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Intelligent control of gas separation during nitric acid production

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Abstract. The article considers the possibilities of modeling the characteristics of gas absorption and cooling processes in the production of nitric acid and controlling this process using the radial basis function and neural networks of direct connection. When training a neural network, the input and output results are obtained from the material balance tables and properties of the absorbing column model to train the network with values. The results obtained using neural network models are mainly compared with the results obtained from modeling books. The result obtained shows that relatively simple neural network models can be used to simulate the stationary state of an absorption column. Using modeling, we will see how the neural network type allows the use of modern management methods.

1 Introduction

The absorption column is one of the most important and basic devices of the nitric acid production process. In modern industrial plants that produce nitric acid, it mainly consists of sieve mesh plates.

The nitric acid production process is based on the dual pressure technology developed by CASALE in Navoiazot, with ammonia conversion at relatively low pressure, absorption of NO_X (nitrogen oxides) at elevated pressure, and selective catalytic removal of the rest of the NO_X (nitrogen oxides) in the tail gas

The plant for the production of nitric acid is designed for the production of nitric acid with a production capacity of 1500 tons per day in terms of 100% concentration. The nitric acid is produced in the CASALE double pressure plant and fed to the plant boundary at a concentration of 60% by weight. Ammonia oxidation is optimal at low pressure, while high pressure improves nitrous gas absorption and acid formation [1].

The liquid ammonia is vaporized and mixed with primary air before being oxidized in the reactor at low pressure (about 4.2 Bar. (0.42 MPa)). The maximum utilization of energy is carried out by cooling the nitrous gas and obtaining steam and further cooling the tail gas by cross heat exchange. This two-stage cooling allows both the production of steam with parameters corresponding to the requirements of the steam turbine, and an increase in the temperature of the tail gas, thereby achieving an increase in the energy production of the turboexpander (figure 1).

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The diameter of the absorption column device used in modern production processes is more than 6 m, and the height of the device is more than 80 m. Due to the high capital costs required to maintain this facility, as well as environmental regulations, accurate mathematical modeling of the process is important. It can be used in the operation of the device through the prediction model of mass flow rate changes, as well as temperature and pressure changes in the device [2].

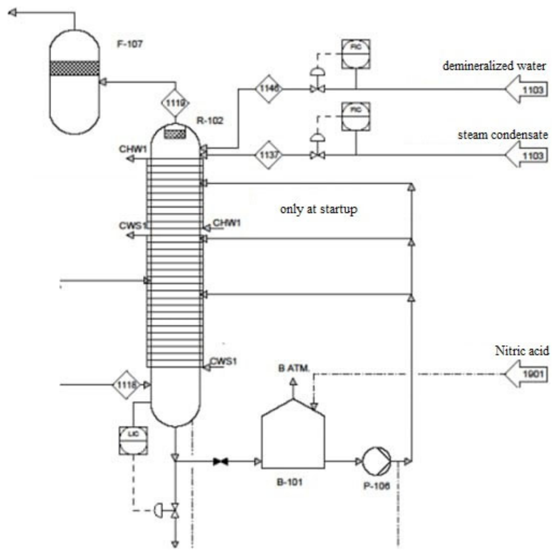

Fig. 1. Technological flow diagram of nitrous gas absorption and cooling process.

In Uzbekistan, the production of nitric acid is not only considered urgent for the agricultural industry, but it is also required that the production and application of this type of inorganic fertilizers does not seriously change the mineral composition of the agricultural land and soils (ecologically, mainly, the not formation of salt). In order to, it is necessary to strictly observe the side effects and usage norms of this type of products.

2 Materials and methods

As the nitric acid production process has been owned, in some literature, the process parameters are represented by the method of graphs. In modern modeling, the ability to more accurately and quickly study the model of the absorption process by computer is being developed.

