
THERMAL DESIGN AND OPTIMIZATION

Adrian Bejan

Department of Mechanical Engineering and Material Science
Duke University

George Tsatsaronis

Institut für Energietechnik
Technische Universität Berlin

Michael Moran

Department of Mechanical Engineering
The Ohio State University



A WILEY-INTERSCIENCE PUBLICATION

JOHN WILEY & SONS, INC.

New York / Chichester / Brisbane / Toronto / Singapore

FOR VIKAS

Library of Congress Cataloging in Publication Data
Bejan, Adrian, 1948-
Thermal design and optimization / Adrian Bejan, George Tsatsaronis, Michael Moran.
p. cm.
Includes index.
ISBN 0-471-58467-3
1. Heat engineering. I. Tsatsaronis, G. (George) II. Moran, Michael J. III. Title.
TJ260.B433 1996
621.402—dc20

PREF

This text is printed on acid-free paper.

Copyright © 1996 by John Wiley & Sons, Inc.

All rights reserved. Published simultaneously in Canada.

Reproduction or translation of any part of this work beyond that permitted by Section 107 or 108 of the 1976 United States Copyright Act without the permission of the copyright owner is unlawful. Requests for permission or further information should be addressed to the Permissions Department, John Wiley & Sons, Inc.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the publisher is not engaged in rendering professional services. If legal advice or other expert assistance is required, the services of a competent professional person should be sought.

Library of Congress Cataloging in Publication Data:

Bejan, Adrian, 1948-

Thermal design and optimization / Adrian Bejan, George Tsatsaronis, Michael Moran.

p. cm.

Includes index.

ISBN 0-471-58467-3

1. Heat engineering.

Michael J. III. Title.

TJ260.B433 1996

621.402—dc20

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

95-12071

This book provides a comprehensive and rigorous introductory system design and optimization from a contemporary perspective. It is intended for engineering students at the senior or graduate level and for practicing engineers and technical managers working in the energy field. The book is appropriate for use in a capstone design course, a technical elective course, and for self-study. Sufficient end-of-chapter problems are provided for these uses. In class testing, the material has been found to work well with the intended audience.

We assume readers have had introductory courses in engineering dynamics and heat transfer and are familiar with the basics of fluid mechanics and thermodynamics. Some background in engineering economics is also desirable but not essential. For readers with limited backgrounds in engineering thermodynamics, heat transfer, and engineering economics, reviews are provided in Chapters 6 and 7, respectively. Our presentation does not provide a detailed treatment of component design or extensive operating and cost data. In these topics is available in various standard references, handbooks, and catalogs. Readers should refer to such sources as needed. The book provides extensive reference lists to facilitate this. The book has been designed to allow flexibility in the use of units. It can be studied using SI units only or a mix of SI and English units.

In the area of thermal systems, engineering curricula are largely design and design analysis oriented. Students initially learn to apply material balances and, increasingly, entropy and exergy balances. Then they learn known engineering descriptions and specifications, students learn to evaluate the size, performance, and cost of heat exchangers, turbines, and other components. These activities are important, but the system design is much wider. Design is primarily system oriented. The objective is to effect a design solution: to devise a means for achieving a stated purpose subject to real-world constraints. Design requires selecting and putting together components to form a smoothly working system. Design also often requires that principles from different disciplines