SUMMARY OF HABILITATION THESIS

FROM NANOSCALE EFFECTS TO MACROSCOPIC QUANTITIES BEHAVIOR: EFFECTS OF ELECTRIC AND MAGNETIC FIELDS ON TWO-PHASE MEDIA

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Abstract

This thesis presents the main scientific achievements after defending my PhD thesis, entitled "Contributions regarding the nucleate boiling heat transfer enhancement using high voltage electric fields", at the Faculty of Mechanical Engineering, Politehnica University of Timisoara on November 13th, 1997 and confirmed by the Ministry of Education Order no.5653 / 22.12.1997.

Part B of this thesis has five chapters, which cover the scientific, professional and academic achievements and the development plan. The first chapter, entitled Milestones and Highlights of the scientific achievements, is presenting, in a time line manner, the contributions to the main research themes that continued and developed the subject of my PhD studies: (i) study of the liquid – vapour phase transition control by electric fields and (ii) magnetic nanofluids: heat transfer control by magnetic fields and thermal properties. The second chapter details the first theme, while the third chapter presents the main results obtained from the second theme.

The first theme emerged as a post-doctoral stage and was approached with the aim of understanding the basics of phase-change phenomena at nanoscale and how manifest at macroscopic scale in change of measurable quantities. To accomplish this, I started learning statistical thermodynamics, molecular simulation and using molecular dynamics simulation codes to obtain, through numerical experiments, answers on the posed problems. Further, I used molecular dynamics method to study the near-critical point phase transition in either two-dimensional or three dimensional systems, of hundreds up to one thousand molecules.

The post-doctoral research was carried out at Toyo University, Faculty of Engineering, Kawagoe Campus (Japan), from February 1999 to February 2000, JSPS Fellow ID P98386 of the Japan Society for the Promotion of Science, and the results were later presented in an ISI article (as first and corresponding author). The obtained results were consistent in part with the macroscopic observations and theory of the critical point phenomena and properties behaviour. Carrying out such numerical experiments after

returning from this stage was a task hard to continue considering the available hardware resources but, with the technical support of Toyo University and the post-doc stage host, by granting access via internet to the university's computing facilities, I proposed and was awarded a CNCSIS grant for Young Scientists, for a period of two years (2001-2002), to study the phase transitions of a fluid under the influence of external force fields. Thus, the molecular dynamics simulation study was oriented toward obtaining an evaluation of the effects of an external electric field at nanoscale. This subject was also studied for both two-dimensional and three-dimensional systems of molecules. An analogy with the macroscopic observations, regarding the boiling phenomenon in applied electric fields and microgravity conditions, has been carried out in a study entitled "Micro – nanoscale effects of electric fields on boiling – modelling and simulation by molecular dynamics", during a fellowship granted by a CNR-NATO (Consiglio Nationale delle Ricerche, Italy – Nord-Atlantic Treaty Organisation) Senior Fellowship program, at the University of Pisa, Italy, between August and October 2004, Bando n.217.35.S del 30/04/2003. The main conclusions of this study were: (a) the increase of the system temperature partially counteracted the effects of the applied electric field; (b) the effect of the electric field on the cluster formation and orientation can be related to the experimental results regarding the "shift" of the boiling curve and change in the critical heat flux value. The results obtained from molecular dynamics simulations matched the macroscopic behaviour observations from microgravity experiments, as pointed out in the end of Chapter II.

The second theme is comprising the main results in terms of my personal scientific contributions to three subsequent research themes, whose common factor is the use of a special class of smart materials in heat transfer related problems, which were studied in a multidisciplinary team, at the Research Center for Engineering of Systems with Complex Fluids from Politehnica University Timisoara (RCESCF-UPT), in framework of five national research projects: CNCSIS A665/2005-2007; Contract UPT 11657/2001-2004 – PNCDI AEROSPATIAL; PN II 21-043/2007-2010 CFEEL; PN II PCCE IDEI 76/2010-2013; PN II 63/2014-2017, and an international research project, FP7 MNT-ERA.NET Project 7-018/2009-2011 MAFINCO. For the underlined projects, I have been the project coordinator for the Politehnica University Timisoara team and, for the international project, I have been the coordinator of the Romanian partners in the project.

This theme gave me also the opportunity to start in 2001, a long-term collaboration with the RCESCF-UPT team, whose results are seen in our common publications, part of it representing 9 (out of the 10) of my relevant publications, as well as in two national patents. My scientific contributions envisaged mainly the experimental design, running the experiments and data analyses, and several experimental set-ups have been built for this researches.

