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Abstract. Nickel and cobalt metal able to process from low grade laterite using solvent extraction and electrowinning. One of electrowinning methods which has good performance to produce pure metal is electrometal-electrowninge(EMEW). In this work, solventextraction was used to separate nickel and cobalt which useCyanex-Versatic Acid in toluene as an organic phase. An aqueous phase of extraction was processed using EMEW in order to deposit the nickel metal in Cathode electrode. The parameters which used in this work were batch temperature, operation time, voltage, and boric acid concentration. Those parameters were studied and optimized using the design of experiment of Taguchi. The Taguchi analysis result shows that the optimum result of EMEW was at 60ºC of batch temperature, 2 Voltage, 6 hours operation and 0.5 M of boric acid.

INTRODUCTION

Low nickel laterite is difficult to process using pyrometallurgy, however it able to process using hydrometallurgy method. One of a major problem in nickel laterite processing is many impurities hence very difficult to get pure Nickel. Liquid-liquid extraction followed electrowinning was able to produce nickel metal from laterite. Liquid extraction was used to separate nickel and cobalt from leaching solution. Meanwhile, electrowining was used to produce nickel metal from nickel solution.

Electro Metal Electro Winning (EMEW) is one of electrowinning method which has good performance to produce high purity metal. EMEW process has many advantages such as :low operational cost, friendly for the environment, easy to install , design is compatible, it can be operate in large scale process, acid electrolyte can be recycle, it can produce high purity of metal and it can be operate in low concentration of metal solution [1,2,3].

In this work, low-grade nickel laterite was from Sulawesi Island which contains Fe, Ni and Co are 43.769%, 0.488 % and 0.120, respectively. Prior to process in EMEW, the laterite was processed in leaching and solvent extraction processes. In this work, Citric acid was used to leach laterite since is more friendly for the environtment than sulphuric acid. Nickel and cobalt in leaching product were separated using liquid extraction. Vericatic acid and Cyanex in Toluene were used as an organic phase in solvent extraction process. This chemical successfully applied to separate of cobalt from nickel ore in sulfate solution [4, 5].

In this research, Taguchi optimization method was used to optimize the parameters in EMEW process. The parameters were boric acid concentration, voltage, temperature and operation time. In this work, boric acid was used as an additive to reduce the effect of hydrogen evolution reaction in an electrochemical process.

EXPERIMENTS

In this work, laterite form south east Sulawesi were grinded and sieved to get a size of 150 mesh. The composition of laterite was tabulated in Table 1. The laterite was leach in 200 ml of 2 M citrate acid for 24 hours in magnetic stirrer. For liquid phase extraction a process, an organic solution of the Cyanex 272 and versatic acid in technical toluene were used. The solvent extraction was carried out in glass separating funnels with capacity 100 ml. The solvent extraction process contains the aqueous and organic phase. The aqueous phase contains an amount of nickel was a process in EMEW. In EMEW process, a cathode is aluminum, meanwhile, anode is graphite as shown in Fig. 1. DC power supply which connected with voltmeter and ampere meter hence able to adjust the voltage. The heater was used to adjust the temperature. The design of experiments of Taguchi was used in this work as listed in Table 2. These experiments have three parameters namely temperature, operation time, voltage and boric acid concentration. The mass of nickel electrodeposits were analyzed using XRF (Delta Premium XRF – Olympus).

