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OPTIMIZATION BASED ON NN-GA TECHNIQUE APPLIED TO A WASTEWATER PURIFICATION PROCESS

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Abstract: *Genetic algorithm optimization based on neural networks methodology has been developed for the electrolyses process of wastes polluted with phenolic compounds. The optimization problem allows the predictions of the COD values for a treated waste depending of the initial characteristics (pollutant concentration, pH), operation conditions (temperature, current density) and current charge passed.*
Key words: *neural network modeling, genetic algorithm, optimization, batch electrolysis process, wastewater*

1. INTRODUCTION

Generally, the phenomenological treatment of an electrolysis system is very complex. The rate of reaction in this system is a nonlinear function of temperature, pH, current density, time etc. Due to these reasons, the ability of neural networks (NN) and genetic algorithms (GA) to recognize and reproduce cause–effect relationships through training, for multiple input–output systems, has gained popularity, in various areas of chemical engineering (Ozkaya et al., 2007), being recommended tools in the field of wastewater treatment (Piuleac et al., 2010a; Piuleac et al., 2010b; Leon et al., 2010).

GAs, part of the so-called evolutionary algorithms, represent search and optimization tool with increasing application in scientific problems because they do not need to have any information about the search space, just needing an objective function that assigns a value to any solution (Deb, 1999).

Recently, many works have been published concerning the use of electrolysis in the treatment of synthetic wastewaters: phenolic (Canizares et al., 2005; Canizares et al., 2007a) carboxylic acids (Canizares et al., 2008a), heterocyclic (Canizares et al., 2008b) and wastewaters with fine chemicals (Canizares et al., 2006), door-manufacturing processes (Canizares et al., 2008b), olive-oil mills (Canizares et al., 2007b). Within these technologies, the use of diamond anodes has an important advantage due to the great removals of COD (no refractory compounds are formed) and to the great energy efficiency of these processes.

The main goal of this work is to develop a general procedure based on neural networks and genetic algorithm which could be applied to complex optimization problems of electrolysis processes applied to wastewater treatment containing phenolic compounds using boron doped diamond electrodes. NNs are used as an efficient modeling tool and GA as solving method of optimization. It is followed a certain final COD, the minimum as possible, related to the optimal working parameters: electrolysis time, temperature, pH, current density, initial COD, and compound type (phenol, 2-chlorophenol, 2,4-dichlorophenol, 2,4,6-trichlorophenol, 2-nitrophenol, 2,4-dinitrophenol). The optimization procedure was applied separately for each type of phenolic compound.

The GA optimization procedure has proved easily to apply with useful and accurate results. Other possible future ways approaching could be focused on the study of how the GA parameters influence to improve this methodology.

2. OPTIMIZATION PROBLEM

The electrolysis data for our modelling and optimization procedure were obtained from literature (Canizares et al., 2005; 2007a, 2007b, Piuleac et al., 2010a). Based on the experimental data, a neural modeling methodology was developed to describe the dependence between the degree of phenol compound elimination and the others working conditions.

The optimization problem implemented here is formulated as:

Which are the optimal working conditions (electrolysis time, *t*, minutes; current density, *j*, A/m^2 and *pH*) necessary to obtain an imposed final COD_q under the given experimental conditions (fixed values of temperature, *T*, ^0C and initial COD, COD_0, mgL^{-1}) ?

The optimization problem include the neural model which is represented as:

$$NN\ [Inputs:\ COD_q,\ T,\ COD_0;\ Outputs:\ t,\ j,\ pH] \qquad (1)$$

A MLP(3:25:20:3) – feed-forward neural network with 3 variables as inputs (COD_q, T, COD_0), two intermediate layers with 25 and 20 neurons, respectively, and three outputs (*t, j, pH*) is designed for process modeling.

The vector of control variables , *u*, has the components:

$$u = [t, j, pH,] \qquad (2)$$

An admissible control input u^* should be formed in such a way that the performance index, *F*, defined by the following equations, is minimized:

$$F = \left(1 - \frac{COD_q}{COD_{qd}}\right)^2 \qquad (3)$$

The final COD_q is a measure of the phenol compounds elimination from wastewater, with values between 5300 and 0 mg L^{-1}. Low values for this parameter mean high degree of phenol compounds elimination.

The constraints are very important to define the range of variation of parameters and to disregard possible solutions that could be interesting in a theoretical approach to the problem.

The fitness function of the GA is the scalar objective function (3). Genetic algorithm provides, after an iterative calculus, the optimal values for the decision variables (*t, j, pH*), which are the outputs for the neural network model. In these conditions, the neural network computes the final value of COD_q, which will be compared with the desired value, COD_{qd}. If the two values are identical or there is a very tight difference between them, it could be concluded that the task of the optimization, represented by minimum of the objective function, F, is achieved.

$$
\begin{aligned}
& u_{min} \le u \le u_{max} \\
& 0 \le t \le 600\ min \\
& 15 \le T \le 60\ ^0C \\
& 50 \le COD_0 \le 5300\ mg\ L^{-1} \\
& 2 \le pH \le 12 \\
& 15 \le\ j \le 60\ A/m^2
\end{aligned} \quad (4)
$$

The model MLP (3:25:20:3) was tested against training and validation data. Good agreement between experimental data and neural network predictions (average relative errors less than 10 % and a correlation over 0.9938) proves that the neural model is appropriate for the optimization procedure.

The variation domains for decision variables are represented by the constraints (4). Imposing different values for COD_{qd} in the interval 0-10 mgL^{-1}, the optimal working conditions obtained by GA optimization procedure are given selectively in Figure 1 and Table 1.

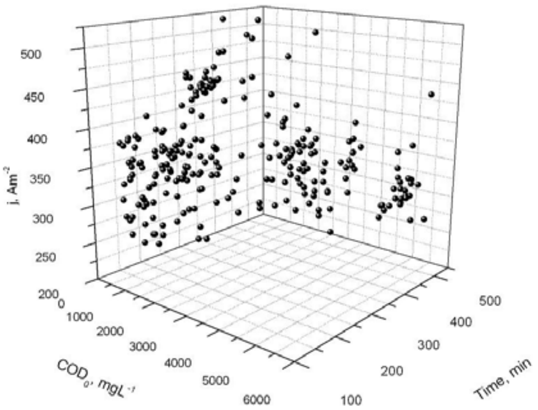

Fig. 1. The optimal values of decision variables for different values of COD_{qd}

Phenol compound type	j, Am^{-2}	pH	Time
Phenol	200÷550	1÷9	120÷500
4-Chlorphenol	200÷550	1÷11	180-600
2,4-Dichlorphenol	50÷550	2÷9	180÷600
2,4,6-Trichlorphenol	200÷570	2÷11	180÷500
4-Nitrophenol	150÷470	2÷11	320÷600
2,4-Dinitrophenol	200÷530	2÷10	360÷600

Tab. 1. The representative ranges values on each phenol compound for the GA optimization problem

3. CONCLUSION

The electrochemical oxidation with conductive diamond electrodes represents one possible method to treat phenolic aqueous wastes. The complexity of the oxidation mechanisms involved in this process and the variety of intermediates generated during the process make difficult the use of model for controlling purpose. The genetic algorithm solves the optimization problem and the neural network constitutes the model included in the optimization procedure. Simple architecture of the neural network is proposed for process modeling: a feed forward neural network with two hidden layers. A simple genetic algorithm proves to be a good tool for solving the optimization problem, providing important information for experimental practice.

The method can be easily extended and adapted to other environmental oriented processes, with high chances of providing accurate results.

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