Ekoloji 27(106): 899-904 (2018)

Study on Temperature Control Strategy for Electrolytic Copper and Its Impacts on Ecosystem and Human Health

Yongyin Qu [1,2], Cheng Liu [1*], Yanming Cheng [1], Ilkyoo Lee [1,3]

[1] College of Electrical & Information Engineering, Beihua University, CHINA

[2] Jilin Institute of Chemical Technology, Jilin, CHINA

[3] Division of Electrical, Electronics & Control Engineering Kongju National University, REPUBLIC OF KOREA

[*] Corresponding author: Cheng Liu

Abstract

Copper is a very common substance that occurs naturally in the environment and spreads through the environment through natural phenomena. Humans widely use copper. For instance it is applied in the industries and in agriculture. The production of copper has lifted over the last decades. Due to this, copper quantities in the environment have increased. This metal, the tea-coloured organic material found in soil and rivers and coastal waters, is not ecologically toxic to humans but it is somewhat toxic to fish and very toxic to phytoplankton" -- a fundamental link in the food chain. Natural humic substances and other copper-binding compounds may also greatly affect the toxicity and bioavailability of metals in rivers and coastal waters. When organic matter binds with metals, noted Professor Voelker, the metals often become less toxic. However, in environments such as groundwater, they may also become more mobile. Among widely used heavy metals, Cu(II) ions have received special attention due to its eco-toxic effect (i.e., negative impacts on ecology and environment), bioaccumulation in food chain and its persistent in nature. Additionally, copper is most valuable substance, which is mostly washed away in wastewater and dissipate to environment resulting in economic loss. Cu(II) ions have major contribution, cause several adverse effects even at very low concentration such as an extreme mucosal bothering, hypertension, hepatic and renal harm, far reaching slender harm, gastrointestinal irritation, vomiting, irritation of the focal sensory system took after by dejection, and conceivable necrotic changes in the liver and kidneys. But human beings needs copper in the life circle, so for improving on the quality of copper cathode and saving energy, the analysis of the whole process of electrolytic copper production is needed. It indicates that the copper ion and acid ion concentration are the most important factors affecting the quality of copper cathode, however, the copper ion and acid ion concentration as major variables of objective function determined by accurate electrolyte temperature control. Therefore, in this paper, an improved differential evolution algorithm is proposed to optimize the multi-objective function, and the optimal solution set of the multi-objective problem is determined. Then, a new improved ideal point method is proposed based on the ideal point method. Finally, the optimal temperature and copper ion concentration are determined to optimize the electrolysis process. The optimal value of temperature is taken as the given value of the control system. The fuzzy adaptive PID algorithm is used for simulation analysis and experimental verification. The results show the correctness and feasibility of the algorithm under the background of low carbon energy saving appeal.

Keywords: ecosystem, electrolytic copper, temperature control, multi-objective decision making, fuzzy adaptive PID, Low Carbon Energy Saving

Qu Y, Liu C, Chen Y, Lee I (2018) Study on Temperature Control Strategy for Electrolytic Copper and Its Impacts on Ecosystem and Human Health. Ekoloji 27(106): 899-904.

INTRODUCTION

Copper is an essential element for all biota, therefore any adverse effects must be balanced against its essentiality. This means that for all organisms, there will be range of optimal copper concentrations. High concentrations of copper can be extremely toxic to plants. General symptoms include chlorotic leaves, early leaf-fall, stunted growth and impaired root development. Plants will subsequently have reduced uptake of water and nutrients, leading to disturbances in metabolism and growth retardation. At the cellular level, copper inhibits a large number of enzymes, and it interferes with several aspects of plant biochemistry (including photosynthesis, pigment synthesis and membrane integrity) and physiology (interference with

 Received: 14 May 2017 / Accepted: 16 Aug 2018

fatty acids, protein metabolism and inhibition of respiration and nitrogen-fixing processes (WHO 1998).

