International Journal of Advanced Science and Technology
Vol. 29, No. 11s, (2020), pp. 32-37

Automatic control system for the concentration of ingredients from vegetable raw materials using liquefied CO_2

I. X. Siddikov, Sh. I. Fayziev, K. Kh. Gafurov and U. M. Ibragimov
Tashkent State Technical University, Bukhara Engineering, Technological Institute

Abstract

The article deals with the creation of an ARS the concentration of extract from vegetable raw materials. Mathematical models of extraction process and technical means of control system are developed. To stabilize the given concentration value, a fuzzy PI-regulator is proposed, which allows considering changes in the load and the environment. A quick-operating algorithm for adaptive adjustment of fuzzy PI controller parameters is proposed. Simulation modeling was carried out to check the adequacy of the taken results. Comparative analysis showed that the proposed algorithm has more significant qualitative indicators than classical ones.

I. INTRODUCTION.

Today, the current environmental and social situation in the world requires new approaches to the production of food and pharmaceutical products. In the food industry is limited, and in the pharmaceutical prohibited the use of a number of extractants that can have a toxic effect. The modern extraction industry is forced to use solvents that have not only greater extracting capacity, but also do not meet the requirements of quality standards and fire safety. One of the solutions to this problem is the use of liquefied carbon dioxide as an extractant.

To solve this problem developed ARS with technological parameters of the setting to obtain qualitatively new highly concentrated extracts from local raw materials.

Installation (Fig.1) designed to produce ingredients from vegetable raw materials with the use of liquefied CO_2, which consists of the following main elements: a high-pressure extractor with a cassette for placing a sample of vegetable raw materials, an extractant supply system, product collection, condensation, a heat pump, CIP and A.

II. METHODS AND MATERIALS

To formalize the process of controlling the technological parameters of the setting is as follows: pre-crushed vegetable raw material is loaded into a mesh cassette, which is installed in the extractor VII. After sealing the extractor, the technological system with the product is purged with CO_2 gas to remove the air.

Carbon dioxide from cylinder I is transferred to compressor II when valve 1 is open and valve 2 is closed (when the unit is first started). CO_2 pressurized by the compressor II passes through the condenser IV, where it is cooled by the working agent of the heat pump, passes into the liquid state (P1=6 ... 10 MPa and t1=20...32^{0}C) and accumulates in the extractant tank V with the valve 3 open. In this case, the extractant pressure at the entrance to the condenser and its temperature at the exit from the condenser are measured by a pressure gauge and a thermometer of the TSM type, respectively. The pressure and level in the tank V is measured by a pressure and level sensor and the signals are transmitted to the control system to control the operation of the valve 3.

For carrying out the process of extraction liquid extractant at the open valve 4 passes through the electric heater VI, where it enters a supercritical state (P2=8...10 MPa and t2=35...70^{0}C) and served on top of the extractor VII, which has a temperature sensor that sends a signal to a regulating system, an electric heater for regulating the temperature of the extractant. The extractant flow rate is regulated by valve 4. Passing through a layer of vegetable raw materials extractant extracts soluble components (eg, grape seed oil) and is derived from the bottom of the extractor, i.e. extraction is carried out by infusing for some time (settling time depends on the type of extracted raw materials) at a closed valve 5. If the extraction technology requires flow extraction, then the process takes place at the open valve 5. After the process time is reached, the valve 5 closes and the throttle valve 6 opens. When passing through this throttle, the pressure and temperature of the miscella are reduced below the critical parameters (P3=5.0...5.5 MPa and t3= 20...30^{0}C) and carbon dioxide passes into a gaseous state.

In the separator-evaporator IX, the precipitation of the extract dissolved in the extractant occurs, where it is necessary to maintain the temperature (t4= 25...30^{0}C). The temperature is maintained by means of the working agent of the heat pump serving for the coil heater of the separator-evaporator by the heat agent. In this case, the precipitated extract is removed from the bottom of the evaporator-separator at the open valve 8, carbon dioxide gas is removed from the top of the evaporator-separator at the open valve 7. The gaseous CO_2 passes through valve 2, is compressed to the operating pressure in the compressor and the cycle is repeated.

The main technical characteristics of the installation are: the volume of the working part of the extractor-1,25 l; the volume of the separator-3,0 l; maximum pressure-15 MPa; maximum temperature-60^{0}C; maximum specific consumption of the extractant-4,0 l CO_2/(min).