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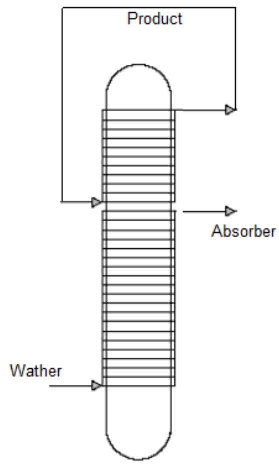

Fig. 2. cooling process with water in production of nitric acid.

The material balance table of this device is given in Table 1 below. At the end of the article, we will analyze the possibilities of using the neural network to create change patterns and use the created patterns in process control.

Table 1.

Flow	**Plate 1-3**	**Plate 3-5**	**Plate 5-8**	**Plate 8-10**
Phase	liquid	liquid	liquid	liquid
Steam fraction (mass)	0.0	0.0	0.0	0.0
Pressure, bar	3	2.435	7	6
Temperature, 0C	33.2	32.8	22.8	19.0
Flow -mass, kg/h	3873105.0	8072633.0	253069.0	2526088.0
Flow - Volume, m3/ h	3882.25	8122.32	2524.85	2527.91
density, kg/ m3	958,30	988,32	990.55	926.33
viscosity, MPa*s	0.731	0.755	0.88	1.02
H_2O	100.0	100.0	100.0	100.0

A neural controller is designed to intelligently control this process, and the neural controller is defined by the temperature neurocontroller window (A), the volumetric flow neurocontroller window (B), and the density neurocontroller window (C).

First, we write the chemical reaction of the process and its realistic mathematical model using the literature and process regulations given below. In the process of obtaining nitric acid, the excess ammonia is given for thermal decomposition, selective purification, the formation of elemental nitrogen is formed in the universal combustion chamber of the turbine and in the heat part of the gas channel to the turbine according to the following reactions [1-5]:

$$NH_3 = 2N_2 + 6H_2 \tag{1}$$

$$6H_2 + 3O_2 = 6H_2O \tag{2}$$

$$4NH_3 + 3O_2 = 2N_2 + 6H_2O \tag{3}$$

The gas stream leaving the ammonia oxidation reactor is cooled in a heat exchanger. If the temperature of the device is below the specified value range, it will turn into and also condensate will form. A part of nitric oxide reacts with water to form a weak nitric acid (product), and its concentration depends on the reaction time and the amount of condensed water. The condensate is then pumped to the next absorption column plate.

The reaction of nitrogen dioxide and N_2O_4 dimerization of nitric oxide:

$$2NO+O_2 \rightarrow 2NO_2 \tag{4}$$

$$2NO_2 \leftrightarrow N_2O_4 \tag{5}$$

Oxidation and tetroxidation reactions with water:

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3 \tag{6}$$

$$N_2O_4 + H_2O \rightarrow HNO_2 + HNO_3 \tag{7}$$

$$3HNO_2 \rightarrow HNO_3 + 2NO + H_2O \tag{8}$$

A mathematical model of the absorption column and its cooling with water was developed using the above parameter changes and reaction progress:

- Ideal mixing of liquid phases between plates.
- There should be no temperature in the pool of plates.
- Absence of concentration-related liquid gradients in the pool of plates.
- Characteristics of gas and liquid phases thrust.
- Relative heat loss.
- To the heat reaction (K) transmitted by the heat exchanger.
- To allow chemical reactions to occur in the bush areas of the device without heat exchange with the environment.

Calculation of the gas pressure between the plates of the device is based on the following equation:

$$P^i = P^i / P - (P^i - P) \tag{9}$$

The pressure difference between the plates is calculated using the Hunt relationship expression [3-5].

The analysis of the low-intensity absorption of ammonia and methylamines and the positional theory of the mass transfer system with the capillary absorber allows us to identify three methods of intensification of the multicomponent absorption process:

by increasing the mass transfer coefficients (KG),

increase the contact area of the phases(F)

Improve the driving force of the process (Δ)

This follows from the basic mass transfer equation:

$$K = KG * F * \Delta \tag{10}$$

The mathematical description of the intensity of mass transfer is a difficult task, since it must take into account the hydrodynamic nature of the movement of gas and liquid flows, heat transfer processes between phases, and mass transfer in each of the phases [6-7]. To simplify the process of transferring a component from the gas phase to the liquid phase during absorption, it is conditionally divided into three stages:

- Transfer of a component from the core of the gas phase to the interface.
- Transfer across the interface.
- Transfer from the interface to the core of the liquid phase.

