

## USING NEURAL NETWORK TO CONTROL CUP-SHAPED PELLETIZER

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**Abstract.** Cup-shaped pelletizer is complex machine in terms of automatic control. A large number of incoming (humidity mixture, cup rotation speed, the angle of cup, mixture and water discharge into the cup), the outgoing (diameter, strength and moisture of pellet) parameters and external influences (air humidity and temperature, the content of iron in the mixture) dependent on each other non-linear and in some cases not explicitly, that creates great difficulties in controlling cup-shaped pelletizer. The definition of a suitable system of automatic control cup-shaped pelletizer series of papers, including this one. In this paper, justified the choice of direction to find a suitable control system. To do this, a mathematical model is made up of single-drive control pan rotation cup-shaped pelletizer. In the model for comparison of automatic control systems use the classic PID controller and a single-layer neural network trained by the algorithm "delta rule". Comparison of control systems for different incoming influences. The main parameters of transient processes (the first matching  $t_1$ , overshoot  $\sigma$ , time of transient process  $t_{trn}$ ) and found error rates positioning  $c_0$ ,  $c_1$  speed and acceleration of  $c_2$  for each type of control system. Showing laws, which are found appropriate error rates. For the visibility of the different control systems are graphs errors  $c_0$ ,  $c_1$  and  $c_2$ .

**Keywords:** neural network, control, cup-shaped pelletizer.

**Introduction.** In the production of pellets, pelletizing process is not energy-intensive. However, the quality of the pellets increases significantly the power consumption in the burning step. On the pelletizing process in cup-shaped pelletizer is influenced by many factors, including: the iron content in the mixture, the basicity of the mixture, size of the mixture, mixture flow into the cup, the angle of cup, cup rotation speed and humidity mixture. Timely response in the management cup-shaped pelletizer to reject parameters significantly improve the quality of raw pellets, which further lead to a reduction of energy consumption for the production of pellets as a whole [1,2].

Analysis of research and publications. With increasing demands on the quality of the finished product, management units without automated systems is not possible [9]. Effective control can be achieved by using multi-level automation systems with the use of computer technology — automated process control systems (PCS) [10]. In this direction, there are many scientific papers as research-all those technological process-pelletizing plants [3, 4, 5, 6, 11] and on the preparatory process raw material (additives) and formation (dosing) mixture for the production of raw and done pellets [7, 8, 13, 14].

**Materials and methods.** Determine the feasibility of using classical and hybrid neural networks for control cup-shaped pelletizer.

Presentation of the material and results. For the analysis of the control object in the theory of automatic control, common to use differential equations. They describe the properties of the system and allow evaluating behavior change input parameters.

There are two basic modes of operation of the automatic control:

- steady state of operation in which the components of the state vector of the system do not depend on the time of measurement;
- dynamic mode, in which the components of the state vector of the system are functions of time.

Steady and dynamic modes of the linear system can exist if the apply on the system signals that change over time. The difference is that in transition process effects or certain derivatives thereof include step changes. For some time after a step change in the value and its derivative, the system undergoes a transition process. After the end of the system is in steady state, until the effects of new or changes in the structure of the system.

One of the main requirements for management systems, is to provide the necessary accuracy in all operating modes. In the steady state of the control system, the quality of its operation can be assessed according to the static characteristic of the system.

An important characteristic of the control system is the relation between the value of the

control parameter and the value of external influence. By type of relationship between the value of the manipulated variable and external influences system is divided into static and astatic. System is called a static reference to external influence, if under the influence tends over time to reach a certain value, the error is also seeking to achieve sustainable value. Therefore, static automatic control system cannot provide managed persistence parameter at variable load.

The automatic control system is called static if the constant input exposure control error tends to zero regardless of the magnitude of the impact. If the concept of a static system is absolute, then the concept of astatic automatic control system is true only for a specific component of the vector of the initial state of the system. Astatic automatic control system characterized by different order astaticism depending on the number of integrating links open loop.

One of the main requirements for the automatic control system cup-shaped pelletizer is to provide an accurate work in all modes. In steady-state operation, automatic control system quality of her work can be estimated from the static characteristic of the system and error rates [12]. For each monitored parameter works cup-shaped pelletizer can determine the error rate, Taylor of the transfer function of  $F_e(s)$  in error, which is caused by exposure to:

$$F_e(s) = \frac{E(s)}{X(s)} = F_e(0) + \frac{F_e'(s)|_{s=0}}{1!} s + \frac{F_e''(s)|_{s=0}}{2!} s^2 + \dots = c_0 + c_1 s + \frac{c_2}{2} s^2 + \dots \quad (1)$$

where:  $c_0$  – error rate position;  $c_1$  – error rate of speed;  $c_2$  – error rate of acceleration.

