Hydrated Lime Roasting of Precious Metal Ores with A Cyclone Reactor

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Abstract :

The roasting of pyrite with a cyclone reactor have been studied in terms of investigating the reaction behavior of pyrite. The development of a fundamental model for pyrite oxidation and lime sulfation in a vertical cyclone reactor. The model assumes a chemical control shrinking core behavior for the pyrite and a fluid film control shrinking core behavior for the lime. The oxygen and sulphur dioxide concentrations and the energy balance for the gas, pyrite and lime particles are solved. The model was solved and characterized numerically. Experiments have been performed to study the influence of reaction parameters such as reactor temperatures, pyrite particle sizes, air flow rates, feeding rates, and mixing ratio of pyrite and lime. The oxidation and sulfation products were characterized chemically and physically.

ROASTING OVERVIEW

1. TECHNOLOGY NEEDED TO TREAT REFRACTORY PRECIOUS METAL ORES (CONTAINING ARSENIC AND SULFUR) IN AN ENVIROMENTALLY SAFE AND ECONOMIC MANNER
2. PRIMARY POTENTIAL PROCESSING CHOICES ARE:
   (1). ROASTING OXIDATION
   (2). AUTOCLAVE OXIDATION
   (3). BACTERIAL OXIDATION
3. ROASTING COULD BE THE CHEAPEST OF ALL THE PROCESSES IF METHODS FOR CONTAINING THE ARSENIC AND SULFUR ARE AVALIABLE
4. OXIDATION BY ROASTING MAY REQUIRE MINUTES, WHILE AUTOCLAVING TAKES HOURS AND BACTERIA TAKES DAYS
5. LIME ROASTING MAY PROVIDE THIS TECHNOLOGY

ROASTING CONSIDERATIONS

1. COMPLETE OXIDATION
2. MODERATE TEMPERATURES (600-700 C)
3. TEMPERATURE TOO HIGH (DUE TO SINTERING)
4. TEMPERATURE TOO LOW (DUE TO INCOMPLETE OXIDATION)
5. SULFUR DIOXIDE MUST BE RECOVERED TO MAKE ACID OR SCRUBBED
6. ARSENIC REQUIRES A SPECIAL RECOVERY SYSTEM AND MAY LACK A MARKET LEADING TO EXPENSIVE DISPOSAL COSTS

CHARACTERISTICS OF CYCLONE REACTORS

1. HIGH THROUGHPUT PER UNIT VOLUME
2. HIGH HEAT & MASS TRANSFER RATE
3. TREAT FINE PARTICLE WITHOUT AGGLOMERATION AND PELLETIZING PROCESS
4. CONTINUOUS PROCESS

OBJECTIVES

1. DESIGN, ENGINEER, AND OPERATE A CYCLONE REACTOR TO TREAT REFRACTORY GOLD ORES

2. CONDUCT EXPERIMENTS ON LIME ROASTING OF PYRITE IN A CYCLONE REACTOR AND EVALUATE THE EFFECTS OF:

   A) ROASTING TEMPERATURES
   B) PYRITE PARTICLE SIZES
   C) AIR FLOW RATES
   D) PYRITE FEEDING RATES
   E) PYRITE / LIME WEIGHT RATIOS

3. DEVELOP A MATHEMATICAL MODEL TO DESCRIBE THE LIME ROASTING OF PYRITE IN A CYCLONE REACTOR

THEORETICAL INVESTIGATIONS

1. **THERMODYNAMIC ANALYSIS**

2. **MATHEMATICAL MODEL**

3. **EXPERIMENTAL EVALUATION**

4. **COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL RESULTS**

Mathematical Relations:

Pyrite Oxidation:

$$1-(1-E_1)^{\frac{1}{3}}=\frac{n_{s_1} K C_{O_2} L}{\rho_{FeS_2} r_0 V} Z$$

Lime Sulfation:

$$1-\left(\frac{R_1}{R_0}\right)^3=\frac{3 n_{s_2} K_D C_{SO_2} t}{R_0 \rho_{CaO}}$$

