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RESEARCH OF THE SYSTEM OF LOOSE MATERIAL AUTOMATED PRECISION BATCHING

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The imitating model of the system of loose material automated batching, including the robust system of engine control of auger feeder has been considered. The model is described in space of conditions by means of the programming language MATLAB, the interface of S-functions and the Simulink environment. The Kalman filter is used for noise filtration in the channel of measurement. Graphic representation of modeling results proves adequacy of the imitating batching model, the efficiency of the method of regulator parameter retuning and expediency of using the algorithm of measured signal filtration. A weight error at parametrical indignations influence on the worm feeder engine without retuning regulator parameters amounts to 0,3 kg (+3 %) at the set 10 kg, and with retuning regulator parameters amounts 0,01 kg (+0,1 %).

Introduction

Labor productivity and efficiency of manufacturing are determined to a large extent by a degree of workflow automation and reliability of information on supply streams and product quality. It is especially topical in food and processing industry.

Besides, at the stage of development the principles of mathematical and simulation modeling, which allow estimating the efficiency of the used algorithms and obtaining preliminary results, are often used for studying the system.

The main feature of the examined objects is their nonstationarity: object parameters changes in a certain range in the course of time. Nonstationarity causes principle difficulties both in studying object structural properties (stability, controllability and observability) and in development of estimation and control algorithms. Thus, robustness is a property of crucial importance of the adaptive methods for information processing. The method statistic reliability and results insensitivity to changes in conditions of observations is understood under the robustness [1].

1. Automation object

The configuration of processing equipment used at batching and introduced on a diagram (Fig. 1):

- 7 auger feeder;
- bunker batcher with carrying capacity to 1000 kg, set on 3 strain sensors;
- bunker mixer provided with asynchronous motor of a mixer with a capacity of 15 kW and ripper motor;
- bunker of finished production shipping with capacitance level sensor;

In general the automation object includes 10 asynchronous motors with a capacity from 1,7 to 15 kW.

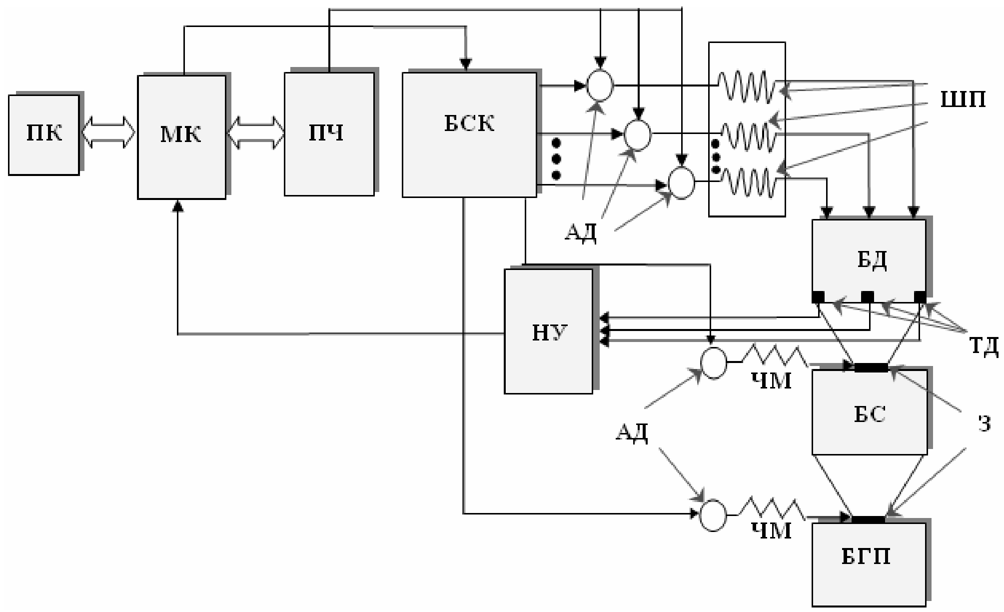

Fig. 1. *Functional diagram of batching system: PC – personal computer; MC – microcontroller; FS – frequency shifter; BPC – block of power commutation; AM – asynchronous motor; AF – auger feeder; SS – strain sensor; NA – norm amplifier; BB – bunker batcher; C – catch; WM – worm mechanism; BM – bunker mixer; BFP – bunker of finished production*

2. Researches on simulation model

Mathematical description of batching process was developed and simulation model was constructed in Matlab Simulink 7 R14 environment. A block diagram of batching process control system is given in Fig. 2. Presence of mechanical links between motors and auger feeders is not taken into consideration in the model.

