DEVELOPMENTS IN
MINERAL PROCESSING 16

THE METRICS OF MATERIAL AND METAL ECOLOGY

HARMONIZING THE RESOURCE, TECHNOLOGY AND ENVIRONMENTAL CYCLES

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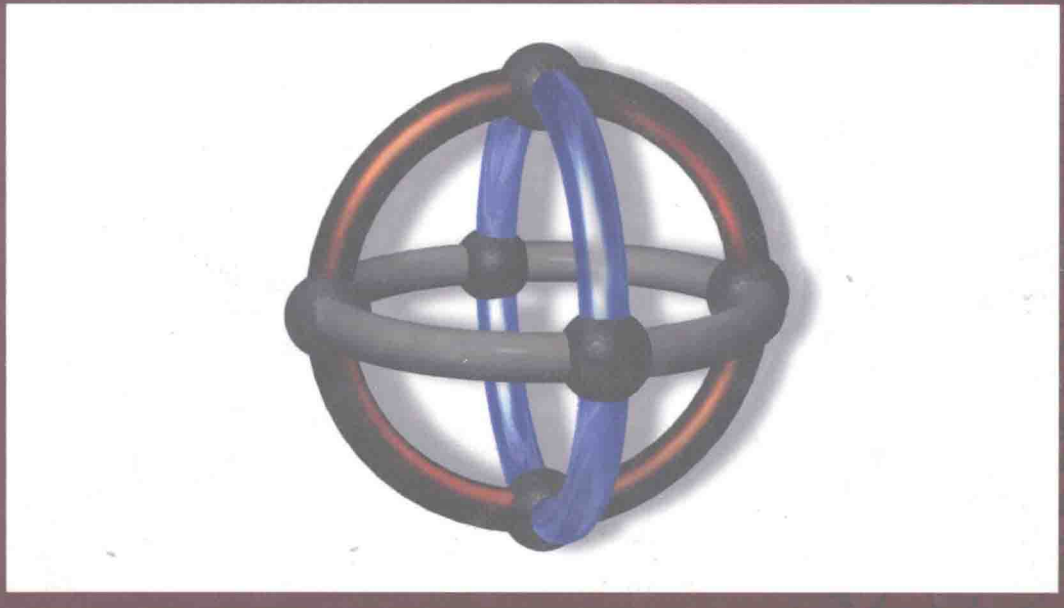

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M.A. REUTER
UNIVERSITY OF MELBOURNE, AUSTRALIA

K. HEISKANEN
HELSINKI UNIVERSITY OF TECHNOLOGY, FINLAND

U. BOIN
OBERUSEL, GERMANY

A. VAN SCHAIK
DEN HAAG, THE NETHERLANDS

E. VERHOEF
BERGEN OP ZOOM, THE NETHERLANDS

Y. YANG
DELFT, THE NETHERLANDS

G. GEORGALLI
DEN HAAG, THE NETHERLANDS

SERIES EDITOR: B.A. WILLS

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Radarweg 29
P.O. Box 211, 1000 AE
Amsterdam, The Netherlands

ELSEVIER Inc.
525 B Street
Suite 1900, San Diego
CA 92101-4495, USA

ELSEVIER Ltd.
The Boulevard
Langford Lane, Kidlington,
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ELSEVIER Ltd.
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Harmonizing the Resource, Technology and Environmental Cycles

Preface

Rapid growth of the world economy is straining our sustainable use of the Earth's natural resources. This makes the economic reuse and recycling of materials and end-of-life products extremely important in the future. Natural Laws, engineering and economics make the closure of the material cycles possible, however also have its limitations.

Metal and Material Ecology links the principles of Industrial Ecology to the fundamentals of separation physics and thermodynamics in the unit operations that close the material cycle. In a unique blend of theory and industrial practice it is explained how to keep second generation materials in the material cycle. This is the product of the authors' research over the past number of years in which recycling theory was developed. Therefore, this book provides an excellent basis to continue research in these areas. It also lays the basis for teaching the fundamental theory of recycling systems and technology to under- and graduate students, linking recycling theory to some aspects of product design - and quantify this in terms of metrics for sustainability. We show how important it is to understand "the bigger picture" of the material and metal production system, the "Web of Metals and Materials" in the context of population balance modelling, fundamental separation physics and thermodynamics. We show that if this is understood the system can be optimized economically and hence a better efficiency can be reached. This is crucial to reaching sustainability in metal and material usage. It also supplies guidelines to the design engineer to show the consequences of poor design.

