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Staying in control

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Using an effective control system can significantly improve the performance of a cement works' grinding facilities. It can not only increase a mill's productivity but also improve energy efficiency and lower maintenance costs.

Closed-circuit grinding with a single-stage ball mill and separator is the cement industry's predominant method to mill raw materials as well as clinker. Cement plants typically assess mill performance in terms of output and energy efficiency and take appropriate action to optimise their mill's operation. An advanced control system is a key tool in this process.

The process control of the mill can be structured as follows (see also Figure 1):

- Y_1, Y_2 – output parameters that can be regulated (grinding fineness and mill productivity)
- L_1, L_2, I, F – indirect parameters that can be regulated (L_1, L_2 – mill loading in first and second chamber, I – elevator loading, F – quantity of the return from the separator)
- f_g, f_b, f_w – disturbances in terms of feed materials grindability, ball charge volume, mill lining wear, respectively
- X_1, X_2, X_3 – control actions (feed material volumes).

Following recent scientific and experimental studies, Bulgaria-based Trapen has developed a new process control system for grinding units.

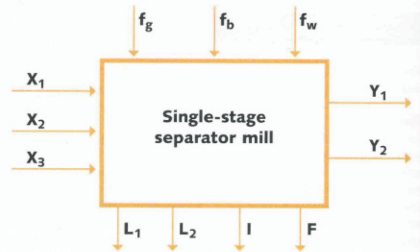

Figure 1: schematic diagram of single-stage grinding mill

Sensor for ball mill loading: SRIP

The SRIP ball mill loading principle reflects a new parameter of impact pulses of mill case vibration. The sensor's signal is sent to the microprocessor module, where software determines a 'grinding factor' (GF). It is related to the material layer resistant to penetration of the grinding bodies in the sensor zone. The material layer's resistance depends on its thickness as well as the size, hardness and grindability of the materials. The GF reflects the changes in layer thickness and the materials' qualities. It is programmed on a case-by-case basis by selecting the frequency area where the impact pulses are located and by the coefficient defining the GF range.

Figure 2: SRIP impact pulse sensor

The SRIP ball mill loading principle reflects a new parameter of impact pulses of mill case vibration. The sensor's signal is sent to the microprocessor module, where software determines a 'grinding factor' (GF).

This measurement principle offers the following advantages:

- The grinding factor is not affected by the work delivered by nearby mills and other aggregate factors.
- The technique obtains timely accurate information about the resistant properties of the material layer in the sensor zone.
- Unnecessary data relating to resonance vibration of the mill casing are eliminated.
- When the grinding factor changes, the system can control the wear of the grinding media and lining.
- When the grinding factor changes suddenly, the system can define the mill breakdown (destruction of grids and lining, clogging up of inner bodies, etc).
- The sensor signal is sent over a distance of up to 200m without additional amplification.

The SRIP sensor used to remotely measure the impact pulses (see Figure 2) consists of two elements [1] of which the electrical signals are generated with amplitudes proportional to the steepness of impact pulses at the grinding of materials. The sensor elements are connected differentially for eliminating of parasitic electromagnetic fields. The signal is transmitted through double-cored armoured cable with isolated shield. By means of special elements, screens, compound etc, the sensor is provided a high sensibility and selection at the measuring of impact pulses. In this case, parasitic vibrations and sound signals from nearby mills and aggregates are avoided.

Microprocessor module Millcont 2A

The microprocessor module of the Millcont 2A (see Figure 3) has two control loops. Each loop consists of:

- input differential amplifier with programmable gain coefficient 1,2, 4 and 8
- analogue high-frequency second-order filter with a 50Hz cutting frequency for the elimination of low-frequency oscillations caused by mill ovality and hatches and bolts nearby the measuring band
- analogue amplifier of the filter signal with gain coefficient 2
- 12-bit ADC
- microprocessor for the signal treatment and the formation of the FG grinding factor, which is transmitted in normal or inverse type to the PID controller input, the analogue output 0(4)-20mA and to the display F on the front panel
- microprocessor (for both loops) for the formation of the PID controller.

The PID controller is controlled by the following formula [2]:

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

where: Y_n = output control value

X_n, $X_{(n-1)}$ = imbalance between set point (SP) and grinding factor (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 input signal

To improve controller operation, the menu provides extra programmable zones: a dead zone (n) and a linear operation zone (L). Most mills have different transitional characteristics at loading and discharge and as a result, the menu allows for two groups of adjustments for P_r, T_i, T_d, n and L which depend on X_n.

