Preface

This book deals with heat and mass transfer intensification in thermal, fluidic and reactive components and energy systems by multidisciplinary actions. The shape optimization through a multi-scale approach is an important and original issue of intensification which I try to illustrate in this book.

The Process Intensification (PI) concept was initially proposed as “increased productivity of a process with reduced occupied space (equipment, system, factory, etc.)”. However, after almost 20 years of development, the notion of PI covers much more than that, thanks to numerous and often diverse contributions made by individuals and research teams. Various definitions, intensive discussions, and incisive viewpoints on PI have appeared in the literature, and its core value has been summarized in a more fashionable manner as: “*produce more with less*”. Moreover, the recent trends in chemical engineering put forward the necessity of a new paradigm[1] and the PI is considered as an essential theme.

As a practitioner on PI, either consciously or unconsciously during my whole research career, I believe that it is worth publishing a book on this concept. Owing to the kind invitation of Springer in 2009, especially the encouragement of Anthony Doyle, senior editor of engineering, the book is finally written three years later. It is regarded not only as a milestone that builds on my previous research work, but also as a stimulator of ideas which may be interesting, original, and of importance for the future. It is not simply a synthesis of the published literature, but rather a deepening of personal reflexions and thoughts that may bring contributions to this rapidly evolving notion.

The book begins by raising the issues of “*what is intensification?*” and “*where might intensification occur?*” and the introductory chapter portrays theoretical reflexions based both on the literature and on a personal analysis. For the first question, a personal definition is proposed based on both the basic equations of heat and mass transfer, and the notion of “interface”. The main objectives of PI

[1] The first paradigm—Unit Operations, 1923; the second paradigm—Transport Phenomena, 1960; the third paradigm—?

have been categorized into five aspects, namely: *productivity intensification*; *compactness intensification*; *energy intensification*; *temporal intensification* and *functionality intensification*. As for the second question, my personal contribution may be the identification of the important role of a multi-scale approach for PI. To improve the global performance (productivity) of a process, intensification should necessarily be implemented at three scales: *local scale*, *component scale* and *system scale*. Intensification on local scale aims at augmenting the density of fluxes transferred through interfaces; intensification on component scale calls for novel designs of fluidic, thermal, and reactive components; intensification on system scale expects the integration of multiple functionalities and seeks for the synergetic effects because the global optimum of a system is usually not the simple accumulation of individual optima of each component or each step.

Chapters 2–6 are devoted to "*how to achieve intensification*" in different contexts. The readers are invited on a journey through detailed research topics that I have developed with my coworkers: gas adsorption processes in porous media (Chap. 2); fluid flow distributors based on meshed circuits or arborescent geometry (Chap. 3); compact heat exchangers for maximization of the heat transfer performance with constraints of pressure drop (Chap. 4); micro-structured mixer/reactors for single- or two-phase application (Chap. 5) and evolutionary CA-based (Cellular Automaton) algorithm for the shape optimization of flow paths (Chap. 6). These chapters cover different topics, but share the central role of intensification.

In these chapters, special emphasis has been placed on the role of *shape optimization* in PI. This aspect has been largely overlooked by classic PI techniques but has been deeply explored in this book. Shape optimization (especially the shape of *interfaces*) implies intensification. The minimization of dissipation at transfer interface is an important criterion for local scale intensification. The distribution of the dissipations at different spatial or temporal scales is also a key issue for performance optimization of a system (or a component). There is a real problematic of multi-scale shape optimization with the establishment of scaling laws where one must distinguish from the optima of design and the optima of operation.

The book logically concludes with prospects and proposes a redefinition of intensification, as being the *optimization of the productivity*, with the constraints of *quality* and *efficiency*. This redefinition somehow extends the PI concept: for global productivity augmentation, PI should be implemented at all three scales (local, component, system) and the internal links between these scales should be carefully examined (should we call this "scale intensification"?).

It should be noted that PI is always an important subject in the course of my research life. Apart from the pursuit of intensification, the interest of this book also lies in the merging of scientific cultures and disciplines, realized with my initial experience as a thermal engineer, my academic culture of process engineering, and also with new domains of thermodynamics, energy conversion, material science, chemical reaction, fluid mechanics, numerical tools, characterization methods, optimization methodologies, and microfabrication. The coverage is broad and diverse, and may be of benefit to academic and industrial researchers, to practicing energy and process engineers, and to industrial energy users and producers. It may also serve as a reference book for undergraduate or postgraduate students during their course work as well as completion of their thesis.

Throughout the writing, so many people have helped me that I cannot list them all. Appreciation is expressed to Dr. Yilin Fan who contributed enormously to the writing, but also to most of the digesting, editing, and revising. Special thanks to my other coauthors for their devotions and diligence: Dr. Daniel Tondeur, LRGP-CNRS France; Dr. Gilles Flamant, PROMES-CNRS France; Pr. Xinggui Zhou, East China University of Science and Technology, China; Dr. Raphaël Boichot, SIMaP-CNRS France, and Dr. Limin Wang, IPE-CAS, China.

I would like to take this opportunity to thank Pr. Yukun Qin, Harbin Institute of Technology, China, Member of Chinese Academy of Engineering. He trained me and guided my research career into the thermal engineering. I also want to thank Pr. Michel Feidt, my Ph.D. supervisor at LEMTA, University of Lorraine, France, who introduced me into the field of thermodynamics and optimization of energetic systems. A special memory is dedicated to late Professor Pierre Le Goff of Nancy. His extraordinary scientific creativity and his generosity always have great influences on many researchers including myself.

