Adaptive Control and Identification of Powdery Materials Granulation Process

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***Abstract*— Powdery materials granulation processes proceed under a sufficient number of supervised and non – supervised disturbances (powdery plus binder quantity and quality fluctuations, temperature fluctuations, ets.). In this connection a real – time system of adaptive control and identification is required for high granulation efficiency achievemen.**

***Keywords*— adaptive identification; adaptive control; granulation; statistical identification; non-linear control**

I. Introduction

Considering that majority of granulation processes are characterized with the phenomena proceeding non-stationary, caused by internal and external disturbances availability, and in the strength of all the disturbing parameters supervision and measurement impossibility, then a problem of adaptive control is required, which integrates the two ensuing sub-problems:

1) adaptive identification,
2) adaptive control.

II. Statement of Problem and Solving the Problem

Statistical identification of process state and model parameters is based upon the theory of linear Kalman filtration [1-3].

Variation of the granules size in a drum is described by the equation

$$\frac{da}{dt} = f(a) - K_1 a + \xi(t)\,, \tag{1}$$

where $f(a)$ is the complex non-linear function of granule size growth rate, which is to be linear by expansion into series for the linear filter can be employed, and K_1 is the breakage rate constant. Note, that at the powdery materials granulation

$$f(a) = \frac{2R_A\omega\lambda(G)}{\pi a},$$

where:

R_A is the apparatus radius,
G is the binder flow rate,
ω is the drum rotational speed,
λ - is the lay – up depth.

Inasmuch as the granulation process is featured by granules failing, hence, in accordance with Kirpichev – Kick law, the comminution velocity is represented as

$$r_i = -K_1 a\,,$$

where $K_1 = c\frac{d\xi_m}{dt}$, ξ_m is *the* energy, transferee to the failed solid mass unit.

The measured value z with error *N(t)* is defined by the equation:

$$z = a + N(t) \tag{2}$$

The problem of estimation for granulation processes is formulated in the following manner:

$$\frac{d\hat{a}}{dt} = -(K + R/Q)\hat{a} + Rz/Q \tag{3}$$

$$\frac{dR}{dt} = -2KR - R^2/Q + G \tag{4}$$

processing with the initial conditions

$$\hat{a}(0) = \hat{a}_0\,, \quad R(0) = \theta_y\,, \tag{5}$$

where $K = -\frac{\partial f}{\partial \hat{a}} + K_1$, $\hat{a}_0$ is the average size of solid particles, R is the covariance error, $\xi(t)$ and $N(t)$ are the ordered white noise with zero mean and covariances G and Q, respectively:

$$M\{\xi(t)\} = 0\,, \quad M\{N(t)\} = 0\,,$$

$$M\{\xi(t)\ \xi(\tau)\} = \begin{cases} G, & for \quad t = \tau, \\ 0, & for \quad t \neq \tau, \end{cases}$$

$$M\{N(t)\ N(\tau)\} = \begin{cases} Q, & for \quad t = \tau, \\ 0, & for \quad t \neq \tau, \end{cases}$$

where $M\{\ \}$ denotes the operator for the expected value.

The integration of Riccati differential equation (4) with initial conditions (5) leads to the following expression:

$$R(t) = \theta_1 + (\theta_1 + \theta_2)\{[(\theta_y + \theta_2)/(\theta_y - \theta_1)]\times \times\exp(2\sqrt{K^2 + G/Q}\ t) - 1\}^{-1} \tag{6}$$

where

$$\theta_1 = Q(\sqrt{K^2 + G/Q} - K),$$

$$\theta_2 = Q(\sqrt{K^2 + G/Q} + K).$$

As it follows from the solution (6) under $t \to \infty$, $R(t) \to \theta_1$ and the filter becomes stationary, and under $t = 0$, $R(0) = \theta_y$, what ensures the solution (6) correctness. The variance of $\theta_{\hat{a}} = M\{\hat{a}(t)\hat{a}(t)\}$ variable estimates in the established mode can be obtained from the system of algebraic equations for a and $\hat{a}$:

$$\begin{cases} 2K\theta_{aa} - G = 0 \\ 2(K + \theta_1/Q)\theta_{\hat{a}} - 2(\theta_1/Q)\theta_{\hat{a}} - \theta^2/Q = 0 \\ (2K + \theta_1/Q)\theta_{a\hat{a}} - (\theta_1/Q)\theta_{aa} = 0, \end{cases} \quad (7)$$

where $\theta_{a\hat{a}} = M\{a(t)\ \hat{a}(t)\}$ and $\theta_{aa} = M\{a(t)\ a(t)\}$. Having solved (7), we obtain the equation:

$$\theta_{\hat{a}} = \frac{\theta_1^2}{2(KQ + \theta_1)}\left[1 + \frac{G}{K(2KQ + \theta_1)}\right]. \quad (8)$$