Starting from (1) loop error behavior in time can be represented by a series [12]:

$$e(t) = c_0 x(t) + c_1 x'(t) + c_2 x''(t) / 2 + \dots \quad (2)$$

If we start from the expression (2), when a predetermined maximum error  $e_m$  control using the principle of equal effects coefficients are [12]:

–  $X_m$  – the maximum deviation of the reference signal for the control system cup-shaped pelletizer, which will ensure the required accuracy:  $X_m < e_m / (3 c_0)$ ;

–  $\max(dx/dt)$  – the maximum rate of change of the reference signal:  $\max(dx/dt) < e_m / (3 c_1)$ ;

–  $\max(d^2x/dt^2)$  – the maximum acceleration signal:  $\max(d^2x/dt^2) < 2 e_m / (3 c_2)$ .

Thus, the coefficients  $c_0$ ,  $c_1$  and  $c_2$  determine the accuracy and speed of the system. Error values indicate the order astaticism system. In the case of a static system error  $c_0$  will have a value different from zero. For a system with first order astaticism error  $c_0$  will be zero, and the errors of higher order will have non-zero values. The physical meaning of the error to your system the drive cup is as follows:  $c_0$  – a mistake on the rotational speed of the cup, and  $c_1$  – a mistake to accelerate the cup.

The model of control system for one control action, the speed of rotation the cup pelletizing, to find the coefficients  $c_0$ ,  $c_1$  and  $c_2$  is shown in Figure 1.

Switch1 and Switch2 are responsible for the shape of the reference signal. At constant reference signal schedule transient speed is shown in Figure 2a. Indeed, with  $t$  tending to  $\infty$  after the transient input signal  $x(t) = 1$ , and its derivatives,  $x'(t) = 0$  i  $x''(t) = 0$ . Therefore, from (2) we have  $e(t) = c_0$ . For a given control signal coefficient  $c_0$  is 0.

To determine the speed error  $c_1$  we make the change of the input signal with a step (Step) on a linearly increasing (Ramp) according to the relation  $x(t) = l_0(t) \cdot t$ , where  $l_0(t)$  – a single step Heaviside function. At the end of the transient process  $x'(t) = 1$ ,  $x''(t) = 0$ , using (2), we get [12]:

$$e(t) = c_0 l_0(t) \cdot t + c_1, \quad (3)$$

then

$$c_1 = e(t) - c_0 l_0(t) \cdot t. \quad (4)$$

Determination of the coefficient errors to speed  $c_2$  is arranged as follows: on the investigated automatic control system will provide a signal to the parabolic shape  $x(t) = l_0(t) \cdot t^2 / 2$ . At the end of the transient process will be derived the following values:  $x'(t) = t$ ,  $x''(t) = 1$ , and the higher derivatives of degree  $k$  for all  $k > 2$ , will be zero  $x^{(k)}(t) = 0$ . Thus, in steady state expression (2) for error becomes:

$$e(t) = c_0 t^2 / 2 + c_1 l_0(t) \cdot t + c_2 / 2 + \dots \quad (5)$$

From this [13] we find  $c_2$ :

$$c_2 = 2(e(t) - c_0 t^2 / 2 - c_1 l_0(t) \cdot t) \quad (6)$$

To find the error factor  $c_1$  and  $c_2$  in our scheme is necessary to switch the reference signal

respectively Switch1 to position II and Switch23 to position 1. The value of the error factor  $c_1 = 0.084$ , and  $c_2 = 0.0236$ , as shown by the corresponding graphs in Figure 2b and Figure 2c. Analyzing

transients describe their main parameters: the first matching  $t_y = 0,133s$  overshoot  $\sigma = 55,7\%$  and time of transient process  $t_{nn} = 2 s$ .