In wetlands, copper has been found to bind to peat, silts and clays (Lau and Chu 1999, Dierks 2001). Copper bound to wetland sediment has been found to inhibit denitrification, resulting in an increased ammonium concentration in the sediment-water environment (Sakadevan et al. 1999). Copper is taken up by the roots of heather (Calluna vulgaris), with root to shoot transfer also reported. Copper was phytotoxic to heather, as evident by decreased shoot length, and reduced shoot and root biomass, with exposure to 100mg/l copper solutions killing 50% of exposed seedlings (Monni et al. 2000).

Copper has also been shown to exert adverse reproductive, biochemical, physiological and behavioural effects on a variety of saltwater organisms at concentrations (WHO 1998). However, large variations due to differences in bioavailability of the copper, and inter-species sensitivity must be taken into account when assessing possible effects. The concentration of total copper is not necessarily indicative of the proportion of bioavailable copper. The bioavailability of copper is determined by various factors, including the chemical speciation of the copper, and the properties of the environment (water salinity, pH and concentrations of suspended particles, dissolved organic matter and inorganic ligands) (US EPA 1984, WHO 1998).

The world's copper production is still rising. This basically means that more and more copper ends up in the environment. Rivers are depositing sludge on their banks that is contaminated with copper, due to the disposal of copper-containing wastewater. Copper enters the air, mainly through release during the combustion of fossil fuels. Copper in air will remain there for an eminent period of time, before it settles when it starts to rain. It will then end up mainly in soils. As a result soils may also contain large quantities of copper after copper from the air has settled.

The temperature of electrolyte is an important indicator for the characterization of copper electrolysis. The temperature of the electrolyte will accelerate the progress of electrolysis reaction, so that the exchange rate of ions in the solution is accelerated, and the conductivity of the solution will be improved. The pressure drop generated in the electrolytic cell becomes smaller, so that the consumption of electric energy of industrial enterprises is reduced, and the development of energy saving and environmental protection is also made, and the comprehensive benefit of the enterprise is also improved. But as the temperature increases, the liquid will evaporate, too much volatile liquid will not only undermine the normal chemical reaction which affect product quality but also make the work environment worse.

The electrolyte system is mainly composed of electrolyte circulation system, plate processing system and net fluid system. The electrolyte process flow chart is shown in **Fig. 1**. The electrolyte after purification is sent from the pump to the reservoir purification workshop, and then through the circulating pump into the electrolytic cell cycle. A part of the electrolyte is pumped into the high tank and heated by a heater, there is also a small part of the flow back to the purification plant to ensure that the ion concentration can be maintained in the range of conditions required. The electrolyte of the high position tank can automatically flow to each electrolytic tank, and each overflow hole can flow out of the liquid to the circulating groove in the electrolysis process. After an electrolysis cycle, the anode plate is almost exhausted, and the cathode plate has grown into a finished product. The liquid in the electrolytic tank can be called as supernatant, and there is a special storage tank; the trough bottom residue, anode mud after filtering to the precious metal processing workshop for further refining, the remaining liquid can be sent to the purification plant after purification to cycle. The whole electrolyte process is a large system cycle.

ESTABLISHMENT AND EXPLORATION OF OPTIMIZATION FUNCTION

To ensure that the electrolytic process can be carried out smoothly and produced standard cathode copper, firstly there should be a suitable temperature also with a reasonable amount of additives and methods. The contents of various impurities in anode plate as little as possible such as As, Zn, Fe, Sb. And the content of copper ion and chloroplatinate ion are the best ideal value of the electrolytic reaction. It is very important to determine whether the two indexes can produce high quality copper, in this paper, copper ion and chloroplatinate ion as the two main factors in the need to optimize (Suresh K et al. 2009) the composition of electrolyte. The overall structure of the design optimization model is shown in **Fig. 2**.