The Millcont 2A microprocessor module, which can be panel mounted, has standard current inputs and outputs programmed as normal or inverse as well as a RS485

Figure 3: Millcont 2A microprocessor control module

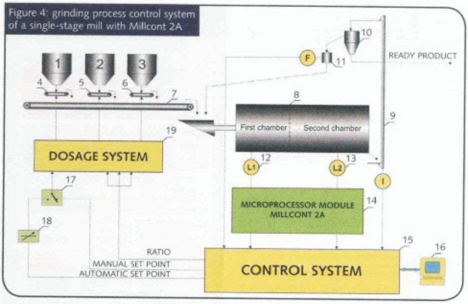

Figure 4: grinding process control system of a single-stage mill with Millcont 2A

communication channel programmed to MODBUS.

System control structure

The structure of the grinding process control system in a single-stage mill with separator using the previously-described set-up is represented in Figure 4. The control system needs to:

- measure the material loading level of the first and second chambers (L_1 and L_2) of the mill
- measure the loading of the elevator I and the returned volume from separator F
- automatically stabilise the set loading by changing the flow rate of the materials fed into the mill
- maintain the set ratio between the input materials at the control of the mill loading.

The aim of the control system is to increase productivity and improve product quality with minimum intervention by grinding personnel.

To select the type of controller and control regime, the obtained mill parameters (gain coefficient K_o, delay τ_0 and time constant T_o) are used. Optimal adjustments to the controller are calculated using the mill parameters and developed algorithm.[3]

The control system has two modes of operation: manual and automatic. In manual mode the operator observes the mill loading in the first and second chamber, and using the control system (see Figure 4 – 15), changes the flow rate of the inlet materials in the required direction. The fineness of the finished product is controlled by sieve analyses of the samples from the mill outlet. The manual mode of operation is not basic.

In automatic mode the switch (Fig 4 – 17) is in the 'automatic' state. The operation of the system in this case is as follows: sensors at L_1 (Fig 4 – 12) and L_2 (Fig 4 – 13) measure the grinding factors which are sufficiently correlated with filling levels L_1 and L_2 of the first and second chamber of the mill. The unified signals of L_1 and L_2 are connected by weight coefficients to the input of controller of Millcont 2A (Fig 4 – 14).

When the signals I and F are passed over the set limit values they also are connected by weight coefficients to the output of the controller.

The set loading of the mill depends on the required grain size, the mill condition and the grinding balls wearing out. The set ratio between the inlet materials is established by the keyboard of the operator station (Fig 4 – 16). The output signal of the controller acts on the total set point (Fig 4 – 18) of the dosage system (Fig 4 – 19). This way the automatic system stabilises the specific set loading of the mill with material, the fineness of grinding of the ready product as well as ensuring maximum productivity of the mill.

The trends of the regulated parameters $L=0.8L_1+0.2L_2$, I, F and the control action $X=X_1+X_2+X_3$ (total quantity of the fresh materials) in automatic mode of the system are shown in Figure 5.

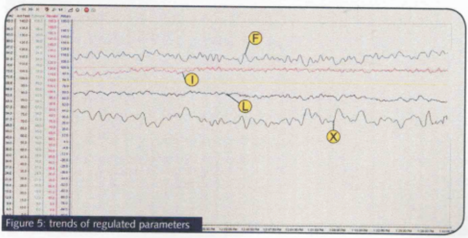

Figure 5: trends of regulated parameters

Conclusion

Recent experiences in cement plants in Bulgaria, Turkey and Iran have demonstrated the following advantages:

- mill productivity increased from 10 to 30 per cent
- energy efficiency increased by up to 30 per cent
- the durability of the lining and grinding bodies increased by about 15 per cent
- the mean quadratic deviations of the finished product by grinding fineness are 1.3 times less in comparison with systems that are manually controlled
- average payback is less than six months.

In addition, control of the grinding process is no longer open to subjective interpretation and the control system reduces manual intervention by grinding personnel.

References

[1] PENZOV, T AND MARINOV, D (2005) 'A new microprocessor system for grinding process control' in: *Proceedings, First Balkan Mining Congress*, Varna, Bulgaria.

[2] MARINOV, D AND PENZOV, T (2006) 'New sensor and microprocessor modules for optimum loading of separator ball mills' in: *ZKG International*, 6.

[3] PENZOV, T AND PENEV, D (2009) 'Modernized microprocessor system for wet grinding control in raw mill' in: *Proceedings, XIII Balkan Mineral Processing Congress*, Bucharest, Romania.