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

The dissertation of Vladimir Chirkov consists of 86 pages, including four original papers in leading journals, a generalizing part, and a conclusion. The generalizing part contains the following sections: 1) introduction, describing the aim of the research, the key point and major complications to be resolved, novelty, topicality, and veracity of the results; 2) brief review of previous and related studies, which contains analysis of main researches in the field of electrophysics of liquid dielectrics; 3) discussion of the data presented in the included articles, containing the main results of Vladimir Chirkov's researches. The author has prepared and published 20 articles with eight papers among them being included in *Web of Science* and *Scopus*. The dissertation well enough reproduces the contents of carried out researches.

The work is devoted to the issue of the direct transformation of the electric field energy into the kinetic energy of fluid motion. Such transformation is possible only due to the formation of space charge inside a liquid. The author considered two mechanisms of the formation of the space electric charge inside the low-conducting liquid—the surface electrochemical mechanism (i.e., injection from the electrode surface) and the bulk electrochemical (i.e., the Wien's effect) one. Electrohydrodynamic method of the energy transformation makes it possible to create micro devices for pumping and atomizing liquid and for intensification of heat transfer, especially under zero gravity conditions. Thus, the investigated processes, undoubtedly, present a great applied interest and are explored by a number of scientists in various countries.

The originality of the presented research is in the fact that investigation of EHD flows was conducted on the base of both the computer simulation and experimental study. Taking into account the current status of the issue, I can state that the subject of the thesis is a topical one. It can be noted also that using software package COMSOL for simulation of EHD processes is very promising.

Simulation of EHD flows in the complete approach on the base of the complete set of EHD equations, and computing the transient regime of formation of two-dimensional EHD flow show the novelty of the presented work.

The analysis of the obtained data let the author explain the zone structure of EHD flows on the base of the calculated force distribution, depict the process of EHD flow formation, and describe the electroconvective mechanism of the electric conductivity of dielectric liquids in highly non-uniform electric fields. Besides, the work presents the original method for getting the integral current characteristics of the EHD flow formation (i.e., current–time characteristics).

The significance of the dissertation research consists in acquiring new knowledge about basics of physical processes, underlying the electrohydrodynamics. The application of the computer simulation is justified by the fact that the phenomenon under investigation is given by the complicated set of several interrelated and non-linear equations, which disallows conducting the detailed analytical analysis of EHD processes and, therefore, prevents the progress of EHD technologies. The developed method for numerical calculation of EHD flows with using

software package COMSOL gives the opportunity to advance substantially in the computer-aided design and optimization of a number of EHD devices.

The validity of the results is provided by the application of tested software and by the comparison between the original experimental and simulation data presented in the work.

The approbation of the results was carried out in a quite complete manner. The author presented a lot of oral reports on the international conferences both in Russia and abroad. Thus, most results included in the thesis get quite full coverage both in Russian scientific community and among leading foreign specialists in the field of electrophysics and electrohydrodynamics.

On the whole, the dissertation presents complete enough description of the results. However, I should note several remarks.

Review of the literature, unfortunately, does not include references to a number of seminal works in the field of electrohydrodynamics directly related to the themes of the dissertation (in particular, the Wien's effect, the bipolar near-electrode structures, the interpretation of time-dependent measurements of currents, etc...) and published by Russian researchers.

At the statement of the problem there is a zero value of the field normal to the lateral boundaries of the computational domain. This corresponds to the presence some surface charge on the dielectric boundaries. It is desirable to vary the amount of this charge, to assess its impact on the overall picture of the distribution of the field and the space charge in the entire computational domain.

It seems unnecessary for numerical simulation made by a simplification about the equality of the transfer coefficients (mobility and diffusion) for positive and negative ions.

On the base of carried out review, I consider the dissertation of Vladimir Chirkov to comply with the international standards for PhD dissertation in the field of electrophysics and electrohydrodynamics and Vladimir Chirkov undoubtedly merits the awarding the PhD degree.

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