Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 27(2017) 946−953
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Copper smelting mechanism in oxygen bottom-blown furnace

Qin-meng WANG, Xue-yi GUO, Qing-hua TIAN

School of Metallurgy and Environment, Central South University, Changsha 410083, China

Received 22 July 2016; accepted 23 February 2017

Abstract: The SKS furnace is a horizontal cylindrical reactor similar to a Noranda furnace, however, the oxygen enriched air is blown into the furnace from the bottom. Mechanism model of the SKS process was developed by analyzing the smelting characteristics deeply. In our model, the furnace section from top to bottom is divided into seven functional layers, i.e., gas layer, mineral decomposition transitioning layer, slag layer, slag formation transitioning layer, matte formation transitioning layer, weak oxidizing layer and strong oxidizing layer. The furnace along the length direction is divided into three functional regions, that is, reaction region, separation transitioning region and liquid phase separation and settling region. These layers or regions play different roles in the model in describing the mechanism of the smelting process. The SKS smelting is at a multiphase non-steady equilibrium state, and the oxygen and sulfur potentials change gradually in the length and cross directions. The smelting capacity of the SKS process could be raised through reasonably controlling the potential values in different layers and regions.

Key words: oxygen bottom-blown copper smelting; mechanism; multiphase equilibrium; oxygen potential; sulfur potential; SKS process

1 Introduction

Copper metallurgy plays a significant role in nonferrous metals industry, and research and development on new pollution-free and high efficient copper extractive techniques are the developing direction, with unceasingly reducing copper ore grades, increasingly complex concentrates components and more stringent environment protection laws and regulations [1]. Oxygen bottom-blown smelting is a newly developed intensified smelting technology after the Noranda smelting, Outokumpu flash smelting, Teniente smelting, Mitsubishi smelting, Ausmelt/Isa smelting, Baiyin smelting, etc [2]. Significant advantages of the technology mainly come from its bottom blowing techniques, and its intellectual property right belonging to China completely [3].

Oxygen bottom-blown smelting process was firstly tested on the Shuikoushan smelter and was named as SKS smelting technology originally. At present, this process has been widely used in lead [4], copper [5] and antimony [6] smelting. In China, the first commercial oxygen bottom-blown copper smelting furnace was installed and operated at Dongying Fangyuan Nonferrous Metals, Co., Ltd., in 2008 with a capacity of 5×10^4 t/a cathode copper initially and being expended to 1×10^5 t/a cathode copper in 2010 [7]. The technology comes into a rapid development stage, and has been successfully applied in Shandong Hengbang Smelter, Inner Monggol Huading Smelter, Zhongtiaoshan Smelter, Henan Yuguang Smelter, Zhongyuan Gold Smelter, etc [8].

Many scholars, such as YAZAWA [9], SERGEI and ARTHUR [10], SRIDHAR et al [11], NAGAMORI and MACKEY [12] and MACKEY [13], have discussed the thermodynamics of copper smelting. And some researches on SKS process have also been reported during the past decade, including fluid dynamics and slag chemistry. ZHANG et al [14,15] analyzed gas−liquid multiphase flows in SKS furnace to optimize the lance structure parameters in CFD method. CHEN et al [16] studied the slag chemistry of bottom-blown copper smelting furnace at Dongying Fangyuan, and analyzed copper losses in industrial smelting slag which is significant to increase copper recovery. But no papers on investigating the reaction mechanism of the commercial furnaces have been published. Therefore, in this work, a mechanism model of the SKS process was constructed by analyzing smelting process deeply, combined with related theories of copper pyrometallurgical

Foundation item: Project (51620105013) supported by the National Natural Science Foundation of China
Corresponding author: Xue-yi GUO; Tel: +86-731-88877863; E-mail: xyguo@csu.edu.cn
DOI: 10.1016/S1003-6326(17)60110-9

thermodynamics [9−13] and dynamic characteristics of the flow field [14,15] in the SKS furnace. In this model, multiphase and multicomponent mass transfer behaviors between interfaces were analyzed at different space points in the smelting furnace. This study focuses on the mechanism of SKS process to provide deep understanding and theoretical guiding for operation practices, technology upgrades and overseas application.

2 Oxygen bottom blown copper smelting process (SKS Process)

2.1 Equipment

The structure of the first commercial SKS furnace is shown in Fig. 1.