Thus, when modeling, the assumptions connected with absence of mathematical description of mechanical and spring links of drives (friction, backlashes etc.) are made. Therefore, the model can not be considered an adequate to the real process; however, the results of investigations prove the efficiency of simulation modeling.

Originally, the structure and parameters of weight regulator for linearized continuous system were determined on the basis of the requirement of batching time minimization at transient aperiodic character and control system astaticism, i.e. a batching error in steady state, equal zero. For this purpose the proportional-integral controller (PI-controller) is sufficient to be used at the given control object [2].

In Fig. 3 the robust adaptation assembly forms the value of controller parameter retuning. The input signal «Velocity (ref.)», corresponding to reference rotational velocity of motor shaft, corresponds to output signal of the reference model of induction motor drive with a constant rated load (Fig. 4). Retuning is carried out by

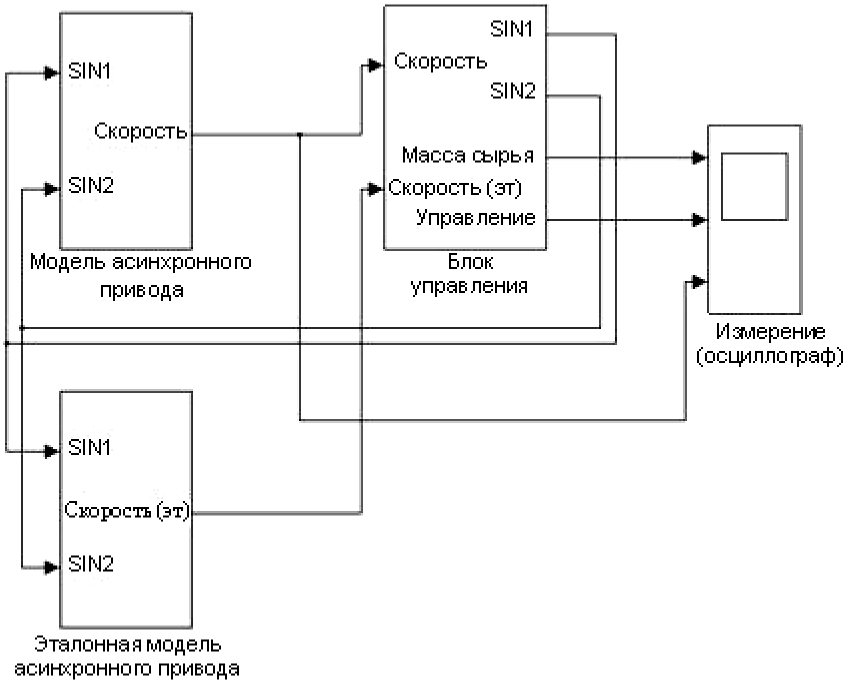

Fig. 2. *Block diagram of batching system*

Скорость – Velocity; Масса сырья – Raw material mass; Управление – Control; Измерение (осциллограф) – Measurement (oscillograph); Блок управления – Control unit; Модель асинхронного привода – Induction motor drive model; Эталонная модель асинхронного двигателя – Asynchronous motor reference model

