Environment Conscious Manufacturing

Environment Conscious Manufacturing

Edited by

Surendra M. Gupta
A. J. D. (Fred) Lambert

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-13: 978-0-8493-3552-5 (Hardcover)

Library of Congress Cataloging-in-Publication Data

Environment conscious manufacturing / editors Surendra M. Gupta and A.J.D. Lambert.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-8493-3552-5 (alk. paper)
1. Manufacturing processes--Environmental aspects. 2. Engineering design--Environmental aspects. 3. Industries--Environmental aspects. 4. Waste minimization. I. Gupta, Surendra M. II. Lambert, A.J.D. III. Title.

TS155.7.E57 2008
670.28'6--dc22 2007020180

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Dedicated to Our Families

Sharda, Monica and Neil
SMG

Teuntje, Henrike, Florian and Frans
AJDL

Contents

Preface

Environment conscious manufacturing (ECM) is an emerging discipline that is concerned with developing methods for manufacturing new products from conceptual design to final delivery, and ultimately to end-of-life disposal, that satisfy environmental standards and requirements.

The environment and global warming are receiving increasing attention these days. The Academy Award winning documentary, "An Inconvenient Truth,"* released in 2006 and presented by former U.S. Vice President Al Gore, has sent a warning signal to the masses to sharpen their awareness about global warming. At the same time, most industrialized nations are facing serious repercussions from the rapid technological development that has taken place in the past few decades. In recent years, environmental awareness and recycling regulations have been putting pressure on many manufacturers and consumers, forcing them to produce and dispose of products in an environmentally responsible manner. Government regulations are becoming more persuasive, and thus many manufacturers are under pressure to use recycled materials whenever possible. Occasionally, manufacturers are even required to take care of the products at the ends of their useful lives. This regulation has created a need to design products that are environment friendly, as well as easy to disassemble and recycle. Hence, there is more than ever a need to develop algorithms, models, heuristics, and software for addressing designing, recycling, and other issues (such as the economic viability, logistics, disassembly, recycling, and remanufacturing) for an ever-increasing number of products produced and discarded.

This text provides a comprehensive coverage of this discipline, exploring topics such as industrial metabolism, product design for the environment, design of reverse and closed-loop supply chains, disassembly modeling, and case studies in ECM. Students, academicians, scholars, consultants, and practitioners worldwide would benefit from this text. It is our hope that this book will inspire further research in ECM and motivate new researchers to get interested in this all too important field of study.

The book is organized into 15 chapters. The first chapter, by Lambert, presents an introduction to the basic concepts of industrial ecology including its historical roots. The author discusses the concepts of industrial metabolism and integrates them with the concepts of reverse logistics. The second chapter by Giudice, takes the life cycle approach to designing the product for the environment, considering all phases of the life cycle, from definition of product requirements to its disposal. In the third chapter, Vadde et al. describe sensor-embedded products in the context of product life cycle management.

* "An Inconvenient Truth," starring Al Gore and Billy West and directed by Davis Guggenheim. Studio: Paramount. Available on DVD.

The effectiveness of the embedded sensors is modeled using simulation and measured in terms of the average downtime, average maintenance cost, average disassembly cost, and average life cycle cost. It is shown that embedding sensors in computers provides a beneficial result.

The fourth chapter by Pochampally et al. illustrates how various quantitative techniques can be employed in the design phase of reverse and closed-loop supply chains to address a variety of decision-making problems. The decision-making problems addressed include the selection of economically used products, collection centers, recovery facilities, production facilities, second-hand markets, and new products; the optimal transportation of goods; the evaluation of marketing strategy; and the futurity of used products. In the subsequent chapter (Chapter 5), Jalil et al. assert that, in closed-loop supply chains, uncertainty could be managed by using information. The authors illustrate their point by considering the case of CopyMagic.

