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Editorial

Advanced Simulation Technologies of Metallurgical Processing

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1. Introduction and Scope

Although the design and performance of metallurgical processes are still carried out on an experimental basis, numerical methods and simulation software—either commercial or open-source—have developed into a standard for these processes. The applications of numerical tools are as diverse as design, analysis, performance, improvements, or optimization. Thus, simulation technology has evolved into an indispensable cornerstone and complementary approach to experimental work. The numerical methods for metallurgical processes nowadays cover a wide domain of applications such as multiphase flow, multi-physics processes, computational material engineering, optimization, and process simulation. The detailed and vast amount of simulation data allows a thorough analysis of the relevant processes and their interactions that reveal the underlying physics. A deep understanding is of critical importance for process design and performance.

2. Contributions

A total of fourteen articles have been published in the Special Issue of Metals entitled "Advanced Simulation Technologies of Metallurgical Processing", addressing a variety of key research areas. They cover a large range of both time and length scales, clearly emphasizing the multi-physics aspects of metal processing. Consequently, contributions cover heat transfer processes that interact intensively with the fluid dynamics during casting with its subsequent solidification behavior, evolving structures on a micro-scale with their impact on material characteristics/performance and analyzing the operation of various processes during metal processing for improved properties. Metallurgical processes generally cover a wide range of tightly linked length scales which currently are not covered by computational methods due to limiting computer power. Therefore, scale-up algorithms based on similarity theorems, analyses through Bayesian networks or multivariable analytical models are of crucial importance.

Five articles address casting [1–5] and its inherently multi-physics aspects that involve a strong interaction between thermodynamics, multiphase fluid dynamics and electromagnetic effects.

The latter was found to strongly influence solute transport through secondary electromagnetic stirring in a linear and rotational mode [6]. Similarly, the importance of dynamic bath mixing was emphasized through investigations of different gas blowing schemes [7]. Segregation during steel casting is largely affected by heat transfer and may result in a rather non-uniform distribution of solutes. The distribution of solutes strongly impacts global performance parameters such as hardness.

Equally or even more important are processes on a micro-scale in the rapidly growing field of additive manufacturing, for which the modelling of process–structure–properties–performance is a key loop [8]. Again, additive manufacturing underpins both the multi-physics behavior and multi-scale aspects, because the grain structure after solidification determines the performance such as mechanical strength to a large extent and depends heavily on process conditions such as laser speed, power or hatch size [7–12]. Solidification was also addressed by a volume-averaged approach for multiphase flow during alloy solidification, indicating that a full 3D calculation with the multiphase volume-averaged solidification will be available in the not too far future due to the development in computer power. The Ruhrstahl–Heraeus (RH) treatment [13] involves also multi-phase flow for distributing aluminum in oriented silicon steel for advanced magnetic properties and was investigated under different super-heating conditions.

Since prediction of the fully coupled process in metallurgy is still not feasible due to limited computer power and sometimes appropriate simulation software, an alternative is to describe the global process on the most relevant length scales that aim at industrial applications. The latter were addressed by investigation heat insulation for an electromagnetic induction-controlled steel-teeming system. Carefully designed insulation contributes to the life time and endurance of induction coils for the EICAST technology. Further contributions dealt with splashing effects in a 200 t converter caused by an oxygen jet from a lance [14] and the open eye area in a gas-stirred ladle.

3. Conclusions and Outlook

Although numerical tools with their advanced simulation technologies have developed into a daily routine for engineers, many phenomena in metallurgical processing are still far from being completely understood. In particular, the multi-physics aspects spanning large time and length scales pose a veritable challenge to the community [15]. Despite a tremendous growth in computational resources and high-performance computing, the computational power of the biggest computers is still not sufficient to cover length scales from a molecular level to the dimensions of work pieces, not mentioning the equally large spectra of time scales. Therefore, the community has to resort to the large research domain of multi-scaling [16]. Advanced and improved algorithms are required that embed phenomena on smaller scales into larger scales. Similarly, the multi-physics character of these and various other applications has to be addressed through cutting edge technologies in high performance computing [17] by coupling different software modules, each representing a particular physical aspect, and organizing a data exchange with a minimal communication overhead.

Conflicts of Interest: The author declares no conflict of interest.

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