Thermochemical surface engineering of steels

Mittemeijer, Eric J. ; Somers, Marcel A. J.

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Mittemeijer, E. J., & Somers, M. A. J. (Eds.) (2015). Thermochemical surface engineering of steels. Woodhead Publishing. Woodhead Publishing Series in Metals and Surface Engineering, No. 62

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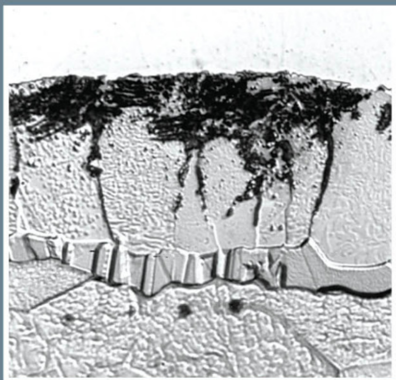

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80 High Street, Sawston, Cambridge, CB22 3HJ, UK
225 Wyman Street, Waltham, MA 02451, USA
Langford Lane, Kidlington, OX5 1GB, UK

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Control Number: 2014943554

ISBN 978-0-85709-592-3 (print)
ISBN 978-0-85709-652-4 (online)

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Typeset by Replika Press Pvt Ltd, India
Printed and bound in the United Kingdom

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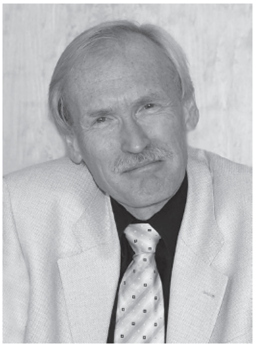
E. J. Mittemeijer



Eric Jan Mittemeijer was born in 1950 in Haarlem, The Netherlands. He studied 'chemical technology', with specialization physical chemistry, at the Delft University of Technology and acquired his 'ingenieur (= Ir.)' degree (comparable to an MSc degree) in 1972 and his Dr. degree in 1978. From 1985 to 1998 he was full Professor of Solid State Chemistry at the Delft University of Technology. Since 1998 he has been Director at the Max Planck Institute for Intelligent Systems (formerly Max Planck Institute for Metals Research) in Stuttgart in conjunction with a full Professorship in Materials Science at the University of Stuttgart. He leads a research department in the field of Phase Transformations. He has (co-)authored more than 600 scientific papers in international scientific journals, wrote a textbook on Materials Science and was editor of several books in his field of science. He has received a number of honours for his scientific work. He can be contacted at: e.j.mittemeijer@is.mpg.de.

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Introduction

Corrosion, wear and fatigue are among the most important mechanisms that lead to materials degradation, which, eventually, leads to failure of components. The annual loss by material degradation owing to these mechanisms alone is assessed at 7–8% of a nation's gross national product (GNP), at least in the western world. Thus there is a great potential for saving resources, provided that the fundamentals of material behaviour, and thus its performance including degradation, are understood, in order to define on that basis strategies to improve the intrinsic properties of materials. This requires acquisition of scientific understanding rather than the accumulation of empirical data.

Corrosion, wear and fatigue involve chemical and/or mechanical interaction of the material component considered with loads imposed by the environment. Hence, materials performance and service life rely in many cases to a high degree on the properties of a material component in its surface region. Accordingly, engineering the intrinsic properties of the surface region to improve materials performance suggests itself, thus giving birth to the discipline of Surface Engineering. Obviously the number of conceivable surface engineering process variants to tailor any possible combination of structural or functional properties is endless. Indeed, the number of surface engineering processes in use at present is overwhelming.

From the very beginning of surface engineering, thermochemical processes have played a dominant role for realizing structural properties. The adjective 'thermochemical' should be interpreted as indicating a deliberate change of the chemical composition of the material at elevated temperature. This is accomplished by a thermally activated chemical reaction of the material's surface with one (or more) component(s) supplied by an appropriate environment as a gas, a plasma, a salt bath or a (powder) pack. Upon dissolution of the externally supplied component(s) into the surface, thermally activated (inter)diffusion, possibly, but not necessarily, accompanied by phase transformations, leads to a desired modification of the microstructure. The best known and most widely applied processes are case hardening[1] by carburizing and nitriding of steel components.

We have deliberately restricted this book to *thermochemical* surface engineering methods, rather than attempting to provide an overview of all possible surface engineering methods, which would have made this book either too bulky or superficial.

