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INTELLIGENT CONTROL SYSTEM OF ALUMINUM CONTAINERS DRYING PROCESS

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Abstract. *The relevance is the wide use of aluminum containers in the food industry. The high quality of products is reached by keeping clear technological standards and using materials of the highest class in the manufacture of aluminum containers for long-term and safe storage of food products. Water-based paints and varnish are used for production, which helps to avoid the negative influence of the printing and varnishing process on the environment.*

A neural network (also called an artificial neural network) is an adaptive system that learns by using interconnected nodes or neurons in a layered structure that resembles a human brain. A neural network can learn from data—so it can be trained to recognize patterns, classify data, and forecast future events. A neural network breaks down the input into layers of abstraction. It can be trained using many examples to recognize patterns in speech or images, for example, just as the human brain does. Its behavior is defined by the way its individual elements are connected and by the strength, or weights, of those connections. These weights are automatically adjusted during training according to a specified learning rule until the artificial neural network performs the desired task correctly. Neural networks are especially suitable for modeling non-linear relationships, and they are typically used to perform pattern recognition and classify objects or signals in speech, vision, and control systems. [2] In our case is control system of the temperature in the drying oven.

Key words: ***neural network; adaptive system, control system, intelligent control system***

The purpose is order to minimize energy costs and maintain quality of product by creating an automated system of comprehensive evaluation of parameters of technological process based on artificial intelligence.

The novelty of this research is the implementation of a neural network, which allows to obtain better quality of work and products and get an economic effect from its implementation. The theoretical basis of the research is the fundamental provisions of the theory of decision-making and the theory of automatic control.

Basic methods of research are the following: mathematical statistics, methods of neural network modeling and forecasting, methods of simulation and mathematical modeling. Methods of expert evaluation are used in building a tree of properties of a complex object of assessment and forming a complex system of indicators.

Practical application. Implementation of the results of research into the practice of building evaluation subsystems in decision support systems may improve product quality and reduce time spent on evaluating technological process indicators in the drying oven. This model of the drying oven of printing machine allows conducting research on control systems without the risk of significant economic losses.

DESCRIPTION OF THE OVEN

The external Pin Oven is a "direct fired" convective hot air, continuous baking oven, which utilizes 2 adjoining heating zones and a cooling section.

Each heating zone is designed to give a "cycle time" of 5.5 seconds at the design production speed of 1900 CPM. Zone 1 and 2 (Fig. 1) will provide sufficient "pre-evacuation" of the water and solvents in the coatings to leave a continuous film on the can. The cooler allows for the temperature of the can to be reduced to manageable levels.

