PARAMETER IDENTIFICATION OF NONLINEAR DYNAMIC SYSTEMS OF INDUSTRIAL PROCESSES

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Abstract. The problem of parameter identification of nonlinear dynamic systems of industrial processes on the set of continuous block-oriented models, the elements of which are different modifications of the Hammerstein and Wiener models, is considered. Method of parameter identification in steady state based on the observation of the system's input and output variables at the input sinusoidal influences is proposed. The solution of the problem of parameter identification is reduced to the solution of the systems of algebraic equations by using the Fourier approximation. The parameters' estimations are received by the least squares method. Reliability of the received results, at the parameter identification of the nonlinear system in industrial conditions at the presence of noise depends on the accuracy of the measurement of system output signals and mathematical processing of the experimental data at the approximation.

Keywords: nonlinear system, block-oriented model, identification, parameter, dynamic, sinusoidal.

1. Introduction

Basis of automatic control of any system of industrial processes is presence of the information on a condition of the system in the form of mathematical model. The majority of the real industrial dynamic systems are nonlinear and possess many "inconvenient" features from the point of view of their control. Such systems can be adequately characterized only by nonlinear models on all working area of change of variables.

The nonlinear systems are generally represented by the block-oriented models consisting of different modifications of the Hammerstein and Wiener models or general models, in particular, the Volterra and Wiener series and the Kolmogorov-Gabor continuous and discrete polynomials.

Despite their simplicity, block-oriented models are successfully used in many fields of the industrial processes (modelling of ball-tube mills of the concentrating factory, distillation columns, hydraulic actuators, electrical water-heater process, heat transfer process, etc.).

In the given work the problem of parameter identification of continuous nonlinear dynamical systems is considered on the set of continuous block-oriented models at the input sinusoidal signals.

2. Theoretical and experimental results

At the representation of nonlinear systems by the block-oriented models [1], most of the existing developed methods of parameter identification is developed for the simple Hammerstein and Wiener models (e.g. [1-4]). Comparatively small quantity of works is devoted to the identification of parameters of other block-oriented models (e.g. [5-7]). That can be explained by the fact that the majority of such models, except for the Hammerstein models (simple and generalized) are nonlinear relative to the parameters, and also because of the big number of estimated parameters. So, for example, the number of estimated parameters of the simple Wiener-Hammerstein cascade model with the nonlinear elements in the form of polynomial functions of n degree and linear dynamic elements described by the differential equations of the m_1 and m_2 order, is equal to $n+m_1+m_2+3$. Therefore, the solution of the problem of parameter identification is analytically possible only for some block-oriented low order models.

In this work the problem of parameter identification is considered on the set of models, elements of which are different modifications of the Hammerstein and Wiener models with nonlinear elements in the form of polynomial functions of second degree and stable linear elements described by the ordinary differential equation of second order. Such models are widely used for the modelling of industrial processes.

Different modifications of the Hammerstein and Wiener models consist of different combinations of connections of linear dynamic and nonlinear static blocks.

When the harmonic signal acts on the input of the nonlinear block-oriented system, the forced oscillation with features for different models is obtained at the output of the system in the steady state after the termination of the transient process.

When a sinusoidal signal acts on the input of the linear element**,** then at the output of the element in the steady state the sinusoidal signal with same frequency and with amplitude and phase, which depends on the frequency, is obtained. In such case, the periodic signal is obtained on the output of nonlinear static element, which is the sum of the sinusoidal signals with multiple frequencies. These facts were used to determine analytical expressions of the forced oscillations on the output of models.

Estimations of Fourier coefficients of the forced oscillations of the model output are obtained by the numerical harmonic analysis. The algebraic equations are taken to determine estimations of unknown parameters by equaling the estimations of Fourier coefficients to their theoretical values.

Below, for example, an estimation of one of the dynamic parameters of the simple Wiener model is given:

$$\hat{T}_{01} = \frac{\left(\sum_{i=1}^{n}\omega_i^2\right)\left(\sum_{i=1}^{n}\frac{\hat{a}_{1_i}^2}{\hat{b}_{1_i}^2}\omega_i^2\right)-\left(\sum_{i=1}^{n}\frac{\hat{a}_{1_i}}{\hat{b}_{1_i}}\omega_i\right)\left(\sum_{i=1}^{n}\frac{\hat{a}_{1_i}}{\hat{b}_{1_i}}\omega_i^3\right)}{\left(\sum_{i=1}^{n}\omega_i^4\right)\left(\sum_{i=1}^{n}\frac{\hat{a}_{1_i}^2}{\hat{b}_{1_i}^2}\omega_i^2\right)-\left(\sum_{i=1}^{n}\frac{\hat{a}_{1_i}}{\hat{b}_{1_i}}\omega_i^3\right)^2},$$

where a_{1i}, b_{1i}, a_{2i}, b_{2i} $(i = 1,2,\ldots,n)$ are values of the Fourier coefficients at the frequency ω_i.

The identification method is investigated by theoretical analysis and computer modelling. The reliability of the received results, at the parameter identification of nonlinear systems of industrial processes conditions, in the presence of noise and errors, depends on the measurement accuracy of the systems' output signals and on the mathematical processing of the experimental data at approximation.

Conclusions

Developed parameter identification method can be used for the modelling of nonlinear industrial processes when the model structure is known a priori. As the estimations of parametres are received by the least squares method, it can be used in the industrial conditions in the presence of the noise and measurement errors. The specification of the method of identification allows to use Fourier coefficients of various harmonics to estimate the parametres and compare the received results.

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