Chapter 1

Introduction

Michael M. Gasik Editor
Aalto University Foundation, Espoo, Finland

Chapter Outline

1.1 INTRODUCTION TO FERROALLOYS

Ferroalloys (and master alloys in general) have been developed to improve the properties of steels and alloys by introducing specific alloying elements in desirable quantities in the most feasible technical and economic way. Ferroalloys are namely alloys of one or more alloying elements with iron, employed to add chemical elements into molten metal. Not a single steel grade is produced without ferroalloys (Wood and Owen, 2005). Ferroalloys production is an important part of the manufacturing chain between the mining and steel and alloys metallurgy: the main task of the ferroalloys industry is the primary recovery (reduction) of needed metals from natural minerals. As ores also include nonmetallic minerals (gangue), they have to be dressed (beneficiated, enriched) by one or several successive methods (gravitational, magnetic, electric, and flotation separation, or in some cases by chemical means) to produce useful mineral concentrates in which the leading content of the metal is much higher in comparison with the original ore (Gasik and Lyakishev, 2005). This allows the production of higher-grade ferroalloys with a higher content of leading elements and a lower content of impurity elements (usually phosphorus, sulfur, and nonferrous metals), and it significantly reduces specific energy consumption and production costs.

There are several reasons why ferroalloys are used to add necessary elements. The alloying element might be difficult to obtain in pure form and it makes less sense to purify it (also from iron) if the purpose is to add it

Handbook of Ferroalloys. http://dx.doi.org/10.1016/B978-0-08-097753-9.00001-0

back to iron-based steel melt. It just may not be stable in a condensed form at steelmaking temperatures. The alloying element alone might have too much affinity to oxygen or nitrogen, which would lead to its premature oxidation before it would be utilized. Eventually, the costs of 1 kg of alloying element in its ferroalloy form are many times lower than the costs for its pure form.

Ferroalloys are usually classified in two groups: bulk (major) ferroalloys (produced in large quantities) and minor ferroalloys (produced in smaller quantities, but of a high importance). Bulk ferroalloys are used in steelmaking and steel or iron foundries exclusively, whereas the use of special ferroalloys is far more varied. About 85% to 90% of all ferroalloys are used in steelmaking; the remaining ferroalloys are used for nonferrous alloys (e.g., those that are nickel or titanium based) and by the chemicals industry (Gasik and Lyakishev, 2005).

Historically, the ferroalloys production technology used in the 19th century was developed for blast furnaces (high-carbon ferromanganese, low-grade ferrosilicon), as at those times it was the main route for cast iron processing. However, in a blast furnace it is not possible to produce ferroalloys with elements that have a higher affinity for oxygen or with low carbon content. This led to the development of ferroalloys to be manufactured (smelted) in electric furnaces at the beginning of the 20th century.

Today, almost all ferroalloys are produced in submerged arc furnaces (Fig. 1.1), where raw materials (ores), reductants (coke, silicon-based ferroalloys, aluminum), iron additions (iron ore or steel scrap), and fluxes (lime, magnesia, dolomite, limestone, fluorspar, etc.) are loaded and smelted, followed by the tapping of slag and metal.

With the first experience of ferroalloys smelting, it became evident that more research was needed to improve our understanding of the thermodynamics of liquid melts; ferroalloy and slag formation (Holappa and Xiao, 2004); the kinetics of reduction and phase transformation; the structure, properties, and stability of solid ferroalloys, mineral raw materials, and reducing agents applied; and the electric and thermal properties of all charge components. Later, the issues of better energy and resource utilization, lower emissions requirements (Tanaka, 2008), and increasing demands to improve the purity and costs of ferroalloys set new challenges for improving the quality and price competitiveness of ferroalloys and their production processes.

It is now well understood that the main technical and economic performance indicators of ferroalloys production and application (i.e., their competitiveness) could be substantially improved with systematic fundamental and applied research, allowing for the development and implementation of better energy-saving smelting processes, the creation of more sophisticated electric furnace equipment with automated control systems, and enhancements to process management.

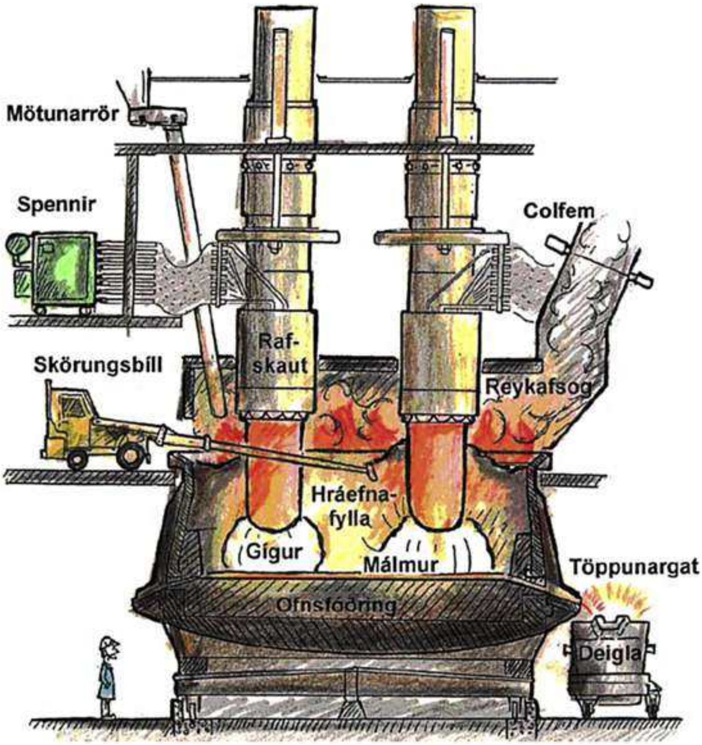

FIGURE 1.1 The general artistic impression of the modern submerged arc furnace process. *(Courtesy of Dr. Þorsteinn Hannesson, Elkem Iceland.)*