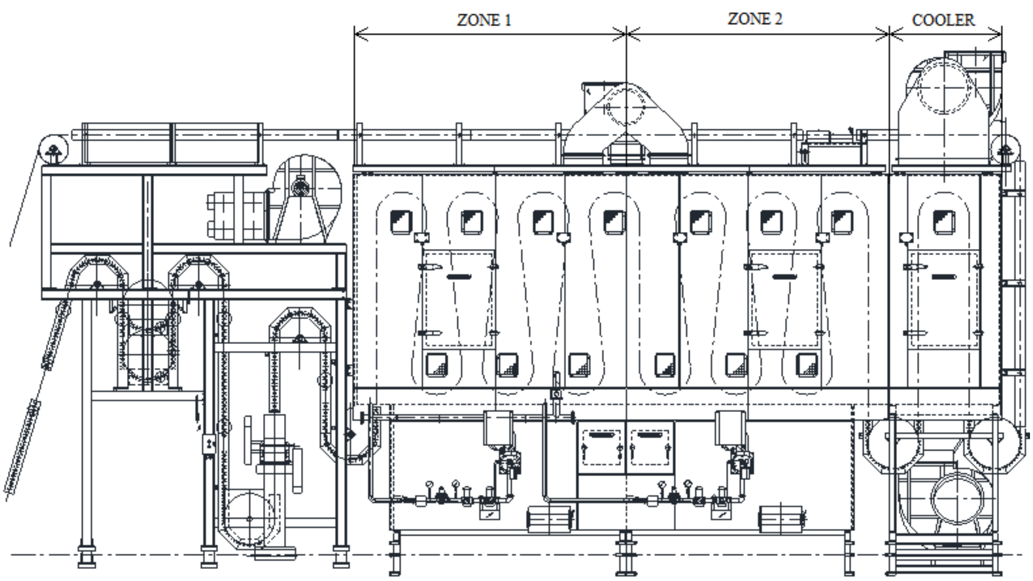

Figure1. Technological scheme of Pin Oven

Air Distribution. The air distribution system in the 2 zone heating section, is powered by 2 direct driven re-circulation centrifugal fans, which distribute the air first into a collection pressure chamber and then through a series of diffuser plates to the discharge nozzles and is then passed over the product/cans in the oven workspace. the air passes through a diffuser plate and is returned to the combustion chamber via the air return area within the oven.

The "discharge nozzles" provide sufficient kinetic energy to provide a heat transfer rate to the product (cans) that will provide sufficient energy/heat to the external coatings on the can to provide a thermo-set cure of the water borne coatings.

Heating Equipment. Each oven zone is heated fully automatic burner. Each burner includes a spark ignited burner, self-checking flame signal amplifier unit - flame rod, solenoid shut-off valves, combustion air blower with filter, motorized gas control valve and gas shut-off cock.

The burners will provide sufficient heat to each of the zones to provide an accurate temperature profile in line with process requirements.

Oven Exhaust System. A single backward blade centrifugal exhaust fan is incorporated to remove the products of combustion and volatile vapors from each of the oven heating zones. The exhaust air is controlled by individual manually adjustable dampers located within an internal plenum in each zone. The total exhaust air is controlled by manually adjustable dampers for Zone 1 and Zone 2 located outside of the oven along with Variable speed control of the fan motors.

Cooling System. The cooling zone provides a minimum of 1.5 seconds cooling time and incorporates two centrifugal blower fans (intake/outlet). The fans are designed and adjusted to provide a negative pressure at the inlet and outlet of the section.

The internal ductwork is constructed similarly to the main oven ductwork utilizing high velocity vertical air nozzles to deliver cool air to the product/cans. The High velocity nozzles also provide better and more rapid cooling then typical designed coolers.

The supply and exhaust fans for the cooler are controlled with manually adjustable external dampers together with direct driven Variable speed control of the fan motors pre-set at the commissioning stage.

The mathematical model. During creating a mathematical model, heat losses from the surface of the drying oven to the environment are assumed negligible compared to the heat flows passing from the coolant to the product. The most important control parameter is the air temperature in the drying oven.

In order to obtain a mathematical model, the diagram of heat flows is draw up (Fig2):

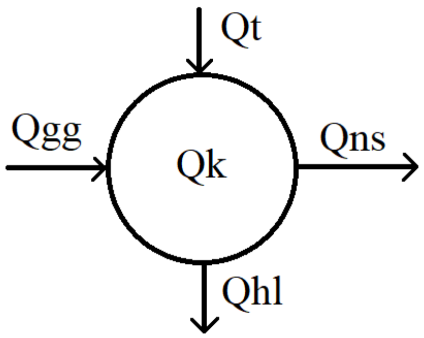

Figure2. Scheme of heat flows in the furnace

where Q_t – heat which comes with the product, Q_{hl} – heat of the product after drying, Q_{ns} – heat loss to the environment, Q_k – the heat in the drying chamber, Q_{gg} – heat from burning gas.

