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POSSIBILITIES OF INTRODUCING AN INTELLIGENT CONTROL SYSTEM IN THE FLOTATION PLANT VELIKI KRIVELJ***

Abstract

In this paper, an analysis of the possibility of implementing the fuzzy logic and artificial neural network controller in the intelligent control system in the flotation plant Veliki Krivelj was performed. Functional positioning of controllers was considered through two approaches. According to one approach, the control of flotation process would be carried out by only one controller, while in the second case two controllers would exist – one for a rough flotation and scavenging and the other for cleaning.

Keywords: *flotation, fuzzy logic controller, artificial neural network controller*

INTRODUCTION

When discussing the process control from the plant operational performances point of view, a quick, precise and adaptive reaction of the system is an essential demand. Moreover, the need for development and utilization the sophisticated control methods is even higher given the lack of information available, an existing non-linear environment, as well as rather complex nature of the system. The requirement for flexibility in production and maximizing the recovery of energy and materials further increase this need [1, 2]. Possible solution of the problem is an intelligent control.

Intelligent control is a discipline where the control methods are developed so that they mimic important characteristics of human intelligence - adaptation and learning, planning under high uncertainty, and com-

puting the immense quantities of data [3]. In other words, intelligent control implies the application of artificial intelligence methods (artificial neural networks, machine learning, fuzzy logic, evolutionary computation, etc.).

Classic control methods require understanding of work with a complete set of data, including sensor information and values within all process parameters. Unless the all necessary data is completely known, the appropriate estimations should always be taken into account. And, if the available information is at all fuzzy, qualitative, incomplete or unclear, the classic regulators and control will not provide the satisfactory results. Furthermore, the classic control techniques are largely based on the assumption that the plant operation is linear and

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*** *This investigation was conducted under the Project TR 33007 "Implementation of the Modern Technical, Technological and Ecological Design Solutions in the Existing Production Systems of the Copper Mine Bor and Copper Mine Majdanpek", funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia*

time - invariable, which does not correspond to the majority of real processes [1, 2]

Unlike the conventional control, the intelligent control techniques possess capabilities that effectively deal with incomplete information concerning the plant and its environment, and any unexpected or unfamiliar conditions [2].

Accordingly, the intelligent methods find increasing application in engineering practice through different approaches – real time process control, diagnostics, modeling and process analysis, optimization, etc. Despite the diversity in applications, the analogies can be noted at several levels, such as a capability for processing imprecise, uncertain

and unclear information, utilization of similar inference mechanisms, etc. [4, 5].

Taking the aforementioned into account, as well as the nature of flotation process, it can be said that the intelligent methods represent a promising technique in the control of flotation systems.

EXPERIMENTAL AND MODEL DEVELOPMENT

For the purposes of this research, the fuzzy logic and artificial neural networks, based flotation models, have been developed. Their brief systematization is shown in Table 1.

Table 1 Basic data about models

SC Method	Input variables					Output variables		
	Cu content in feed	Collector dosage (roughing)	Frother dosage	Pulp pH	Collector dosage (scavenging)	Final concentrate grade	Copper recovery	Final tailings grade
Fuzzy logic (Mamdani system)	+	+	+	+	+	+	+	+
Fuzzy logic (Takagi-Sugeno system)	+	+	+	+	+	+	+	+
Artificial neural networks	+	+	+	+	+	+		
Artificial neural networks	+	+	+	+	+		+	
Artificial neural networks	+	+	+	+	+			+

Data for models were collected from the industrial flotation plant "Veliki Krivelj", whose technological scheme is shown in Figure 1. The ore processing in the plant includes:

(1) two-stage grinding and classification,

(2) rough flotation of copper minerals,

(3) regrinding of the rougher and scavenger concentrate,

(4) three-stage cleaning of the copper concentrate,

(5) scavenging after the first cleaning.

The experimental research was performed in virtual conditions, using the MATLAB programming language. The validation of the proposed flotation mo-

odels was carried out in Microsoft Excel. More details on the development and results of these models are given in the literature [6].

Figure 1 *Technological scheme of the flotation process in “Veliki Krivelj”*

INTELLIGENT CONTROL SYSTEM – PROPOSALS AND DISCUSSION

The purpose of a process modeling is exactly the possibility of implementing the developed model into an automatic system for that process control. Figures 2 and 3 contain suggestions for the simplified control schemes of the flotation plant “Veliki Krivelj” that would include controllers based on the soft computing methods as a form of decision support (fuzzy logic controller), or as an independent control unit (ANN controller). In this case, the classical PID controllers would be used for the lower hierar-

chical control levels, such as: air flow rate, pulp pH value, pulp level in flotation cells, redox potential value (Eh), etc.

Based on the developed fuzzy logic and ANN models, it is possible to consider recommendations for the positions of appropriate control modules within the automatic control system in the “Veliki Krivelj” Flotation Plant.

The results of the models development allow the functional positioning of the fuzzy logic controller in two variants of the control

system architecture (Figure 2). According to one variant, the flotation process control would take place through the control actions of a single fuzzy logic controller, while in the another variant, the functional-

ity of fuzzy logic model would be realized through the separate fuzzy logic controllers: (1) for rough flotation and scavenging on one side, and (2) cleaning on the other side.

Figure 2 Scheme of intelligent system for the flotation process control based on the fuzzy logic controller(s)

Figure 3 Scheme of intelligent system for the flotation process control based on the artificial neural network controller(s)

Architecture of the automatic control system allows the elaboration of both variants. By the first variant, the fuzzy models would perform the high level control of the

practically entire flotation process. (Note: Although technologically closely related to the flotation, grinding and classification would be omitted from this decision support

CONCLUSION

system, due to the specificity of fuzzy rules construction and qualitatively different characteristics. In that respect, it would be necessary to employ a new soft computing-based controller, or some other type of controller.)

Model performances, in spite of the large fuzzy rule base (753 rules in total), enable control of the plant operation in described manner. However, if the number of monitored parameters significantly increase, a large expansion of the fuzzy rule base would be necessary, and in a such case, the model performances would potentially decrease. In this situation, the justification of the second variant (i.e. employing of two connected, but according to the rule bases and membership functions independent fuzzy controllers) would be certain.

The rougher flotation and scavenging on one side, and cleaning on the other side are technologically enough different, therefore introducing the additional control stage would be economically justified. The flexibility of the fuzzy rule base is such that, with the adjustment of membership functions, development of the new fuzzy controller would be facilitated. Accordingly, there would be no significant differences in the way in which both controllers operate.

Similar conclusions are also justified when it comes to the artificial neural network - based controller (Figure 3), but it is necessary to examine the performances of the controller in a real dynamic system. It is usual that the ANN - based algorithms and models generally show better performances than fuzzy logic - based [6], but this is not the case in all industrial (and test) flotation systems. The decision on which control variant is optimal for the given technological process needs to be made "on the spot", taking into account the specificity of observed system.

Intelligent control methods are developed in a manner that they emulate characteristics of the human intelligence such as adaptation and learning, planning under high uncertainty and computing immense quantities of data. Therefore, these methods may be suitable for the flotation system control. In this paper, the possibility of introducing an intelligent controller into the industrial flotation plant "Veliki Krivelj" was considered. It was concluded that the fuzzy logic or ANN - based controllers can be positioned in two ways. In the first case, control of the entire process would be performed through the control actions of a single intelligent controller. In the second case, there would be two intelligent controllers: for rough flotation with scavenging, and cleaning the copper concentrate.

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