1.2 THE SCOPE AND STRUCTURE OF THE BOOK

In the 20th century, several books were published and numerous conferences were held concerning the domain of ferroalloys. However, whereas several editions and new titles have been published in the Commonwealth of Independent States (CIS) (previously Union of Soviet Socialist Republics [USSR]) and China, in the Western world possibly the last specifically dedicated book by Durrer and Volkert was released in German as its next edition (Durrer and Volkert, 1972). This book has been translated into several languages and remains one of the basic books on this topic.

Contemporary publications in ferroalloys are widely spread among different journals, reports, and conference proceedings, and it is not an easy task to present a coherent picture to a reader. Taking into account the developments in ferroalloys processing theory and technology, a need has been identified to collect and unite modern knowledge in a consistent way, suitable for students and professionals. The current text was originally formulated as a comprehensive collection of theory and technology outlooks in ferroalloys, but later it was tailored to a handbook-like style.

The goal of this book is to provide a unified, combined overview of ferroalloys technology, which is reasonably formulated to answer questions concerning specific ferroalloys, their processing peculiarities, and used equipment and its operation, as well as relevant environmental issues.

The book is divided in three sections: a general section (I), a section on major (bulk) ferroalloys (II), and a section on minor ferroalloys (III). The general section deals with ferroalloy basics, thermodynamics, the kinetics of reduction and general processing issues, electric furnace operations, environmental issues, and so on. The second section describes the theory and technology of ferroalloys with silicon, manganese, and chromium. The last section explores all other industrially relevant ferroalloys, as well as the peculiarities of their processing and applications. For every specific ferroalloy (i.e., its leading element), there is a chapter that includes brief information about the element and its properties, reactions, and equilibria with other major relevant elements (iron, oxygen, carbon, silicon, aluminum, nitrogen, etc.). Raw materials (minerals, ores) for this element and methods of their preparation are described, and the ferroalloy's smelting techniques are presented, along with the practical details and peculiarities one needs to know to ensure successful processing.

The authors have decided not to spend too much time discussing, for example, specific reactions between different substances and their thermodynamic parameters, as recently all thermodynamic data are retrieved from databases using more complex Gibbs minimization methods for equilibrium assessment, and thus the numerical values of the parameters do not need to be explicitly known. The same concerns phase equilibria diagrams, which in this book have been mostly recalculated using the latest available software programs (FactSage 6.2 and ThermoCalc R) with their own proprietary databases. Some thermodynamic analyses and diagrams were also calculated with HSC Chemistry 7.1 (Outotec Corp., Finland).

It is not possible to gather and present the most complete information about specific ferroalloys or details about their processing: many such features are plant or mine specific and might not be valuable for general use. Therefore, the book's philosophy is to present knowledge about general ferroalloys worldwide, along with sufficient details for practical use, rather than focusing on the thermodynamics for reducing specific oxides or the like (this information can be easily found in other metallurgy books and conference proceedings).

The materials in this book are also intended to help students, plant engineers, managers, and researchers in the fields of electrometallurgy, mining, and steelmaking to obtain a basic knowledge of the theory and technology of smelting different ferroalloys in accordance with the modern world practice and scientific level of development.

ACKNOWLEDGMENTS

As the editor of this book, I would like to acknowledge the enormous support received from all contributors and my colleagues at Aalto University, especially Dr. Y. Bilotsky, Dr. A. Lokkiluoto, Lic. Tech., and M. Malinina, and to thank them for their valuable assistance in materials gathering and preparation. Special thanks also to Outotec Corp. (Finland) and the Foundation of Helsinki University of Technology, which provided the financial support that made this book possible.

Michael M. Gasik

Espoo, December 2012

REFERENCES

Durrer, R., Volkert, G., 1972. Metallurgie der Ferrolegierungen. 2. Auflage. Metallurgy of Ferroalloys, second edition. Springer-Verlag, 700 pp.

Gasik, M.I., Lyakishev, N.P., 2005. Physical chemistry and technology of electro-ferroalloys, Systemnye tekhnologii. Dnepropetrovsk, Ukraine, 448 pp.

Holappa, L., Xiao, Y., 2004. Slags in ferroalloys production – review of present knowledge. Journal of the South African Institute of Mining and Metallurgy 104, 429–437.

Tanaka, K., 2008. Assessment of energy efficiency performance measures in industry and their application for policy. Energy Policy 36, 2887–2902.

Wood, E., Owen, M., 2005. Ferro-alloy directory. Metal Bulletin plc, 13–97.