Electro-Magneto-Fluid-Dynamics (EMFD): Analytical Models and Numerical Simulations

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Fluid flow influenced by electric and magnetic fields has classically been divided into two separate fields of study: electro-hydro-dynamics (EHD) studying fluid flows containing electrically charged particles moving within the carrier fluid under the influence of an electric field and no magnetic field, and magneto-hydro-dynamics (MHD) studying fluid flows containing no free electric charges under the influence of an externally applied magnetic field and no electric field.

Traditionally, this division was necessary to reduce the extreme complexity of the coupled system of Navier-Stokes, Maxwells and constitutive equations describing combined electro-magneto-hydro-dynamic flows. Recent advances in numerical techniques and computing technology, as well as rigorous derivation of the combined effects, have made analysis of combined electro-magneto-hydro-dynamic flows well within reach. A brief survey of electro-magnetics and the theory describing combined electro-magneto-fluid-dynamic (EMFD) flows is presented with an emphasis on the intricacies of the mathematical model and the boundary conditions for fluid flows involving linear polarization and magnetization.

Examples of numerically simulated EHD, MHD and combined EMHD flows involving solidification from a melt and optimization of such flows confirm the extremely wide possibilities for practical applications of these combined phenomena.