The speed of the first and third stages is described respectively by the following equations:

$$K = \beta_g * F * (C_g - C_{gr}) \tag{11}$$

$$K = \beta_l * F * (C_{gr} - C_l) \tag{12}$$

In accordance with equations (11, 12), the mass transfer rate within the phase is proportional to the driving force and the phase contact surface. The mass transfer coefficient in equations (11, 12) is a kinetic characteristic that takes into account the physical properties of the phase, the hydrodynamic characteristics of the flows and the geometric parameters of the contact device.

The amount of nitric acid formed on the plate depends on the efficiency of the plate, NO_x the theoretical ratio of the reaction and falling on the plate NO_x depending on the amount:

$$X_{HNO_3} = \eta y \sum_{j=NO}^{N_2O_4} G_j^{i-1} \tag{10}$$

$$\eta = 1 - \exp\left(A \frac{\left(1 + \frac{C^i_{HNO_3}}{100}\right)^{1.49}}{(w_g^i)^{0.546} (p_{NO}^{i-1})^{0.0483} (T^i)^{1.248}}\right) \tag{11}$$

With the help of mathematical models, the existence of a precise (analytical) mathematical model is assumed. But there is a possibility that the technological process may be affected by uncertain parameters that cannot be taken into account in the developed models. Taking into account the various effects, there are modern intelligent control possibilities of absorption column and water cooling systems in nitric acid production using neural networks using neural network, and by imitating the process through this controller, it does not limit the linearity of the system, it is effective in noisy conditions, and after the training is completed, it is realistic. provides timely control [8-10].

3 Results and discussion

Control systems of neural networks are flexibly adapted to real conditions, allowing to form models that fully correspond to the task without the restrictions associated with the construction of real systems [1,7-10].

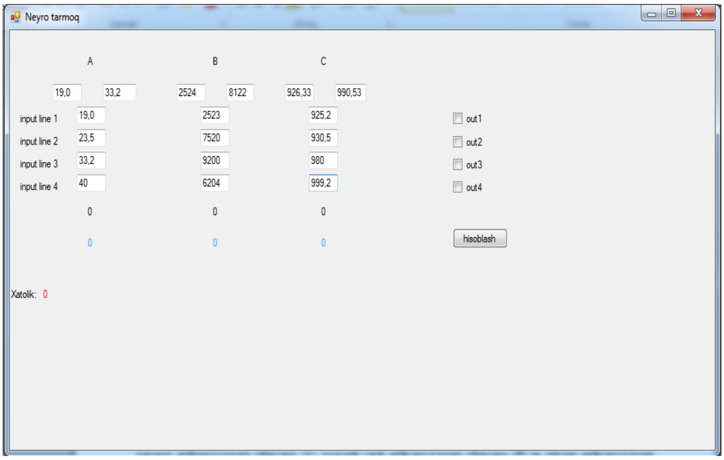

Fig. 3. A window of the neurocontroller system.

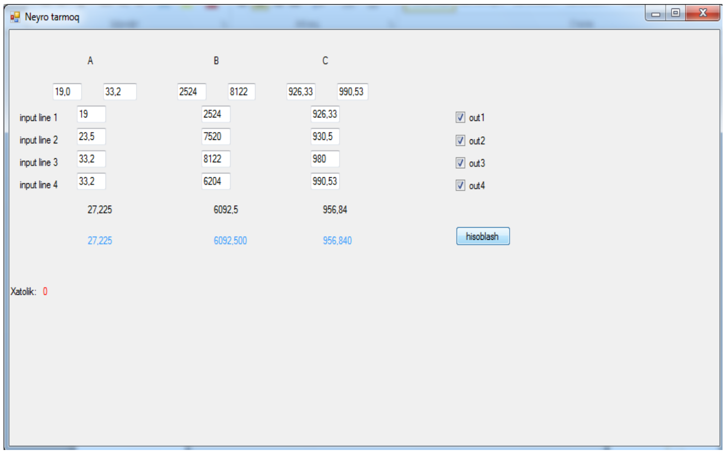

Fig. 4. Material balance parameter training of neurocontroller and process control window.