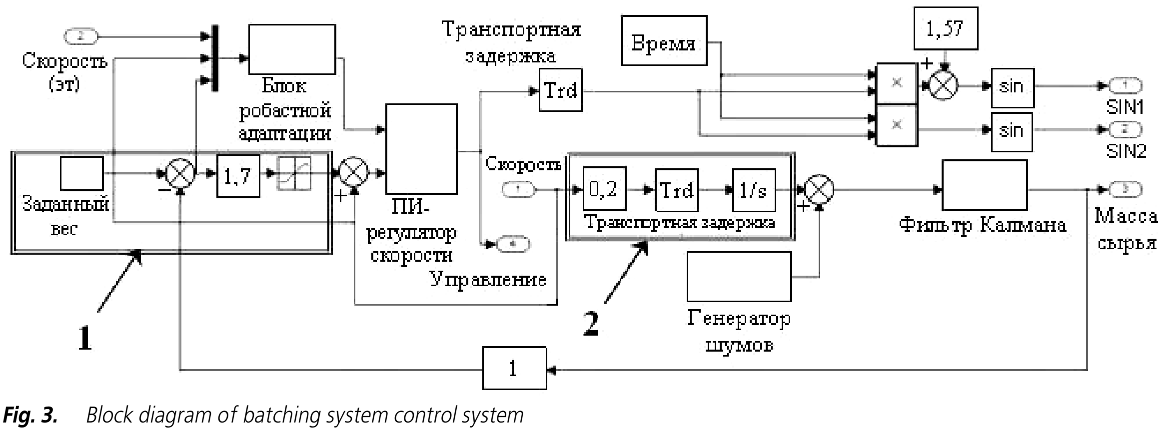

Fig. 3. *Block diagram of batching system control system*

Скорость (эт.) – Velocity (ref.); Блок робастной адаптации – Robust adaptation assembly; Транспортная задержка – Transport delay; Время – Time; ПИ регулятор скорости – PI speed controller; Заданный вес – Target weight; Управление – Control; Генератор шумов – Noise generator; Фильтр Калмана – Kalman filter; Масса сырья – Raw material mass

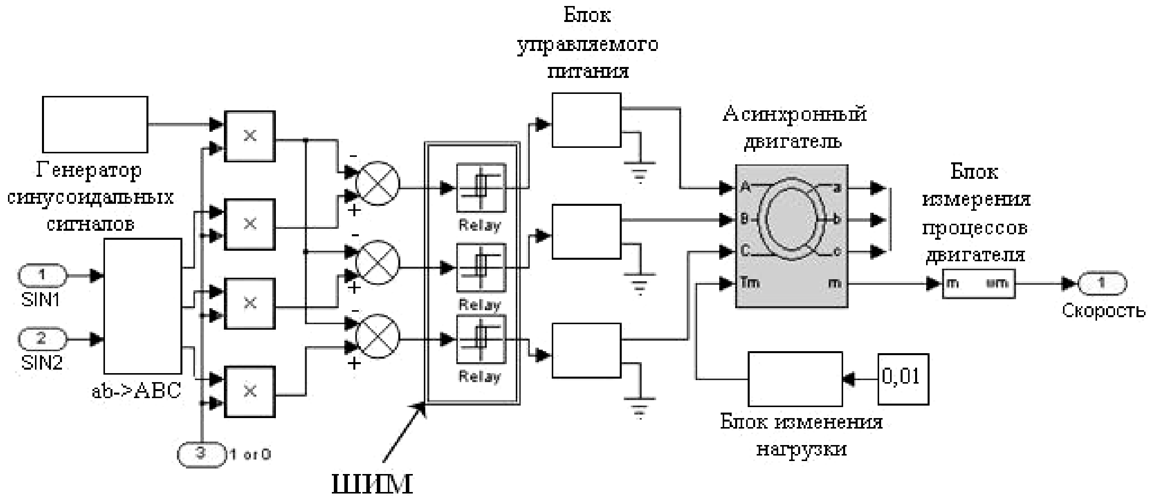

Fig. 4. *Block diagram of a model of auger feeder induction motor drive*

Генератор синусоидальных сигналов – Sinusoidal signal generator; Блок управляемого питания – Control power unit; Асинхронный двигатель – Asynchronous motor; Блок измерения процессов двигателя – Measurement unit of motor process; Скорость – Velocity; Блок изменения нагрузки – Load measurement unit; ШИМ – PDM

adding the value of reconfiguration coefficient to the control ratio of PI-controller. The retuning value is calculated by the form [1, 3]

$$g(k)=\sqrt{|\omega(k)-\omega_{эт}(k)|\cdot e^2(k)}, \qquad (1)$$

where ω, $\omega_{эт}$ are the current and nominal (by the reference model) rotating frequencies of motor shaft, e is the weight control error; noise filtering unit implements the operation of Kalman filter [4, 5]; sector – 1 includes weight units, weight controller and units modeling quantization of velocity signal by the level (communication channel characteristics); sector – 2 contains units modeling the control object: the transfer constant of the auger feeder with specified productivity, transport delay link (fall time of batched material) and integrator (growing-up mass of the bunker batcher). The weight sensor in the model has the reduced single transfer constant.