TABLE 1. Laterite composition using XRF

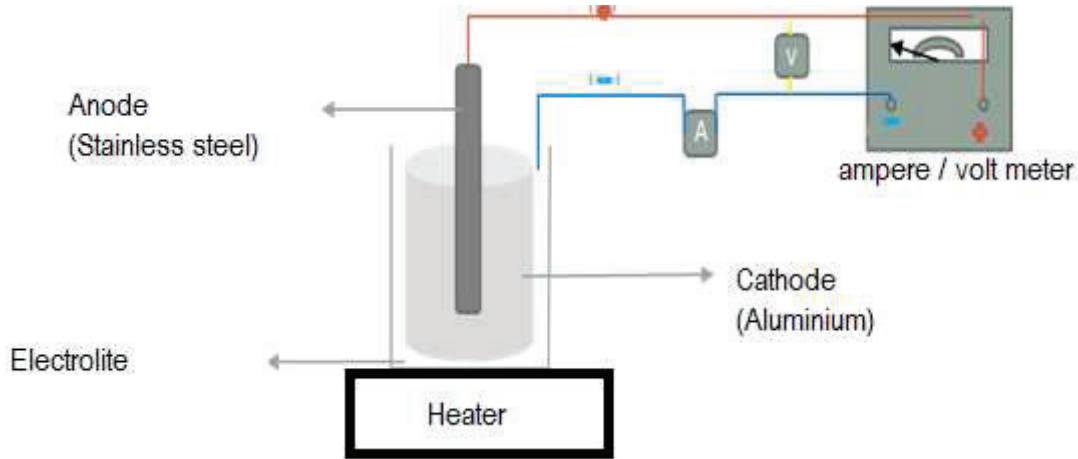| El	wt (%)	El	wt (%)
LE	79.2882	MnO	0.216
Fe	10.998	Co	0.046
Si	3.88	S	0.046
K	2.079	Sb	0.02
Al	0.701	Cd	0.013
Ni	0.488	Sn	0.014
Ca	0.65	Ti	0.022
Cl	1.253	Zn	0.0076
Cr	0.284		

FIGURE 1. Experimental set up of electrometal-electrowinning (EMEW)

TABLE 2. Design of experiment Taguchi and Experiment Results

| Run | Design of Experiment | | | | Results |
	Temp. (°C)	Time (hour)	Voltage (v)	Boric acid concentration (M)	Nickel electrodeposits (mg)
1	50	2	2	0.0	0.56680
2	50	4	4	0.5	0.0868
3	50	6	6	1.0	0.0663
4	60	2	4	1.0	0.1296
5	60	4	6	0.0	0.5038
6	60	6	2	0.5	0.5798
7	70	2	6	0.5	0.1065
8	70	4	2	1.0	0.1512
9	70	6	4	0.0	0.1800

RESULT AND DISCUSSION

The results of this work were analyzed using a signal to noise (SN) ratio of larger the better of Taguchi were listed in Table 3. From the table shows that highest value of delta is the parameter of boric acid concentration, hence this parameter is the first rank of the parameter which affects the amount of nickel electrodeposits. The second and third rank is the voltage and temperature, respectively.

TABLE 3. Response Table for Signal to Noise Ratios Larger is better

Level	Temp. (°C)	Time (hour)	Voltage (v)	Boric acid concentration (M)
1	76.37	73.84	68.49	68.39
2	69.48	74.53	77.96	75.14
3	76.92	74.40	76.33	79.24
Delta	7.44	0.69	9.47	10.85
Rank	3	4	2	1

The Effect Boric Acid Concentration towards theMass of Nickel Electrodeposits

In this research, the boric acid concentration was varied from 0 to 1 M. Fig. 2 shows the effect of boric acid concentration towards the amount of nickel in the cathode. The results show that the increase of boric acid concentration will decrease the amount of nickel electrodeposits in the cathode. The increase of boric acid will increase the viscosity of electrolyte hence will decrease the mass transport in an electrode. However, boric acid is useful to decrease the disturbance of hydrogen generation in the cathode [6].
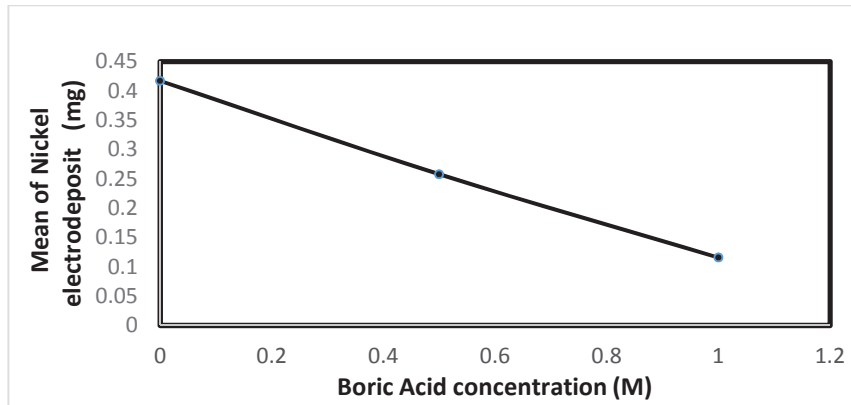
FIGURE 2. Mean effect plot for boric acid concentration towards a mass of nickel electrodeposits

