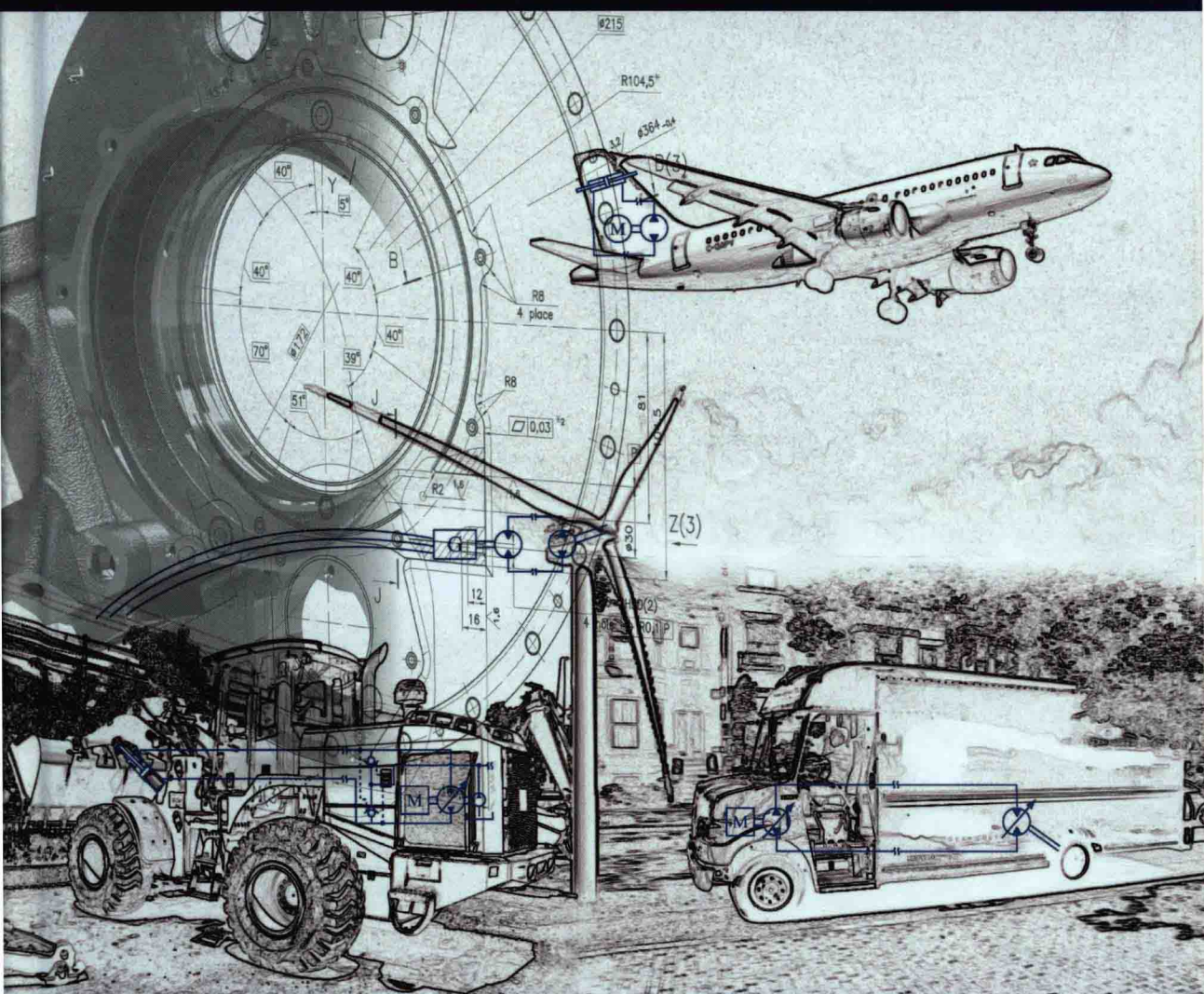


HYDROSTATIC

TRANSMISSIONS AND ACTUATORS

OPERATION MODELLING AND APPLICATIONS

GUSTAVO KOURY COSTA • NARIMAN SEPEHRI



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OPERATION, MODELLING AND APPLICATIONS

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HYDROSTATIC TRANSMISSIONS AND ACTUATORS

To Flávia Maria, my beloved wife

Gustavo Koury Costa

To Aresh, Parisa and Anoush, the joys of my life

Nariman Sepehri

Preface

The need for transmitting mechanical power has always been present in many fields of engineering. Take, for example an automobile where power must be transferred either from the engine to the wheels or from the driver's foot to the wheels during braking. This book focuses on two specific power transfer situations: (a) transmission between two rotating shafts, and (b) transmission between a rotating shaft and a hydraulic actuator. The power-conveying medium, in both cases, is a hydraulic fluid.

