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Book Review

Finite Difference Methods in Heat Transfer: Second Edition
ISBN: 978-1-4822-4345-1
Authors: M. Necati Özişik, Hélcio R. B. Orlande, Marcelo José Colaço, Renato Machado Cotta
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Reviewed by Jean-François Sacadura

The original edition of this book published by M. N. Özişik as single author in 1994 was a textbook intended for advanced or graduate courses. It has been widely used over several decades by many students, researchers and educators in the area of thermal engineering.

Considering the high quality of the book, the growing importance of the computational methods that became common engineering tools, and the significant evolution of that methods for the solution of heat transfer problems, CRC Press placed bets on a new updated edition. It is not common nor easy to update, refresh and supplement an outstanding book several years after the author's death. Who else than the three additional co-autors invited by the publisher to prepare the new edition had been more appropriate to take over the task, modifying the original work and adding new material without losing the features of the original work ? Two of them, HRBO and RMC, were PhD students and then co-workers of Professor Özişik. All three are outstanding scientists and educators worldwide recognized in the areas of Heat Transfer and computational methods in Heat Transfer.

A parallel reading of the two editions shows that the new edition has kept the main qualities of the original book which are the clear, comprehensive and detailed presentations of methods aimed to be readily applied by the reader, with mathematical derivations kept to a minimum.

The new edition with around 600 pages including the prefaces, contents list, several appendices, and a Reference list, is divided into 12 chapters. Chapters 1 through 6, as in the original edition, contain basic material for a first contact of students with finite difference discretization techniques and their application to elliptic, parabolic, and hyperbolic problems. Discretization schemes specific for each kind of problem as one-dimensional steady state, one-dimensional transient, transient multidimensional problems, are presented and organized in a sequence of gradually increasing difficulty aiming to easy the self-study. Unlike the first edition where the equations are introduced according to their mathematical classification, as elliptic, parabolic or hyperbolic equations, in the new edition the equations are displayed according to the physical domains of application, as “diffusive systems”, or “advective-diffusive systems”, for instance. This and some other changes as additional explanatory notes and more detailed discretizations of boundary conditions clearly show the objective of the new co-authors of making the text clearer and more organized, more aimed at end-users. The concepts of verification and validation of computer codes are discussed and techniques for code and solution verification are presented based on a specific ASME standard. Some academic examples of the first edition have been replaced by recent examples of practical applications in which the new co-authors bring their own research experience as for instance an application related to the hyperthermia treatment of cancer, presented in Chapter 6.

Non-linear diffusion systems are addressed in Chapter 7 including several techniques as: lagging properties by one time step, three-time-level scheme (in this case implicit), linearization, and false transient method. Applications to coupled conduction and radiation in participating media which are typical non-linear problems are addressed through two problems: a one-dimensional problem where the radiative transfer equation is modelled through the Rosseland’s Diffusion Approximation, and a three-dimensional case where the principle of solution of the coupled conduction-radiation problem is presented by using the finite volume method combined to a method of integration of the radiative intensity over the whole directional domain. In this case readers wishing to apply the method of resolution will have to find more details elsewhere, particularly for the selection of the directions of discretization.

Chapter 8 is devoted to Multidimensional Incompressible Laminar Flow. Finite difference method is presented for both the vorticity-stream function formulation of Navier-Sokes equations and the primitive variables formulation. In the second case the equations are discretized by using the finite volume technique and the solution method using the SIMPLEC algorithm is detailed. This chapter is significantly expanded as compared to the previous edition, and concludes with a section on a two-dimensional steady state boundary layer problem.

The topic of chapter 9 devoted to the “compressible flow” was addressed under the title “Hyperbolic systems” in chapter 8 of the first edition. The selected physical situation is the so-called quasi-one-dimensional compressible flow, a simplified model that applies to compressible flows in pipes and nozzles in which the fluid velocity and properties are assumed to be uniform in the cross section. The method of solution selected is the MacCormack's explicit predictor-corrector scheme.

In Chapter 10 entitled "Phase Change Problems", the new book retrieves the chapter numbering and title of the first edition. After a listing of the main families of numerical methods for solving phase change problems, the mathematical formulation of such problems is reviewed. Then the presentation is focused on numerical methods of solution for one-dimensional purely diffusive cases, with both the variable time step and the enthalpy methods. A new section is added in which a formulation for a diffusive-convective problem is presented using the finite volume methodology previously introduced in chapter 8. The sample problems addressed, dealing with binary alloys melting/solidification involving natural thermal or thermosolutal convection in square cavities, come from the research contribution of one co-author (MJC) and co-worker.

Chapter 11 entitled "Numerical Grid Generation" addresses a family of techniques aimed to use finite difference methods for handling the solution of problems involving arbitrarily shaped complex geometries where regular grids do not allow accurate solutions. The basic idea to overcome the difficulty is using some coordinate transformation for mapping from the real irregular physical domain to a regular computational domain. After a presentation of the basic concepts of coordinate transformation, numerical grid-generation (a boundary value problem), and discretization of the grid-generation equation and its boundary conditions, the basic steps in the application of numerical grid-generation are illustrated by addressing a steady-state heat conduction problem over an irregular though simple physical domain. Two other examples are then presented. One is a problem of steady-state laminar free convection inside an irregular enclosure, using the vorticity-stream function formulation, and the second one, which is new in the second edition, addresses a problem of transient laminar free convection in irregular enclosures in primitive variables formulation. The chapter concludes with some basic concepts aiming to reduce errors in the computation of the transformation metrics, which are illustrated in two examples dealing with a one-dimensional advection-diffusion problem, and a two-dimensional heat conduction in a hollow sphere problem, respectively.

The last chapter, N° 12, which requires perhaps a higher mathematical background of the reader, is entitled "Hybrid Numerical-Analytical Solutions". It has been significantly revised and supplemented since the original edition. It starts by a comprehensive overview of the development of integral-transforms methods and of the hybrid numerical-anlytical methods for solving partial diffferential equations. The presentation is then focused on the generalized integral transfrom technique (GITT) used for the analytical part of the solution combined with finite difference for the numerical part. The hybrid approach is first introduced and its use illustrated step-by-step with a simple example of transient forced convection in a channel (constant properties, viscous dissipation, free convection, and axial conduction neglected). Then a unified view of the methodology aimed to be applied to a more general class of diffusion and convection-diffusion problems is presented. It is illustrated by a test case based on a three-dimensional nonlinear Burgers' equation. Several alternative solution schemes are described, as total or partial transformation (in partial transformation the terms relative to one spatial variable are not integral-transformed), and the convective eigenvalue problem (eigenvalue expansions accounting for the convective effects). The material contained in this chapter comes in part from recent research contributions of RMC and coworkers.

Five appendices provide different subroutines and one program aimed to solve an example addressed in the book. Informations are also provided inside the chapters on softwares and user guides that can be downloaded.

Regarding the editorial aspects, the new edition shows significant progress since the original edition. The airy text and the better quality of the figures and drawings make the book a lot more pleasant to read.

To conclude, this new edition, updated, reorganized and supplemented with a lot of recent material, gives new life to "Finite Difference Methods in Heat Transfer" while preserving the main qualities of the original book. It certainly is of great value for a wide public of engineering students and educators for different course levels, from undergraduate to graduate, and also for engineers and researchers wishing to improve or refresh their background in numerical techniques in heat transfer.