The copper ion and chloroplatinate ion as the main variable to be optimized in the electrolyte composition, determine the optimization objective function as follows:

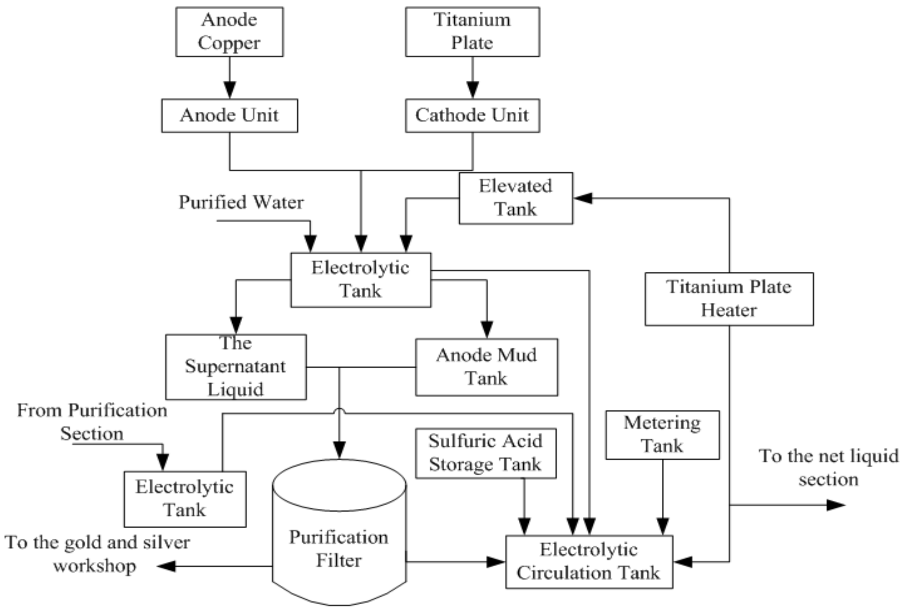

Fig. 1. Electrolyte process flow chart

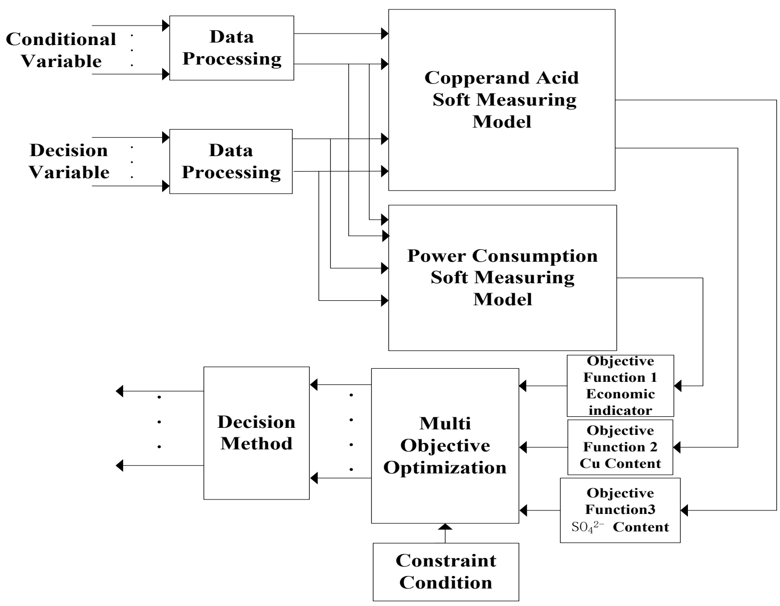

Fig. 2. Optimization model of the overall structure

$$\begin{aligned} min|s_1 - s_1'| \\ min|s_2 - s_2'| \end{aligned} \quad (1)$$

s_1, s_2 stand for real time predictive value of support vector machine after training. s_1', s_2' stand for a summary of the ideal value of experienced workers.

Multi-objective Optimization and Decision-making

By using evolutionary algorithm to solve multi - objective problems, the convergence rate is faster, and an approximate optimal solution set with uniform distribution can be obtained. And an approximate Pareto optimal solution set with uniform distribution can be obtained (Piotrowski 2014, Wang et al. 2011). As an excellent multi-objective evolutionary algorithm, we must first guarantee the convergence of the algorithm, and secondly to ensure the diversity of the population (Karthik et al. 2013, Wang et al. 2012). In this paper, the differential evolution algorithm is improved to make it perform well in solving the multi-objective table optimization problem.