Chapters 6 through 10 address various issues associated with disassembly, which is the first step in product recovery. Product recovery seeks to obtain materials and parts from old or outdated products through reuse, remanufacturing, or recycling to minimize the amount of waste sent to landfills. Disassembly is defined as the methodical extraction of valuable parts or subassemblies and materials from discarded products through a series of operations. Chapter 6, by McGovern and Gupta, deals with disassembly line balancing. Since a disassembly line is the best choice for automated disassembly, it is essential that the disassembly line is designed and balanced to work efficiently. The disassembly line balancing problem seeks a disassembly sequence that is feasible, minimizes the number of workstations, minimizes total idle time, and ensures similar idle times at each workstation as well as addresses other disassembly-specific concerns. As finding the optimal balance is computationally prohibitive due to exponential growth, the chapter presents several metaheuristics algorithms that are easy to implement to solve the problem. Chapter 7, by Udomsawat and Gupta, presents a variant of the Toyota Production System (known as the multikanban system) that is implemented in a disassembly line. The authors' investigation reveals that the multikanban system is effective in controlling the system's inventory while providing a decent customer service level. In Chapter 8, Tripathi et al. suggest several random search techniques that can be used to solve a disassembly sequencing problem. Chapter 9, by Tang and Zhou, presents an overview of two models for uncertainty management in disassembly process planning, owing to human intervention. The first model mathematically represents the influence of human factors on disassembly, while the second incorporates fuzzy learning strategy into the disassembly process. In Chapter 10, Inderfurth and Langella discuss the planning of disassembly for the remanufacture-to-order systems. The authors argue that linear programming models can be used to plan disassembly for simple situations when yields are known. Their model, first discussed in the context of a single period, is subsequently relaxed to accommodate multiple periods, which necessitate the use of heuristic methodologies. The authors suggest the use of

recourse models to incorporate the randomness to accommodate the uncertain yields of disassembly.

Chapter 11, by Topcu et al., highlights the issues arising from the design of facility and storage space in the context of remanufacturing. The authors argue that the number of usable parts or candidates for remanufacture retrieved from returned products varies significantly, causing fluctuations in inventory capacity and configuration requirements. Therefore, remanufacturing requires storage designs that not only minimize warehousing space and inventory-holding costs but also facilitate effective coordination of facilities planning and remanufacturing decisions. The authors use two mathematical models to illustrate their views. In Chapter 12, Mukherjee and Mondal highlight the current status of Indian remanufacturing. They point to the lack of such economic activities in the country and examine the reasons for such absence through empirical investigation. Chapter 13, by Nakashima, proposes a Markov model to evaluate and optimize environment-conscious manufacturing systems with stochastic variability stemming from customer demand, recovery rate, and disposal rate. The model can be used to calculate the total expected cost per period. In Chapter 14, Dhanda and Peters report that while the developed countries are guilty of discarding a majority of electronic products in the waste stream, most of the waste is actually shipped overseas to Asian countries. The authors analyze the reasons for such behavior and suggest some solutions to this problem. In the final chapter, Sarkis et al. point out that the adoption of environment conscious manufacturing practices needs to overcome a variety of barriers. The authors propose the use of interpretive structural modeling to help investigate, analyze, and overcome these barriers. The chapter provides an overview of the major barriers and an illustrative example with initial insights.

This text would not have been possible without the devotion and the commitment of the contributing authors. They have been very patient in preparing their manuscripts. We would also like to express our appreciation to Taylor & Francis and its staff for providing seamless support in making it possible to complete this timely and important manuscript.

Surendra M. Gupta

A.J.D. Lambert

Editors

Dr. Surendra M. Gupta, PE, is a professor of mechanical and industrial engineering and director of the Laboratory for Responsible Manufacturing at Northeastern University in Boston, Massachusetts. He received his BE in electronics engineering from Birla Institute of Technology and Science (India), an MBA from Bryant University, and an MSIE and PhD in industrial engineering from Purdue University. Dr. Gupta's research interests are in the areas of production or manufacturing systems and operations research. He is primarily interested in environment conscious manufacturing, manufacturing of electronic products, MRP, JIT, and queueing theory. He has authored or coauthored about 350 technical papers that have been published in prestigious journals, books, and conference proceedings. His publications have been cited by thousands of researchers all over the world in journals, proceedings, books, and dissertations. He has traveled to all seven continents, that is, Africa, Antarctica, Asia, Australia, Europe, North America, and South America and presented his work at international conferences there (except Antarctica). He is currently the area editor of environmental issues for *Computers and Industrial Engineering*, the associate editor for *International Journal of Agile Systems and Management*, and an editorial board member of a variety of journals. He has also served as a conference chair, track chair, and member of technical committees of a variety of international conferences. Dr. Gupta has been elected to the memberships of several honor societies and is listed in various *Who's Who* publications. He is a registered professional engineer in the state of Massachusetts and a member of ASEE, DSI, IIE, INFORMS, and POMS. Dr. Gupta is a recipient of the Outstanding Research Award and the Outstanding Industrial Engineering Professor Award (in recognition of teaching excellence) from Northeastern University. His recent activities can be viewed at http://www1.coe.neu.edu/~smgupta/, and he can be reached by e-mail at gupta@neu.edu.