In Fig. 4 the unit of sinusoidal signal generation forms a continuous sinusoidal signal in the form

$$O(t)=Amp\cdot\sin(2\pi\cdot Fr\cdot t+Ph),$$

where Amp is the amplitude (400); Fr is the frequency (1000 rad/s); Ph is the phase shift ($\pi/2$); the unit of load change imitates load «surge» on motor shaft by 60 % at time points = 1, 2 and 4 with duration 0,5 s (in the reference model of auger feeder drive the motor load is considered to be constant and rated (0,5 H·m)).

In Fig. 5 the results of modeling at weight batching of 10 kg are shown.

Presence of transport delay in the system results in the fact that after motor stoppage, i.e. loss of control of batching process, the weight continues increasing, at least, by the value of mass of material «falling column» and the delay and mass decrease at bunker filling. Besides, the column mass decreases proportionally to velocity preceding the auger feeder stop. In particular, in this connection, such parameter of electric drive as velocity control range turned out to be important.

Graphic data in Fig. 5 show that the constructed model is adequate, the control error in raw material weight equals zero in time point of 13 seconds that indicates the efficient control of the process of high-frequency batching of loose materials.

To filter random variables simulating various factors influence on weight sensor (irregularity of raw material unloading, setting out of air masses with high pressure to the batcher bottom) and resulting in random errors in measuring consumable raw material mass, the Kalman filter is used in control system. It was determined experimentally that the error of measuring weight m caused by factor influence on sensor amounts to 3 kg on the average and does not depend on raw material current mass being in the weighed bunker. Thus, $m_v=m+3v$, where v is the white Gaussian noise.

The results of modeling at filtration of random values (noises) by Kalman filter in the measuring line and without filtration are introduced in Fig. 6. The results confirm the adequacy of filter functioning and appropriateness of its use in the control system.

The analysis of the results of modeling in Fig. 7 allows drawing the conclusion about compensation of load «surge» on the motor shaft by retuning (1) the controller parameters. By the time point of 14 s the raw material mass in the batcher at modeling without controller parameter retuning amounts to 10,3 kg (+3 %) at specified weight of 10 kg that indicates the «loss» of control system accuracy.

The system modeling allowed drawing a number of other conclusions; in particular, it is confirmed that at the given system parameters the control resolution of controlled electric drive on the level of 1...2 Hz is sufficient. Such control resolution may be fully provided by the interface RS-232 with communications protocol ModBus RTU built-in the frequency converter.

