Optimization of the second and third stages of grinding based on fuzzy control algorithms

Morkun Vladimir

D.Sc, Professor,
Kryvyi Rih National University

Savytskyi Oleksandr

PhD, Associate Professor,
Kryvyi Rih National University

Tymoshenko Maxim

M.d-student,
Kryvyi Rih National University

Abstract
The paper considers aspects of managing the processes of grinding on each stage taking into account features. Developed algorithm of grinding complex control with the use of fuzzy logic.
Key words: GRINDING, AUTOMATION, FUZZY LOGIC

Most works on the grinding process automation pay most attention to management of ball mill grinding in the first stage, because the loss in the first stage is the biggest - 30-55% of the total iron losses in tails [1, 5-9]. To control the three-staged grinding complex is advisable to apply traditional automatics in conjunction with the methods of fuzzy logic, that allow you to operate not with numeric values but with linguistic variables. This allows to treat all complex as a more adequate system, close to the actual conditions, and to carry out control in real time on the basis of some expert knowledge base. In [1] is proposed a scheme of expert control system of grinding, which is based on using of fuzzy logic processor. For development of algorithm used part of the technological scheme of enrichment from one of Kryvyi Rih MPCs [2]. Source [3] shows the benefits of the combined use of clear and fuzzy regulators. Thus, taking some simplification, some of the options we control by clear regulators, reducing the number of rules and reducing the load of fuzzy logic CPU. To narrow range of control before the grinding process should determine the identity of iron ore to a mineralogical and technological kind. Checking with technological card, we can provide approximate value of the final product parameters for a particular kind of ore and manage toward reducing discrepancies and got the desired results. Control is operated by adjusting the additional water in the stage. In addition, taking that level of hydrocyclone sump is adjusted by clear regulators, with some assumptions we can also supply the pulp to the miln.

For the development of fuzzy logic rules must establish patterns between the measured value and control actions. Thus, density of pulp at the entrance of hydrocyclone is associated with the performance as follows:

$$\rho = \frac{\rho_l * (1+R) * \rho_s}{1+\rho_s * R}, \qquad (1)$$

where R – dilution (R=W/G); W and G – performance by liquid and solid phases of pulp respectively; ρ_l and ρ_s – density of liquid and solid phases.

The [4] proposed way of deciding the part of useful component in the solid phase of iron ore pulp and corresponding formula for

$$\eta = \frac{(\rho_{nm}-\rho_l)*(\mu-1)nJ_0C_v l}{\ln\left(\frac{I_{0v}}{I_v}\right)\rho_{pl}I_m-(\rho_m-\rho_{nm})*(\mu-1)nJ_0C_v l}, \qquad (2)$$

where ρ_l - is density of liquid phase; ρ_{pl} – is density of measuring devices plate material; ρ_m and ρ_{nm} – are densities of magnetic and nonmagnetic components of pulps solid phase; μ – is magnetic permeability of the pulp; n – is the proportion of the number of turns of the solenoid to its length; J_0 – is current intensity in the solenoid; C_v -is constant; l – is distance between source and receiver of waves; I_{0v} and I_v – are Lamb wave intensity before and after passing through the pulp; I_m – is theoretical value of the magnetization of pure magnetite (100%).

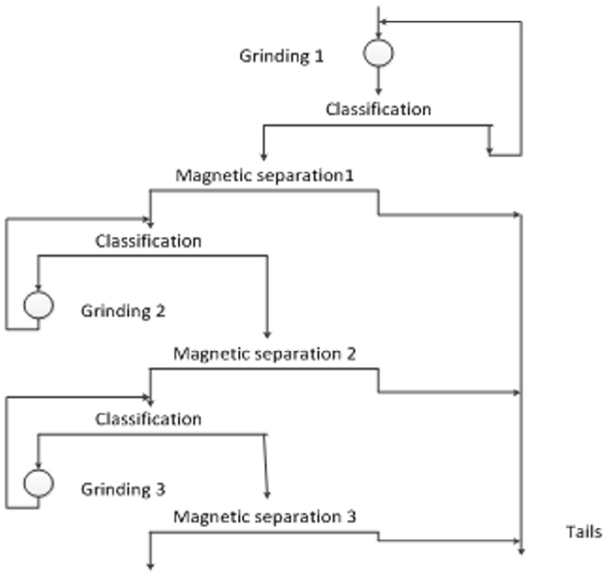

Figure 1. Part of the technological scheme of enrichment

Changing the estimated class size after grinding reflects the relative performance of the mill. And since it is tabulated value for specific models can be derived pattern

