Simulation of ore beneficiation based on the Hammerstein structure with distributed parameters

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Abstract
Article deals with the tasks of ore beneficiation decentralized control based on the Hammerstein structure with distributed parameters. It is found that the real distributed Hammerstein system can be obtained through the traditional by means of space-time decomposition Simulation results of useful component content in the output product of the magnetic separation were obtained.

Key words: HAMMERSTEIN STRUCTURE, MAGNETIC SEPARATION, BENEFICIATION, PULP

The right conclusions about the quality of the technological process can be done only on the basis of a fairly complete data set about raw material classes extraction various by composition and size in specific conditions of processing production. In other words, the information about the behavior in a separation zone of such a complex particles system as real pulp may be represented by a set of fractional extractions or separation numbers for each elementary particle category (class) with known parameter of separation and fineness. The greater a number of such classes the material is divided, which fed to the separation, the better the calculated information for the technologist or designer about the behavior of material in separation zone. Based on the obtained data the beneficiation process can be adjusted by changing the material feed speed (productivity), the magnetic force (magnetic separation), reagent regime (flotation), etc. by the condition of specified useful component particle extraction to the concentrate [1, 2].

The most accurate estimation about the technological units operation quality in processing industry can give the information about the mineral content by the whole spectrum of the particle size characteristics of processed ore.

Because this characteristic is a nonlinear function with a lot of input and output parameters, we'll use a Hammerstein structure with distributed parameters. The Hammerstein structure of a distributed system consists of a static non-linear element $N(\cdot): R^m \to R^m$, connected with the distributed linear structure with a transfer function $G(x,q)(1\times m)$ [3, 4]

$$y(x,t) = G(x,q)v(t), \qquad (1)$$

where *t* – is the time variable; *x* – is the spatial variable defined on the region Ω; *q* – is the shift operator.

The dependence of the input - output of the system is given by

$$y(x,t) = G(x,q)N(u(t)), \qquad (2)$$

where $u(t) \in R^m$ – is the time input; $y(x,t) \in R$ – is the spatiotemporal input.

Let's assume that the transfer function G (x, q) is represented by the infinite number of orthogonal spatial basis functions $\{\varphi_i(x)\}_{i=1}^{\infty}$

$$G(x,q) = \sum_{i=1}^{\infty}\varphi_i(x)G_i(q), \qquad (3)$$

where $G_i(q)$ (1×*m*) – is the transfer function of the traditional Hammerstein system.

Then the real distributed Hammerstein system can be obtained through the traditional one by means of space-time decomposition. Let’s assume that the distributed Hammerstein system is controlled by *m* control inputs of *u(t)* with a certain spatial distribution, and the output is measured in *N* spatially localized points $x_1,..,x_N$. For precise simulation and control of the structure with distributed parameters of infinite dimension the infinite number of control actions and sensors throughout the space is necessary. Under real conditions, it can be used a limited number of control actions and sensors, which depend on the complexity of the process, the desired accuracy of modeling and control, as well the physical and cost factors, etc. The task of modeling is to identify the non-linear space-time model of a truncated dimension from the input data $\{u(t)\}_{i=1}^{t}$ and output $\{y(x,t)\}_{i=,j=1}^{N,t}$, determined on the time interval of *L*.

The modeling procedure includes two stages [5]. First stage involves spatio-temporal decomposition based on principal component analysis PCA, and on the second stage the identification of the traditional Hammerstein model (including the structure and parameters) is made. Using the spatiotemporal synthesis, this model allows to restore spatiotemporal dynamics of the whole system. The main problem of using the spatiotemporal decomposition based on principal component analysis is to identify the most characteristic spatial structure $\{\varphi_i(x)\}_{i=1}^{N,L}$ from the spatiotemporal input data $\{y(x,t)\}_{i=1,j=1}^{N,L}$. The finding of a typical $\{\varphi_i(x)\}_{i=1}^{N,L}$ can be performed by minimizing the following target function [4]

$$\min_{\varphi_i(x)} < \|y(x,t) - y_n(x,t)\|^2 > \qquad (4)$$

$$subject \;\; to \; (\varphi_i, \varphi_i) = 1, \varphi_i \in L^2(\Omega), i = 1,...,n$$

The orthonormal limitation $(\varphi_i, \varphi_i) = 1$ is imposed in order the function $\varphi_i(x)$ to be the sole. Let’s consider the nonlinear dynamic Hammerstein model with distributed parameters. Each channel of such structure is represented by a cascaded bunch of static nonlinear block and dynamic linear block, based on the spatiotemporal Laguerre model.

As shown in [6] the signal *x(t),* defined on the interval (0,∞), can be represented as a series in the system of Laguerre functions

$$x(t) = \sum_{i=0}^{\infty}\lambda_i l_i(t) \qquad (5)$$

The representation of linear block of Wiener-Hammerstein structures in the form of spatiotemporal Laguerre model was used in the simulation of the formation process of the useful component distribution by the crushed ore various size factions by the beneficiation plant technological units. The transfer functions of each channel were obtained as follows

$$k_1(s) = \frac{\sqrt{2\xi}}{s+\xi}, \quad k_2(s) = ... = k_l(s) = \frac{s-\xi}{s+\xi}, \qquad (6)$$

where ξ - is the coefficient determining the time scale.

As an example the simulation results of the useful component content in the output product of the magnetic separation (fraction size -74 μm) are shown in Fig.1.

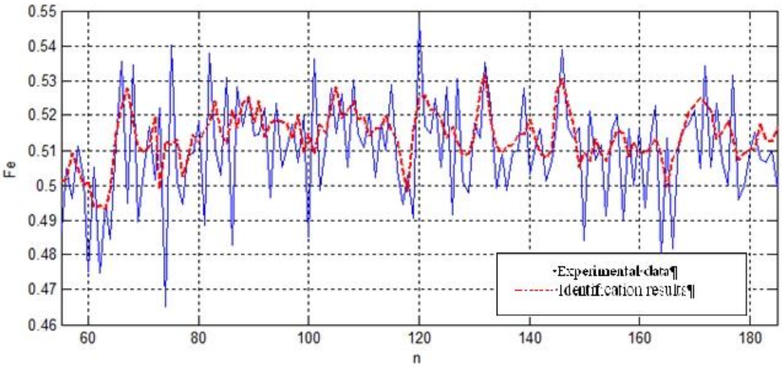

Figure 1. Simulation results of useful component content in the output product of the magnetic separation

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