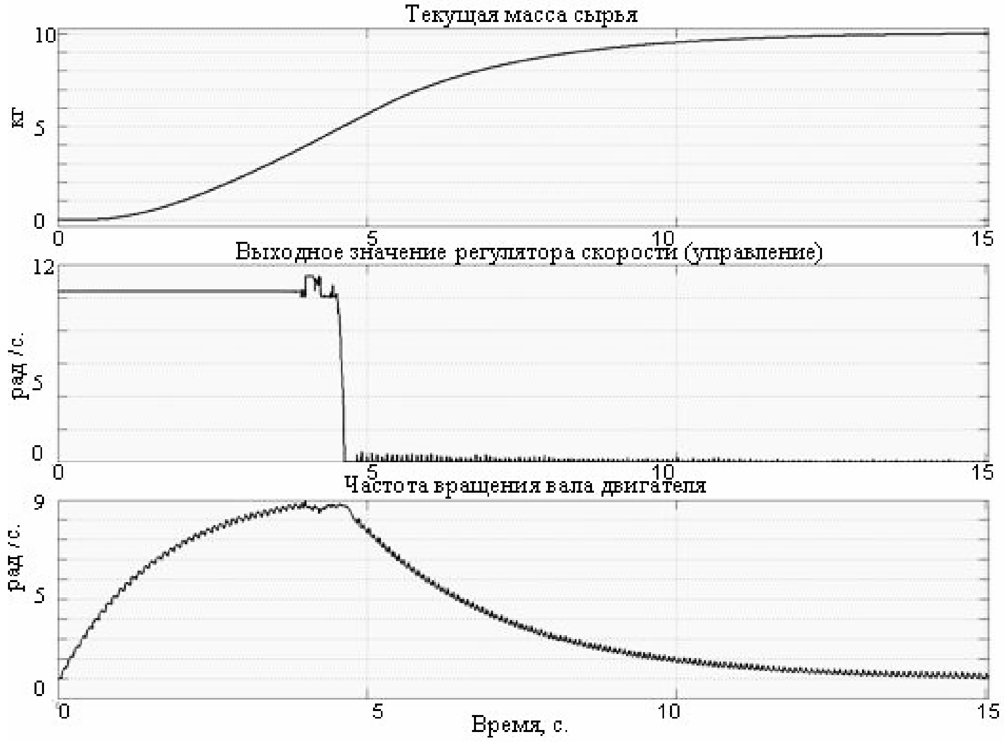

Рис. 5. *The results of modeling without disturbance*

Текущая масса сырья – Current mass of raw material; Выходное значение регулятора скорости (управление) – Output value of velocity controller (control); Частота вращения вала двигателя – Rotation frequency of motor shaft; Время, с – Time, s

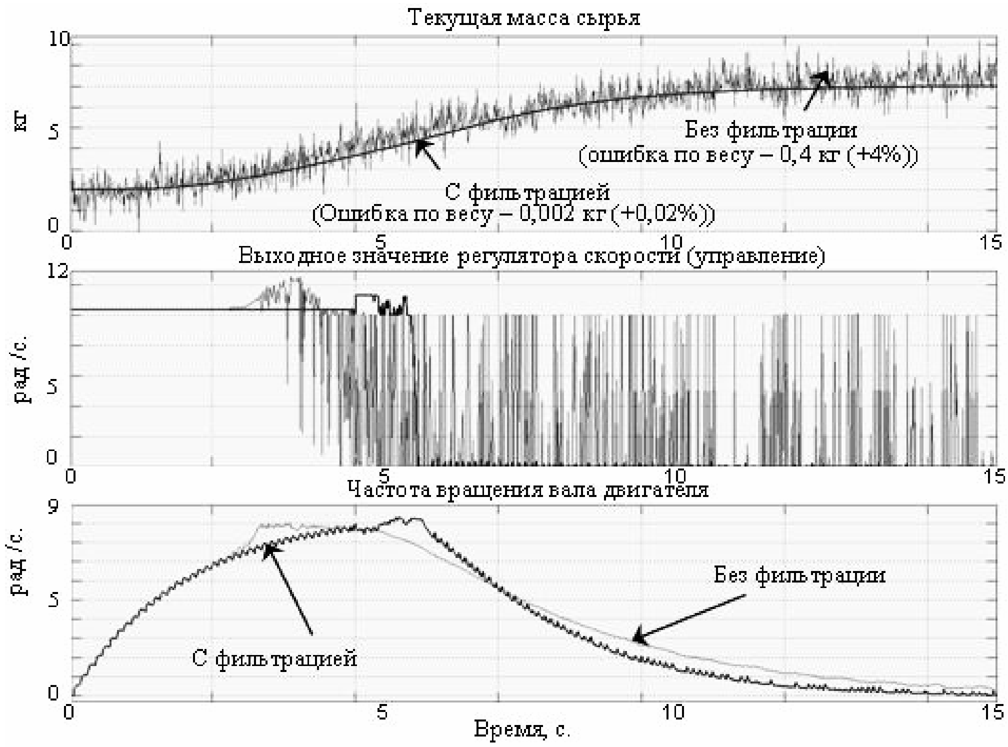

Fig. 6. *The results of modeling with noise filtration in measuring line and without filtration*

