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MICROPROCESSOR CONTROL SYSTEM FOR OPTIMIZATION OF ORE–GRINDING PROCESS IN SEMIAUTOGENOUS MILL

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ABSTRACT

As a result of recent scientific and experimental study improved technical means for monitoring and control of the grinding process in semiautogenous (SAG) mill have been developed. The short description of two kind of sensors for measuring of impact pulses provoked at the grinding as well as modernized microprocessor module MILLCONT 2M for control of the mill's loading is given in the paper. The structure of the automatic system for optimization of the process in SAG mill with above mention technical means and the loops for measuring and control of the basic technological parameters are presented in the paper. The aim is to be increased productivity of the grinding aggregate as well as to be improve the quality characteristics of the ready pulp at minimal interference of the operator. The nowadays achieved economical results from exploitation of control system implemented on SAG mill in ore-dressing factory of Dundee Precious Metals Inc. - Chelopech (Bulgaria) are given as well.

KEYWORDS

mill loading, impact pulse sensor, microprocessor module, control loops

INTRODUCTION

The grinding of the ore in Dundee Precious Metals-Inc. Chelopech (Bulgaria) is performed on SAG mill working in close cycle with hydrocyclone battery. In the control channels the mill aggregate can present with the structure shown in Figure 1, where:

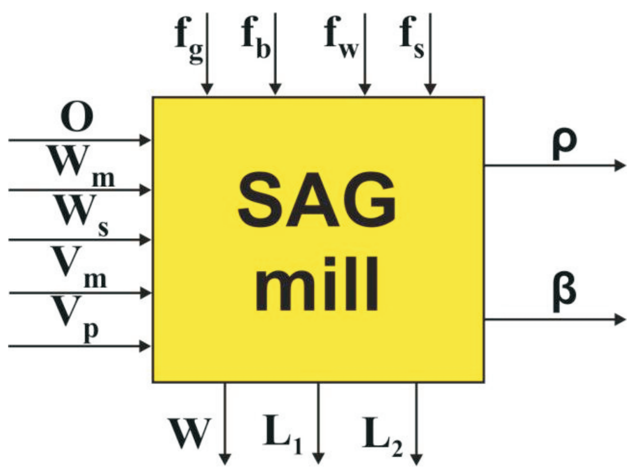

Figure 1- Schematic diagram of the SAG mill

Control actions

O – flow rate of the ore sent to the mill;
W_m – flow rate ofthe water sent to the mill;
W_s – flow rate of the water sent to the sump;
V_m – revs of the mill;
V_p – revs of the pump aggregate

Indirect regulable parameters
W – weight of the mill;
L_1 – impact pulses vibration of the casing of the mill;
L_2 – impact pulses vibration of the gear of the driver motor

Disturbances of the technological process
f_g – grindability of the ore;
f_b – quantity of the ball charge;
f_w – wearing out of the mill lining;
f_s – quantity of the sands

Regulable parameters
ρ – pulp density at the mill outlet;
β – fineness of grinding of the pulp

As a result of the resent scientific and experimental studies improved variant of microprocessor control system MILLCONT 2M for optimal loading of SAG mill has been developed the brief description of which is given here below.

NEW MICROPROCESSOR SYSTEM MILLCONT 2 M

The system MILLCONT 2M contains two sensors for measuring of impact pulses and microprocessor module.

The sensibility of the developed new remote pulse sensor SRIP (Figure 2) and direct pulse sensor SDIP (Figure 3) is increased in comparison with the acoustic sensor (Golder & Hagenbach, 1994) and nowadays used magneto - electric sensor (Penzov et al., 2006)

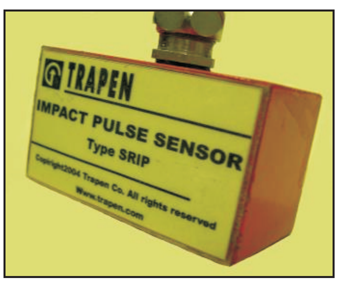

Figure 2- Remote sensor SRIP

Figure 3- Direct sensor SDIP

The sensors consist of two sensitive elements differentially connected for elimination of parasitic signals They are generator type and do not need additional power supply. Out put voltage signals from the sensors are up to 1V with amplitudes proportional to impact pulse slope, i.e. the sensors differentiate the impact pulses without distortion.The signals are transmitted through double - core armoured cable to 500 m without further amplification. The sensors are covered with special compound reducing the parasitic signals and protecting against outside influences: spattering water, dust, explosion - hazardous mixtures, etc. They areresistant to impacts and rough handling as the sensors have not driving parts and do not need maintenance as well as they are in practice everlasting. The sensors resist to temperature from – 40^o to $+100^o$ C.