The Effectof Voltage towards theMassof Nickel Electrodeposits

In this research, the voltages were varied from 2 to 6 volt. The effect of voltage towards nickel deposit in electrode was shown in Fig. 3. The result shows that the increase of voltage will increase the amount of nickel electrodeposits in the cathode. The increase of voltage will increase the mass transport in an electrochemical cell. However, at the certain voltage, the hydrogen evolution effect is increasing hence disturb the nickel deposited at the cathode as shown in the result of 4 volts.
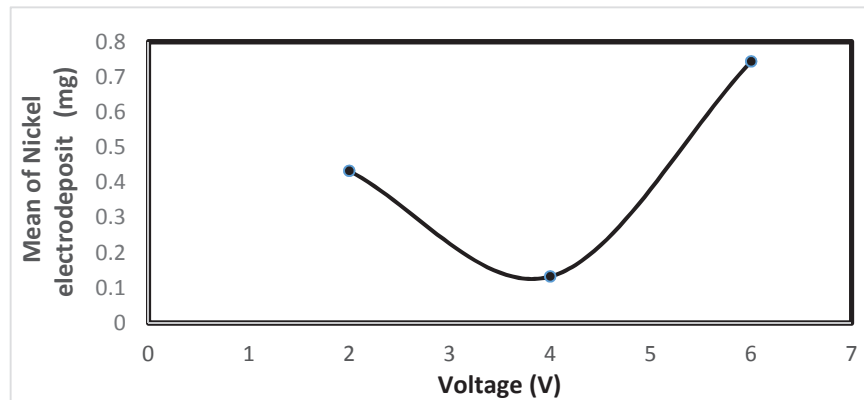

FIGURE 3. Mean effect plot for voltage towards a mass of nickel electrodeposits

The Effect of Voltage towards theMassof Nickel Electrodeposits

Temperature was varied from 50 to 70 °C in this research. The effect of temperature towards means of nickel electrodeposits was shown in Fig. 4. The figure shows that the optimum temperature was at 60°C.The increment of temperature will increase the rate of corrosion of anode electrode [7]. This phenomenon indicates that temperature process will enhance the rate of electrowinning process [8]. The increasing of temperature also enhances the electrolyte conductivity and mass transfer [9]. However, the increment of temperature in the acidic electrolyte will enhance the hydrogen evolution which decreases the current efficiency. The increasing temperature also decreases the hydrogen overpotential, hence hydrogen evolution problem can be solved by increasing hydrogen over potential[10]. Hence, the optimum temperature is important to solve the hydrogen evolution problem.

At the temperature of 70°C the mass of nickel electrodeposits decrease as shown in Fig. 3. The increasing temperature will increase the hydrogen evolution effect. Moreover, the increment of temperature will increase the overall mass transfer include the impurities mass transfer [8]. Hence it caused the decreasing of the mass of nickel electrodeposits.
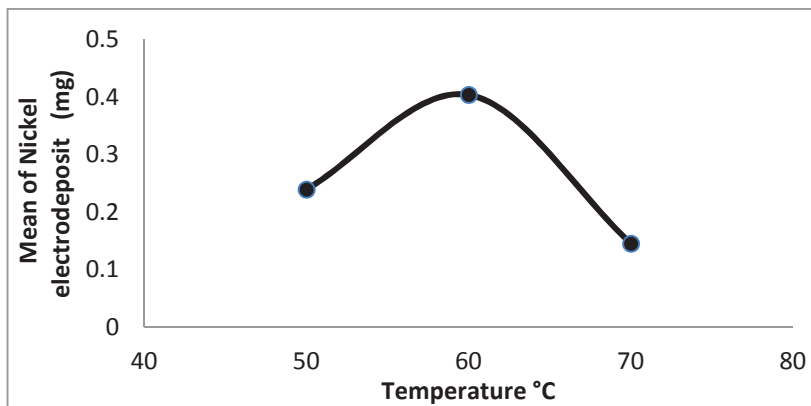
FIGURE 4. Mean effect plot for temperature towards nickel electrodeposits

The Effect of Operation Time towards the Mass of Nickel Electrodeposits

In this work, operation times were varied from 2 until 6 hours. The effect of operation time towards the mass of nickel electrodeposits were shown in fig. 5. The figure shows that the optimum operation time is at 6 hours operation.