The furnace of the SKS process is a horizontal cylindrical reactor similar to a Noranda furnace or a Teniente furnace. The size of the furnace is *d*4.4 m × 16.5 m and it is lined with 380 mm thick chrome−magnesia bricks. Nine oxygen lances are installed at the bottom of the furnace to blow oxygen-enriched air into the molten bath. The nine oxygen lances are arranged in two rows at the bottom. The lower row with 5 lances is located 7° from the vertical axis and the upper row with 4 lances is located 22° from the vertical axis [17].

2.2 Raw materials and products

According to the requirement for feed compositions, copper concentrates first are mixed with silicon oxide flux. Then the mixed feed materials are directly added into the furnace from the top feed port without grinding, drying or pelleting. The chemical composition of the mixed feed materials is listed in Table 1.

This process produces high-grade matte, and moderate copper-content slag. The chemical compositions of the matte and slag are listed in Table 2.

2.3 Process characteristics

Oxygen-enriched air is constantly blown into matte layer from the bottom of the furnace through the lance, split into tiny flows at high speed, and dispersed in melt mass, as shown in Fig. 2. The gas and liquid contact sufficiently, which strengthens the reacting efficiency in the smelter [14,15]. The oxidizing and slagging reactions take place vigorously in the furnace. The smelting process carries on continuously, but the slag and matte are tapped intermittently.

The oxygen bottom-blown copper smelting process has demonstrated significant advantages compared with other copper pyrometallurgical processes [17,18]. The batch process is simple, and the furnace could process a variety of feed materials, including low-grade complex ores. The heat generated from oxidization of sulphur and iron is sufficient enough to maintain the required bath smelting temperatures, which shows high energy utilization efficiency of the process. The SO_2 could not leak off the furnace due to the negative operating pressure (50−200 Pa lower than atmospheric pressure), so the working environment is clean. The "foaming slag" is difficult to form in the furnace, so the operation is uncomplicated.

3 Mechanism analysis and discussion

Mechanism model of the SKS process was constructed by deeply analyzing smelting process and dynamic characteristics of the flow field in the SKS furnace, combined with related theories of copper metallurgical thermodynamics. Mass transfer behaviors of multiphase multicomponent through the interface between different phases were analyzed, and the SKS mechanism modeling results on cross section and longitudinal section were shown in Figs. 3 and 4, respectively.

3.1 SKS mechanism modeling on cross section and mass transfer behavior

Mixed concentrates are directly added into the SKS furnace from the top feed port, and oxygen-enriched air

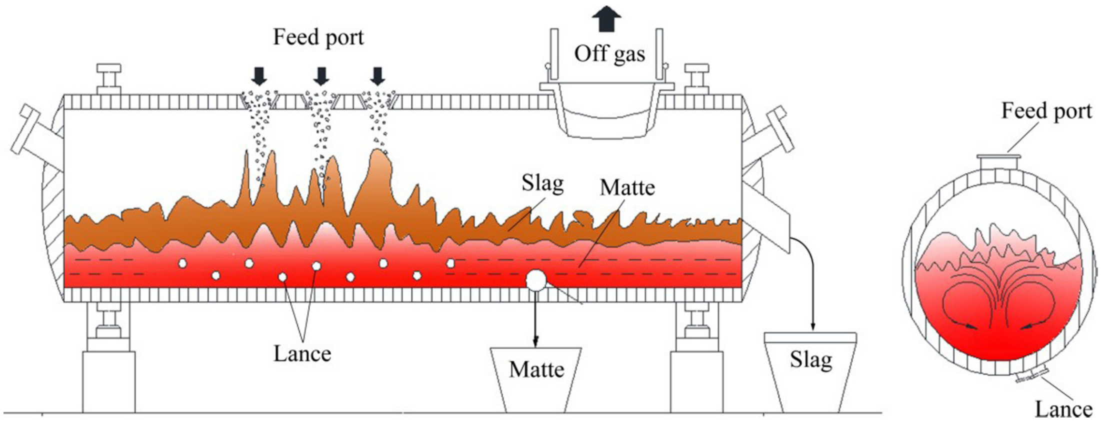

Fig. 1 Schematic diagram of SKS furnace