The microprocessor module of the system MILLCONT 2M (Figure 4) consists of two solo control loops (Marinov & Penzov, 2006).Each loop has analogue differential amplifier with controlled amplification factor,digital component with adjustable parameters for shaping factor of grinding FG special digital PID regulator, which can be adjusted to work in different mode at mill loading and discharging.Both loops are free configuring, as they can operate with input signal from the sensors or with unified signals from other sources. The module is with standard current inputs and outputs, which can be programmed as normal or inverse and also with serial communication channel RS 485 programmed to MODBUS. The module is for panel mounting

Figure 4 - Microprocessor module

The special regulators of MIL LCONT 2M are with analog outputs given by the formula (Penzov & Marinov, 2008) :

$$Y_n = \left[P_r X_n + \frac{T}{T_i} \sum_{K=0}^{n} X_K + \frac{T_d}{T} \left(X_n - X_{(n-1)} \right) \right] \frac{100}{f_r} \% + bo \qquad (1)$$

where:

Y_n - output control value;

X_n , $X_{(n-1)}$ - disbalance between set point (SP) and factor of grinding (FG);

P_r - gain coefficient; T_i - time constant of integration; T_d - time constant of deviation;

T - tact of the control law ; f_r - range of the input signal ; bo - initial output control value

The module is built in PVC box with dimensions 65 x 135 x 165 mm, inserted in aperture with dimension 67 x 137mm. The sensor SRIP is installed on the stand hardly connected to the foundation as its adopt part is directed from over 200mm under 30 - 40° against the waterfal l side of the mill . The sensor SDIP is fixed on the casing of the gear by means of incorporated magnets. In order to escape a disturbances the armoured cables, connecting the sensors with the module are transmitted on the cable shelf a far from high voltage cables and high frequency tyristor or transistor motor drivers.The cables are withdrawn in steel pipes for protection from disturbances and outer intervention.

INFORMATION CONTROL STRUCTURE OF THE SYSTEM FOR OPPTIMIZATION OF THE GRINDING PROCCES

The automatic system for ore grinding control in semiautogenous mill with above mention technical means has the structure diagram given in Figure 5. The aim is to be increased productivity of the SAG mill as well to be improved the quality characteristics of the ready pulp at minimal interference of the exploitation personnel.

The purpose of the automatic system is:

- to measure the loading (feeling level) of the mill with ore;
- to stabilize the set loading by change of the flow rate of the inlet ore;
- to measure and stabilize the flow rate of the water sent to the mill and the sump as well;
- to keep up the set ratio material-water at the control of the mill loading;
- to stabiizel the set density by change of the water sent to the sump;
- to correct the set density by the water sent to the mill.

At such way the control system of the wet ore grinding process stabilizes the outlet parameters (fineness of grinding and density) of the ready product and provides optimal throughput of the grinding aggregate.

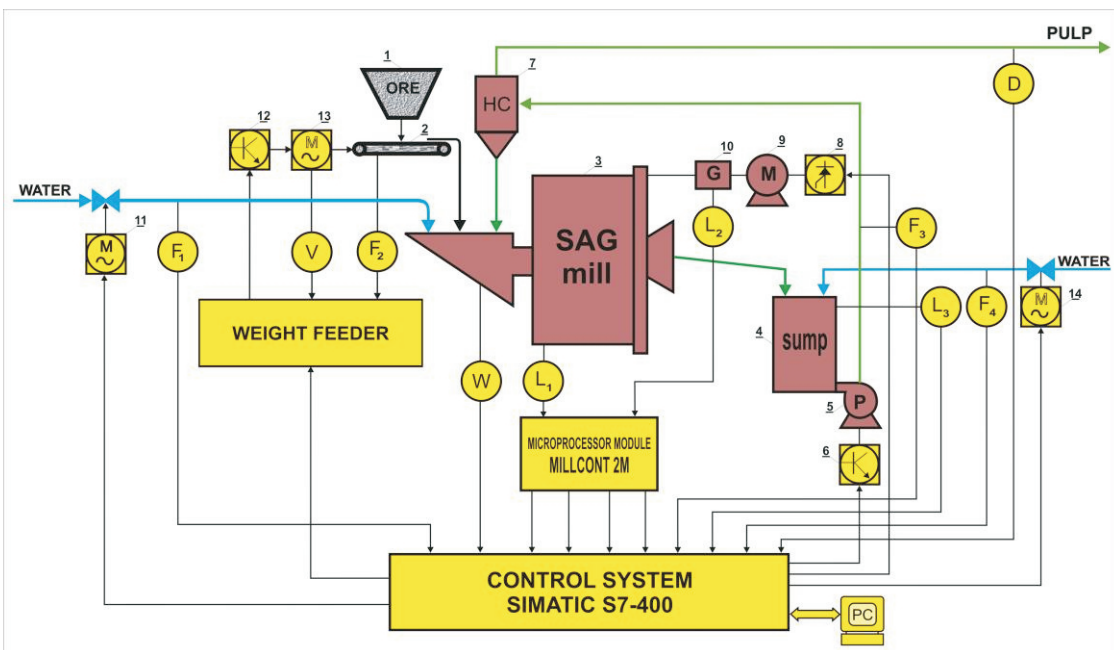

Figure 5 - Schematic diagram of the control system

The system realizes the following measuring and control loops:

Measuring loops of technological parameters

F_1, F_4 – the flow rate of the water sent to the mill and the sump respectively ;
F_2 – the weight flow rate of the ore sent to the mill;
F_3 – the flow rate of the pulp sent to the hydrocyclone;
V – the revs of the band feeder;

W – the weight of the mill;
L_1, L_2 – the loading (filling level) of the mill;
L_3 – the pulp level ofthe sump;
D – the pulp density of the ready product.

