Metal Smelting and Furnace Tapping

DEAN GREGUREK,^{1,5} ZHIWEI PENG,^{2,6} CHRISTINE WENZL,^{3,7}
and JESSE F. WHITE^{4,8}

1.—RHI AG, Technology Center Leoben, Magnesitstrasse 2, 8700 Leoben, Austria. 2.—School of Minerals Processing and Bioengineering, Central South University, Changsha 410083, Hunan, China. 3.—RHI AG, Wienerbergstrasse 9, 1100 Vienna, Austria. 4.—Elkem Carbon AS, 4675 Kristiansand, Norway. 5.—e-mail: dean.gregurek@rhi-ag.com. 6.—e-mail: zwpeng@csu.edu.cn. 7.—e-mail: christine.wenzl@rhi-ag.com. 8.—e-mail: jesse.white@elkem.no

The present topic “Metal Smelting and Furnace Tapping” provides *JOM* readers with an interesting update on these high-temperature pyrometallurgical processes.

Metal smelting is a fundamental process in pyrometallurgical metal production. The process parameters and furnace operating conditions need to be adjusted and optimized for the individual process, covering a wide range for the various metals due to their differences in properties and final product requirements. Additionally, the furnace operators and metallurgists have to handle varying input materials, due to availability of raw materials, as well as changes in ore and scrap compositions (i.e., content of accompanying elements, new materials). The main goal is to achieve sufficiently high product quality, as well as efficient and safe process operations.

Safety is a key issue in all high-temperature processes as applied in pyrometallurgy: these processes generally always involve liquid, high-temperature process phases that in case of incidents represent an imminent hazard for the furnace personnel and also the environment. The aim is to safely contain the process phases and tap the produced metal and slag phases in a controlled manner. Therefore, tapping operations and tap-hole design are of vital importance, as this procedure involves the creation of a hole in the furnace shell and high-temperature fluid flow, hence establishing the contact between the contained high-temperature phases and the environment.

In the first paper titled “Preparation of Al-Si Master Alloy by Electrochemical Reduction of Lunar Soil Simulant in Cryolite Molten Salt”, Aimin Liu

et al. propose a electrochemical method for the preparation of an Al-Si master alloy from a Chinese volcanic rock similar to Apollo lunar soils. The alloy is produced using a 52.7 wt.% NaF-47.3 wt.% AlF₃ melt with addition of 5 wt.% volcanic rock. The electrochemical process and produced alloy were thoroughly studied, showing that it is possible to produce an alloy of 90.5 wt.% aluminum, 4.4 wt.% silicon, 1.9 wt.% iron, and 0.2 wt.% titanium comprising the phases Al, Si, Al₅FeSi and Al₃Si_{0.47} with this process.

The next contribution is an example of how materials formerly considered as not processable become the source of valuable products by new developments in smelting technology. The paper titled “Bog Manganese Ore: A Resource for High-Manganese Steel Making” by Swatirupa Pani et al. characterizes the properties of manganese ore from the banded Iron Formation of the Iron Ore Group (IOG), the largest deposits in northern Orissa, India. This ore is generally difficult to process and is considered as waste, but the authors describe a novel possible process for the recovery of Fe and Mn using a plasma furnace. This process would allow the production of a valuable product from a material that until now has not been considered as suitable for processing.

With the increasing complexity of process routes and process intensity, it becomes more and more important to get an overview of the interrelationships of the processes and influences of various process parameters. One approach is the statistical evaluation of process data to create suitable models for process optimization. The next paper, “Meta-modeling and Optimization of Blister Copper Two-Stage Production Process,” by Piotr Jarosz et al. deals with modeling approaches for the description of copper production in a double-flash route, namely flash smelting and flash converting. Three different methods (i.e., artificial neural networks, support

Dean Gregurek, Zhiwei Peng, and Jesse F. White are the *JOM* advisors for the Pyrometallurgy Committee of the TMS Extraction & Processing Division, and, along with Christine Wenzl, are the guest editors for the topic Metal Smelting and Furnace Tapping in this issue.

vector machines and random forests) are compared with regard to their suitability to model the processes based on real process data including a certain noise portion. Then, the best-suited methods were used to attempt to optimize the whole process, namely the definition of the optimal set of control parameters for the smelting and subsequently for the converting stage.