The heat balance equations are compiled:

$$Q_k = V_k \times \rho_{pov} \times c_{pov} \times t_k, \quad (1)$$

$$Q_{ns} = F_k \times K \times (t_k - t_{zov}), \quad (2)$$

$$Q_t = G_t \times C_t \times t_t, \quad (3)$$

$$Q_{hl} = G_{hl} \times C_{hl} \times t_{hl}, \quad (4)$$

$$Q_{gg} = \left(\frac{(V_{gaz}+V_{pov})\times\rho_{dg}\times c_{dg}}{3600}\right) \times G_{gg} \times t_k, \quad (5)$$

where V_k– chamber volume 24,64 m^3; ρ_{pov} – air density 0.865 kg/m^3; c_{pov} – heat capacity of air 1030 J; F_k – camera area 8,33 m^2; K– coefficient of heat transfer of mineral wool from which insulation is made 0.045 W/m°C; t_k– temperature in the oven 200 °C; t_{zovn}– outside temperature 23 °C; G_v – consumption of wet material 0.09 kg/s; C_t– heat capacity of wet material (paint, varnish)2350 J; t_t – temperature of the wet material 23 °C; G_{hl} – consumption of dry material 0.09 kg/s; C_{hl} – heat capacity of aluminum containers 880 J; t_{hl} – temperature of the aluminum container 160 °C.

The heat balance equation for the drying oven is compiled:

$$V_k \times \rho_{pov} \times c_{pov} \times \frac{dt_k}{d\tau} = \left(\frac{(V_{gaz} + V_{pov}) \times \rho_{dg} \times c_{dg}}{3600}\right) \times G_{gg} \times t_k +$$

$$+G_t \times (C_t \times t_{zovn} - C_{hl} \times t_k) - F_k \times K \times (t_k - t_{zovn}) \quad (6)$$

The time constant of the object in terms of temperature is determined from the equation:

$$T = \frac{V_k \cdot \rho \cdot C_{al}}{a \cdot F}, \quad (7)$$

where V_k – volume of the chamber of the drying oven, m^3, ρ – air density, kg/m^3, C_{al} – heat capacity of aluminum containers, α – heat transfer coefficient, W/m^2, F – camera area m^2.

The delay time is calculated as the time of passage of fuel from the regulating body to the chamber of the drying oven:

$$\tau_z = \frac{V_{tr}}{V_g}, \quad (8)$$

where V_{tr} – pipe volume, m^3, V_g – volume consumption of fuel, m^3/s.

