LUBRICATION PROCESSES IN COMPLEX CONDITIONS:

POROUS MEDIA, TEXTURED SURFACES, THERMO-ELASTIC EFFECTS

ABSTRACT

This Thesis summarizes my research and academic activities I have performed in the field of Tribology, after june 1997 when I defended my PhD thesis entitled *Studies on Thermohidrodynamic Problems of Fluid Film Mechanical Face Seals*. An important part of the activities presented herein are the result of teamwork in the Tribology Group of University POLITEHNICA of Bucharest (UPB), led by professor Mircea D. Pascovici. Another part of my achievements have been obtained by collaboration with my scientific partners from University of Poitiers, a strong scientific partnership I developed after 1994. A third important part of my activity includes results obtained as PhD associate advisor or research team leader.

The first section, the most extended, addresses in five chapters, the most relevant subjects of my research activity.

The first Chapter presents my activities during postdoctoral period when I pursued the studies on thermo-elasto-hydrodynamics of fluid film mechanical face seals. My original analytical model that allows a quick calculation of ring thermo-elastic deflection (”coning”) is presented as well as a numerical approach (1D) used to simulate thermo-elastic instabilities that can occur during start-up. The accuracy of the previous models is evaluated by a more complex (2D) model which joins a finite differences approach of fluid flow in the seal gap with a finite elements model for heat transfer and elastic deflection of seal rings. Most of these studies have been performed in collaboration with my collegues from the Laboratory of Solid Mechanics (LMS) at University of Poitiers. The second part of the chapter describes my experimental studies on vaporisation in very thin films, performed at LMS. An original experimental arrangement evidenced the evolution of vaporisation in a narrow gap (~10μm) and confirmed one of the two theoretical models previously proposed in the literature. This pioneering work has been later developed at LMS and remains a subject of continuous interest; recently (2017), I was invited in the Jury for a PhD thesis at University of Poitier, dedicated to vaporisation. This subject was the point in the professional career of my former student Aurelian Fătu, presently full professor at University of Poitiers and a regular collaborator of mine. These activities have been reported in 11 publications (3 WOS indexed) and 5 technical reports.

The second Chapter is dedicated to my theoretical studies on brush seals, a subject absolutely unknown in Romania when these studies have been initiated (1997). The original, analytical thermo-elasto-tribological models proposed revealed the importance of bristle-shaft contact temperature as a limiting factor for the durability of the seals. These results opened a new direction of studies focused on thermo-tribology of bristle contact; presently many studies are dedicated to thermal analysis of brush seal. This subject has been presented in extenso in a book published in 2007 which can be considered the first monograph dedicated to brush seals. Five publications (1 WOS indexed) and 6 technical reports included the results of these studies.

Chapter 3 summarizes my contributions on lubrication with textured surfaces. An original analytical model based on the collective effect of successive step (Rayleigh) configurations has been proposed for parallel sliders. Based on this model an extended parametric analysis revealed optimum design and operating parameters. The analytical model has been validated using a complex (2D) numerical approach, based on finite volumes method. The numerical approach has been also used for the analysis of various texture arrangements for both parallel and plane inclined sliders. The results have shown the important load support generated for parallel sliders and reduced effects for convergent gaps. After publication, these results became a reference for many similar studies of textured surfaces. The final part of this chapter presents the innovative experiments developed in the Tribology Laboratory of the Department on a test rig acquired with my important contribution. Tests made on partially textured surfaces demonstrated significant load carrying effects for nominally flat and parallel surfaces. The same experiments brought to light the suction effects produced by

cavitation. The results can be found in 11 publications (5 WOS indexed) and 5 technical reports. Two of these papers have been cited more than 130 times.

The fourth Chapter, the most extended, includes my contributions in the lubrication effects within highly compressible porous layers subjected to normal forces. The activities started in 1998 and broadly developed after 2008 when the setup of experimental facilities have been initiated. The fundamentals of the so-called exporohydrodynamic (XPHD) lubrication are presented for the case of normal relative motion, applied to some of the most important contact configurations (sphere/plane, disc/plane and cylinder/plane). All these models are absolutely original and their results predict high load support for impact loading. In the following part of the chapter the multidisciplinary experimental activities are briefly presented, with emphasis on impact tests at low and medium speed. There are also presented the related experiments for characterisation of soft porous materials which are atypical for classical mechanical applications. These experiments have been conducted in the Tribology Laboratory of UPB, at INSA Lyon as well as at Institut Pprime in Poitiers. The various results from impact tests done in the Tribology Laboratory of UPB and Technical Military Academy of Bucharest (ATM), showing all the high damping capacity of the porous layers imbibed with fluids are summarily presented. These successful results allowed recent the development of the first prototypes of supplementary protective layers for bullet-proof vests or helmets. The results were disseminated in 14 publications (6 WOS indexed) and 9 technical reports.

The last chapter of this section presents two theoretical contributions on hydrodynamic lubrication with application to sliding bearings. Compliant thrust bearings and worn journal bearings respectively, are analysed using simplified, quasi-analytical models. Both subjects have been developed with prominent students during their engineering diploma work. Four papers and a research report have been published as result of these studies. The results were reported in 5 publications (1 WOS indexed) and 3 technical reports

The second section of the Thesis, divided into three chapters includes my academic activities. My teaching activity is, to a large extent, consistent with my research. My managerial duties are mostly related to internationalization and promotion of study programs of UPB.

The first chapter outlines the main courses I have taught in Romanian, English and French all of them related to Tribology or Machine Elements. The original contributions, result of my research outcomes, included in some course chapters (i.e. seals, sliding bearings) are briefly underlined. There are also presented the course notes, project handbooks, laboratory notes, collections of problems, for which I contributed lately. In the second part of this chapter I collected other academic and managerial activities, which include but not limited to: the setup and management of the Bachelor study programs "Mechanical Engineering" taught in English and French, implementation of the long term internship programs, the European exchange programs for students and staff (SOCRATES, LEONARDO, ERASMUS) the promotion of the study programs in European Universities and some countries from Africa.

The second chapter is dedicated to one of my noticeable activity: students coaching. Supporter of the idea that promising students must be tutored and stimulated for research from the early years of studies, every year I selected and I coached in extracurricular research activities 1-3 students, most of them reporting presently excellent professional results. With some of them I pursued coaching as advisor for master Dissertation or even more, as associate advisor during PhD studies. The most outstanding students with success stories in Tribology are briefly presented herein. Former students I coached can be found today as R&D engineers or professors, authors of papers in the field of Tribology: Aurelian Fătu (full-professor at University of Poitiers), Mihai Dobrică (Group Leader - Bearing & Rotordynamics Bosch & Danfoss) Alexandru Apostolescu or Brânduşa Ilie (both Project Manager at Renault Technologie Roumanie). At the end of this chapter I included a short presentation of my contributions as associate advisor for PhD students I coached during previous studies, from the first attempts, in 2007 until latest PhD student, Mihaela RADU where I had a major contribution.

At the end of the thesis a perspective of my scientific and academic perspectives, with emphasis on the main topics which will be proposed for my future PhD students as well as for research grant proposals. For each topic several subjects are listed and briefly described showing its necessity and the main objectives. The viability of these subjects is sustained by solid arguments like continuity, the existence of experimental facilities and the interest of my traditional partners of research activities.

The Annex contains a list of the Engineer Diploma Projects (45) and MSc. Dissertations (10) I was advisor or co-advisor, a list of PhD theses where I contributed as co-advisor (6) as well as the list of PhD thesis where I was member of the Jury.