

Clutches and Brakes

Design and Selection

Second Edition

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Library of Congress Cataloging-in-Publication Data

A catalog record for this book is available from the Library of Congress.

ISBN: 0-8247-4876-X

This book is printed on acid-free paper.

Headquarters

Marcel Dekker, Inc., 270 Madison Avenue, New York, NY 10016, U.S.A.
tel: 212-696-9000; fax: 212-685-4540

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*To Helen, my adorable wife, who improved
my life by having been here*

Preface to the Second Edition

[Chapter 1](#), Friction Materials, has been rewritten for two reasons. The first is that graphical data of the sort found in the first edition can no longer be obtained from many of the lining manufacturers. It appears that this absence of graphical data is due to the Trial Lawyers Association curse that has made it risky to provide such data because it may be misinterpreted by technically illiterate judges and juries to place blame where there is no basis for it. The second reason is that asbestos is no longer used in brake and clutch lining materials manufactured in the United States. Thus, data for lining materials containing asbestos are obsolete.

Other changes in the second edition consist of correcting the misprints that have been discovered since the publication of the first edition, a corrected and expanded discussion of cone brakes and clutches, a simpler formulation of the torque from a centrifugal clutch, an update of antiskid control, the addition of a chapter dealing with fluid clutches and retarders, and a chapter dealing with friction drives.

The flowcharts in the first edition that were given as an aid to those readers who may have wished to write computer programs to simplify brake and clutch design have been eliminated in this edition. The availability of commercial numerical analysis programs that may be used in engineering design has eliminated most, if not all, of the need for engineers to write their own analytical programs. The two analytical programs used in the book are listed here with the addresses of their providers at this time. Suppliers for more extensive computer-aided engineering and design programs advertise in engineering magazines. Their addresses and capabilities may also be found

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Changes in ownership of many of the manufacturers of the products illustrated in this book have occurred since the publication of the first edition. Although the products available and their principles of operation generally have remained unchanged, the credit lines for some of these illustrations may refer to manufacturers' names that are no longer in use. Others may become obsolete in the future.

William C. Orthwein

Preface to the First Edition

This book has two objectives. The first is to bring together the formulas for the design and selection of a variety of brakes and clutches. The second is to provide flowcharts and programs for programmable calculators and personal computers to facilitate the application of often lengthy formulas and otherwise tedious iteration procedures indigenous to the clutch and brake design and selection process.

Formulas for the torque that may be expected from each of the brake or clutch configurations and the force, pressure, or current required to obtain this torque are derived and their application is demonstrated by example. Derivations are included to explicitly show the assumptions made and to delineate the role of each parameter in these governing relations so that the designer can more skillfully select these parameters to meet the demands of the problem at hand. Where appropriate, the resulting formulas are collected at the end of each chapter so that those not interested in their derivation may turn directly to the design and selection formulas.

Following the torque and force analysis for the sundry brake and clutch embodiments which dissipate heat, attention is directed to the calculation of the heat generated by these devices during the interval in which the speed is changing. Pertinent relations are derived and demonstrated for braking or accelerating of vehicles, conveyor belts, and hoists.

Calculation of the acceleration, temperature, and heat dissipation may be quite complicated and may be strongly dependent upon the location of the brake on the machine itself and upon the environment in which the machine is to operate. Discussion of acceleration, acceleration time, temperature, and

heat dissipation are, therefore, limited to a common—and simple—brake configuration and to a standard environment of 20°C or 70°F, no wind, and no vibration.

Flowcharts follow the formula collection as appropriate to demonstrate their step-by-step application in arriving at the final design. They are written in the interactive mode (computer or calculator prompting for each variable and its increments) to permit use of programmable calculators and small personal computers for the comparison of several possible designs. With little modification they may be used as subprograms in larger computers having control programs to automate clutch and brake selection to whatever extent desired.

Even though the calculations may be lengthy, no flowcharts are given for those cases where branching is minimal (as in the case of acceleration or deceleration and heat dissipation calculations) where the reasoning is straightforward. It is intended that computer programs will be used for all but the simplest calculations.

William C. Orthwein

Introduction

It is the purpose of this book to briefly derive, where possible, the design formulas for the major types of clutches and brakes listed in the contents and to display an example of their use in a typical design. Some pertinent computer programs for longer formulas are listed in the references.

Each chapter is independent of the others, with the possible exception of [Chapters 1](#) and [8](#), which are concerned with friction materials and with acceleration or deceleration time and heat dissipation during clutching and braking. The friction and pressure characteristic of friction materials used for brake and clutch linings and pads are discussed in Chapter 1 so that they may be available for applications in the following chapters. Chapter 8 deals with acceleration and heat dissipation considerations which apply to all chapters, and consequently draws upon the other chapters for brake types to be discussed in its examples. The logic to be delineated in that chapter is, however, contained entirely within that chapter, so that it may be read and understood without prior reading of any of the other chapters.

To Convert	To	Multiply by
pounds/in ² (psi)	megapascals (MPa)	0.00689476
megapascals (MPa)	pounds/in ² (psi)	145.03774
horsepower (hp)	kilowatts (kW)	0.7457
kilowatts (kW)	horsepower (hp)	1.34102
pounds (lb, force)	Newtons (N)	4.4482
Newtons (N)	pounds (lb, force)	0.2248

To Convert	To	Multiply by
Btu	calorie	251.995
calorie	Btu	0.003968

Since force and mass are misused in both systems it is necessary to use the acceleration of gravity to convert to proper units when confronted with incorrect usage, e.g., kg/cm^2 . The acceleration of gravity in the two system of units is commonly taken to be

$$g = 32.1736 \text{ ft/s} \quad \text{Old English}$$

$$= 9.80665 \text{ m/s} \quad \text{SI}$$

As implied by these previous numbers, we shall retain three or four places of significant digits in most calculations to minimize computational error. After all calculations are complete we shall round to the number of places that are practical for manufacture.

For those not familiar with SI stress and bearing pressure calculations, it may be well to point out that the Pascal is a rather awkward unit of stress, since

$$1 \text{ Pascal} = 1 \text{ N/m}^2$$

is an extremely small number in many applications. Two alternatives may be selected: to present pressure and stress in terms of atmospheres (atmospheric pressure at sea level) or in terms of megapascals, denoted by MPa. In the remainder of the book stress and bearing pressure in the SI system will be presented in terms of MPa because of the convenient relations

$$\text{N/mm}^2 = \text{MPa} \quad \text{and} \quad \text{MPa}(\text{mm}^2) = \text{N}$$

Since atmospheric pressure at sea level is often taken to be about 14.7 psi, it follows from the listing above that 1 MPa is approximately 10 atmospheric pressures. Conversion from MPa to atmosphere is, therefore, quite simple.

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