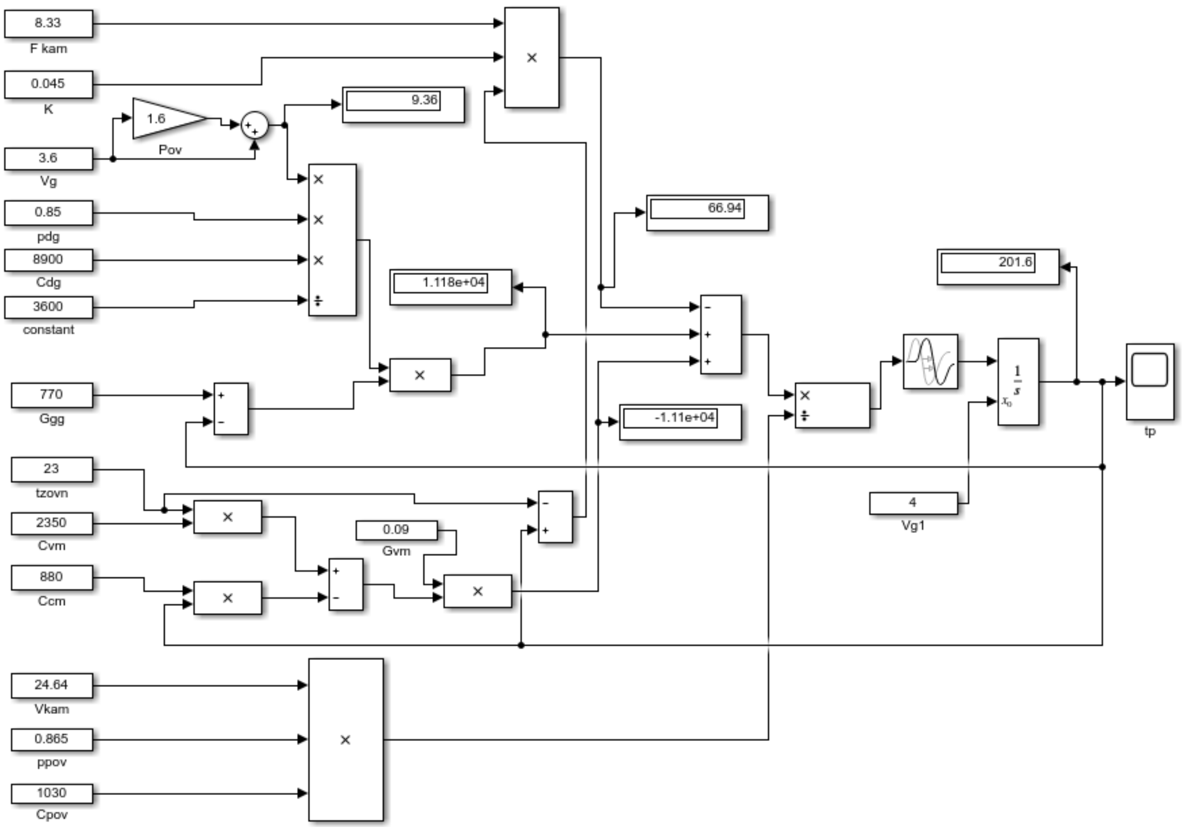

Figure 3. Scheme of the simulation model of the drying oven chamber in Simulink MATLAB

The Simulink software package is used for building the acceleration characteristics of the control object. Figure 3 illustrate the scheme of the simulation model of the chamber of the drying oven.

Figure 4 illustrates the acceleration characteristics of the industrial object.

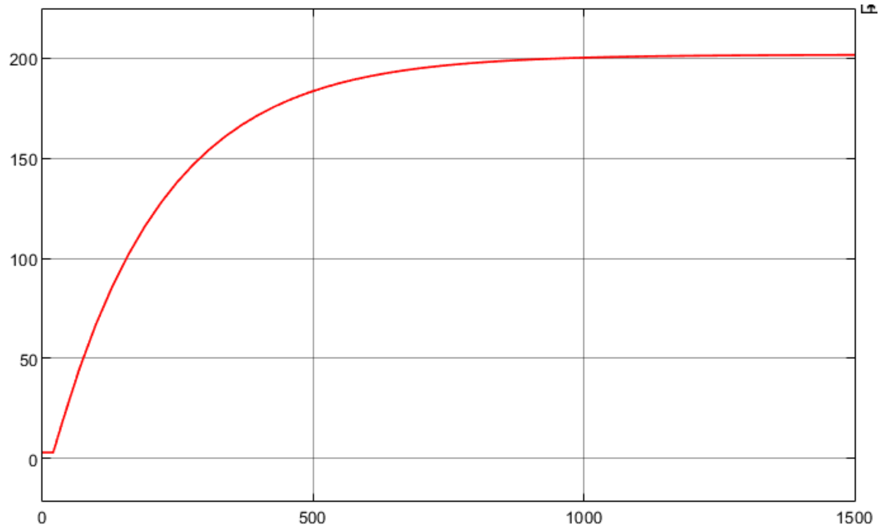

Figure4. Acceleration characteristic of the control object in Simulink

The results and discussion. The identification of dynamic objects using neural networks was considered on the example of a control object described by a first-order link with a delay [1]:

$$W_0(s) = \frac{k_0 \cdot e^{-\tau_0 s}}{T_0 s+1}, \qquad (9)$$

where k_0 - object transfer coefficient; T_0 - time constant of the object; τ_0 - time delay.

$$W_0(s) = \frac{0.02 \cdot e^{-25s}}{375s+1}. \qquad (10)$$

The dynamic single-layer linear neural network was used to identify a dynamic object. The integral quadratic criterion was used as a criterion for comparing models with each other and for evaluating their adequacy to the object. There is a question of choosing the discreteness rate (discretization step) of neural networks, because the dynamic object is continuous, and the neural networks that will reproduce it are discrete.