The enhancing of operation time increase the mass of nickel electrodeposits, since more nickel were deposited at the cathode. At the beginning of electrowinning, the mass of nickel electrodeposits were fluctuated since many impurities in electrolyte disturb the electrowinning process. There are colloid particles which have negative charge in electrolytes which were coagulated through the electrocoagulation process in EMEW reactor. These phenomena produce coagulation sludge in the EMEW reactor.
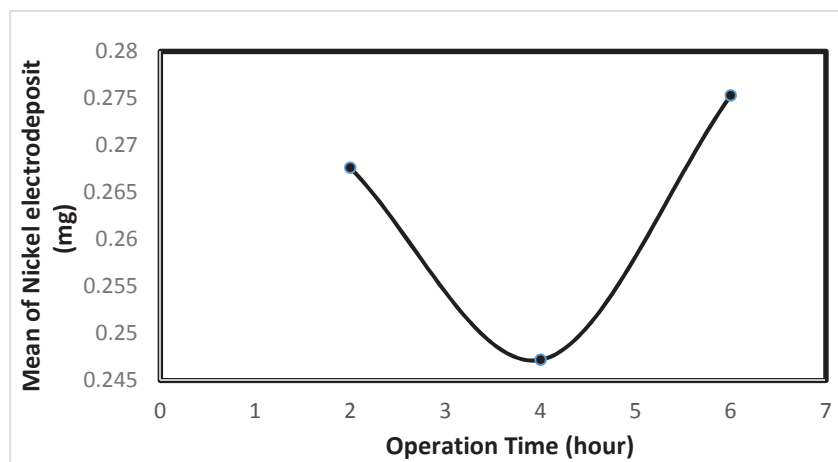

FIGURE 5.Mean effect plot for operation time towards nickel electrodeposits

CONCLUSIONS

Electro metal electrowinning (EMEW) process from nickel laterite was conducted in laboratory scale. All parameters studied have a significant influence towards the mass of nickel electrodeposits. The optimum conditions for the EMEW process were determined using Taguchi analysis. The optimum operation conditions are at without boric acid additions, a voltage of 6 V, temperature of 60°C and operation time of 6 hours.

ACKNOWLEDGMENTS

REFERENCES

1. M. B. Mooiman, I.Ewart and J. Robinson, Electrowinning Precious Metals from Cyanide Solution Using EMEW Technology,

2. P.A.Treasure (2005). EMEW electrowinning: Treatment of copper sulphate pickling and etchant solutions. (Electrometals Technologies Ltd, 2005)

3. E. Roux, J. Gnoinski, I. Ewart and D. Dreisinger . Cu-Removal From The Skorpion Circuit Using EMEW Technology. The Fourth Southern African conference on Base Metals(2010) Pp. 27-44.

4. A. S.Guimarães, P. S. da Silva 1, M.B. Mansur, Purification of nickel from multicomponent aqueous sulfuric solutions by synergistic solvent extraction using Cyanex 272 and Versatic 10. Hydrometallurgy 150(2014) pp. 173–177

5. G. H. Nikamand B. S.Mohite,Liquid-Liquid Extraction and Separation of Cobalt(II) from Sodium Acetate media using Cyanex 272 [Research Journal of Chemical Sciences . Res.J.Chem.Sci., Vol. 2(1)(2012) pp. 75-82.

6. J. Lu,Effects of additives on nickel electrowinning from sulfate system. School of Chemical Engineering, Sichuan University, Chengdu China, 2009.

7. Z. Wei, The performance of lead anodes Used for zinc electrowinning and their effects on energy consumption and cathode impurities. Faculte des Sciences et de Genie. Universite Laval. Quebec (2010)

8. E.Arman, Influence of polyoxometalates as the additive on electro-winning of copper. Mining and Mineral Processing Eng. Dept., Adana Science and Technology Univ., Adana, Turkey (2016)

9. R.Xiulian,Study of the electrodeposition conditions of metallic manganese in an electrolytic membrane reactor. School of the Marin, Harbin Institute of Technology at Weihai, Wenhua West Road 2, Weihai, Shandong, China (2010)

10. B. Muhamed,An investigation of the failure mechanisms of aluminum cathodes in zinc electrowinning cells. Department of Metals and Materials Engineering. The University of British Columbia. Vancouver (1999)