Stricter requirements for final product quality for the respective applications require new, advanced processes for achieving these. One example are pyrometallurgical techniques that should guarantee low impurity levels in the main metal to be produced, also under the aspect of minimum impact on the environment regarding emissions and by-products. The next paper by Longgang Ye et al. entitled “Separation of Lead from Crude Antimony by Pyro-Refining Process with NaPO_3 Addition” investigates a novel refining method for antimony, namely the removal of lead from crude antimony by an oxidative pyrorefining process. NaPO_3 is used as the lead elimination reagent. It was found that in this refining process a certain amount of sulfur, cobalt and silicon can also be removed, hence suggesting that NaPO_3 is also a potential lead elimination reagent for bismuth and copper refining processes.

Tap-holes are an important furnace feature and a high-risk area due to the frequently repeated procedure of opening and closing. As incidents in this area can have disastrous consequences, the design and maintenance of tap-holes is a crucial factor. In the paper “Tap-Hole Life Cycle Design Criteria—A Case Study Based on Silicomanganese Production”, Joalet Dalene Steenkamp et al. describe the challenges for the proper managing of furnace tapping, exemplarily studied on a silicon manganese furnace. Design criteria for the life-cycle of the tap-hole are proposed, not only for complete relines and normal operation including frequent opening and closing but also in case of emergency situations. Furthermore, tap-hole maintenance and repair are discussed, with the general aim of minimizing the risks associated with tap-hole failure.

Lancing with oxygen is a common practice to open furnace tap-holes, especially the innermost part of the tapping channel, namely close to the liquid

phases inside the furnace. Oxygen lancing is mostly carried out manually and involves high temperatures at the lance tip, hence the lancing operations are a vital factor for tap-hole refractories' performance and lifetime, and additionally influence the process inside the furnace. Markus Wouter Erwee et al. describe models for oxygen lancing in the last paper, “A Comparison of 2D And 3D Computational Multiphase Fluid Flow Models of Oxygen Lancing of Pyrometallurgical Furnace Tapholes”. They present a comparison of 2D and 3D modeling of the fluid flow involved in oxygen lancing and how the lancing operations affect the various aspects of furnace operation.

The following papers being published under the topic of Metal Smelting and Furnace Tapping provide excellent details and research on the subject. To download any of the papers, follow the url <http://link.springer.com/journal/11837/68/6/page/1> to the table of contents page for the June 2016 issue (vol. 68, no. 6).

- “Preparation of Al-Si Master Alloy by Electrochemical Reduction of Lunar Soil Simulant in Cryolite Molten Salt” by Aimin Liu, Zhongning Shi, Junli Xu, Xianwei Hu, Bingliang Gao, and Zhaowen Wang.
- “Bog Manganese Ore: A Resource for High-Manganese Steel Making” by Swatirupa Pani, Saroj K. Singh, and Birendra K. Mohapatra.
- “Metamodelling and Optimization of Blister Copper Two-Stage Production Process” by Piotr Jarosz, Jan Kusiak, Stanisław Malecki, Paweł Morkisz, Piotr Oprocha, Wojciech Pietrucha, and Łukasz Sztangret.
- “Separation of Lead from Crude Antimony by Pyro-Refining Process with NaPO_3 Addition” by Longgang Ye, Yuejie Hu, Zhimei Xia, and Yongming, Chen.
- “Tap-Hole Life Cycle Design Criteria: A Case Study Based on Silicomanganese Production” by J.D. Steenkamp, J.J. Sutherland, D.A. Hayman, and J. Muller.
- “A Comparison of 2D and 3D Computational Multiphase Fluid Flow Models of Oxygen Lancing of Pyrometallurgical Furnace Tap-Holes” by M.W. Erwee, Q.G. Reynolds, and J.H. Zietsman.