The book is written in four self-contained parts, that can essentially be read as separate parts. The structure of the parts is such that it also demonstrates the basic philosophy of the book i.e. we move from the systems perspective of Metal and Material Ecology, to the population balance theory of recycling systems and finally to reactor technology of recycling systems. We illustrate everything with numerous simulation models, figures and data. In doing so we would like to provide the reader with all the models and data, available on the included CD rom: i.e. we would like to create a trend of "share-data" to ensure that data is freely available to everyone, ensuring that the system of material recycling can at all times be transparently modelled and optimized economically but also environmentally. We believe this is essential if the beautiful principles of Industrial Ecology are to be realized! This fundamental approach provides a basis for harmonizing and connect the material streams of different industries and hence also level the legislative playing field, with the objective to minimize environmental impact and damage. At the same time it provides a fundamental metric for Design for Recyling and Recovery.

This book is also a result of the philosophy the authors developed for an international MSc course in which they were involved. Many fruitful discussions with the master students have contributed to the contents of this book. They are the carriers of our message into the future, therefore we dedicated this book to them.

The Authors

Something will have gone out of us as a people
if we ever let the remaining wilderness be destroyed,
if we permit the last virgin forest to be turned into comic books and plastic cigarette cases;
if we drive the few remaining members of the wild species into zoos or extinction;
if we pollute the last clean air and dirty the last clean streams,
and push our paved roads through the last of the silence,
so that never again will people be free in their own country from the noise,
the exhausts, the stinks of human and automotive waste,
and so that never again can we have the chance to see ourselves single, separate,
vertical and individual in the world, part of the environment of trees and rocks and soil,
brother to the other animals, part of the natural world and competent to belong in it.
We simply need that wild country available to us,
even if we never do more than drive to its edge and look in,
for it can be a means of reassuring ourselves of our sanity as creatures,
as part of the geography of hope...

Wallace Stegner

Contents

Part I

Introduction

Chapter 1

Harmonizing the resource, technology and environmental cycles

Rapid growth of the world economy is straining our sustainable use of the Earth's natural resources. This makes the economic reuse and recycling of materials and end-of-life products extremely important in the future. Natural Laws, engineering and economics make the closure of the material cycles possible, however also have its limitations.

It is the principle objective of this book to explore the limits of the resource system as a whole on the basis of technology and its principles by applying the systemic approach of Industrial Ecology and provide first principles metrics to measure Design for Recovery and Recycling and approach sustainability in order to minimize environmental impact.

This book bridges the gap between physics and chemistry of the various highly interconnected actors within the Metal and Material Ecology system, linking resources to products and finally to recycled materials. The holistic concepts of ecology are linked to process technology via the first principles governing the phenomena within process reactors and manufacturing plants within the constraints of economics. This fundamental approach provides a basis for harmonizing and connect the material streams of different industries and hence also level the legislative playing field.

These concepts can be summarised into the three cycles depicted by Figure 1.1, symbolically showing the links between three interconnected cycles: the resource cycle, the technology cycle and the life cycle [1, 2, 4, 5, 6, 7]. These have to be among others connected to realize the ambitions of the sustainable use of materials. Therefore, Figure 1.1 is the golden thread or rather, the golden sphere, of this book [3, 8]. The various intersections of Figure 1.1 will be discussed, at which the complex interplay between systems dynamics, (sampling) statistics, separation efficiency (recovery), metallurgical thermodynamics, grade of recycling (intermediate) products, liberation, product design and performance, system architecture, economics etc. will be explored. These intersections will drive the changes. However, there is no possibility to fulfil this task without combining knowledge and technology from the simplest separation and sorting technology to most complex metallurgical reactor optimization via fundamental studies on flow and kinetics in pyrometallurgical reactors, process layout, as well as product design. Moreover, it requires that new and innovative designs and production methods must be developed. This suggests that the optimization of the resource cycle