Formation of the training sequences. In order to study the influence of the discretization step on the quality of the dynamic neural network model of the object, a neural network was created with a discreteness cycle of 5 s. The discretization rate of the neural network should correspond to the discretization step of the training sequences. MATLAB Simulink software was chosen for forming the training data set (Fig.5)

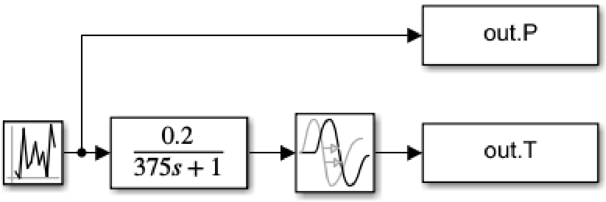

Figure 5. Scheme for formation of training sequences

Identification using a dynamic single-layer forward-propagation linear neural network. The NNTool GUI interface was used to creating and training a linear single-layer neural network, which is "called" as a result of executing the command of the same name in the command window of the MATLAB system:

```
>> nntool;
```

Linear layer (train) was chosen as type of neural network and set the following parameters:

- input ranges,
- number of neurons,
- input delay vector,
- learning rate [3].

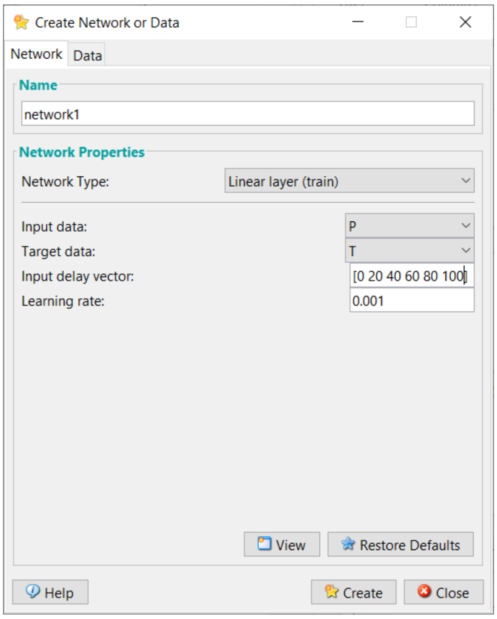

Figure 6. Creating a neural network using the nntool command

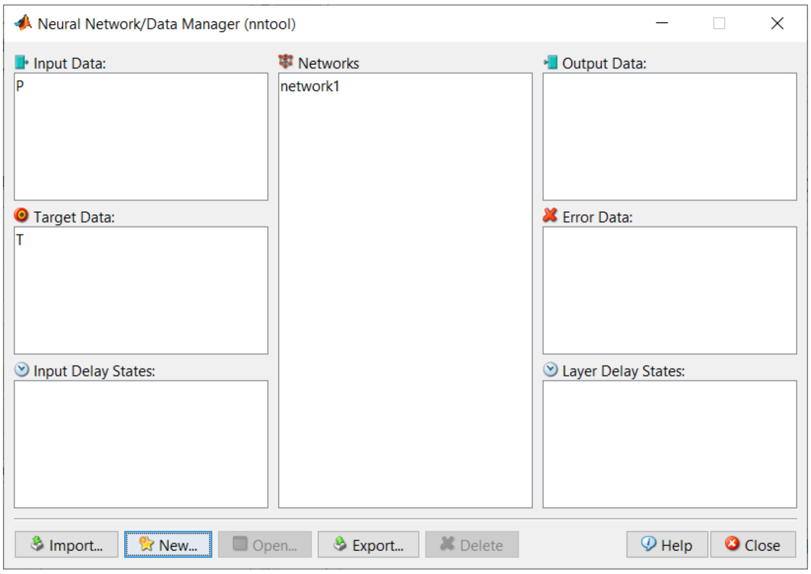

Figure 7. The window Data Manager

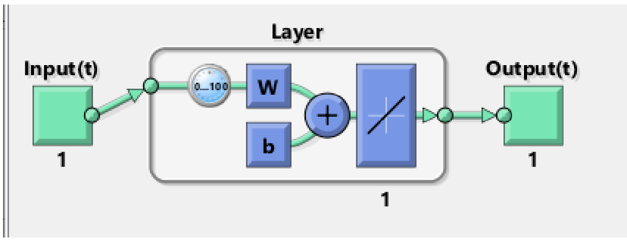

Figure 8. The structure of the radial basis neural network: P - input vector; W{1}- matrices of weights of the first layer; b{1}- shift of the first layer; T - the output vector

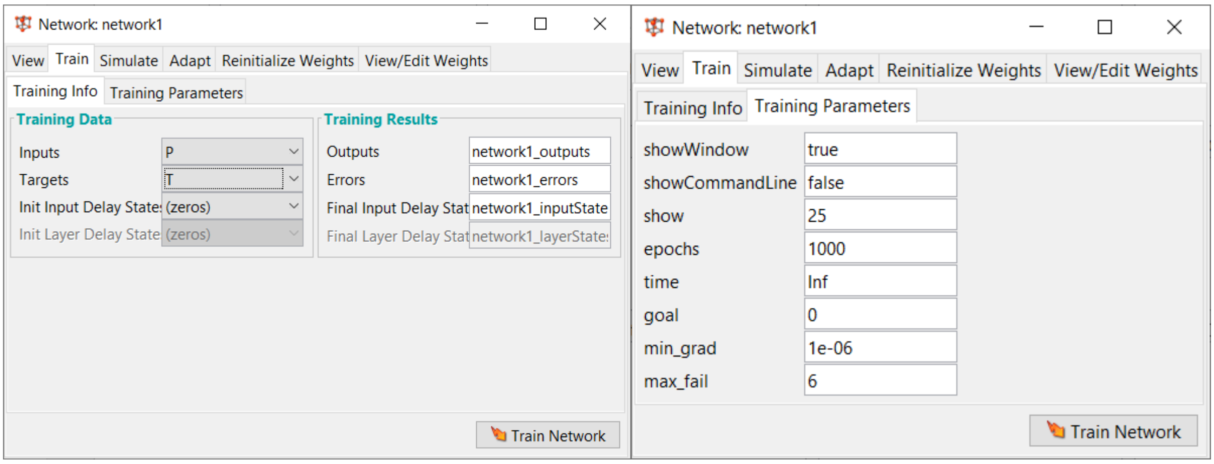

Figure 9. Training Info tab and Training Parameters tab

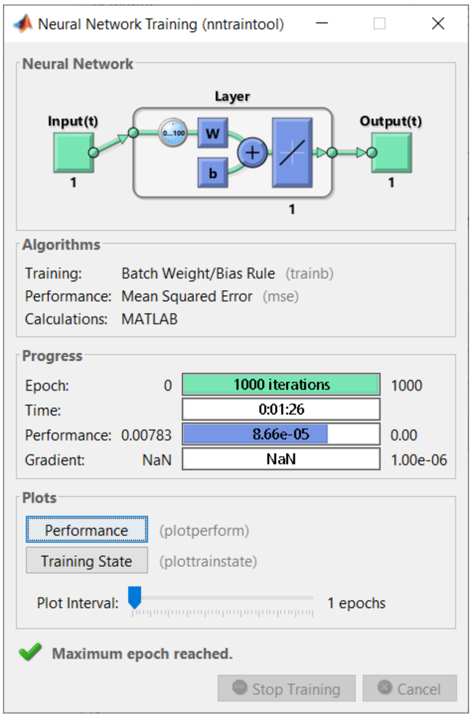

Figure 10. Testing of neural network and analysis of identification accuracy

Figure 11 illustrates the graph of the error change depending on the number of training cycles performed.

