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High Frequency and High Power Electro-Magneto-Hydro-Dynamics and Heat Transfer

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ABSTRACT

It is well known that simultaneously externally applied electric and magnetic fields can influence flow pattern of a moving liquid and convection heat transfer in a process known as Electro-Magneto-Hydro-Dynamics (EMHD). This paper analyzes computationally the high frequency, high intensity electric and magnetic fields combined with a strong convection/conduction (conjugate) heat transfer in the flowing liquid and the container walls. It also offers an answer to the intriguing question: Is it possible for cooling fluid and its flow-field and temperature field to influence high frequency and high intensity electric and magnetic fields. This "reverse EMHD" effect has been proven analytically to exist when physical properties vary significantly with temperature [1,2]. Numerical simulations were performed using a modified version of COMSOL software to explore possible back-influence of liquid flow on the high frequency (10MHz to 10GHz) electric and magnetic fields, while accounting for physical properties of liquid that depend on temperature and frequency of the applied fields.

Recently, the "reverse EMHD" effect was confirmed numerically [3] for cases of very weak, high frequency electric fields in case of pure water and strong heat transfer (heat flux as high as 1000 W m^{-2}) typical of integrated cooling of high power microelectronics. The objective of this work is to examine if such "reverse EMHD" effect is significant also in cases of very strong high frequency electric fields applied to strong conjugate heat transfer. Moreover, since the "reverse EMHD" effect was not noticeable in the case of very weak high frequency magnetic fields [3], it is of interest if this effect is important in case of very strong high frequency electric and magnetic fields applied to strong conjugate heat transfer. All simulations were fully three-dimensional, fluids were pure water and sea water, and flow was steady and laminar.

[1] H.-J. Ko and G.S. Dulikravich, "Non-reflective boundary conditions for a consistent two-dimensional planar electro-magneto-hydrodynamic flow model", *International J. of Non-Linear Mechanics*, Vol. 36, No. 1, pp. 155-163 (2000).

[2] H.-J. Ko and G.S. Dulikravich, "Non-reflective boundary conditions for a consistent model of axisymmetric electro-magneto-hydrodynamic flows", *International J. of Nonlinear Sciences and Numerical Simulation,* Vol. 1, No. 4, pp. 247-256 (2000).

[3] A. Abdoli, S.R. Reddy and G.S. Dulikravich, "Effect of cooling fluids on high frequency electric and magnetic fields in microelectronic systems with integrated TSVs", *Microelectronics Journal* (2017).