Process Modeling of Nickel-Copper Matte Leaching – High Pressure Conditions

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Abstract

This article deals with modeling and simulation of high pressure leaching process of nickel-copper matte, with the perspective of getting insight on its operability. The modeling of this process was performed on a computer simulation package known as Aspen Plus, mainly to investigate the behavior of the process when flow rates and operating conditions are subjected to vary. For the nature of leaching process during the operation stage, the leaching mechanism of the matte is explained. Through simulation the effects of oxygen flow rate, operating temperature, and acid concentration were investigated. For optimal conditions of temperature, sulfuric acid concentration, and oxygen flow rate 75% of nickel, 18% of iron, 28.2% of copper, 12.5% of cobalt and 5% of zinc are extracted.

Key words: Nickel-copper matte, high pressure leaching process, computer simulation.

1. Introduction

Nickel is a chemical element with multitude forms of usage: coinage, armor plating, catalyst, it is also used in ceramics, magnets and batteries. Nickel is commonly found in iron meteorites as the alloys kamacite and taenite. Nickel ores are of two types [1]: (1) Primary sulphide deposits associated with mafic and ultramafic rocks, (2) Near-surface laterite deposits formed over olivine-rich host rocks following intense weathering. The sulphide ores have been the major source of nickel; however, the lateritic ores have been estimated to constitute about 73% [2] of the known nickel reserves of the world.

Traditionally pyrometallurgical process was used to produce nickel; with depletion of high-grade sulphide ores, a high pressure acid leaching process (HPAL) process has been developed and sounds environmentally attractive [3]. In the leaching process of Ni-Cu matte two process routes are often used: first leaching process route employs a pre-leach step, which is essentially a matte pulping step prior to atmospheric leach step; the second one involves both atmospheric and pressure leaching in acidic nickel-copper sulphate solution,

with oxygen being the oxidizing agent. In this study case, the matte is first leached under atmospheric conditions followed by a high pressure leach step, and in both steps O_2/air is splashed into the leaching vessels. Figure 1 illustrates Ni-Cu matte leaching process [4].

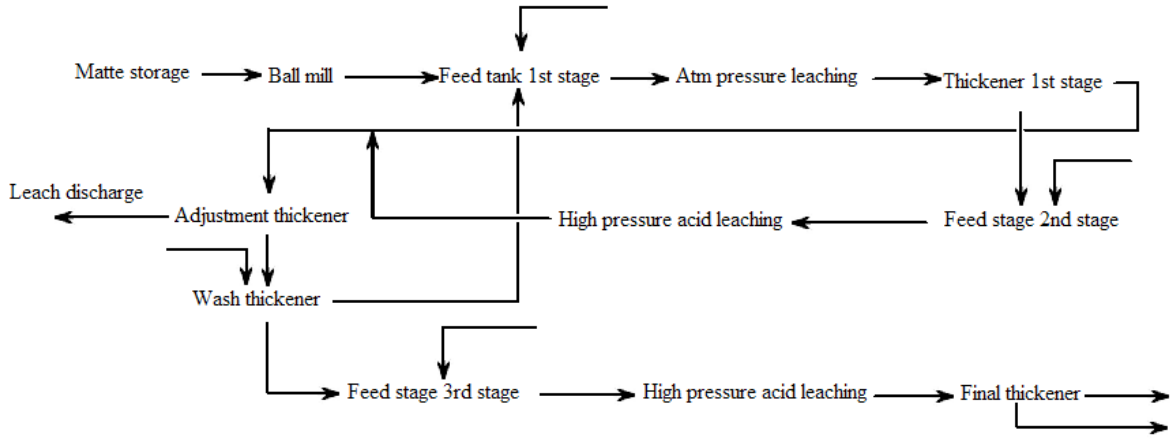

Figure 1. Schematic process flow sheet of Nickel refinery leaching process

2. Leaching mechanism

During atmospheric and pressure leaching processes in acidic nickel-copper sulphate solution, the reacting system is a much more complex series-parallel reaction network involving metal oxidations and progressive oxidation of sulfides. For pulping process, when the pulping solution includes copper sulphate, copper sulphate may induce a cementation process where metallic nickel is leached according to reaction 1. The dissolution of metallic iron is believed to proceed according the well-known reaction of cementation of copper by metallic iron [4, 5], reaction 2.

The other possible reactions are the leaching of mineral sulphides by the sulphuric acid, reactions 3 through 5. In the presence of air the minerals are leached through an oxidative dissolution in the sulphuric acid, reactions 6 through 9.

$$Ni^0 + CuSO_4 \rightarrow Cu^0 + NiSO_4 \quad (1)$$

$$Fe^0 + CuSO_4 \rightarrow Cu^0 + FeSO_4 \quad (2)$$

$$NiS + H_2SO_4 \rightarrow NiSO_4 + H_2S \quad (3)$$

$$FeS + H_2SO_4 \rightarrow FeSO_4 + H_2S \quad (4)$$

$$Cu_2S + H_2SO_4 \rightarrow Cu_2SO_4 + H_2S \quad (5)$$

$$Ni(s) + H_2SO_4 + \frac{1}{2}O_2 \rightarrow NiSO_4 + H_2O \quad (6)$$

$$Fe(s) + H_2SO_4 + \frac{1}{2}O_2 \rightarrow FeSO_4 + H_2O \quad (7)$$

$$2Cu(s) + H_2SO_4 + \frac{1}{2}O_2 \rightarrow Cu_2SO_4 + H_2O \quad (8)$$

For the leaching of metals by direct acid attack in the absence of an oxidant such as air or oxygen, some of the nickel, cobalt and copper from the alloys are believed to be leached by sulfuric acid according to the following reactions [5]:

$$Ni - Cu + 2H_2SO_4 \rightarrow NiSO_4 + CuSO_4 + 2H_2 \quad (9)$$

$$Ni - Fe + 2H_2SO_4 \rightarrow NiSO_4 + FeSO_4 + 2H_2 \quad (10)$$

$$Ni - Co + 2H_2SO_4 \rightarrow NiSO_4 + CoSO_4 + 2H_2 \quad (11)$$

3. Results and discussion

To model an autoclave of three compartments, three leaching reactors are arranged in series where the output from the first compartment serves as feed stream to the second one, and the output from the second compartment feeds the third. The analyze effect of changes in operating conditions, sensitivity analyses were performed; the results illustrated in Figures 2, 3 and 4 are produced from the first compartment of the autoclave modeled for this study case.

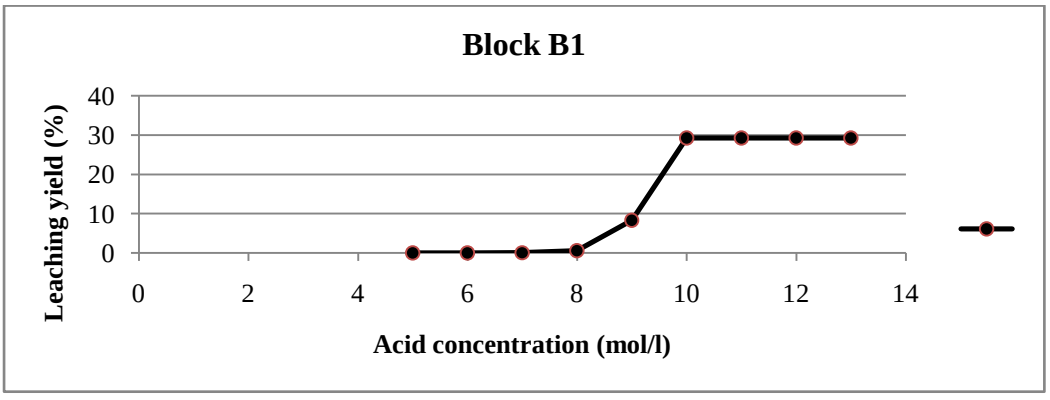

Figure 2. Effect of acid concentration on matte extraction

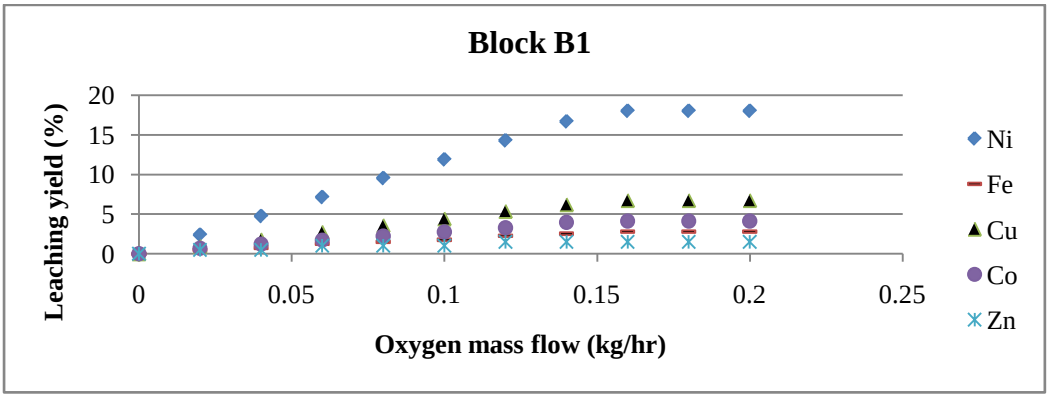

Figure 3. Effect of oxygen flow rate on the leaching yield

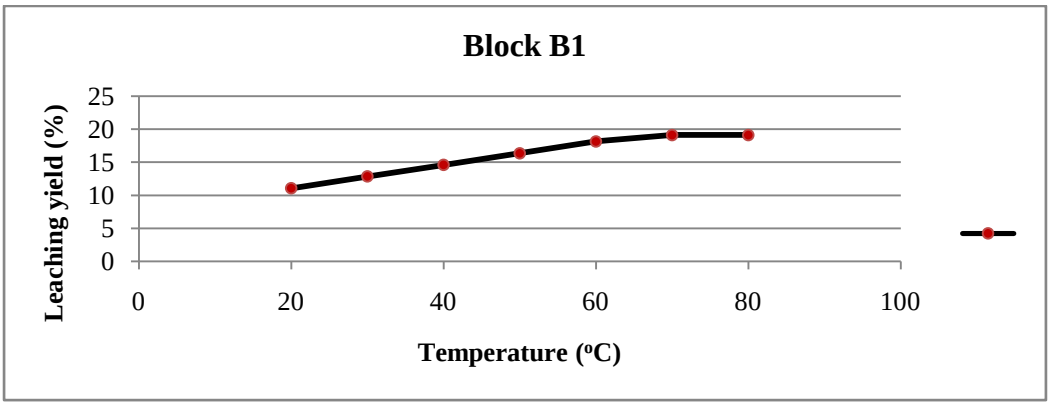

Figure 4. Effect of temperature on overall matte extraction

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