This graph is built automatically when the train function is executed.

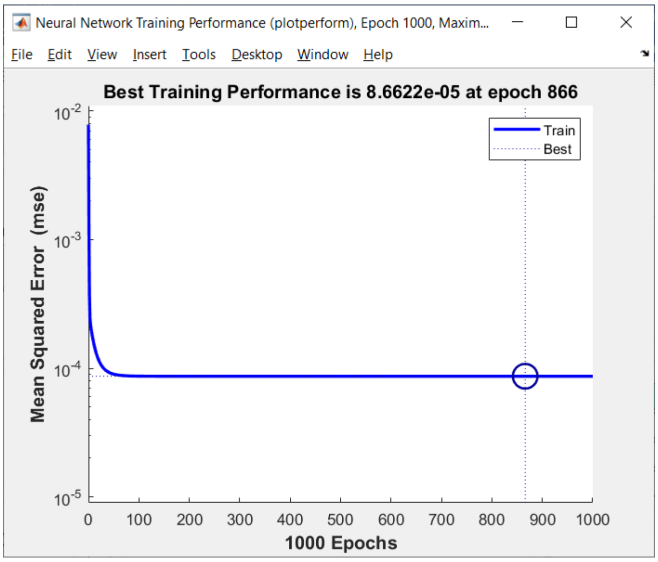

Figure 11. Graph of the error change

At first, object identification was considered by using a dynamic single-layer linear neural network of direct propagation.

The trained neural network was exported to the MATLAB workspace and formed their S-models using the gensim function (net, TS). As the created neural networks are discrete, the value of the TS parameter was set for forming the S-model to be equal to the discreteness tact of the network. Figure 12 illustrates the scheme for testing the dynamic neural network models.

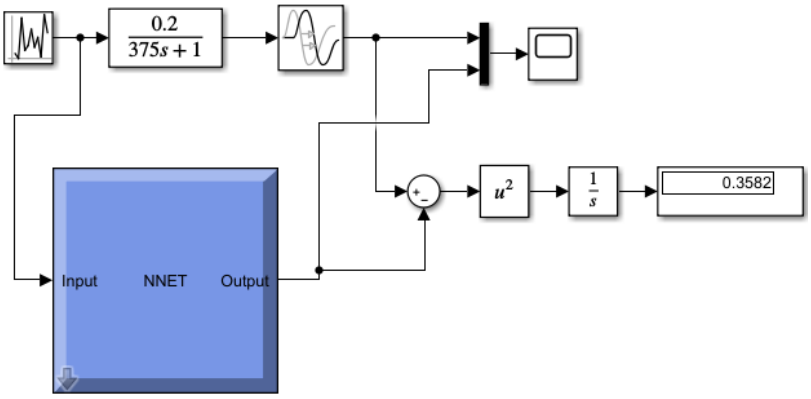

Figure 12. The scheme for testing the dynamic neural network models

Figure 13 illustrates the results of the object identification using the neural network.