$$q_d = \left(\frac{Q}{V}\right)(\beta_d - \alpha_d), \qquad (3)$$

where q_d – specific performance of the mill in the newly formed class; α_d, β_d – content of the settlement class size before and after grinding; Q – performance of miln; V – volume of the milns work area.

On the basis of the measured and calculated parameters for formulas, there formed the fuzzy logic rules. Each of input and output parameters has five terms, respectively, “very little”, “little”, “medium”, “many” and “very much”. The content of useful component (%) in the final product depends on the pulp density (ρ) and the contents of the settlement class size (K) and displayed direct dependence, for example (in the form of supply rules in environment of Matlab) *«IF (ρ is many) AND (K is many) THEN (% is many)»*. Overall performance is defined as a set of performances for water and for pulp, which, unlike other options have only three terms, i.e. high productivities for pulp and water will mean that overall performance is very high. This can be represented as a directly proportional dependence “(Qw + Qp) : Q”. Data values are expressed conventionally in the range [0.0 1.0].

Density of pulp depends on volume of hard and liquid phases, therefore there defined through productivities by water and pulp, moreover, the greater productivity Qp of productivity Qw is, the greater the density. It can be seen from “Qp/Qw : ρ”.

The content of the current class size in pulp (K) has a direct dependency on the time and intensity of grinding (that is expressed in the performance of Q) and from the pulp density (ρ), for example *"IF (ρ is many) AND (Q is many) THEN (K is many)"*. However, one should consider the processes of too great or insufficient grinding, that even with great productivity do not give the expected result. This occurs when the pulp is too thick and did not have time to become fully grinded (besides that too much load mill, that affects its performance) or too liquid, which means that too grinded product leaves right in tails. Therefore, when the density reaches extreme values, the direct relationship is broken, that is *"IF (ρ is very many) OR (ρ is very many) THEN (K is little)"*. In this case, at small values of performance parameter (K) is set to "very little". Due to a lack of real data from production processes or laboratory data calculations are made in conventional units. Figure 2 shows the hardware part of the algorithm.

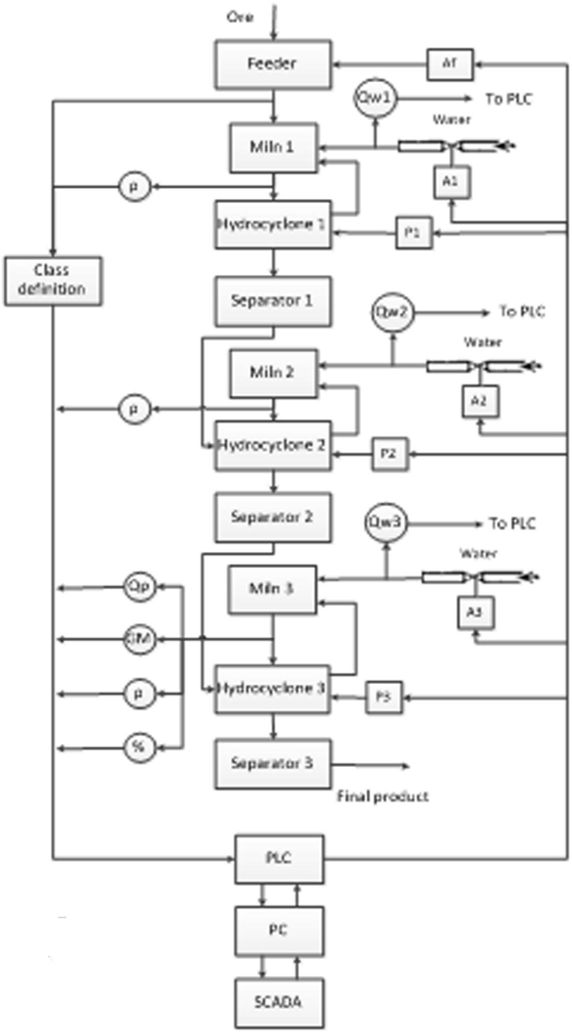

Figure 2. Hardware part

To the mill in the first stage iron ore comes from the feeder. Controlling the amount of ore is driven by control of feeder with feeders actuator (Af).

