Petroleum Research
Petroleum Research 2019 (June-July), Vol. 30, No. 111, 32-33
DOI: 10.22078/pr.2020.3832.2747

Nickel Extraction from Fuel Oil Ash Using Sonoleaching Process

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DOI: 10.22078/pr.2020.3832.2747

Received: June/25/2019 Accepted: February/17/2020

Introduction

Fly ashes, which contain metals such as vanadium (V) and nickel (Ni), would create many environmental problems, including soil, water and air pollutions [1-3]. Therefore, the extraction of metals from produced fly ashes is very desirable in both environmental and economic aspects [3]. Nowadays, material processing using hydrometallurgical techniques is becoming a good and effective way to recover metals [4]. Although hydrometallurgy has many advantages, including low-cost equipment, non-sensitivity to environmental conditions, and reduced air pollution, it still has problems such as relatively long operating periods [5]. To assist the effect of acid in the leaching process, different methods including ultrasound, H_2O_2 and microwave have been used [6]. In this study, sulfuric acid has been used as a leaching agent, as well as ultrasonic as an auxiliary agent for the extraction of Ni from the power plants oil-furnace ash. In addition, the response surface method has been used to optimize the factors. In order to better examine the process, kinetic and thermodynamic studies have also been studied.

Experimental Procedure

Preparation of the Fly Ash

A fuel-oil fly ash sample was collected from the Neka thermal power plant, Mazandaran, Iran. Aqua regia was prepared for the complete digestion of the sample. Inductively coupled plasma optical emission spectrometry (ICP-OES) (Vista Pro, Varian, Inc., California, USA) was used to analyze chemical elements. The major elements were 4665 ppm V, 1346 ppm Ni, 1059 ppm Fe, 5.25 ppm Cu and 90.45 ppm Al by mass.

Leaching Experiment

In each experiment, a certain amounts of the fuel oil ash and sulfuric acid were put into a 250 mL glass beaker. An ultrasonic probe (UC-5150B, ChromTech, Taiwan) was inserted in the solution during leaching. Furthermore, atomic adsorption (AAS-NORDANTEC990) was used to determine the concentrations of metals in the liquor.

Experimental Design

Design Expert 7.0.0 software was adopted to optimize the leaching parameters. Response Surface Methodology (RSM) was applied to study the effects of three main factors, namely solid/liquid (S/L) ratio (1-4 %w/v) sulfuric acid concentration (1-70 %v/v) and ultrasound power (5-80 W) on Ni recovery. Analysis of Variance (ANOVA) was used to determine the significant models and parameters.

Results and Discussion

Statistical Analysis

A reduced second model was used for the Ni extraction. The correlation between Ni recovery and the three defined factors is shown as follows:

$$\text{Ni extraction (\%)} = +16.13 - 3.89A + 3.81B + 1.71C - 0.80BC - 3.83B2 \quad (1)$$

where A, B and C are S/L ratio, sulfuric acid concentration and ultrasound power respectively. ANOVA results showed that at a 95% confidence level, the calculated p-value of the model was less than 0.05. Fig. 1 shows the interaction between S/L ratio and sulfuric concentration at constant 61.6 W ultrasound power. According to it, the Ni extraction was enhanced when acid concentration increased from 15 %v/v to 56 %v/v and decreasing S/L ratio from 3.4 %w/v to 1.6 %w/v.
The goal of optimization was to achieve the highest Ni extraction. The optimal conditions were 1.61 %w/v of S/L ratio, 64.8 %v/v of sulfuric concentration and ultrasound power of 43.6 W. The experimental result fell within the 95% confidence interval (C.I.) of the model value.

Kinetic and Thermodynamic Study

The kinetic parameters of the process were analyzed using the shrinking core model. The obtained R^2 values indicated that the data were fitted with the diffusion-controlled model slightly better than the reaction-controlled model. Using the definition of k based on the Arrhenius equation in the reaction equation, then by plotting ln(r) vs. 1/T, the activation energy was estimated to be 9.57 $kJ \cdot mol^{-1}$ which is less than 25 $kJ \cdot mol^{-1}$. This suggests diffusion control in the leaching process.

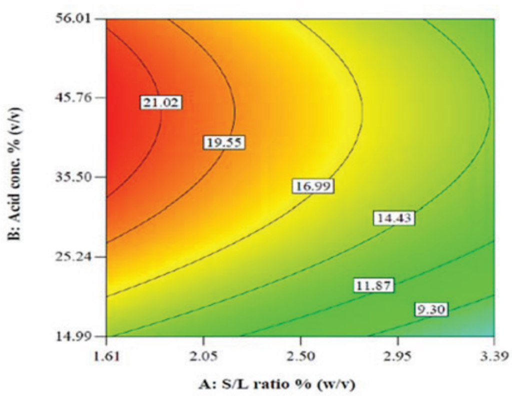

Fig.1. Contour plots of the S/L ratio and Acid concentration on Ni extraction.

Conclusions

The extraction of nickel from ash was investigated using sonolization method. The recovery of Ni was optimized using RSM. The optimal conditions were 1.61 %w/v of S/L ratio, 64.8 %v/v of sulfuric concentration and ultrasound power of 43.6 W. The results of reaction kinetics analysis showed that the diffusion-control model was favored over the overall reaction-control model. Finally, the activation energy of the reaction was found to be 9.57 $kJ \cdot mol^{-1}$.

Nomenclatures

RSM: Response Surface Methodology
ANOVA: Analysis of Variance

References

1. Navarro R, Guzman J, Saucedo I, Revilla J, Guibal E (2007) Vanadium recovery from oil fly ash by leaching, precipitation and solvent extraction processes, Waste Manag., 27, 425 – 438.
2. Tsygankova M V, Bukin V I, Lysakova EI, Smirnova AG, Reznik AM (2011) The recovery of vanadium from ash obtained during the combustion of fuel oil at thermal power stations, Russ. J. Non Ferrous Met., 52, 19 – 23.
3. Moskalyk RR, Alfantazi AM (2003) Processing of vanadium: a review, Miner. Eng., 16, 793–805.
4. Jadhav U U, Hocheng H, (2012) A review of recovery of metals from industrial waste, J. Achiev. Mater. Manuf. Eng., 54, 159–167.
5. Mohanty U S, Rintala L, Halli P, Taskinen P, Lundström M (2018) Hydrometallurgical Approach for Leaching of Metals from Copper Rich Side Stream Originating from Base Metal Production, Metals, 8, 40-51.
6. Huang Z, Chun F, Ma Y (2011) Ultrasonic recovery of copper and iron through the simultaneous utilization of Printed Circuit Boards (PCB) spent acid etching solution and PCB waste sludge, J. Hazard. Mater., 185, 155-161.