Numerical Study of DC Electromagnetic Pump of Liquid Metal: Limits of the Model

Nedeltcho Kandev[1]

[1]Institut de recherche d'Hydro-Québec, Shawinigan, QC, Canada

Abstract

This work presents the results of a 3D numerical magneto-hydrodynamic (MHD) simulation of an electromagnetic DC pump of liquid metal using a rectangular metal flow channel subjected to an externally imposed transversal inhomogeneous magnetic field. In this study, 3D numerical simulation based on the finite element method was carried out using the computer package COMSOL Multiphysics version 3.5a. For this simulation, the liquid aluminum is used as an electrically conductive fluid. This complex MHD problem is not necessarily symmetrical and, therefore, a fully 3D high resolution simulation only allows seizing all spatial aspects of the electromagnetic phenomena and flow structure. In this study, where the model has to represent a real pump working at different operating conditions, a relatively high metal flow velocity of up to 1m/s was used. For the simulation of the pumping conditions a pair of electrodes is introduced on the vertical lateral walls of the channel at a right angle to the magnetic field. A DC electrical potential difference is applied between these two electrodes to impose an external electrostatic field in the molten metal with desired magnitude and direction. The formulation of the steady state magneto hydrodynamic 3D model has been derived from the Maxwell equations (electromagnetic part) for moving medium coupled with the Navier-Stokes equations (fluid dynamics part) for the laminar flow or with the Reynolds-Averaged Navier-Stokes equations and the standard k-ε turbulence model for the turbulent flow. The application and the limits of the electromagnetic and the hydrodynamic models are discussed herein. The results of several typical examples are summarized here, including brake flow and pumping conditions for both laminar and turbulent metal flow. These simulations correctly represent the formation of an M-shaped velocity profile of liquid metal under the influence of the imposed non-uniform magnetic field and are consistent with the results of recently published works.