Oxygen Balance:

$$\frac{d}{dZ}(QC_{O_2})=-\left(\frac{33}{4}\right)\left(\frac{n_{s_1} m_{FeS_2} K C_{O_2} r_1^2}{V\rho_{FeS_2} M_{FeS_2} r_0^3}\right)-\left(\frac{6 n_{s_2} m_{CaO} K_D C_{SO_2} R_1^2}{V\rho_{CaO} M_{CaO} R_0^3}\right)$$

Sulfur Dioxide Balance:

$$-\frac{d(QSO_2)}{dZ}=-\frac{d}{dZ}\left(\frac{m_{FeS_2}}{2M_{FeS_2}}\right)\left(\frac{r_1^3}{r_0^3}\right)+\frac{d}{dZ}\left(\frac{m_{CaO}}{M_{CaO}}\right)\left(\frac{R_1}{R_0}\right)^3$$

Gas Temperature:

$$-\frac{d}{dZ}(M_g \overline{T_g C_{pg}})=\pi D h_w(\overline{T_g}-\overline{T_w})-\left[-\frac{d}{dZ}(-\Delta H_p)\left(\frac{m_p}{M_p}\right)\left(\frac{r_1}{r_0}\right)^3-\frac{d}{dZ}(\overline{C_{pp}}T_g)\left(\frac{m_p}{M_p}\right)\right]$$

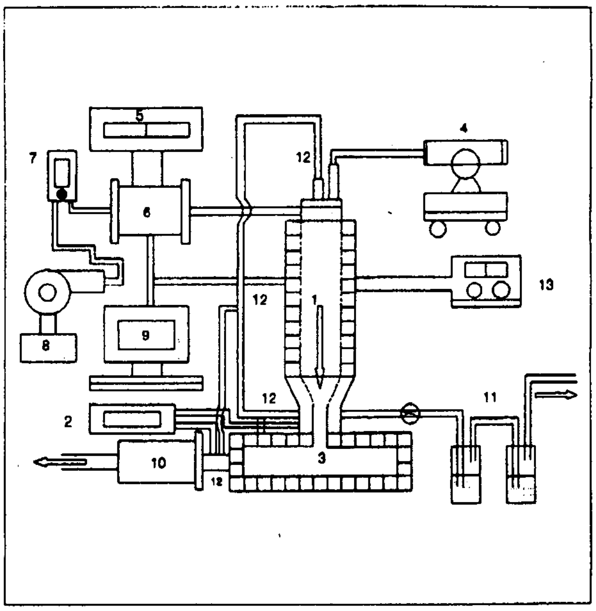
$$-\left[\frac{d}{dZ}(-\Delta H_L)\left(\frac{m_L}{M_L}\right)\left(\frac{R_1}{R_0}\right)^3-\frac{d}{dZ}(\overline{C_{pL}}T_g)\left(\frac{m_L}{M_L}\right)\right]$$

Pyrite Temperature:

$$\frac{dT_p}{dZ}=-3T_p\lambda_1-\frac{3hL}{\rho_{FeS_2} V\overline{C_{pp}} r_0}(T_p-T_g)+\frac{3\Delta H_p}{\overline{C_{pp}}}\lambda_1\left(\frac{r_1}{r_0}\right)^2$$