Determination of Minimum Energy Consumption Objective Function

In general electrolysis process, the current efficiency is basically constant. Therefore, according to the

Table 1. Range of decision variables

variable	High tank temperature	High temperature tank level	1#2# circulating tank level	1# anode mud level	2# anode mud level
Express	t	L_1	L_2	L_3	L_4
Range	59~66	2.712~2.829	2.233~2.357	0.422~0.728	0.534~0.887

formula can be derived from the minimum objective function for power consumption:

$$\frac{\left[Con. + \frac{\min\ \rho \times l}{S(0.134 - 0.00356 s_1 + 0.00249 s_2 + 0.00426 t)}\right] \times 1000}{\eta \times 1.1852} \quad (2)$$

Minimum energy consumption objective function $min(X)$, where X represents every production of one ton of refined copper DC power consumption. ρ is current density. l is electrode spacing. S is electrode cross - sectional area. η is current efficiency. $Con.$ stands for constant.

Constraint Conditions of Optimization Function

According to the characteristics of copper electrolyte circulation system, the constraint conditions of steady state optimization model can be determined.

$$Subject\quad to$$
$$\begin{cases} t^{min} \le t \le t^{max} \\ L_i^{min} \le L_i \le L_i^{max}, i = 1,2,3,4 \\ \rho_{Cu^{2+}}^{min} \le \rho_{Cu^{2+}} \le \rho_{Cu^{2+}}^{max} \\ \rho_{so_4^{2-}}^{min} \le \rho_{so_4{}^{2-}} \le \rho_{so_4^{2-}}^{max} \\ |electrolytevolume - electrolytestandardvolume| \le 30 \end{cases}$$

where t is electrolyte temperature, L_i is electrolytic tank level.

According to a certain electrolytic copper enterprise for many years of accumulated technical experience. The technical indicators are: $con.$=17.8, ρ=238, l =0.103, η =0.976, s=0.95. In the process of steady state optimization, The content of copper ion in the electrolyte is in the range of [44,49], The ideal range of acid ion content is [135,225], The range of decision variables is shown in **Table 1**.

Optimized Program Simulation

The parameters of differential evolution algorithm are: Population size NP=200, Variation constant F=0.5, Crossover probability factor CR=0.7. The maximum number of evolution iterations is 50. Using NSGA-Ⅱ and improved differential evolution algorithm for the above multi-objective optimization function simulation results are shown in **Figures 3-4**. It can be seen that the improved differential evolution algorithm is superior to NSGA-Ⅱ in improving the diversity of solutions. Thus proving the advantage of the improved differential evolution algorithm in dealing with multi-objective optimization problems.

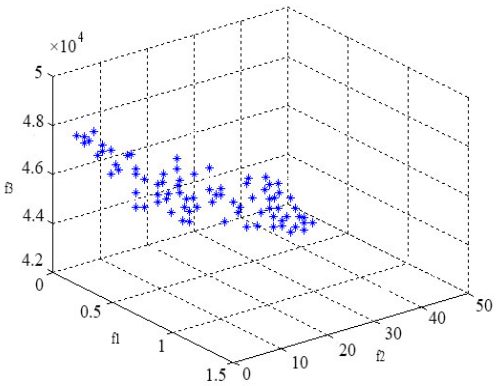

Fig. 3. Results of NSGA - Ⅱ multi - objective optimization

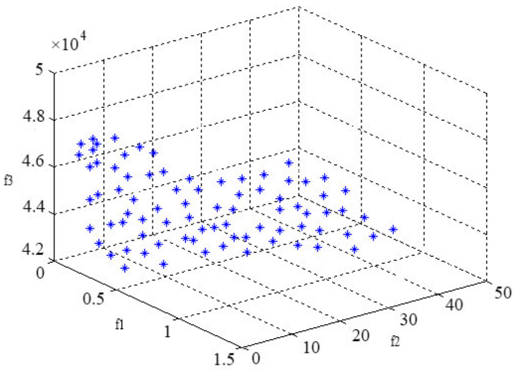

Fig. 4. Improved Differential Evolution Algorithm for Multiobjective Optimization

According to the result calculated by the difference algorithm, the ideal point method is used to analyze and make the Pareto solution, and the results are shown in **Table 2**. According to the ideal point method according to the size of the degree of close to sort, find a close degree of a group of solutions is to seek the optimal solution, which is the optimal parameter $\vec{x} = [64.902,2.776,2.236,0.702,0.855]$ The optimal value of the objective function is $\vec{f} = [1.034,40.462,5.380]$.