The sections of the third chapter are presenting my scientific contributions to the following research themes: (1) the fundamentals of controlling the nucleate boiling of a magnetic nanofluid, by an applied magnetic field; (2) natural convection heat transfer in water based magnetic nanofluids; (3) thermal properties and heat transfer control by an applied magnetic field, in transformer oil based magnetic nanofluids.

The first theme, part of the research carried out in the project Contract UPT 11657/2001-2004 – PNCDI AEROSPATIAL, envisaged the possibilities of using magnetic nanofluids as cooling agents in microgravity thermal management systems. A fundamental study was carried out with respect to the dependence of characteristic parameters of nucleate boiling (bubble emission frequency and bubble departure diameter) with the applied magnetic field and the magnetic nanofluid magnetic properties. The main contributions to this research were published in 3 ISI conference papers (2 papers, as first and corresponding author), found in the list of relevant publications.

The second theme envisaged also fundamental aspects, regarding the natural convection in water based magnetic nanofluids, in view of using this type of magnetic nanofluid in cooling applications for automotive engineering. This research was started in the project CNCSIS A665/2005-2007 and continued in the project PN II PCCE IDEI 76/2010-2013, which represented a collaboration with the team from the Romanian Academy – Timisoara Branch, Laboratory of Magnetic Fluids. The main outcomes of this research were presented in 2 ISI articles (both as first and corresponding author), included in the main publication list.

The third theme had both fundamental aspects as well as application-oriented, as the targets were related to the use of transformer oil based magnetic nanofluids in electric transformers, either as cooling and insulating medium in power transformers or as magnetic liquid core in miniature planar transformers.

The first type of application was the research theme in the projects: PN II 21-043/2007-2010 CFEEL and FP7 MNT-ERA.NET Project 7-018/2009-2011 MAFINCO. My contribution to this theme envisaged the study of thermal properties, the cooling capacity and control by an applied magnetic field. The results have been published in 1 ISI article and 3 conference papers (2 papers, as first and corresponding author), all four part of the relevant publication list. Also, a national patent (co-author) has been filed, approved and published.

The second type of application is the theme of project PN II 63/2014-2017, being an ongoing research, my main scientific contribution being related to the study of thermal and electrical properties of highly concentrated magnetic nanofluids, for use as magnetic liquid core. To date, in the framework of this project, I have been studying the thermal conductivity of magnetic nanofluids, the results being part of a patent request, approved and planned for publication in March 2017.

Chapter IV of this thesis summarises the most important achievements of the candidate's academic and professional activities since defending the PhD thesis, covering the period January 1998 - present. Thus, achievements in academic activities with respect to the following aspects are highlighted: academic teaching and new courses for graduate students; published textbooks, lecture notes, teaching materials, in print or online; coordination of diploma projects and dissertations; contributions to the infrastructure for academic activities. The professional achievements during the same period are briefly presented in terms of publications, coordination of research projects, research stages, presentations at international seminars abroad, organisation of seminars and workshops, expert membership, awards, PhD referee activity, expert evaluator for national projects, ISI journal reviewer activities and professional membership.

The V^{th} chapter is introducing the main directions to follow for future scientific and academic activities. For short and medium term, the scientific activities will be oriented toward the ongoing project PN II 63/2014-2017 regarding the study of thermal conductivity and electrical properties of the highly concentrated magnetic nanofluids, followed by studies regarding the effects of magnetic fields on the thermal conductivity of magnetic nanofluids. As medium term directions of research are planned: (i) a study regarding the potential of using magnetic nanofluid and magnetic composite media, for heat transfer applications and thermal storage; (ii) the use of molecular dynamics to study the effect of the representative volume size on bulk thermal properties. The short-term directions of research have the potential to be approached using the existing infrastructure, which would give the opportunity to enrol new PhD students in these directions of research. The medium-term directions will need funding support, thus new projects proposals.

The development plan regarding the academic activity in general, the following paths are considered: integration of the research results as part of the teaching subjects, especially for graduate students, as well as integration of undergraduate and graduate students in the candidate's research team along with the new PhD students; development of the course materials and infrastructure, in such a manner to attract students toward the will of learning, academic study and research. In view of pursuing as PhD adviser, the candidate will look for the integration of new PhD students in the well-established interdisciplinary research team working at RCESCF-UPT and the research theme that are carried out or planned for; tutoring of the new PhD students, based on the experience gained as an independent researcher, regarding the way of conduct their research, in an ethical manner, such that, they will be able to accomplish their research plan and PhD thesis.