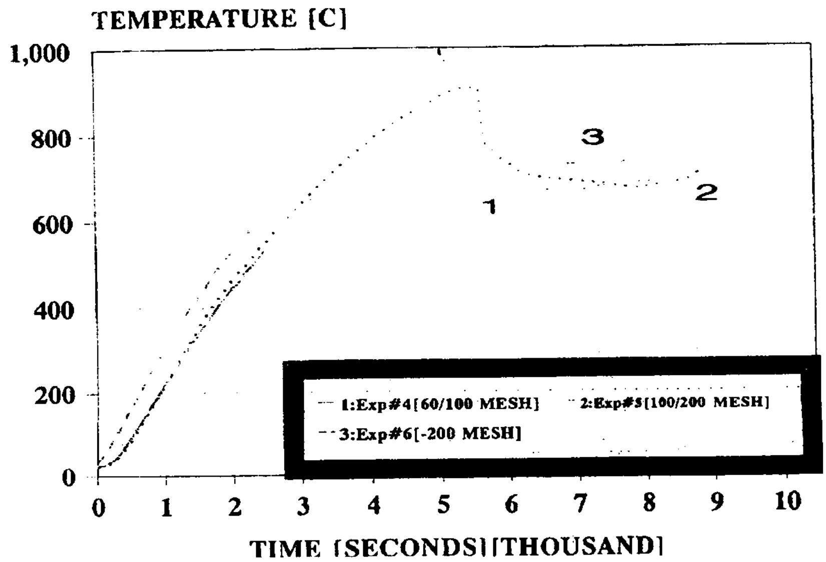
Lime Teperature:

$$\frac{dT_L}{dZ}=-3T_L\lambda_2-\frac{3hL}{\rho_{CaO} V\overline{C_{pL}} R_0}(T_L-T_g)+\frac{3\Delta H_L}{\overline{C_{pL}}}\lambda_2\left(\frac{R_1}{R_0}\right)^2$$

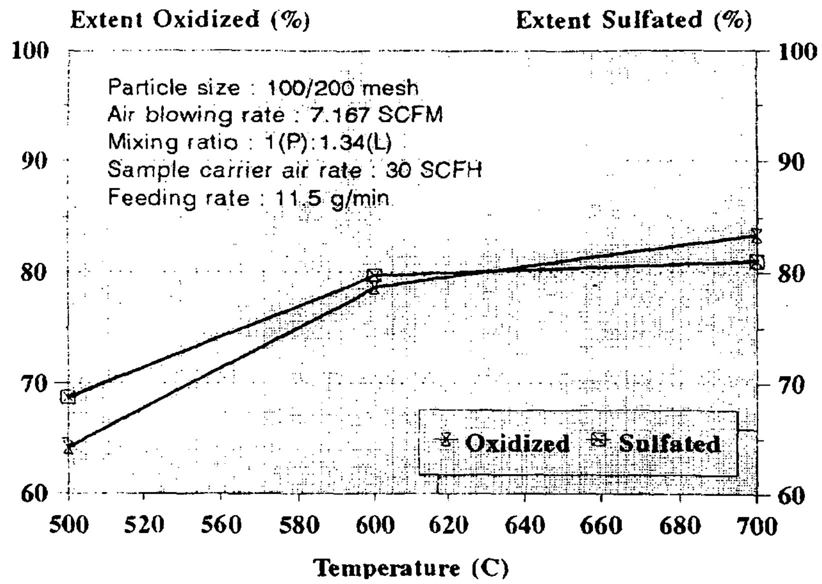


Schematic Representation of Cyclone Roaster System
1. Convection cyclone reactor
2. Initial cooling chamber
3. Cooling chamber
4. Feeder
5. Furnace controller
6. Pre-heater
7. Manometer
8. Air blower
9. Data acquisition system
10. Filter
11. Gas analysis system
12. Thermocouple
13. Furnace Controller

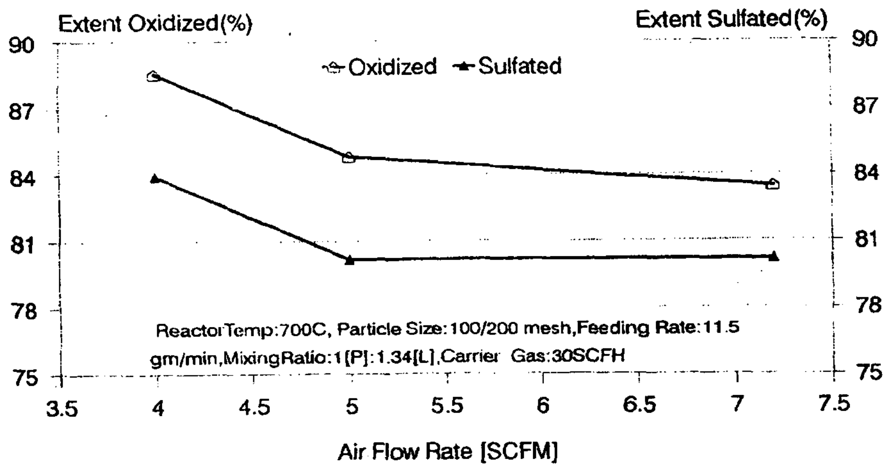
TEMPERATURE AT REACTOR CENTER VERSUS TIME