The temperature of the electrolyte in the bath at this point is within 64.902℃ of the change in the decision variable. The value of the high level liquid level in the range of the decision variable is 2.776m, the value of 1# and 2# circulating tank level in the range of decision variables is 2.235m, the value of 1# anode mud trough level is 0.704m in the range of decision variable, the value of 2# anode mud trough level is 0.854m in the variation range of decision variables.

Table 2. Closeness degree

No.	t	L_1	L_2	L_3	L_4	f_1	f_2	f_3	c
1	64.902	2.776	2.235	0.704	0.854	1.036	40.643	5.382	0.836
2	64.785	2.776	2.238	0.702	0.855	1.057	40.604	5.385	0.833
3	64.754	2.776	2.234	0.701	0.854	1.012	40.763	5.384	0.832
4	64.726	2.773	2.235	0.694	0.856	1.001	40.845	5.386	0.825
...	...	...	...	...	...	...	...	...	...
100	60.416	2.812	2.314	0.556	0.884	0	48.265	5.614	0.416

Table 3. Close degree of improved method

No.	t	L_1	L_2	L_3	L_4	f_1	f_2	f_3	c
1	62.912	2.715	2.263	0.644	0.883	0.164	43.167	5.546	0.665
2	62.806	2.714	2.265	0.636	0.885	0.114	43.273	5.462	0.663
3	62.792	2.716	2.265	0.634	0.885	0.095	43.413	5.464	0.647
4	62.764	2.715	2.234	0.635	0.885	0.033	43.504	5.465	0.645
...	...	...	...	...	...	...	...	...	...
100	60.416	2.713	2.315	0.556	0.884	0.001	48.265	5.615	0.473

Finally, the improved ideal point method is used to analyze and make the *Pareto* solution, in order not to run the system caused great fluctuations in the impact of system stability, it is necessary to run the current system parameters to take into account the various decision-making mechanism. The current parameter values are $\vec{x} = [62.901,2.754,2.321,0.613,0.740]$, the final point of this state to improve the ideal point method of optimization. The results are shown in **Table 3**.

According to the improved ideal point method of decision-making, and ultimately close to the degree of the ideal as the optimal solution. Therefore, we can know that the best control scheme at this time is the decision-making variables when the sticking progress is 0.665, the decision variable is $\vec{x} = [62.912,2.715,2.263,0.644,0.883]$, The optimal value of objective function is $\vec{f} = [0.164,43.167,5.456]$.The final control scheme is known from the decision variable value: the temperature of the high slot is 62.912 ℃, high tank level is 2.715m, 1 # 2 # circulating tank level is 2.263m, 1 # anode mud tank level is 0.644m, 2 # anode mud tank level is 0.883m.

By using the differential evolution algorithm to optimize the electrolytic copper optimization model, the optimal ideal point method is used to find the optimal control parameters. In this way, it can solve various control parameters of the steady state process of copper electrolytic electrolyte, which can make the electrolysis process reach the optimum state, which can not only produce high quality cathode copper but also save electricity for enterprises, Enterprises can get more benefits, increase operating profit.

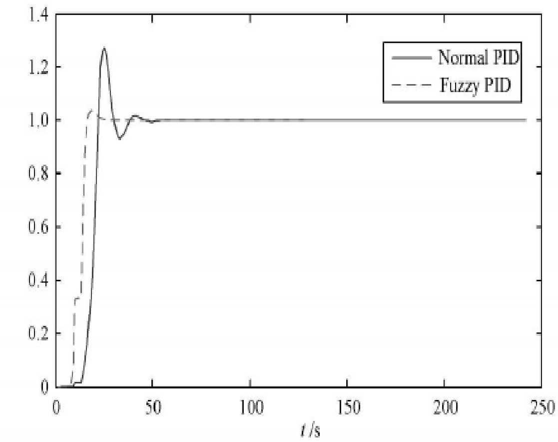

Fig. 5. Simulation results

SIMULATION RESULTS BASED ON FUZZY ADAPTIVE PID

For electric heating furnace temperature control system, the mathematical model is $G(s) = \frac{0.5}{50s+1}e^{-5s}$ Fuzzy factor k_c=0.12, k_{ec}=0.02, defuzzification factor K_1=1.8, K_2=0.03, K_3=0.01, PID parameter values are K_P=3.5, K_I=0.025, K_D=0.1, the simulation result is shown in **Fig. 5**.

