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Charge injection in horizontal eccentric annuli filled with a dielectric liquid

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Abstract: In this paper, we carry out a numerical study of the Coulomb-driven electro-convection flow in a dielectric liquid using the finite volume method (FVM). The system under study consists of an eccentric annulus layer subjected to strong unipolar injection from an inner cylinder. All equations are written in bi-cylindrical coordinate system and are expressed using the vorticity – stream function method. The behaviour of the fluid for different system parameters is well studied. The taken parameters are in the range of eccentricity $0 \leq e \leq 80\%$, injection strength in the range of $0.5 \leq C \leq 10$ and electric Rayleigh number in the range of $30 \leq T \leq 1600$.

The distributions of the electric charge density and stream function are carefully examined. The computations highlight a significant effect of the eccentricity value on the flow topography. Indeed, increasing the eccentricity value leads to a significant reduction in electro-plumes as well as circulation cells number. Furthermore, an intensification in cells rotation, of about 116%, was recorded when eccentricity reaches 80%. Depending on torque values e-T, we observe the existence of multicellular regime made of counter-rotating vortexes.

Key words: Computational fluid mechanics, electro-Hydro-Dynamic (EHD), electro-convection, dielectric liquid, eccentric annular space, numerical simulation, multicellular flow.

1. Introduction

In the past 20 years, the analysis of an electric field's effect in a dielectric liquid has received extensive attention due to its wide field of applications in major industries. This phenomenon, known as electro-hydrodynamic (EHD), has been widely investigated theoretically, experimentally because of the additional flows that it induces. Today the study of EHD is still very attractive because of its numerous industrial applications, e.g. electrostatic precipitators [1-2], EHD pumps [3-4], EHD laminar and turbulent mixing [5-6], enhancement of heat transfer [7-8]. This technology provides the benefits of providing a simple design, ease use, rapid control, low operating power, low vibration and low noise level.

When a dielectric liquid is subjected to an electric field, ionic migration takes place from one of the electrodes (the emitter) towards the other electrode (the collector). This unipolar injection plays the major role in the establishment of the induced secondary flow. When some ions are injected from the emitter electrode in the fluid and as soon as T exceeds the linear stability criterion T_c electroconvection is induced.