

**Compact Heat Exchangers – Analysis,  
Design and Optimization using FEM  
and CFD Approach**

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# Compact Heat Exchangers – Analysis, Design and Optimization using FEM and CFD Approach

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## Preface

The importance of compact heat exchangers (CHEs) has been recognized in aerospace, automobile, process plants and other industries for 60 years or more. This importance is further demanded in the aerospace sector, with its requirements such as weight optimization, high compactness and high performance leading to the demand for cost-effective design and manufacturing techniques. While several books dealing mainly with heat exchangers have been published worldwide in English, no complete source of design data can be found on the many important aspects of CHE design, which an engineer can use as a comprehensive source of generalized design data for the most widely used fin surfaces. One of the first comprehensive books on the design of CHEs using primarily air or gases as working fluid was first published by Kays and London in 1967 with the SI unit edition appearing in 1984. This book is still widely used worldwide, with most design data referenced from 1967, for fin data experimentally generated. Because manufacturing technology has progressed significantly since the beginning of 21st century, many new and sophisticated forms of heat transfer surfaces have been used in CHEs. The design data for these surfaces is limited in the open literature and most of the aerospace industry CHE manufacturers keep their design data proprietary.

This book is an attempt to bring new concepts of design data generation numerically, which is cost-effective and more generic design data, which can be used more effectively by design and practising engineers. It is hoped that researchers and designers will find it of value, as well as academics and graduate students. The specialty of this book is numerical design data based on FEM and CFD. Numerical methods and techniques are introduced for estimation of performance deterioration such as flow non-uniformity, temperature non-uniformity and longitudinal heat conduction effects using FEM for CHE unit level and Colburn  $j$  factor and Fanning friction  $f$  factor data generation methods for various types of CHE fins using CFD at fin level. In addition, worked examples for single- and two-phase flow CHEs are provided, and the complete qualification tests are given for CHEs used in aerospace applications, typically, which are unavailable in open literature, as these are provided only in some standards. In order to keep the book to a reasonable size, some topics of relevance to CHE applications, which are available in other accessible books, such as *Compact Heat Exchangers* by Kays and London, 3rd edition, McGraw–Hill Book Company, New York [1984], *Compact Heat Exchangers* by J.E Hesselgreaves, Pergamon [2001] and *Plate-fin Heat Exchangers Guide to their Specification and Use* by M.A. Taylor, HTFS, UK, [1987] have been omitted, in particular those of transients (for regenerators), the effect of temperature dependent fluid properties and analytical solutions for flow in tubes.

The first three chapters of the book deal with the fundamentals of heat transfer, heat exchangers and numerical techniques of FEM and CFD. The application of FEM to compact heat exchangers is presented in Chapter 4, where heat conduction effects using FEM on evaporator tubes in pool boiling is also provided. Chapter 5 gives the complete information about CFD analysis of various fins of CHEs for generation of Colburn  $j$  and Fanning friction  $f$  factor correlations. In addition, the endurance life estimation of a typical CHE is also provided, based on FEM and CFD techniques. The basic concepts of sizing and design methodologies are provided for CHEs in Chapter 6 along with several worked examples for direct transfer type heat exchangers, boiling and condenser heat exchangers. Finally, in Chapter 7, the construction details and several qualification tests are presented for qualification of CHEs especially for aerospace applications.

Many people have helped either directly or indirectly throughout the preparation of this book. Primarily, the authors are greatly indebted to their family members Lakshmi and Puji Krimmel (Dr C. Ranganayakulu) and Uma, Anil, Vani and Samartha Shastry (Prof. K.N. Seetharamu) for their unfailing support and patience during the development of this book. In particular, the authors wish to thank Aeronautical Development Agency and PES University, Bangalore for allowing us to work on this book. Dr C Ranganayakulu acknowledges his colleagues Mr R. Swaminathan, Mr A. Panigrahi and Mr Shahbaz Ulum for their support; in particular, Prof. Stephan Kabelac, Prof. Dieter Gorenflo, Prof. P. Nithiarasu and Prof. V. Vasudeva Rao for their guidance and encouragement; as well as Dr Saik L. Ismail, Dr A.C. Bhaskar, Dr R. Balasundar Rao, Dr M. Amaranatha Raju and Mr K.V. Ramana Murthy for their PhD works and Mr M.H. Prasad, Mr B. Mahesh and Mr C. Deepak Varma for book documentary works. Prof. Seetharamu also acknowledges Dr H.W. Lee, Dr Anvar Mydin, Dr G.A. Quadir, Dr Z.A. Zainal and in particular Dr T.R. Seetharam, Dr V. Krishna and Dr K.N.B. Murthy for their encouragement to write this book. Finally, the authors would like to thank the staff of John Wiley & Sons Ltd, UK, in particular Ms Anita Yadav and Mr Paul Beverley, for their constant support and encouragement during the preparation of the book.

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## Series Preface

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