CHAPTER I

INTRODUCTION

Copper is an excellent conductor of electricity and heat and can be easily worked into wire, rod and cable. According to such useful properties, copper has been one of the important commodities which are mostly consumed in electrical and electronic products, building construction, industrial machinery and equipment, transportation, and consumer and general products. In addition, copper is alloyed with various metals (e.g., zinc, tin) which are used in the production of tubing, brass, and bronze products.

In the production of copper for either domestic consumption or export, most producers generate full plate copper cathodes as a final product from the complex manufacturing process consisting of smelter and refinery units. The full plate copper cathodes are normally marketed via the LME and Comex if the cathode product meets the chemical and physical standards. However, some producers ship their output as wire-bar to hot rolling mills and a few specialized producers provide copper powders plus bronze and brass alloys.

1.1 Production of copper cathode

The ore usually containing less than 1% copper is used as a raw material for the production of copper. It is mined in open pits or underground production units. In general, the ore obtained is then ground and floated with water and chemical reagents in order to extract the copper. The concentrated copper is then used for subsequently smelting processes.

1.1.1 Pyrometallurgy

Pyrometallurgy is one of two processing methods used to refine or smelt a concentrated copper with copper sulfide and iron sulfide minerals. In this process, the concentrated copper is dried and fed into a furnace with oxygen and air for the reactions and silica for fluxing. The minerals are partially oxidized and melted at temperature over 1250°c, resulting in segregated layers. The matte layer refers to the iron-copper sulfide mixture which sinks to the bottom due to its higher density. The slag, which refers to the remaining impurities, floats on top of the matte. The slag is discarded on site or sold as railroad ballast and sand blasting grit. Sulfur dioxide gases are also collected and made into sulfuric acid

In general, the matte is tapped out and transferred to the converter, a long cylindrical vessel into which the copper is poured. Air, lime and silica are added to react with the metal oxide. Scrap copper may also be added as a coolant inside the furnace. Iron slag is removed and often recycled back into the furnace. Sulfur dioxide is captured and converted into sulfuric acid. The converted copper, known as "blister copper", is recovered.

The blister copper then undergoes fire refining. Air and natural gas are blown through the copper to remove any remaining sulfur and oxygen. The copper is cast into copper anodes and placed in an electrolytic cell. Once charged, the pure copper collects on the cathode and is removed with over 99.99% purity.

1.1.2 Hydrometallurgy

Another method for refining copper is through the hydrometallurgical process. This process begins with oxidized copper ores or oxidized copper wastes. The oxidized material is leached with sulfuric acid from the smelting process. The sulfuric acid is percolated through piles of oxidized metal and collected with acid resistant liners.

Solvent extraction is more commonly used to refine copper. An organic solvent in which copper is soluble is introduced. As the copper is more soluble in the organic layer than the aqueous phase, it enters an organic-copper solution and is separated. Sulfuric acid is added to strip the copper from the organic solvent into an electrolytic solution.

1.2 Pyrometallurgy of copper

The general description of smelting processes varies with respect to the charge materials, process, operation parameters and technology of furnace. For the El Teniente bath smelting technology, studied in this work, a general process of copper