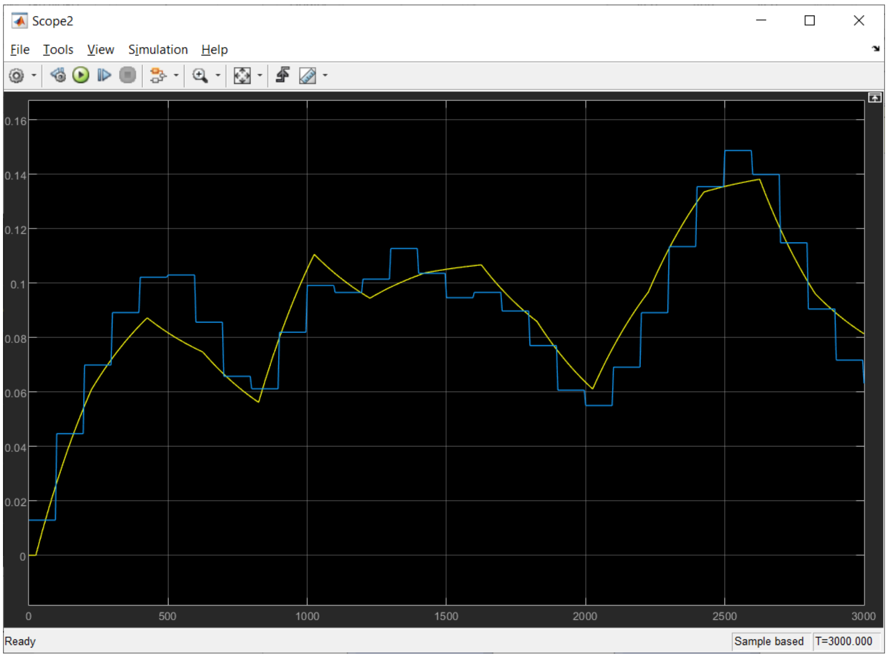

Figure 13. Results of dynamic object identification using a dynamic single-layer linear neural network with a discrete time of 5 s and a depth of the delay line of 100 cycles

Conclusions and prospects for further research. Neural networks increase the accuracy of the decision and reduce its subjectivity, speed up decision-making processes. They make it possible to reach better quality of work and products, get an economic effect from their implementation, provide an opportunity to learn independently and automatically based on samples. A neural network can be a great addition to an automation system, as it is an effective tool for processing large databases. The model of the drying oven of printing machine allows conducting research on control systems without the risk of significant economic losses.

References

1. Lysenko, V. P., Reshetyuk, V. M., Shtepa, V. M., Zayets, N. A. (2014). Artificial intelligence systems: fuzzy logic, neural networks, fuzzy neural networks, genetic algorithm. Kyiv: NUBIP of Ukraine.

2. Neural Networks. The MathWorks, Inc, 1994-2022.

3. Lysenko, V., Zayets, N., Gachkovska, M., Savchuk, O. (2019). Intelligent systems for managing biotechnical objects. Kyiv: KomPrint.

ІНТЕЛЕКТУАЛЬНА СИСТЕМА КЕРУВАННЯ ПРОЦЕСОМ СУШІННЯ АЛЮМІНІЄВОЇ ТАРИ

О. Кисляк, А. Дудник

Анотація. *Доречним є широке використання алюмінієвої тари в харчовій промисловості. Висока якість продукції досягається дотриманням чітких технологічних стандартів і використанням матеріалів найвищого класу при виготовленні алюмінієвої тари для тривалого і безпечного зберігання харчових продуктів. Для виробництва використовуються фарби та лаки на водній основі, що дозволяє уникнути негативного впливу процесу друку та лакування на навколишнє середовище.*

Нейронна мережа (також названа штучною нейронною мережею) – це адаптивна система, яка навчається за допомогою взаємопов'язаних вузлів або нейронів у багатошаровій структурі, що нагадує людський мозок. Нейронна мережа може навчатися на даних, тому її можна навчити розпізнавати закономірності, класифікувати дані та прогнозувати майбутні події. Нейронна мережа розбиває вхідні дані на рівні абстракції. Її можна навчити на багатьох прикладах розпізнавати шаблони в мові чи зображеннях, наприклад, так само, як це робить людський мозок. Її поведінка визначається способом з'єднання окремих елементів і силою або вагою цих зв'язків. Ці ваги автоматично регулюються під час навчання відповідно до заданого правила навчання, поки штучна нейронна мережа не виконає потрібне завдання правильно. Нейронні мережі особливо підходять для моделювання нелінійних зв'язків, і вони зазвичай використовуються для виконання розпізнавання образів і класифікації об'єктів або сигналів у системах мовлення, зору та керування. У нашому випадку це система контролю температури в сушильній шафі.

Ключові слова: ***нейронна мережа; адаптивна система, система керування, інтелектуальна система керування***