Regulation of pulverization in drum-type ball mills is based on automatic control systems using various controlled quantities and control actions [1]. The efficiency of an automatic control system depends greatly on how closely the chosen mathematical representation of the pulverization process corresponds to reality. Compilation of a complete mathematical model of the pulverization process in a drum mill is a complex problem, owing to the large number of factors affecting the process and to our inadequate knowledge of the grinding process itself.

In a mathematical model intended for automation purposes, the number of factors which can be taken into account is limited by practical considerations. For example, such relevant characteristics of the materials as grain size, crushability, etc. cannot be controlled automatically. In addition, complication of the model may lead to complex control laws, hard to realize.

Derivation of generalized indirect indices characterizing the grinding process in the mill and the qualities of the raw and final products will simplify the problem of creating a mathematical model. We must remember that in normal functioning of an automatic control system the increments of many variables will be small and we can limit ourselves to linear representations of complex laws.

Our suggested model is based on the amplitude of the mill noise as a generalized indirect index of the grinding process and of the quality of the initial product. The quality of the final product is estimated by the relative content of a given class.

We used a two-chamber ball mill, 1635 x 6020 mm in size, grinding chromite and magnesite to give a product with 90% of the -0.06 mm class; the block diagram is shown in Fig. 1. Here \( \Delta S_{in} \) is the deviation of the input productivity; \( \Delta \rho_2 \) is the deviation of the noise amplitude of the mill due to change in the input productivity; \( \Delta \eta \) is the deviation of the amplitude of the mill noise due to change in the particle size and crushability of the initial product; \( \mu \) is the grinding fineness, determined by the fraction of the target class in a given product; \( \beta \) is the weight of target class; and \( S_0, \mu_0 \) are the base values of the productivity and grinding fineness at which the transfer functions of the model are defined.

The transfer functions were determined for normal operation by a statistical interpolation method [2]. A disturbance in the form of high-frequency oscillations \( \Delta \mu \) was superimposed. The disturbance is easily averaged by the running average method with a span of 4–6 min, and can be ignored.

The grinding cycle is closed by imposing positive feedback, via the separator, on the block diagram of the open cycle. We assume that the separator provides ideal separation of the output grinding product into the target product \( \beta \) containing only a given class, and the circulating charge \( C \) which, after a transportation delay time \( \tau_C \), returns to the mill for further grinding. The block diagram of the closed grinding cycle is shown in Fig. 2.
Fig. 2. Block diagram of closed grinding cycle. For notation, see text.

where \( \Delta Q \) is the deviation of the input productivity, \( \Delta S_{\text{in}} \) is the deviation of the total charge in the mill, and \( \Delta C \), \( C_0 \) are the deviation and base value of the circulating charge.

Let us consider steady-state operation of the mill system, when the disturbance \( \Delta \eta \) and the input productivity \( \Delta Q \) are slowly-varying functions of time in comparison with the times of transient processes in the system. For any steady conditions we have the following equations representing the grinding process:

\[
\begin{align*}
\beta &= \mu S_{\text{out}}; \\
C &= S_{\text{out}} - \beta; \\
\Delta \mu &= K_\phi \Delta \varphi; \\
\Delta \varphi &= \Delta \varphi_s + \Delta \eta; \\
\Delta \varphi_s &= -K_s \Delta S_{\text{in}}; \\
\eta &= \eta_0 + \Delta \eta; \\
Q &= Q_0 + \Delta Q.
\end{align*}
\]

(1)

Here \( \beta_0 \), \( C_0 \), etc. are the base values characterizing the above-mentioned steady conditions; \( \Delta \beta, \Delta C \), etc. are the deviations undergone by the variables on transition to a new set of stationary conditions characterized by values \( \beta, C \), etc.

Solving (1) for \( \beta \), we get

\[
\beta = \nu_0 S_o + K_\phi S_o \Delta \eta + (\nu_0 - K_\phi K_s S_o + K_c \Delta \eta) \Delta S_{\text{in}} - K_\phi K_s \Delta S_{\text{in}}^2.
\]

(2)

This equation gives the target-product productivity in terms of the total charge in the mill for a disturbance \( \Delta \eta \).

The maximum target-product productivity is attained when

\[
\Delta S_{\text{in}}^* = \frac{\nu_0 - K_\phi K_s S_o}{2K_\phi K_s} + \frac{1}{2K_s} \Delta \eta.
\]

(3)

\[
\beta_{\text{max}} = \nu_0 S_o + K_\phi S_o \Delta \eta + (\nu_0 - K_\phi K_s S_o + K_c \Delta \eta) \Delta S_{\text{in}}^* - K_\phi K_s \Delta S_{\text{in}}^{*2}.
\]

(4)