

Numerical simulation of electro-thermo-convection in a dielectric liquid lying between two between two eccentric cylinders

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Abstract — Two-dimensional numerical simulations are carried out for electro-thermo-convective phenomena in a dielectric liquid confined between two eccentric cylinders. The liquid is under the simultaneous actions of a direct current (D.C.) electric field and a thermal gradient. The electrochemical reaction that takes place at the liquid/electrode interface leads to the generation of free charges (ions). The Coulomb force exerting on these ions tends to destabilize the system and to induce flow motion known as electro-convection. Such flow motion can be used to actively enhance heat transfer. Most of previous numerical studies were mainly concerned with the planar electrode geometry. In this study, we consider a more intricate problem of the cylindrical geometry, a situation that is closer to practical applications, considering the case of electrohydrodynamically enhanced heat transfer with the forced flows in pipes (wire/cylinder). We develop an in-house solver based on the 2nd order finite volume method to solve all governing equations including a reduced set of Maxwell's equations, Navier-Stokes equations and the energy equation. Numerical results for the radius ratio of 0.1 and considering silicon oil as the working medium are presented. The numerical solver is first validated with two cases: the natural convection and pure electro-convection. For the thermal case, we compare our results with available numerical and experimental results. For the electrical case, we compare our results with the ones obtained by a finite element method. For both cases, perfect agreements are obtained. As an application example, we will evaluate the heat transfer enhancement due to the electric field in a wide range of Rayleigh number Ra . In addition, we will highlight the influence of the eccentricity on the heat transfer rate. This study can be viewed as an extension of our recent works with electro-convection and electro-thermo-convection in the concentric cylinder configuration [1, 2]. Keyword : Electrohydrodynamics, numerical analysis, dielectric liquid, charge injection, natural convection, annular convection. [1] Wu J, Vázquez P A, Traoré P, et al. Finite amplitude electroconvection induced by strong unipolar injection between two coaxial cylinders[J]. Physics of Fluids (1994-present), 2014, 26(12): 124105. [2] Wu J, Traoré P, Zhang M, et al. Charge injection enhanced natural convection heat transfer in horizontal concentric annuli filled with a dielectric liquid[J]. International Journal of Heat and Mass Transfer, 2016, 92: 139-148