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MAGNETOHYDRODYNAMIC MODELING OF THERMAL PLASMA FLOW AND ITS APPLICATION TO DIRECT-CURRENT PLASMA TORCH

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Abstract

Direct-current plasma torch is a widely adopted thermal plasma device applied to various industrial applications, where high-temperature plasma jets are produced due to the substantial interaction between neutral working gases and arc columns. The applied electric arc principally works as the main energy provider to accelerate the plasma flow along with elevating its temperature to obtain the required processing capabilities. A steady magnetohydrodynamic model is proposed to describe the thermal plasma flow of a direct-current plasma torch where the continuity, momentum and energy equations incorporated with a turbulence model are considered to depict the dependence among the flow velocity, working pressure and gas temperature of the plasma jet subjected to an applied electric accompanied by a self-induced magnetic field. The azimuthal velocity component is also considered in the proposed model for capturing the significant rotational motion of plasma flow as a consequence of tangential inflow design. The thermal plasma is assumed electrically neutral, optically thin and in local thermal equilibrium. The time-averaged solution is employed because of a focus on engineering operation. For reactive thermal plasmas, the transport equations of charged particles described by a drift-diffusion approximation as well as the transport equations of the neutral species are modeled following the chemical and plasma kinetics among different plasma components. The energy balance equation of electron is furthermore introduced when the non-thermal equilibrium plasma is considered. The governing equations are segregated solved on a Cartesian grid via a finite volume discretization, where a linear parallelization is achieved through the MPI library. The proposed numerical scheme is implemented in an in-house code PTCAX. Several applications of the direct-current plasma torch are discussed to disclose the complex physics of thermal plasma flow interacting with a direct-current arc.

Keywords: Magnetohydrodynamic Modeling, Thermal Plasma, Direct-Current, Plasma Torch.

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