Computational Modeling Of Plasma Using Single-Fluid And Two-Fluid Modeling Approaches

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Abstract

Plasma, a complex fluid consisting of electrons, ions, neutrals, and excited species, exhibits both fluid-like behavior and electrical conductivity due to the presence of charge carriers. Consequently, computational modeling of plasma requires the integration of fluid and electrical models. This research paper presents a study on the steady-state computational modeling of a plasma torch with a 2D axisymmetric geometry using single-fluid and two-fluid modeling approaches in the COMSOL Multiphysics® software. The single-fluid modeling (SFM) approach combines the individual equations governing the behavior of different particles into a unified equation. Specifically, the SFM approach utilized in this study focuses on a fully ionized plasma and employs the equilibrium discharge interface (EDI) model available in COMSOL Multiphysics®. The EDI model solves the magnetohydrodynamic (MHD) equations, encompassing electric and magnetic fields, heat transfer in solids and fluids, and laminar models. By employing this approach, the researchers simulated and analyzed the behavior of the plasma torch. In contrast, the two-fluid modeling (TFM) approach separates the fluid equations for electrons and ions, considering a weakly ionized plasma. The TFM model is developed by deriving fluid equations based on kinetic theory for neutrals, ions, and electrons. These equations are then implemented in COMSOL Multiphysics®, utilizing models for the transport of diluted species, laminar flow, heat transfer in solids and fluids, and electric and magnetic fields. By adopting the TFM approach, the researchers aimed to gain insights into the behavior of the plasma torch. Throughout the study, various properties such as temperature, velocity, current density, and particle concentrations are analyzed within the plasma torch. Results obtained from both the single-fluid and two-fluid modeling approaches are compared and evaluated. This comparative analysis allows the researchers to highlight the advantages and challenges associated with each modeling approach. In conclusion, this study contributes to understanding plasma behavior by employing computational modeling techniques. The research presents and compares the outcomes of single-fluid and two-fluid modeling approaches applied to a plasma torch. By examining the advantages and challenges of each approach, the study offers valuable insights for future plasma modeling endeavors.