1 'Case hardening' is a name usually reserved for carburizing methods, but in fact it is a generic name; it expresses that a hard 'case' (the surface region) is produced on an unaltered, relatively soft 'core'. Because, on the one hand, this interpretation limits severely the range of properties possibly and deliberately modified by surface engineering, and, on the other hand, identifying case hardening with carburizing (of steels) is an illogical narrowing of the field covered, we prefer to avoid using 'case hardening' for 'carburizing', although this is done frequently in the literature.

Materials are usually not used in a state of equilibrium. This holds in particular for materials in components subjected to a thermochemical surface engineering treatment, where the composition and the associated microstructure in the surface region of the component are (very) different from those in the bulk. Therefore, understanding the properties of materials *of graded composition and microstructure*, requires knowledge of the thermodynamics, i.e. the state of equilibrium strived for, and the kinetics of the surface engineering processes applied. On the one hand and unfortunately, such knowledge is only available to a limited extent at a fundamental level. On the other hand, a wealth of phenomenological data is offered by the literature and forms the basis for many surface engineering methods applied in (commercial) practice. Yet, we have tried with this book also to provide an overview of the scientific knowledge available on thermochemical surface engineering. It appears that such fundamental knowledge is largely restricted to gaseous treatments, because gaseous media, in contrast to salts, packs and plasmas, can be controlled such that the prevailing chemical potentials of the (active) species are known and can be measured and controlled precisely. For the same reason the kinetics of the surface reactions are practically only known comprehensively for the metal–gas reactions.

Against the above background, in the first chapter of this book, we have tried to present an overview of what is known about the thermodynamics of gaseous media used for carburizing and nitriding processes and their variants, and about the kinetics of the associated metal–gas reactions. The data provided and the calculation methods presented offer a unique review of the state of the art not available in any other literature source known to us. In particular, we have integrated in the text original and important data hitherto only available in papers written in German, thereby making possible their use worldwide.

Chapter 2 is devoted to a general description of the kinetics of (a) transport of species originating from the outer atmosphere through the solid, and (b) the possible reaction of this species with components in the solid, leading to phase transformation, with the product phase(s) emerging as (a) separate layer(s) at the surface or as dispersed particles in the substrate matrix.

Chapter 3 is devoted to the general principles of the process technology of the (usual) thermochemical surface engineering methods. As will be clear to the reader of this chapter, the strictly science-based approach of Chapters 1 and 2 is substituted by an overview of also more experience-based knowledge of great importance for successful thermochemical surface engineering.

The basis for understanding current thermochemical surface engineering processes is provided by these first three chapters.

The chapters in Part Two are devoted to the optimization of certain properties by dedicated thermochemical surface engineering: the fatigue resistance (Chapter 4), the wear resistance (Chapter 5) and the corrosion resistance (Chapter 6).

As indicated above, thermochemical surface engineering is dominated by nitriding/nitrocarburizing (Chapters 7–12) and carburizing (Chapter 13) and their variants. In these chapters (Part Three) fundamental aspects of the effects on the generated microstructure (especially Chapters 7, 8 and 13) as well as the process technological aspects (Chapters 9, 11 and 13) are dealt with. Specific examples of practical application are provided in Chapter 12.

A development of recent years is 'low temperature surface hardening of stainless steels', sometimes indicated by the unfortunate name 'S-phase surface engineering', which is the topic of Part Four. The purpose is the uptake of an unusually large amount of interstitial nitrogen and/or carbon in the surface adjacent region of a stainless steel, nickel or cobalt alloy. After a historical review of the development and the fundamental aspects of this method (Chapter 14), its variants for application using gaseous media (Chapter 15) and plasma media (Chapter 16) are presented and discussed. The final chapter of this part provides specific examples of practical application (Chapter 17).

The final part of this book (Part Five) presents a number of less often, but still frequently applied and thus important thermochemical surface engineering methods for dedicated applications: boriding (Chapter 18), thermoreactive deposition and diffusion (Chapter 19), sherardizing (Chapter 20) and aluminizing (Chapter 21).

This book, as follows from the description above, is intended to provide an overview of the current knowledge on thermochemical surface engineering. Therefore we are particularly grateful to the many authors who contributed enthusiastically to this project and enriched it with their knowledge.

This book was long in the making and thus we are grateful for the patience of those of the contributing authors who had to wait a long time to see their manuscript in print. The team at Woodhead Publishing, Francis Dodds and Emily Cole, helped us with many small but important details, not least by their understanding for and willingness to accept shifting deadlines. Last but not least, we are very much obliged to our spouses, Marion and Sussi, for their infinite support; without their acceptance of numerous private hours being consumed by us, a project like this would have been impossible.

It is then hoped that this book will be used by many and will stimulate young people to contribute to future developments in the field.

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