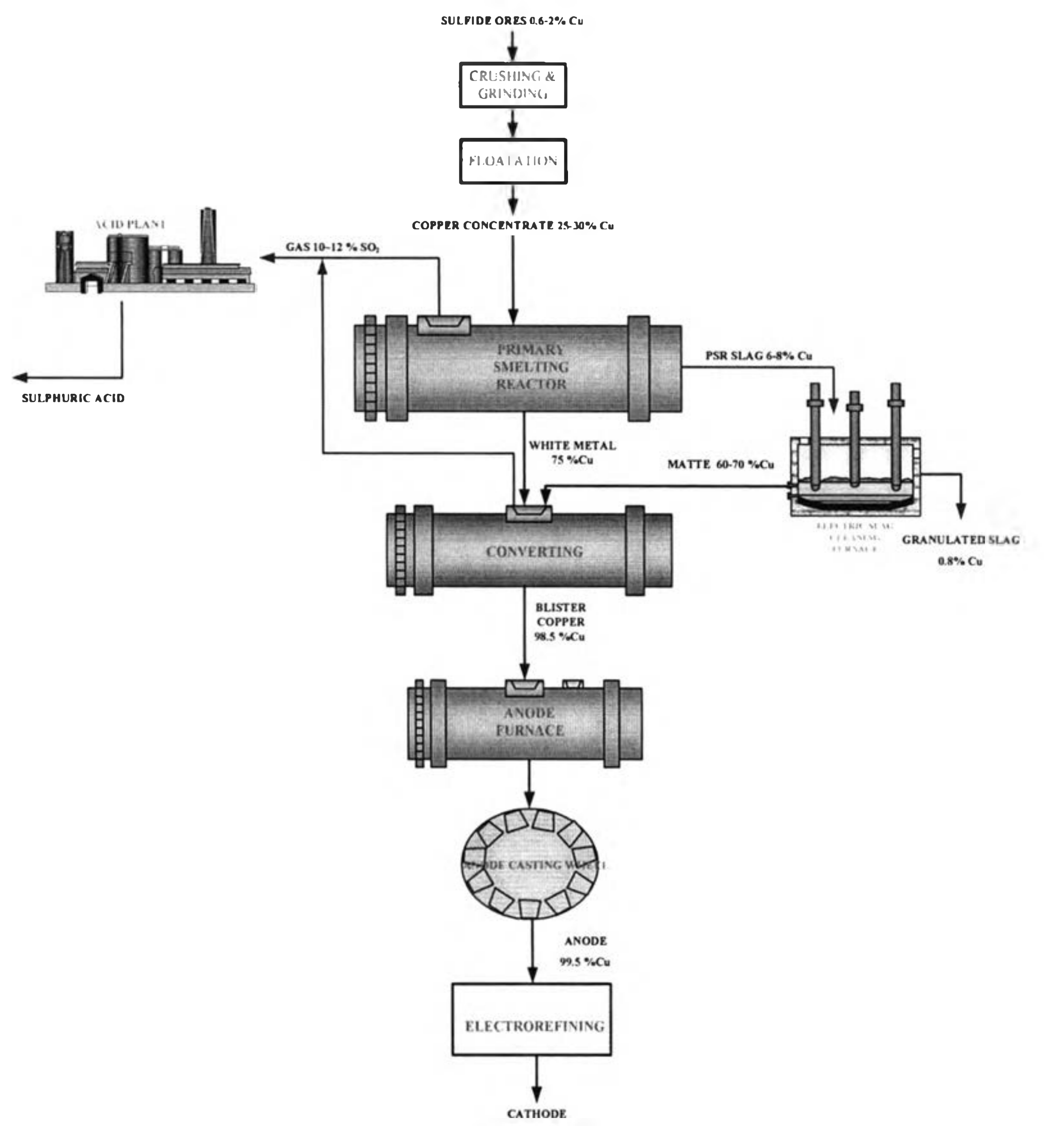

Figure 1-1: Processes for extracting copper from sulfide ores which using El Teniente Technology

cathode production can be illustrated in Figure 1-1. The raw materials in this process are copper sulfide concentrates which are obtained from various sources around the world such as Chile, Australia, etc. Copper concentrates are mixed with revert materials and dried flux, and smelted to a high-grade matte (75% copper, called "white metal") in a continuous Primary Smelting Reactor (PSR). The high-grade matte is converted in batches to blister copper, fire refined, and casted into anodes for electrorefining. Anodes, containing approximately 99.5% copper, are refined to copper cathodes of LME (99.995% copper). By-products of these processes consist of sulfuric acid and refinery slimes that contain the precious metals (e.g., Silver, Gold) which are originally contained with the raw material. Another by-product is the discarded slag which could be granulated or cooled down and broken to larger particles. It can be sold out for cement-making plant or road and building construction because of its high iron content.

The production of copper anode through this smelting process consists of four types of furnace: Primary Smelting Reactor (PSR), Electric Slag Cleaning Furnace (ESCF), Hoboken Syphon Converter (HSC), and Anode Furnace (AF). It is noted that this technology is also known as the Teniente smelting process because the PSR used in the process perform the function in the same way as El Teniente converter.

1.3 Teniente converter technology

Teniente converter (TC) smelting technology was developed in Chile during the 1970's, at the Caletones Smelter. Other similar Teniente converters are being operated at Chuquicamata, Potrerillos, Las Ventanas and Hernan Videla Lira Smelters in Chile and at Nkata Smelter in Zambia, Ilo Smelter in Peru and La Caridad Smelter in Mexico (Moskalyk *et al.*, 2003). In Thailand, the Teniente converter was installed in 1995 at Thai Copper Smelter in Rayong.

This technology basically makes use of the energy generated by copper matte oxidation (exothermic reaction) inside the converter to bring about the decomposition of the concentrate mineralogical components (endothermic reaction) and to obtain a high grade matte or "white metal". It consists of a continuous smelting-converting process based on the bath smelting technology. In general, to improve the energy balance, industrial oxygen is used to enrich the air that is blown under the bath surface through the tuyeres.