The estimation of state parameters (granules sizes) for powdery materials granulation process in a drum granulator was implemented for the following data: $R_A = 0.9$ m, $\omega = 0.57C^{-1}$, $\hat{a} = 2 \cdot 10^{-3}$ m, $\lambda = 10^{-6}$ m, $G/Q = 0.5$, $K = -0.3$. The state variation mode and the covariance errors are specified in Fig.1.

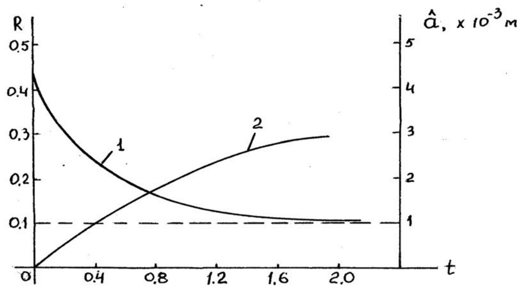

Figure.1. Dependence of R (1) and a (2) on t

The necessity of adaptive optimal powdery materials granulation process control systems development is mainly caused by real – time operation of the process mathematical model under various external and internal disturbances. Due to this, the following requirements to the mathematical model must be underlined:

1) necessity and possibility of all process parameters consideration, including the external and internal disturbances variation character;
2) maximum structure simplicity (non-complexity) and reliability at the large information content of input and output parameters;
3) adequacy to the described process, limited by a specified accuracy for some adaptation time interval;
4) possibility of its numerical solution and correction for the minimum time, what is mainly important for the disturbances, extensively varying in time.

The criterion of the model adaptability to a really running process is the granules sizes empirical and calculated values (1) deviations minimum:

$$I = \int_0^{T_p}\int_0^{\tau_p} (a - a_p)^2 d\tau\, dt, \quad (9)$$

where a_p are the measured values of sizes by the time of existence τ and the time of controlled object operation. Provision of the condition

$$I(t,\tau) < \varepsilon \qquad \forall t \in [0, T_p]. \quad (10)$$

enables the mathematical model adequacy to the real – time process. Violation of the (10), caused by internal and external disturbances, leads to the model inadequacy, which requires the adaptive identification problem solution. Satisfaction of (10) requires solution of the adaptive control problem, the objective of which is the development of such control U, which would have reached the specified optimality function extremely. In granulation processes the binder flow rate can be considered as the parameter under control. By employment of the random search method the following control law can be formulated:

$$U(n) = U(n-1) + \Delta U(n-1)(2\alpha - 1),$$

where α is the normalized random number.

III. CONCLUSIONS

The structure of adaptive non-linear control is demonstrated in Figure.2.

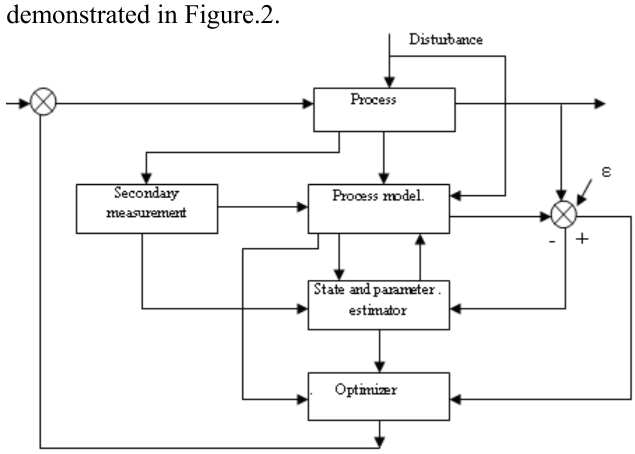

Figure.2. Structure of Adaptive and Non–linear Control

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