Theoretical study of thermal convection in a liquid metal battery : Linear stability analysis

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Abstract

Rapid developments in harnessing the natural sources of energy has lead to a strong demand of efficient energy storage techniques. Among the proposed systems, liquid metal battery (LMB) is a novel system of energy proposed to store the electrical outputs from intermittent sources of energy such as wind energy, solar energy, etc., LMBs are composed of liquid alkali metals in top electrode, molten salts as electrolyte and alloys as bottom electrode. These liquids are immiscible and super imposed in a stable density stratification. With the application of current across the battery, several physico-chemical phenomena occurs. The objective of this thesis consists in the investigations of thermal convection induced due to Joule's volumetric heating in the electrolyte. Initial study has been done on a single layer with volumetric heating subject to different thermal and kinematic boundary conditions. Later a horizontal magnetic field has been applied to detect its effects on the critical parameters of thermal convection. Equations governing thermal convection induced by Joule heating in the whole battery have been formulated together with the boundary conditions including the interfaces. A numerical code has been developed to solve these equations. These thresholds are found to depend on the ratio of fluid properties of electrodes to those of the electrolyte. The variation of the ratio of electrodes thicknesses to that of the electrolyte leads to a new mode of thermal instability in the upper electrode for very large thickness. The effect of heat exchange of the battery with its ambient environment is to destabilize the conduction state and to facilitate thermal convection. Joule heating in the electrolyte can affect the interfacial tension at both the interfaces and induce thermocapillary (Marangoni) convection, threshold of which depends on the ratio of the electrodes thicknesses. In shallow electrolytes, thermoconvection can appear in the upper electrode before it occurs in the electrolyte. An applied external magnetic field along the horizontal plane increases the threshold of thermal convection elongates the convection cells. All the modes of thermal convection induced by Joule heating are stationary