Figure 1-2 shows the detailed configuration of a primary smelting reactor, the main unit in the smelting process. Oxygen-enriched air (about 36% oxygen) is injected into the reactor to promote oxidation reactions. In order to operate the PSR efficiently, attaining the designed product quality (75% Cu in white metal and iron to silica ratio of 1.40 in PSR slag) and the required production capacity of the plant, it is very important to control the process parameters such as oxygen enrichment

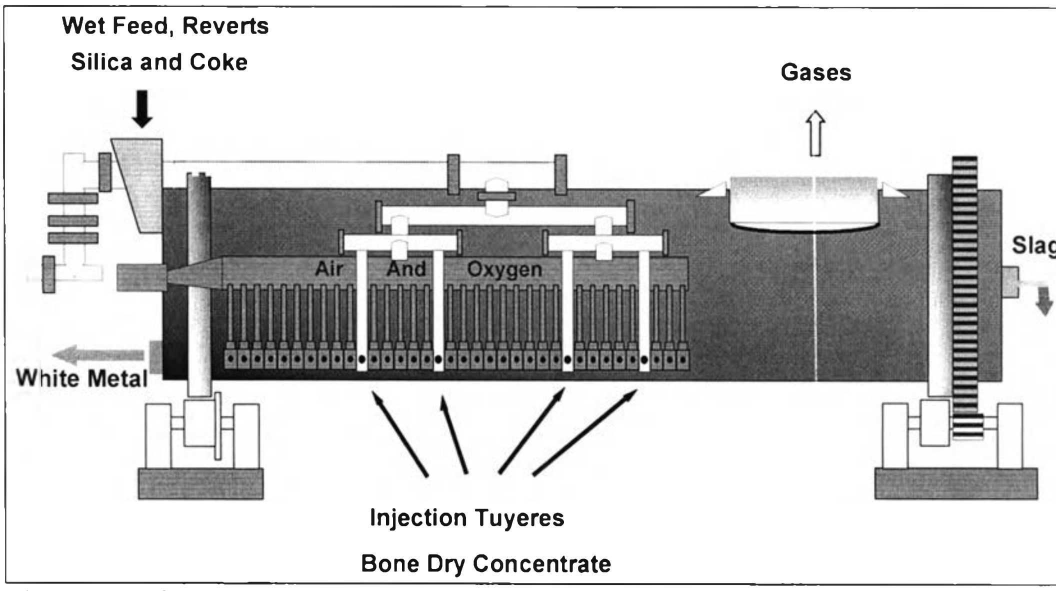

Figure 1-2: Schematic diagram of the Primary Smelting Reactor (PSR)

or sulfur content which affect thermal balance inside the PSR. It is noted that this process is generally known as autogenous smelting process since there is no external heat supplied but uses the heat energy generated from oxidation reactions.

There are other alternative processes for pyrometallurgical processing of copper in addition to the Teniente smelting process as previously mentioned. An example of other smelting technologies includes Outokumpu flash smelting, Mitsubishi continuous smelting and converting, Mt. Isa smelting, Ausmelt smelting, Blast furnace smelting, Reverboratory furnace smelting and Flame cyclone smelting. In addition, plant operations may be either be batch, semi-continuous, or fully continuous to produce blister copper or other end products.

Currently, about 25 billion pounds or 12 million tons of copper are produced worldwide by smelting copper sulfide concentrates. However, it has been known that major losses in a copper manufacturing process are found in a discarded slag.

Approximately, 400 million pounds of copper are discarded in the slag every year (Sridhar *et al.*, 1997). Therefore, the recovery of copper from the discarded slag is an important issue in order to increase the performance of a smelting process, resulting in a higher yield. To achieve this objective, there is a need to have a better understanding of the influences of operating parameters on the performance of a smelting reactor in order to operate the reactor efficiently and minimize copper losses in the of a copper smelting process.

1.4 Objectives

The purposes of this work are to model and simulate a primary smelting reactor (PSR), the first step and important reactor for smelting copper concentrates, using METSIM program and to study the effects of operating parameters on the performance of the PSR.

1.5 Scope of works

1. Develop models for the simulation of a primary smelting reactor by using METSIM program and compare the results with plant data.
2. Study the effects of operating parameters such as copper concentrate feed rate, oxygen and blowing air flow rate, flux flow rate and revert feed rate which are related to controlled process parameters such as %Cu in white metal, %Cu in slag, %Magnetite in slag, %Silica in slag, and reactor temperature.
3. Study the effect of different chemical compositions in copper concentrates, which are the main raw material, on the performance of the PSR.