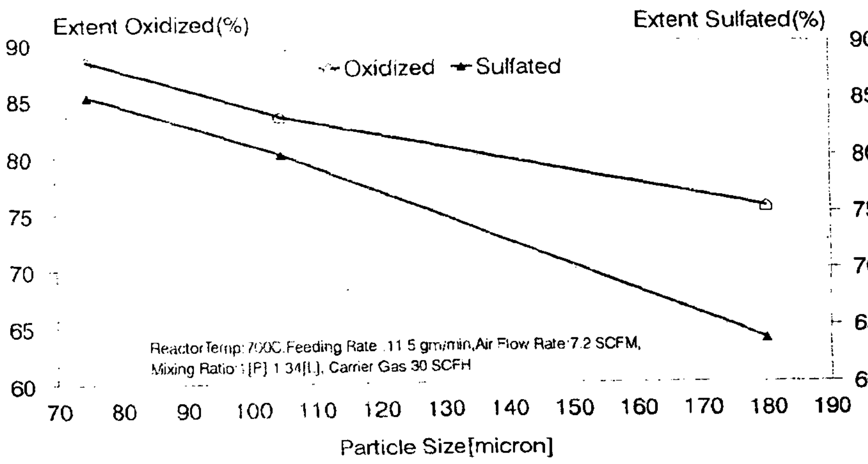
EFFECT OF TEMPERATURE ON OXIDATION AND SULFATION



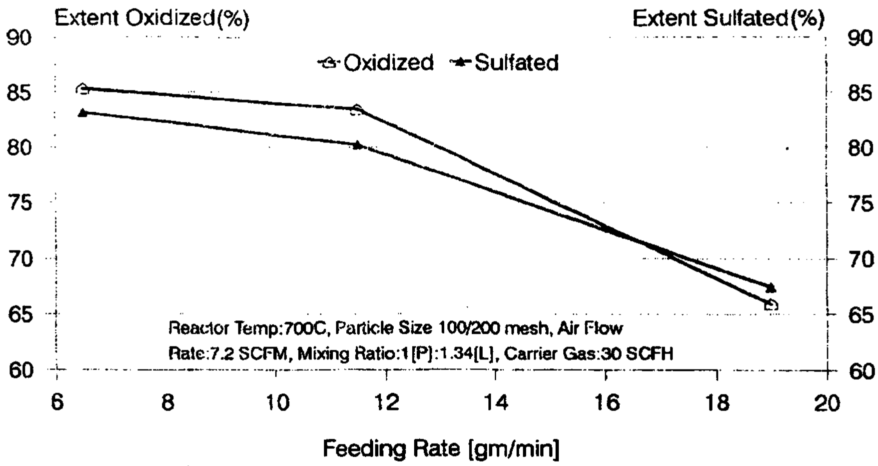
EFFECT OF AIR FLOW RATE ON OXIDATION AND SULFATION



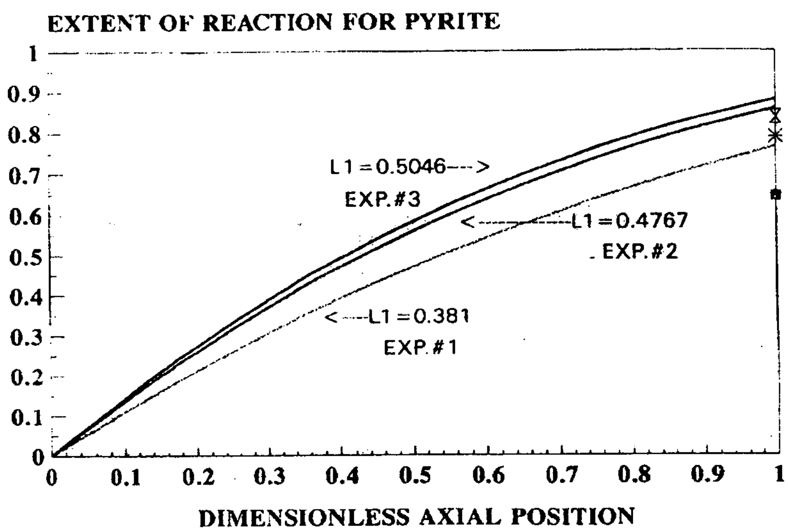
EFFECT OF PYRITE SIZE ON OXIDATION AND SULFATION



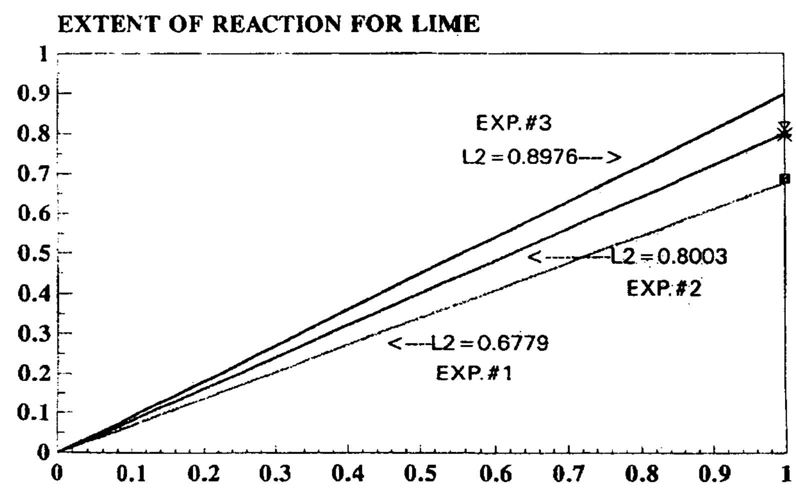
EFFECT OF FEEDING RATE ON OXIDATION AND SULFATION



MODEL AND EXPERIMENTAL RESULTS FOR PYRITE OXIDATION



MODEL AND EXPERIMENTAL RESULTS FOR LIME SULFATION



CONCLUSIONS(A)

1. THE EXTENT OF OXIDATION AND SULFATION OF PYRITE / LIME IS PROPORTIONAL TO REACTOR TEMPERATURES WITHIN THE RANGE STUDIED. AN OPTIMUM ROASTING TEMPERATURE IS BETWEEN 650 - 750 C, BUT LONGER RESIDENCE TIME IS REQUIRED.

2. THE EXTENT OF OXIDATION AND SULFATION INCREASES WITH A DECREASE IN AIR FLOW RATE.

3. THE EXTENT OF OXIDATION AND SULFATION DECREASES WITH FEEDING RATE BETWEEN 12-20 g/min.

4. THE EXTENT OF OXIDATION AND SULFATION INCREASES WITH AN INCREASING WEIGHT RATIO OF HYDRATED LIME TO PYRITE.

5. A FUNDAMENTAL THEORETICAL MODEL WAS DEVELOPED TO CHARACTERIZE THE OXIDATION SULFATION OF PYRITE / LIME.

6. THE MODEL ALLOWS THE PREDICTION OF THE EXTENT OF PYRITE OXIDATION, LIME SULFATION, CONCENTRATIONS OF SULFUR DIOXIDE AND OXYGEN IN THE GAS PHASE, AND TEMPERATURES OF PYRITE, LIME AND THE GAS AS FUNCTION OF THE AXIAL POSITION.

7. THE INFLUENCE OF IMPORTANT PARAMETERS ON THE OXIDATION AND SULFATION REACTIONS WAS EVALUATED THEORETICALLY AND EXPERIMENTALLY.