For Whom This Book Has Been Written

This book has been written for undergraduate students but will also be useful to practical engineers and junior graduate students who need to have introductory knowledge on the subject of hydrostatic power transmissions and actuation. The pre-requisites for the reader are minimal; no more than a little knowledge about power hydraulics and a basic understanding of calculus and physics are necessary. The book has been constructed in such a way that students do not need to refer other sources of information to understand the text. Every effort has been made to derive most of the equations found in the text. Only a few of the many formulas found in the book do not have a formal development because of either the degree of complexity involved or their straightforward nature. To help solidifying the concepts, we have also included a list of exercises at the end of most chapters.

Book Organization

The book is organized in a way that caters to different audiences with varied backgrounds. For students who do not have a strong foundation in fluid power, this book is best read from cover to cover. On the other hand, a practical engineer who wants to learn how to calculate the efficiency of hydrostatic transmissions, can go straight to Chapters 3 and 4. However, we have made every attempt to follow a logical and progressive way of exposing the theme, having in mind the students who will read the book from the first chapter to the last chapter. In that sense, we have followed an approach whereby the reader obtains a complete overview of the subject matter in the first chapter. And then in subsequent chapters, details are provided so that when the reader arrives to the end of the book, he or she will have acquired a solid and concise knowledge of the exposed themes.

In terms of the subjects explored in each chapter, there is a clear division following the overall exposition given in Chapter 1. From Chapter 2 to Chapter 5, we focus on power transmissions between rotating shafts (hydrostatic transmissions). Chapters 6 and 7 concentrate on hydrostatic actuators. Finally, Chapter 8 focuses on conventional and new applications of both hydrostatic transmissions and actuators.

To ensure practicality, most of the examples in the book use catalogue data from manufacturers. While great care has been taken in the reproduction of illustrations and/or information taken from manufacturers, inadvertent typographical errors or omissions may have occurred. In some particular cases where catalogue data are unavailable, or when it is not strictly necessary to provide this data, we follow a purely theoretical approach in presenting the concepts. The overall idea behind using real catalogue data is to introduce the students to real-world applications as they work through the examples of the book.

In what follows, we briefly describe the subjects covered in every chapter of this book.

Chapter 1 presents an introduction to hydrostatic transmissions and actuators. Since applications now using mechanical power transmissions constitute a potential field for hydrostatic transmission usage, we review the subject of mechanical transmissions first. Hydraulic components are gradually introduced in this chapter.

Chapter 2 reviews some basic definitions and concepts about hydraulics, such as fluid compressibility and viscosity, pressure losses and internal flows in hydraulic circuits.

Chapter 3 focuses on hydrostatic pumps and motors. After exploring the fundamental aspects of pumps and motors in general, a succinct description of some representative models is given. The definition of efficiency takes up a considerable portion of the chapter, given its importance in hydrostatic transmissions. We also explore the basics of digital displacement and floating cup technologies.

Chapter 4 explores the steady-state operation of hydrostatic transmissions. After reading this chapter, the student will be able to create a basic design of a typical hydrostatic transmission.

Chapter 5 complements the steady-state analysis of hydrostatic transmissions carried out in Chapter 4 by exploring the transient regime. In this chapter, the student has the chance to study the oil compressibility effects, introduced in Chapter 2, that occur when the hydrostatic transmission is subject to dynamic loads.

Chapter 6 focuses on the theme of hydrostatic and electrohydrostatic actuators. Several circuit designs are described in detail. The chapter closes with a description of the common pressure rail technology and its relation with hydraulic transformers.

Chapter 7 introduces the dynamic analysis of hydrostatic actuators. A nonlinear analysis is carried out, and the equations describing the model are solved numerically.

Chapter 8 puts together current and potential applications of hydrostatic transmissions and actuators. Each application is described in detail, so that students can have a good knowledge of the benefits and drawbacks of the hydrostatic technology in every case.

Appendix A lists the several ISO hydraulic symbols used in the book.

Appendix B contains the necessary mathematical tools for a complete understanding of the book. Special emphasis is given to the solution of second-order linear differential equations, where the method of the Laplace transform is briefly presented.

Appendix C reviews the basics of fluid dynamics with a special emphasis on the Navier–Stokes equations, which are developed in detail. For students who are not familiar with the theme, this appendix constitutes a sufficient basis for the subjects covered in the book.

Some examples given in this book require a numerical solution. In this case, the reader can find the source code for the corresponding computer programs written in Scilab script language¹ www.wiley.com/go/costa/hydrostatic. The parts of the book for which a computer script is available have been marked with the download icon ↓.

We have done our best to make the text as clear and rich as possible to the student, and it is our most sincere desire that this book contributes to the understanding and the development of this very important field of fluid power engineering.

¹ Scilab is a free programming environment available at <http://www.scilab.org> (April 2014).

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Gustavo Koury Costa
Nariman Sepehri
August 2015

About the Companion Website

This book's companion website www.wiley.com/go/costa/hydrostatic provides you with additional resources to further your understanding, including:

- A solutions manual
- Scilab scripts
- Links to useful web resources

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