

Chapter 13

Modeling of Steelmaking Processes

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ABSTRACT

In the field of experiment, theory, modeling and simulation, the most noteworthy progressions applicable to steelmaking technology have been closely linked with the emergence of more powerful computing tools, advances in needful software's and algorithms design, and to a lesser degree, with the development of emerging computing theory. These have enabled the integration of several different types of computational techniques (for example, quantum chemical, and molecular dynamics, DFT, FEM, Soft computing, statistical learning etc., to name a few) to provide high-performance simulations of steel-making processes based on emerging computational models and theories. This chapter overviews the general steps and concepts for developing a computational process model including few exercises in the area of steel making. The various sections of the chapter aim to describe how to developed models for various issues related to steelmaking processes and to simulate a physical process starts with the process fundamentals. The examples include steel converter, tank vacuum degassing, and continuous casting, etc.

1. INTRODUCTION

Computational models are nowadays increasingly accepted in steel industry to simulate metallurgical processes, such as converters, ladle treatments, continuous casting etc. These models are typically used for process designing, process optimization, process control, forecasting etc. All these day to day largely perfumed industrial metallurgical processes are obviously involved many complex physicochemical reactions. A lot of specific single models for this field have been evolved for specific purposes (Yu & Louhenkilpi 2013; Yu, Miettinen & Louhenkilpi 2013; Yu, Miettinen, & Louhenkilpi n.d.; Yu, Miettinen, & Louhenkilpi 2014; Miettinen, Louhenkilpi & Holappa 1996; Braun & Pfeifer 2007; Louhenkilpi et. al 2005; Clark, Wagner & Troussset 2003; Sahai & Emi 1996; Mazumdar, Yamanoglu & Shankarnarayanan,

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& Guthrie 1995; Kuzmin & Turek 2004; Chakraborty & Sahai 1991), and stochastic and/or hybrid nature of models based on physicochemical laws but including these non-physical features.

In the very recent times, more attention has been attracted on developing real-time models which can be available for on-line use in industry for development of reliable process control system (Louhenkilpi, Laitinen & Nieminen 1993; Louhenkilpi et al 2005a; Louhenkilpi et al 2005b). Real-time calculation of an industrial process offers many new possibilities in on-line process control (Allendorf et al 1998). In real-time calculation, many practical requirements will be set for the model. The computing time must, for instance, be short enough and special process conditions must be included in the model. Due to the increasing power of modern computers available, the requirements concerning the computing time can today, however, be met more and more easily.

For developing a comprehensive process model, the modelers and group must have multiple skills: good knowledge about the process to be modeled, must know the general modeling principles including the numerical methods and they must have wide knowledge about thermodynamics, metallurgical kinetics, and transport phenomena. Moreover, they should have needful expertise in the area of modern computational science. One challenge is the coupling of the thermodynamic and kinetic models with transport modeling as with CFD (Väyrynen & Wang 2010; Vapalathi et al 2006; Thomas & Najjar 1991). The other bottleneck is the determination of time when a process phenomena changes from one length scale to another length scale such as atomic regime to molecular or molecular regime to microstructural regime and modeling the interface of the two process over different length scale (Introduction 2005; Kruskopf et al 2012).

This chapter targets to present the overviews of the fundamentals of how to develop a comprehensive metallurgical process model pertinent to the complex industrial situation. The specific focus of the chapter is on the steel making processes only. The fundamental concepts of modeling, modeling techniques and the basic steps for developing a computational process model followed by heat transfer and mass transfer simulation examples are described in the first few sections. Nevertheless, the latter part of the chapter focuses on the mathematical modeling of few important processes in steel making technology. The mathematical model of BOF converter steel making process is discussed. A comprehensive discussion on BOF simulator CONSIM (Kruskopf et al 2012) is also highlighted. The methods of mathematical modeling of degassing process, continuous casting of steel, and solidification and microsegregation of steel along with few more issues in steel making process modeling has been exemplified.

2. FUNDAMENTALS OF MODELLING TECHNIQUES IN STEELMAKING PROCESSES

2.1 General Classification of Modeling Techniques Used in Steel Making Process

There are many kinds of models and modeling concepts implemented in steel industries for modeling various metallurgical processes in steelmaking. They can be grouped broadly into three major classes:

1. **Empirical/Statistical Models**
 - a. Based on observations and/or measurements
 - b. A lot of experimental data are usually needed (for data analysis)

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