefficients method [1, 2]. Diffusion processes due to concentration, temperature and pressure gradients, and due to an external electric field are taken into account. Energy losses from the argon-steam plasma by radiation are calculated by the partial characteristics method [3]. Turbulent effects, even though very small, are treated by Large Eddy Simulation with the Smagorinsky subgrid-scale model.

In contrast to our previous study [4] mixing of argon, oxygen and hydrogen species and its impact on the thermal and fluid-dynamic properties of the discharge have been studied for a broader range of currents (150-600 A) and argon mass flow rates (15-40 standard liters per minute). Results of calculation reveal inhomogeneous mixing of argon and oxygen-hydrogen species with the argon species prevailing near the arc axis. All the combined diffusion coefficients exhibit highly nonlinear distribution of their values within the discharge, depending on temperature, pressure and argon mass fraction in the plasma. The argon diffusion mass flux is driven mainly by the concentration and temperature space gradients. Some physical quantities, such as temperature, reabsorption of radiation, power losses from the discharge and arc efficiency, depend only slightly on the argon mass flow rate. The results are compared with our previous calculations for the simplified assumption of homogeneous mixing and with available experiments.

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