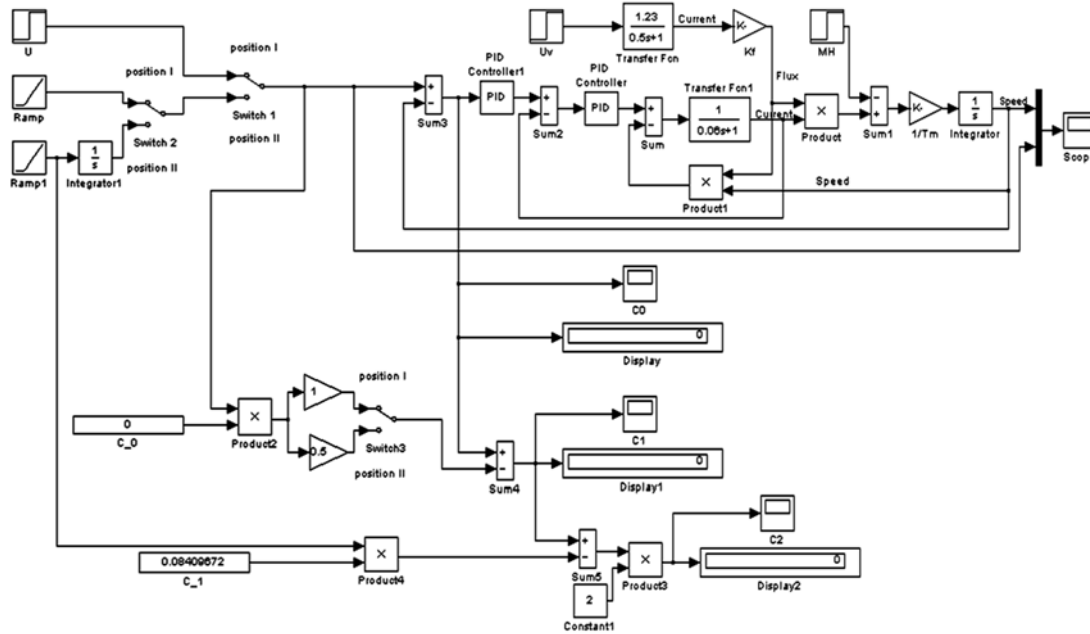


Figure 1. A model for finding the coefficients  $c_0$ ,  $c_1$  and  $c_2$  using classical PID controllers

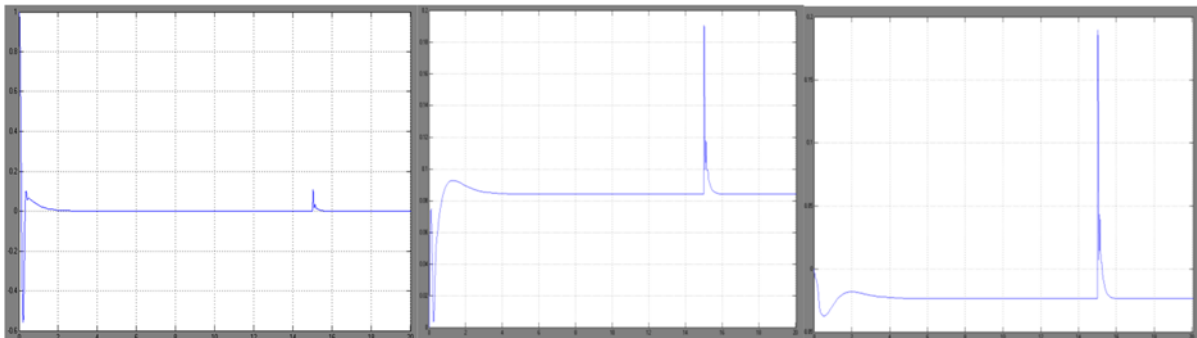


Figure 2. Transient processes for error  $c_0$ ,  $c_1$  and  $c_2$  in the management of the cup speed using PID controllers

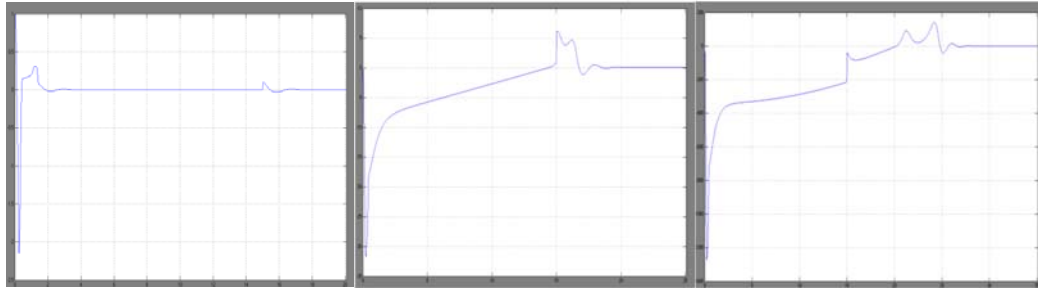
In reviewing the operation of the system control on one channel - cup rotation velocity in the model system instead of PID will attend a classical neural network trained by the simple algorithm - delta rule. Leave unchanged model of the electric rotating the cup of pelletizer for comparative analysis to determine the accuracy of its work and compare the results obtained previously.

The results of the simulation are as follows: positioning error rate takes the value  $c_0 = 1,69e-6$ , which is comparable to modeling errors, so it can be considered equal to zero (Figure 3a); speed error

rate  $c_1 = 0.1$  (Figure 3b); accelerate error rate  $c_2 = 0.1621$  (Figure 3c).

Transition process for a control system based on neural network characterized by the following parameters: the first matching  $t_y = 0,125 s$ , overshoot  $\sigma = 21\%$  and time of transient process  $t_{tp} = 2 s$ .

Thus, the control system error rates characterized by its accuracy and speed in any type of signal, which allows to determine the dynamic error control and use them for teaching network in real time.



**Figure 3.** Transient processes for error  $c_0$ ,  $c_1$  and  $c_2$  in the management of speed the cup with neural networks

Conclusions and future research. Analyzing the work of the two considered control systems using different regulators on the errors values, it is clear that better quality control system works using a neural network. Quality transients also better in the second variant.

Convenient determination of the error coefficients  $c_0$ ,  $c_1$  and  $c_2$  in real time makes them suitable for online learning neural network.

Further research will be directed at providing a method of neural network training based on error rates  $c_0$ ,  $c_1$  and  $c_2$ .

Comparison of control quality with the use of different learning algorithms makes it possible to determine the best configuration of the neural network and learning algorithm.

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