Control loops of material flow rates and technological parameters

- The weight flow rate of the ore sent to the mill by the weight feeder (signals V, F_2) with effect on the transistor frequency inverter 12, changing the revs of the band feeder 2;
- The flow rate of the water F_1 sent to the mill in set ratio with the weight flow rate of the ore with effect on the actuator 11 of the water tap;
- The weight of the mill. The loop includes the sensor W and regulator configured from control system SIMATIC S7-400 and connected in cascade with the loop for weight flow rate of the ore;
- The loading (filling level) of the mill. The loop includes the sensors L_1 and L_2 connected by weight coefficients to the microprocessor module MILLCONT 2M. The sensor L_1 is remote sensor SRIP installed on stand against the waterfall side of the mill. The sensor L_2 is direct sensor SDIP installed on the casing of the gear. The regulator of MILLCONT 2M acts by the control system on the frequency inverter 8 corrected the revs of driver motor of the mill 9;
- The pulp level ofthe sump by the signal L_3 with effect on the transistor frequency inverter 6, changing the revs of the pump 5. The signal for flow rate of the pulp F_3 is sent as a position feedback to the regulator of the loop configured from the control system;
- The density of the pulp for flotation. The loop contains the densimeter D, the regulator configured from the control system and the actuator 14 of the water tap. The flow rate of the water F_4 is sent as a position feedback to the regulator of this loop. Also the signal of the density is used for correction of the water flow rate sent to the mill.

The obtained parameters at the identification of the SAG mill as a object of automation (gain coefficient K_0, transport delay τ_0, time constant T_0) are used in the developed algorithm for the choice of the type of regulator and the optimal adjustments of its parameters.

The trends of the regulable parameters L_1 and L_2 after optimal adjustment of the filling level control loop with effect on the revs V_m of the mill are given in Figure 7 .

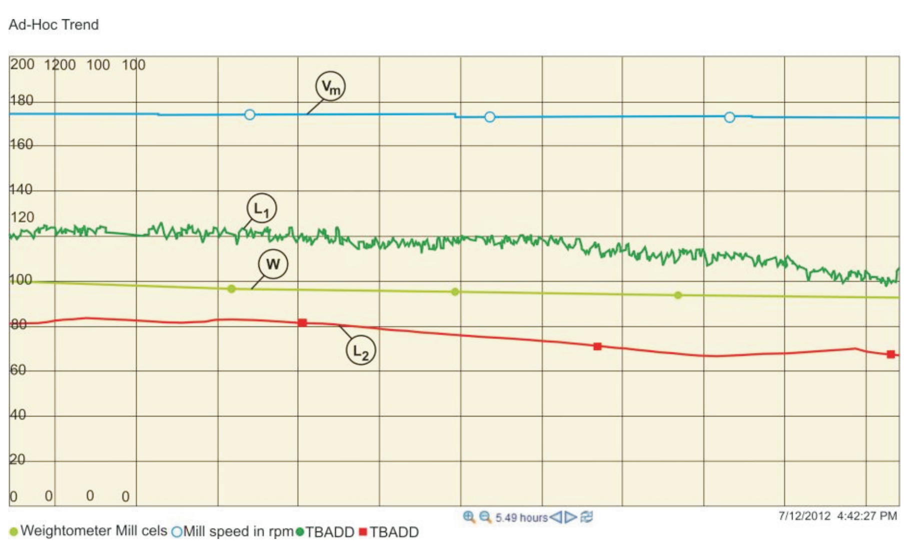

Figure 7- Trends of the main regulable parameters

CONCLUSION

The nowadays achieved economical results from exploitation of automatic system implemented fractionaly on SAG mill in ore-dressing factory of Chelopech mining (Bulgaria) are following:

- The mill output grows over 15 %;
- The specific energy consumption is reduced approximately to the same percentage;
- The durability of the lining and grinding bodies extends with 3-4 months;
- The mean square deviations of ready product by fineness of grinding and pulp density are reduced with an average of 1,3 times in comparison with those at manual control of grinding process;
- The average time for system buying back is under 6 months.

Besides these good economic results the system eliminates subjectivism at the control of grinding process and improves the overall labor organization of the workshop.

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