Текущая масса сырья – Current mass of raw material; Без фильтрации – Without filtration; Ошибка по весу – Weight error; С фильтрацией – With filtration; Выходное значение регулятора скорости (управление) – Output value of velocity controller (control); Частот вращения вала двигателя – Rotation frequency of motor shaft; Время, с – Time, s

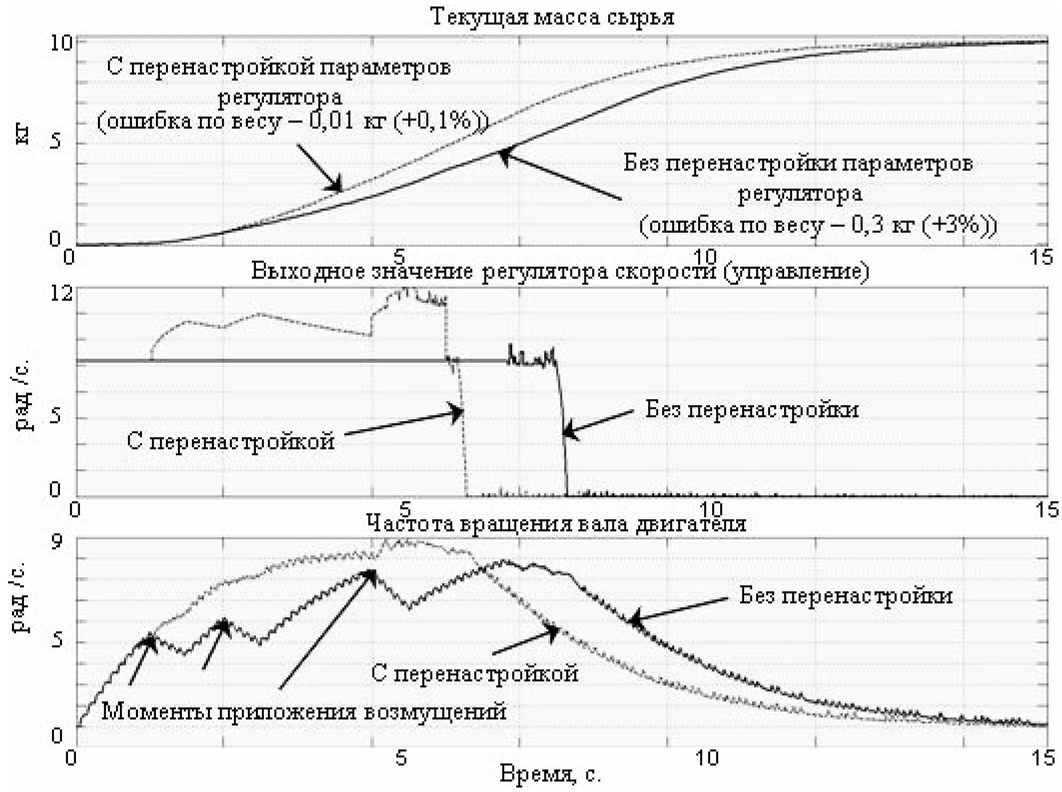

Fig. 7. *The results of modeling at disturbances*

Текущая масса сырья – Current mass of raw material; Выходное значение регулятора скорости (управление) – Output value of velocity controller (control); Частота вращения вала двигателя – Rotation frequency of motor shaft; Время, с – Time, s; С перенастройкой параметров регулятора – With controller parameter retuning; Ошибка по весу – Weight error; Без перенастройки параметров регулятора – Without controller parameter retuning; Моменты приложения возмущений – Moments of disturbance application; рад/с. – rad/s

Conclusion

The modeling and studying the system of high-frequency batching of loose materials, where the algorithm of parametric disturbance compensation on control object is implemented, were carried out.

The developed robust control system of the process of loose material high-precision batching supports the efficient control of processing at parametric disturbance influence on auger feeder motor. The results prove the efficiency of functioning the retuning procedure of the controller parameters. The control error in material weight at the parametric disturbance influence on auger feeder motor without retuning the controller parameters amounts to 0,3 kg (at specified 10 kg) (+3 %), and at the controller parameter retuning – 0,01 kg (+0,1 %).

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