Review

of the Ph. D. thesis of Vladimir Chirkov

entitled"Influence of Charge Formation Mechanism on the Structure of Electrohydrodynamic Flow in Highly Non-Uniform Electric Field"

submitted for the degree of Doctor of Philosophy in Physics

at the St. Petersburg State University

Topicality.

The dissertation of Vladimir Chirkov presents investigation of a poor studied issue about the influence of charge formation mechanisms on the structure of electrohydrodynamic (EHD) flows, taking place in liquid dielectrics in a highly non-uniform electric field that is specific for blade–plane or point–plane systems. The topicality of the question is provided by both scientific interest and promising applications of EHD phenomena. The challenge of the study is a simultaneous passage of a number of uncontrolled physicochemical processes like injection from the electrodes, incomplete dissociation of ion pairs and recombination of the latter, formation of composite ions, and, at last, chemical interaction between electrode material and molecules of liquid and dissolved impurities. This all conditions the fact that till now there is no complete theory of EHD flows, and therefore the topic of Vladimir Chirkov's thesisprovokes indubitable interest and great attention in the scientific community.

The dissertation consists of Introduction and Main part.

The **Introduction** presents analytical review of works on electrohydrodynamics, provides the analysis of state-of-the-artof the theory on EHD flows and results of the experimental investigations on EHD flow structure, and formulates the goal and tasks of the study.

Major results of the research are presented in the **Main part** that consists of 5 sections and Conclusions.

Section 2.1 formulates a boundary problem, discusses the method of numerical calculations, and presents the geometry of a computational domain. Numerical computations are performed in 2D axisymmetrical statement (in needle-plane type electrode system) and realized in standard software COMSOL Multiphysics based on the finite element method.

The experimental technique for visualization of streamlines of EHD flows in transformer oil, which is based on the digital video recording of tracks left by seeding particles, is discussed in Section 2.2. Andthe description of the method of tracks processing for obtaining velocity cross-section distributions along the model axis (the central line)is also presented in the section.

Section 2.3 discusses structure of EHD flows in various models of the electric conductivity and, in particular, in the model of unipolar conductivity (in subsection 2.3.1). The corresponding results of computations of EHD flow structures are presented in Fig. 2, 3, and 5.

Subsection 2.3.2 investigates the bipolar model of the electric conductivity, in which ions emerge due to both the injection from needle tip and the dissociation of ion pairs in the bulk. Results of numerical calculations are presented in Fig. 6 and 7.

At last, EHD flow structure in the model of charge formation due to the field-enhanced dissociation (i.e., due to the Wien effect) is studied in subsection 2.3.3. The corresponding results are presented in Fig. 8 and 9.

Section 2.4 explores current–voltage and current-time characteristics (CVC and CTC, respectively) for 3 models described above. Dynamic CVC are plotted in Fig. 10.

Section 2.5 expounds results of the experimental investigations of EHD flow structures in the needle–plane electrode systems in transformer oil. The author studies lines of fluid flow (Fig.11) and the voltage dependence of the velocity distribution along the model axis (Fig. 12). Subsection 2.5.2 gives a comparison between the experimental data and the computer simulation results. The comparison is carried out for CVC, cross-section velocity distribution (Fig. 13), and shape of velocity contours (Fig. 14).

In section 2.6 (Conclusions), the author summaries the research and makes a conclusion that agreement between numerical calculations and experimental data can be achieved only in the model of unipolar conductivity under the injectionfrom the point electrode.

The analysis of contents of PhD thesis revealed several **shortcomings**: 1) the general set of equations is not presented in the generalizing part; 2) the only one injection law corresponding to cold emission from the cathode (Eq. 3) is taken into consideration while the other injection mechanisms (e.g., oxidation-reduction electrochemical reactions) is disregarded; 3) the mechanisms of ion neutralization and processes of electrode degradation is not taken into consideration while they are of great importance for the estimation of the life time of EHD devices.

Revealed shortcomings do not reduce the general good impression of the level of carried out investigations. The author proved that the injection processes play a major role in systems with point electrodes, which is a substantial contribution to the development of electrohydrodynamics of dielectric liquids.

Considering the dissertation as a whole, I should note the completeness of study of both specific issues and general aims of the work. The thesis is written in a literary language and all conclusions are clearly formulated.

In view of the above, I can conclude that Vladimir Chirkov's dissertation "Influence of Charge Formation Mechanism on the Structure of Electrohydrodynamic Flow in Highly Non-Uniform Electric Field"fully complies with the international standards for PhD dissertation in the corresponding field.

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