Thermal Engineering in Power Systems

WIT PRESS

WIT Press publishes leading books in Science and Technology.
Visit our website for the current list of titles.
www.witpress.com

WIT eLibrary

Home of the Transactions of the Wessex Institute, the WIT electronic-library provides the international scientific community with immediate and permanent access to individual papers presented at WIT conferences. Visit the WIT eLibrary at http://library.witpress.com

International Series on Developments in Heat Transfer

Objectives

The Developments in Heat Transfer book Series publishes state-of-the-art books and provides valuable contributions to the literature in the field of heat transfer. The overall aim of the Series is to bring to the attention of the international community recent advances in heat transfer by authors in academic research and the engineering industry.

Research and development in heat transfer is of significant importance to many branches of technology, not least in energy technology. Developments include new, efficient heat exchangers, novel heat transfer equipment as well as the introduction of systems of heat exchangers in industrial processes. Application areas include heat recovery in the chemical and process industries, and buildings and dwelling houses where heat transfer plays a major role. Heat exchange combined with heat storage is also a methodology for improving the energy efficiency in industry, while cooling in gas turbine systems and combustion engines is another important area of heat transfer research.

To progress developments within the field both basic and applied research is needed. Advances in numerical solution methods of partial differential equations, high-speed, efficient and cheap computers, advanced experimental methods using LDV (laser-doppler-velocimetry), PIV (particle-image-velocimetry) and image processing of thermal pictures of liquid crystals, have all led to dramatic advances during recent years in the solution and investigation of complex problems within the field.

The aims of the Series are achieved by contributions to the volumes from invited authors only. This is backed by an internationally recognised Editorial Board for the Series who represent much of the active research worldwide. Volumes planned for the series include the following topics: Compact Heat Exchangers, Engineering Heat Transfer Phenomena, Fins and Fin Systems, Condensation, Materials Processing, Gas Turbine Cooling, Electronics Cooling, Combustion-Related Heat Transfer, Heat Transfer in Gas-Solid Flows, Thermal Radiation, the Boundary Element Method in Heat Transfer, Phase Change Problems, Heat Transfer in Micro-Devices, Plate-and-Frame Heat Exchangers, Turbulent Convective Heat Transfer in Ducts, Enhancement of Heat Transfer and other selected topics.

Thermal Engineering in Power Systems

Edited by:

R.S. Amano
University of Wisconsin-Milwaukee, USA

&

B. Sundén
Lund University, Sweden

WIT*PRESS* Southampton, Boston

R.S. Amano
University of Wisconsin-Milwaukee, USA

B. Sundén
Lund University, Sweden

Published by

WIT Press
Ashurst Lodge, Ashurst, Southampton, SO40 7AA, UK
Tel: 44 (0) 238 029 3223; Fax: 44 (0) 238 029 2853
E-Mail: witpress@witpress.com
http://www.witpress.com

For USA, Canada and Mexico

WIT Press
25 Bridge Street, Billerica, MA 01821, USA
Tel: 978 667 5841; Fax: 978 667 7582
E-Mail: infousa@witpress.com
http://www.witpress.com

British Library Cataloguing-in-Publication Data

A Catalogue record for this book is available
from the British Library

ISBN: 978-1-84564-062-0
ISSN: 1369-7331

Library of Congress Catalog Card Number: 2008921657

The texts of the papers in this volume were set individually by the authors or under their supervision.

Printed in Great Britain by Athenaeum Press Ltd.

Contents

Preface

This book focuses on thermal engineering topics for power systems. The topic ranges over all power systems that include fossil power plants, associated environmental cleaning methods, safety of nuclear power plants, development of virtual engineering design environments, cooling technologies and associated problems related to high-temperature gas turbine blades, highly efficient compressors, steam turbines, and hybrid cars. The objective is to present the current state-of-the-art technologies in various power systems such as power plants, aero-jet engines, utilities, thermal management, and safety issues in nuclear power plants.

The first chapter presents the relevance of heat transfer and heat exchangers for development of sustainable energy systems. The authors use numerous research examples and demonstrate why heat transfer and heat exchangers are important in the development of sustainable energy systems. The key factors necessary to develop sustainable energy systems are discussed.

The second chapter deals with advanced technologies for clean and efficient energy conversion in power systems. The main focus is an efficient fossil energy use with low pollution in all kinds of power plants, in all industrial sectors. The use of energy by many countries is growing steadily worldwide due to the desire for higher standards of living and increased productivity. Efficient energy use is favorable for better productivity, product quality, costs, and quality of human life, but energy use adversely impacts our environment.

The third chapter describes virtual engineering and the design of power systems. This chapter examines how these virtual engineering design environments will be created and utilized to build a new generation of power plants. Examples of how virtual engineering is currently being used in the power industry are given. In addition, the US Department of Energy's use of virtual engineering in the development of near-zero-emission power plants is discussed.

The fourth chapter focuses mainly on steam turbine power systems. The emphasis is on efficient fossil energy utilization in power generation together with low pollution issues in conventional thermal power plants. This chapter briefly highlights the fouling problem in power plant water walls and proposes a monitoring, inspection and maintenance schedule. The information provides a quick guide to

the commonly faced operation problems and methods to enhance energy conversion efficiency.

The fifth chapter presents enhancement of nuclear power plant safety by condensation-driven passive heat removal systems. This chapter discusses the numerous ways in which passive condensation heat transfer enhances nuclear power plant safety in current and future nuclear power plants. The discussion extends to US-design light water reactors and US reactor safety codes, although there are many commonalities to reactors of other designs. The physical phenomena are described and the state-of-the art in analysis methods are presented. Challenges for improved analysis are summarized.

The sixth chapter presents modern CFD application on aero-thermal engineering aspects of natural draft cooling towers. The chapter demonstrates various designs of cooling towers using computer simulation technology.

The seventh and eighth chapters present more on the detailed technology development of gas turbine blade cooling systems. Both these chapters give better understanding of the physics of engine heat transfer by developing from simple ideas to complex heat transfer phenomena. The authors address how the engineer applies heat transfer tools available in the literature to support designs which will advance engine life and enhance machine efficiencies. If successful, the newcomer will establish a foothold in the technology and the more experienced engineer will be reminded of some basic concepts.

The ninth and tenth chapters cover more detailed studies on compressors for both industrial usage and aircraft engines. Whereas Chapter seven presents an overview and details of blade designs for both axial and centrifugal compressors and Chapter 8 focus mainly on centrifugal compressors, these two chapters discuss the developments for better understanding of the flow in an impeller and the contributions of this knowledge towards better and advanced impeller designs.

The final chapter presents the current development of hybrid cars. This chapter summarizes modern hybrid car systems and their thermal management issues. These thermal issues are important since commercial hybrid cars employ gasoline/diesel-electric systems, which are the major factors for improving tank to wheel efficiencies.

All of the chapters follow a unified outline and presentation to aid accessibility and the book provides invaluable information to both graduate researchers and industrial research engineers/scientists.

We are grateful to the authors and reviewers for their excellent contributions. We also thank the ceaseless help provided by the staff members of WIT Press, in particular Mr Brian Privett and Mrs Elizabeth Cherry, for their strong encouragement in the production of this book. Finally our appreciation goes to Professor Carlos Brebbia who gave us support and encouragement to complete this project.

Ryoichi S. Amano and Bengt Sundén
2008