Several factors were taken into account in the creation of the neurostimulator. In the production of nitric acid, the parameters of pressure, temperature and density, which we have taken as the main parameters, from the material balance equations and the technological regulations, are given limits for obtaining the results observed in the training of the neuro controler. otherwise, it accepts the lower bound and implements the possibility of controling the process using the average value of the results obtained while training the network.

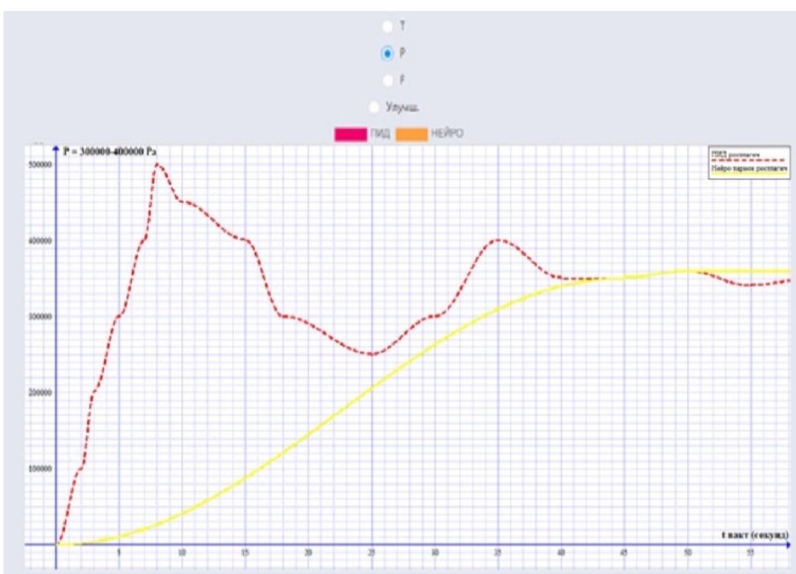

Fig. 5. Control of pressure with PID controller and NC.

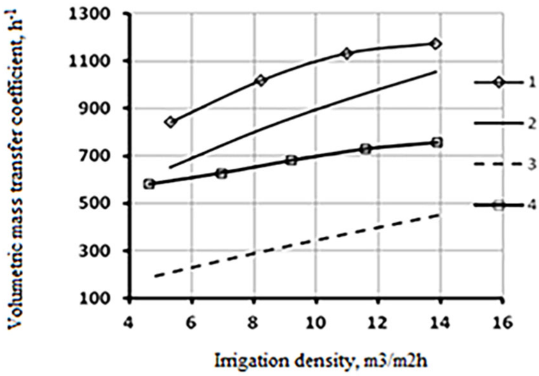

Fig. 6. Control of pressure with PID controller and NC.

7-size Dependence of the volumetric mass transfer coefficient on different packings on the irrigation density: 1 - tape modification packing; 2 - chord attachment (d=0.022m); 3 - tubular nozzle; 4 - Raschig rings (25*25*3) [10-13]

In these graphs, nitric acid production is plotted against the density value of product production volume. From the graph representing the relationship between a typical PID controller and a neuro controller, it can be seen that the PID controller controls to approximately 0.4 MPa for 6 seconds, while the neuro controller controls to a specified (trained) value of 0.42 MPa for 42 seconds.

4 Conclusion

Based on the researches of the intelligent control system of complex technological processes, a control system with a neuro-adapter was proposed. In the NSC control system, the controlment time is longer compared to linear P, PI and PID-controlers, but the advantage of the NC controlment system is the small number of errors of the measured values in the control. Reducing the error helps to increase the quality of the product.

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