I am especially grateful to Dr. Daniel Tondeur, with whom I collaborated since 1992. I always admire his courage, his passion, his imagination for science, and I benefited a lot from his knowledge, his expertise, and his experience. His contribution to this book is certainly not limited to coauthoring one chapter, and he offered incisive comments and remarks for additions and modifications of various sections. My most sincere thanks to Dr. Lufei Jia, CanmetENERGY, Canada, who read through the whole manuscript and provided valuable suggestions for improving the readability and intelligibility of the book. Contributions of Dr. Gilles Flamant and Pr. Jack Legrand to the final modifications of the manuscript are also greatly appreciated.

I want to express my particular appreciation to some French colleagues who helped me, supported me, and accompanied me during the years when I was the head of the laboratory LOCIE of CNRS and the University of Savoie in Chambéry, France. Without their full backing and long-term friendship, I would not have been able to maintain the rhythm of my research activities out of the heavy administrative and management responsibilities. To list some of them: Dr. Michel Trinité, CORIA-CNRS; Dr. Denis Veynante, EM2C-CNRS; Dr. Pierre Guillon, former director of INSIS-CNRS; Dr. Gilles Flamant, PROMES-CNRS; Dr. Dany Escudié and Pr. Jocelyn Bonjour, CETHIL-CNRS; Pr. Jack Legrand, GEPEA-CNRS; Dr. Joel Bertrand, Vice president of CNRS; Pr. Francis Allard, LSIE-CNRS; Pr. Jean-Léon Houzelot, Pr. Michel Sardin and Dr. Gabriel Wild, LRGP-CNRS; Pr. Fabrice Lemoine, Dr. Christian Moyen, Pr. Denis Maillet and Pr. Alain Degiovanni, LEMTA-CNRS; Pr. Lounes Tadrist, IUSTI-CNRS; Dr. Patrick Le Quéré, LIMSI-CNRS; Dr. Cathy Castelain and Dr. Didier Delaunay, LTN-CNRS; André Manificat, GRETh; Pr. Laurent Foulloy, director of Polytech' Annecy-Chambéry…

I also received significant and steady encouragement from my colleagues and friends: Dr. Quan Yuan, Member of the Chinese Academy of Sciences (CAS);

Dr. Jinghai Li, Vice President of CAS, Member of CAS; Pr. Weikang Yuan, Member of Chinese Academy of Engineering; Dr. Tao Zhang and Dr. Shudong Wang, DICP-CAS; Dr. Wenli Song, IPE-CAS; Pr. Xigang Yuan, Tianjin University, China; Pr. Mark Rood, University of Illinois, USA; Dr. Thomas Schmidt, Leuphana University, Germany; Pr. Joseph Pastor, Pr. Alain Bernis, Dr. Nolwenn Le Pierrès, Pr. Yves Gonthier, Dr. Julien Ramousse, Pr. Amen Agbossou, Pr. Gilles Fraisse, Pr. Christophe Menezo and Pr. Gérard Merlin, LOCIE-CNRS; Dr. Nathalie Mazet, Pr. Sylvain Mauran, Dr. Driss Stitou, Pr. Xavier Py, Pr. Pierre Neveu and Pr. Françoise Bataille, PROMES-CNRS; Pr. Philippe Marty, LEGI-CNRS; Pr. Hassan Peerhossaini, LIED-University Paris Diderot; Pr. Christophe Gourdon, LGC-CNRS; Pr. Hervé Combeau, Ecole des Mines de Nancy; M. Pierre Odru and Mme. Isabelle Morelon, ANR; Pr. Guy Lauriat, Université Marne la vallée; Dr. Bernard Veyssière, Institut P'; Pr. Jean Pierre Dumas and his colleagues in LaTEP; Mme. Monique and M. André Lallemand; Mme. Annie Frey, Mme. Tatiana Gorner, Mme. Madeleine Bourdais, Mme. Catherine Albouy, Mme. Ying Ma and many other old colleagues and friends of laboratory LEMTA and LRGP in Nancy and of laboratory LOCIE in Chambéry.

I was really fortunate to have some brilliant and outstanding doctoral students and postdoctoral researchers: Marc Bonnissel, Karine Bonnot, Fengdong Yu, Wenli Song, Julien Berthiaud, Hongxia Xi, Jun Yue, Nolwenn Le Pierrès, Raphaël Boichot, Zhiwei Fan, Matthieu Cosnier, Yilin Fan, Yu Bai, Qiang Ma, Hui Liu, Benjamin David, Limin Wang, Edem N'Tsoukpoe, Bin Cao, Hua Zhang, Vivian Houzelot, Qi Li, Tong Zhang, Armel Gonda, etc. Many of them have benefited from a joint-training of Ph.D. or Post-doctoral scholarship within the framework of Sino-French Collaboratory of process and environmental engineering (Collaboratory, 1998–2006) and its successor Sino-French laboratory for sustainable energy (LIA-LSE, 2008 to present) that I initiated and coordinated. Their work exhibited throughout this book shows the scientific achievement of the exchanges and cooperation programs between the two countries. The long-term trust and support from the French National Center for Scientific Research (CNRS) and the CAS are gratefully appreciated.

The staff of Springer is always ready to help. Many thanks are due to the editors Claire Protherough and Grace Quinn for their efficient and patient work.

I devoted myself totally to my professional activities, especially during the writing of this book, so that I spent less time with my family. I would like to take this opportunity to express my sincere apologies to my husband Shi and my son Yue. Without their unreserved support and continuing encouragement, this task would never have been accomplished. I feel guilty toward my son because I did not give him all my attention during his growth. But I am also very proud of him as he succeeds in his studies through consistent efforts.

Nantes, France, October 2012 Lingai Luo