Preface

Optimization problems commonly found in engineering are divided into three categories. These categories are briefly mentioned next, in order of increasing complexity.

The simplest type of optimization problem asks to find the values of independent variables, which minimizes or maximizes a function of those variables. This first category of problems consists of usual extreme problems. They are commonly solved by using methods of differential and integral calculus.

A more complicated category of problems requires to finding a function that makes an expression that contains that function (and possibly derivatives of that function) to reach an extreme. Essential for this category of problems is the notion of *functional*, which is defined as a function that depends on the whole variation of one or more functions (and, possibly, directly depends on a number of independent variables). The domain of a functional is a set of *admissible functions* that belong to a space or a class of functions (and not to a domain in the space of coordinates). The problems in the second category are solved by using methods of *variational calculus*, originally developed by Euler and Lagrange.

For defining the third category of optimization problems, one should notice that there are applications in engineering where functions of independent variables are involved, some of these functions satisfying, in addition, a number of differential equations. The functions appearing in differential equations under the form of time derivatives are called *state variables*, while the "free" functions (i.e. those functions that can be modified over time, according to engineer's will) are called *control functions* (or, in short, *controls*). The fundamental issue in this case of optimization is to determine the control functions which extremize some defined functional depending on the state variables, under some additional boundary conditions. Problems in the third category are *optimal control* problems. They are solved by using specific methods, which are presented in this book:

- the principle of maximum (or principle of Pontryagin);
- the gradient method;
- the dynamic programming (or Bellman method).

The optimal control problems first appeared in engineering in connection with attempts to improve the operation of aircrafts, the first large-scale applications referring to the optimization of aircraft and missiles trajectories. From this point of view one may say that the optimal control applications in mechanical engineering have a relatively old tradition, and an already rich literature.

The purpose of this book is the short presentation of the first two categories of optimization problems and the exposure in more detail of the methods used to solving optimal control problems. Applications considered here mainly refer to *non-mechanical problems* (defined here as problems where the second law of dynamics is not of special importance) with emphasize on situations of interest in thermal engineering. This area of the optimal control applications is less covered by books and this aspect makes the present book, to our knowledge, a first event in the international literature.

The book is organized in three parts, as follows. The first part consists of two chapters and includes a brief presentation of theoretical results which should be known in the next chapters. Thus, Chap. 2 briefly covers the methods of solving usual unconstrained and constrained optimization problems while Chap. 3 refers to the variational calculus, showing the main concepts, the traditional notations and the methods used to solve optimization problems involving functionals.

The second part consists of four chapters and presents a summary of the optimal control theory. Chapter 4 shows the classifications of optimal control methods and some criteria for choosing between these methods, analyzed in function of specific applications. Chapters 5–7 separately expose three of the most commonly used optimal control methods: the maximum principle (Chap. 5), the gradient method (Chap. 6) and the Bellman method (Chap. 7).

The third part consists of 17 chapters and describes several applications of optimal control theory in solving various thermal engineering problems. These applications are grouped in four sections: heat transfer and thermal energy storage, solar thermal engineering, heat engines and lubrication.

The manner of presentation used throughout the book is adapted for ease of access of readers with engineering education. Thus, most mathematical demonstrations of theoretical results with higher degree of difficulty are omitted, and reference to relevant literature is provided.

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