From the final simulation curve, it can be seen that the effect of fuzzy adaptive PID control is more ideal than that of conventional PID control. The overshoot of fuzzy adaptive PID control is very small, and the overshoot of conventional PID is very large. There is no oscillation, to achieve steady-state time is also very fast, very high control accuracy.

The simulation shows that fuzzy adaptive PID algorithm is adopted, and the rise time is much faster than that of conventional PID, and there is no oscillation. As long as the overshoot is very small, the time of fuzzy adaptive PID algorithm can be calculated from the simulation graph. PID algorithm is very long adjustment time is more than twice the fuzzy adaptive PID algorithm, to 58s or so; the gap is very obvious. The overshoot of the fuzzy PID algorithm is only 5.2%, while the overshoot of the conventional PID algorithm is several times, reaching 27%, the control effect of the contrast is very obviously, fuzzy adaptive PID algorithm is superior to conventional PID algorithm.

CONCLUSION

Environmental effects of copper is that when copper ends up in soil it strongly attaches to organic matter and minerals. As a result it does not travel very far after release and it hardly ever enters groundwater. In surface water copper can travel great distances, either suspended on sludge particles or as free ions.

Copper does not break down in the environment and because of that it can accumulate in plants and animals when it is found in soils. On copper-rich soils only a limited number of plants has a chance of survival. That is why there is not much plant diversity near copper-disposing factories. Due to the effects upon plants copper is a serious threat to the productions of farmlands. Copper can seriously influence the proceedings of certain farmlands, depending upon the acidity of the soil and the presence of organic matter. Despite of this, copper-containing manures are still applied.

Copper can interrupt the activity in soils, as it negatively influences the activity of microorganisms and earthworms. The decomposition of organic matter may seriously slow down because of this.

When the soils of farmland are polluted with copper, animals will absorb concentrations that are damaging to their health. Mainly sheep suffer a great deal from copper poisoning, because the effects of copper are manifesting at fairly low concentrations.

Aiming to further improve the quality of copper cathode and saving energy and also balance its effect in the environment, this paper analyzes the most important factors affecting the quality of copper cathode the copper ion and acid ion concentration, specially, the effects of temperature on the reaction of copper ions and cupric ions of the objective function during the whole process of electrolytic copper production.

An improved differential evolution algorithm is proposed to optimize the multi-objective function and obtain the optimal solution set of the multi-objective problem, and then a new improved ideal point method is proposed based on the ideal point method. Consequently, the optimal temperature and copper ion concentration are determined to optimize the electrolysis process. Simulation analysis and experimental verification are implemented through the fuzzy adaptive PID, the results show that the algorithm proposed are the correct and feasible.

ACKNOWLEDGEMENTS

The paper was supported by the Jilin provincial development and reform Commission (Grant: 2018C035-1), Jilin provincial science and Technology Department (Grant: 20160101276JC and 20150312040ZG).

REFERENCES

Karthik S, Kaisa M, Deb K (2013) A hybrid framework for evolutionary multi-objective optimization. IEEE Transaction on Evolutionary Computation, 17(4): 495-511.

Piotrowski AP (2014) Differential Evolution algorithms applied to Neural Network training suffer from stagnation. Applied Soft Computing, 21(5): 382-406.

Suresh K, Kundu D, Ghosh S, et al. (2009) Data clustering using multi-objective differential evolution algorithms. Fundamenta Informaticae, 97(4): 381-403.

Wang L, Li L (2011) Fixed-structure controller synthesis based on differential evolution with level comparison. IEEE Transactions on Evolutionary Computation, 15(1): 120-129.

Wang Y, Cai Z (2012) Combining multi-objective optimization with differential evolution to solve constrained optimization problems. IEEE Transaction on Evolutionary Computation, 16(1): 117-134.