Dr. A.J.D. (Fred) Lambert, is an assistant professor of industrial ecology in the Department of Technology Management at the University of Technology at Eindhoven, the Netherlands. He received his BS in electrical engineering from the Technical College at Vlissingen and his MSc in technical physics and his PhD in theoretical plasma physics from the University of Technology at Eindhoven, all in the Netherlands. In addition to the University of Technology at Eindhoven (the Netherlands), Dr. Lambert has participated in research projects at the Philips Company, the University of Greifswald (Germany), the University of Trieste (Italy), the Technical University at Lausanne (Switzerland), and the FOM Institute for Plasma Physics at Rijnhuizen (the Netherlands). Dr. Lambert has published papers on several topics, including nuclear fusion, nonequilibrium thermodynamics, MHD power

generation, energy systems modeling, process integration, materials flow modeling, and, more recently, on disassembly sequencing. He has published more than 40 research papers in various scientific journals and has contributed to numerous books, conference proceedings, and professional papers. Dr. Lambert teaches undergraduate students energy efficiency and the managerial aspects of reuse and recycling; he supervises group projects on industrial ecology–related topics. He coaches graduate students on topics such as energy and waste management in industry, and sustainable energy resources. His recent activities can be viewed at http://w3.tm.tue.nl/en/subdepartments/aw/ (technology studies). Dr. Lambert can be reached by e-mail at A.J.D.Lambert@tue.nl.

Contributors

Shubham Agrawal Department of Manufacturing Engineering, National Institute of Foundry and Forge Technology (NIFFT), Ranchi, India

James C. Benneyan Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Thomas P. Cullinane Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

K. Kathy Dhanda Department of Management, De Paul University, Chicago, Illinois, USA

Fabio Giudice Department of Industrial and Mechanical Engineering, University of Catania, Catania, Italy

Surendra M. Gupta Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Mohd. Asif Hasan University Polytechnic, Aligarh Muslim University, Aligarh, India

Karl Inderfurth Faculty of Economics and Management, Otto-von-Guericke-University Magdeburg, Germany

Muhammad N. Jalil Department of Decision and Information Management, RSM Erasmus University, Rotterdam, the Netherlands

Sagar V. Kamarthi Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Harold Krikke Department of Organization and Strategy, Tilburg University, Tilburg, the Netherlands

A.J.D. Lambert Faculty of Technology Management, Eindhoven University of Technology, Eindhoven, the Netherlands

Ian M. Langella Faculty of Economics and Management, Otto-von-Guericke-University Magdeburg, Germany

Seamus M. McGovern National Transportation Systems Center, U.S. DOT Research and Innovative Technology, Cambridge, Massachusetts, USA

Sandeep Mondal Department of Management Studies, Indian School of Mines University, Dhanbad, India

Kampan Mukherjee Department of Management Studies, Indian School of Mines University, Dhanbad, India

Kenichi Nakashima Department of Technology Management, Osaka Institute of Technology, Osaka, Japan

Satish Nukala Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Adrian Peters Neohapsis, Chicago, Illinois, USA

Kishore K. Pochampally School of Business, Southern New Hampshire University, Manchester, New Hampshire, USA

Joseph Sarkis Graduate School of Management, Clark University, Worcester, Massachusetts, USA

Ravi Shankar Department of Management Studies, Indian Institute of Technology Delhi, New Delhi, India

Ying Tang Electrical and Computer Engineering, Rowan University, Glassboro, New Jersey, USA

M.K. Tiwari Department of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur, India

Aysegul Topcu Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Mukul Tripathi Department of Metallurgy and Material Engineering, National Institute of Foundry and Forge Technology (NIFFT), Ranchi, India

Gun Udomsawat Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Srikanth Vadde Laboratory for Responsible Manufacturing, Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

Ibrahim Zeid Department of Mechanical and Industrial Engineering, Northeastern University, Boston, Massachusetts, USA

MengChu Zhou Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, New Jersey, USA

Rob A. Zuidwijk Department of Decision and Information Management, RSM Erasmus University, Rotterdam, the Netherlands