Thermoelectric Current and Magnetic Field Interaction Influence on the Convection of Liquid Phase During Solidification of Metallic Alloys

I.Kaldre[1,2], A.Bojarevics[2],Y.Fautrelle[1], J.Etay[1], L. Buligins[3]

The current work addresses the analysis of thermoelectric current and magnetic field interaction influence on the liquid metal motion. At the crystallization front of metallic alloy the temperature variations can exist in length scales comparable with dendrite spacing order of magnitude, which means that a large temperature gradient can exist locally. This can lead to a thermoelectric current circulation in the vicinity of the solidification front. If an external magnetic field is applied, the Lorentz force appears, and flow of the liquid phase emerges (thermoelectromagnetic convection). This flow can have an influence on the heat and mass transfer conditions in the melt, which can eventually lead to changes in the grain and dendrite structure of metal.

In this work a theoretical estimation of characteristic velocity and heat transfer quantities has been derived. A liquid phase motion is damped by the induced magnetic field and thermoelectric current interaction, and for each geometry and material one magnetic field magnitude exists, at which the velocity is maximal.

The mathematical simulations of thermoelectric current distribution and liquid phase motion with the present magnetic field are done as well. The modelling has been completed in different geometries and length scales. Most of the modelling has been done with FLUENT.

The necessary properties for the alloy to expose stronger thermoelectromagnetic convection and thus influence of the magnetic field on the structure of the alloy, are a good electric conductivity and high differential thermo-EMF between a solid and a liquid phase at the melting temperature. Pb-Sn and Sn-Bi alloys are used as the test alloys because they have relatively low melting temperature and it simplifies the control of the directional solidification experiment. These alloys were chosen also because absolute thermoelectric power of Pb-Sn alloy has been measured as a part of this work in a wide temperature and composition range in both solid and liquid phases while for most of the alloys these data are unavailable.

The simulations and experiments have been carried out with the external electric current through the solidification interface and magnetic field interaction. The convection created by this interaction is similar to the thermoelectric convection, and a similar influence on the structure might be achieved.

[1] SIMAP-EPM, PHELMA-Campus, BP75, 38402 St Martin d'Heres Cedex, France
[2] Institute of Physics University of Latvia, Miera str. 32, LV-2169, Salaspils, Latvia
[3] University of Latvia, Faculty of Physics and Mathematics, Zellu str. 8, LV-1002, Riga, Latvia