After the first and second grinding stages density measurements are made intermediate between stages using density meter (ρ). Knowing the amount of ore and water received in the first stage of grinding, and the resulting pulp density, block of class definition determines the membership of grinded ore to a mineralogical and technological kind. This allows to consult with technological card and get the desired end product parameters that need to be oriented. Considering the specified variety of iron ore, operating range of influences can be significantly reduced and speed of algorithm in general increased. Besides the density of the final product after the third stage, much more necessary parameters such as the size of crushed material using granulometr (GM), the content of useful component (magnetic iron), fixed by sensor, that is indicated in the figure as (%), and performance of the water and the whole pulp (respectively flow Qw and Qp) are measured. All data is measured and entered into the PLC and then to the PC. Based on the data algorithm calculates the control action and submit it to the actuators (A1, A2 and A3), which, in turn, control the supply of additional water in the mill. Therefore formed three control actions that are applied to pumps of hydrocyclone (P1, P2 and P3). At the same time visualization in SCADA system based on the data on PC happens.

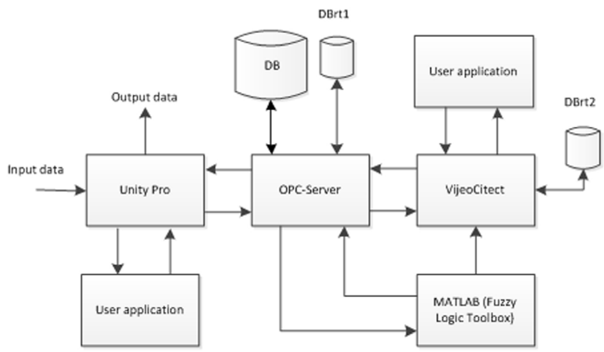

Figure 3. Program part

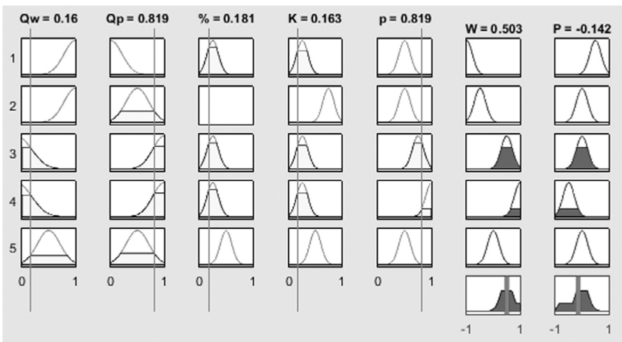

Figure 4. Fuzzy decision

Figure 3 shows the program part of the system. The collected information from sensors and parameters of pulp grinding process goes to the PLC (for example, Modicon M340) to the appropriate software environment. The main mean of communication is an OPC server, that converts data into an universal format and provides communication and data exchange between different programs. Thus, Matlab, and Unity Pro, and SCADA-system VijeoCitect communicate through OPC-Server. For visualization in SCADA-system data come to it directly from Matlab, via internal OPC-Server. The operator can carry out surveillance and control system using VijeoCitect. Figure 4 shows a part of test group of fuzzy logic rules, performed in an environment MATLAB, namely by means of Fuzzy Logic Toolbox. Specifically, said the case shows the lack of ore grinding through a large load of the mill and low density of the pulp. The decision is to increase the water supply.

Conclusions

Modern means of control and automation and hardware level allow to consider a whole grinding cycle, not just the first stage. As an example, fuzzy logic tools allow to focus on experience, expert knowledge base, establish linguistic relationship between the input and output values of grinding cycle, while follow and express them mathematically is extremely difficult. Thus, control and optimization of grinding are possible.

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