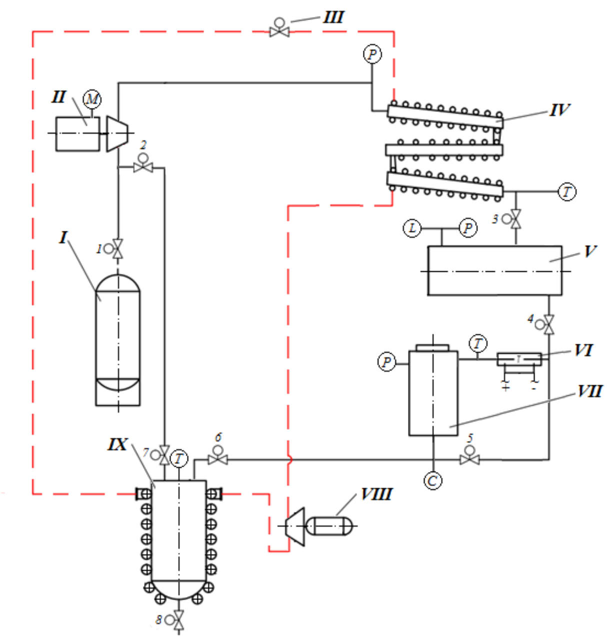

Fig.1. Schematic diagram of the laboratory unit for the study of the process of CO_2 extraction of ingredients from plant raw materials.

The main output value is the concentration of the miscella *C* at the outlet of the extractor VII. When the set quantity is reached, the valve 6 is activated and the miscella passes into the separator-evaporator IX to separate the ingredient from the solvent.

Analysis of the principles of operation of the system showed that among all the factors considered, the most important is the channel G2→C, i.e. supporting, in which the values of C are maintained in a given mode. For this purpose, we will develop ARS by this process. To do this, consider the technological scheme in expanded form (Fig.2).

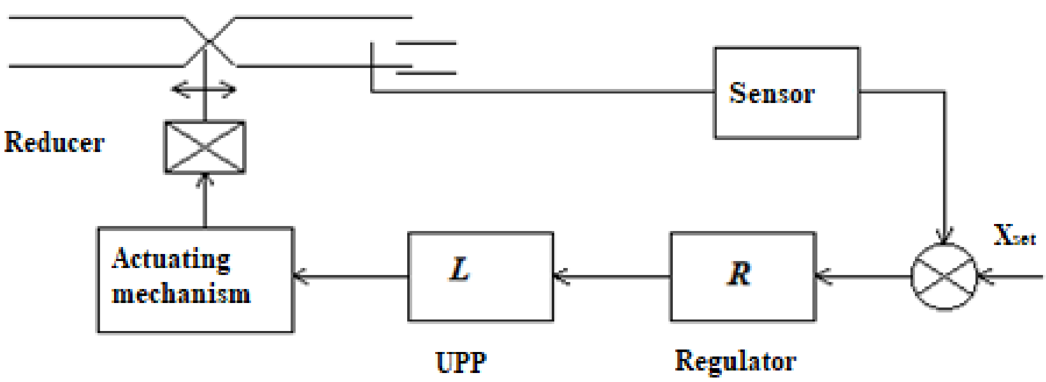

Fig.2. Technological scheme of process control

The expense of the value *C* depends on the position of the valve, which is maintained depending on its deviation from the required value. The valve is driven by a motor. For clarity, make a diagram (Fig.3).

For the study of this system, we draw up the equations of motion. The kinematic mechanism (valve-gate) is described by the equations obtained on the basis of Newton's second law:

$$\dot{\omega} = \omega; \quad (1)$$

$$J\dot{\omega} = M_n - M_c$$

where ω is the shaft rotational speed of the kinematic mechanism; Mn –torque applied to the shaft (load); Mc-given moment of resistance; J-reduced moment of inertia.

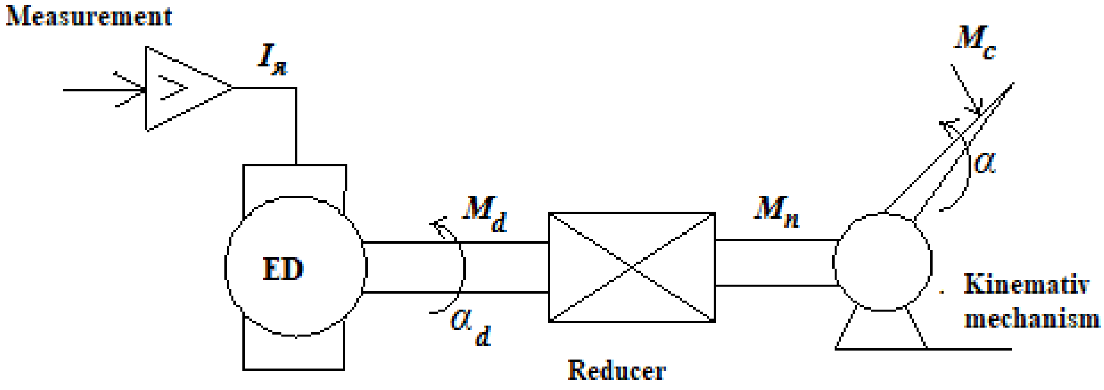

Fig.3. The scheme of the kinematic mechanism work of regulation of the valve position

The reducer provides conversion of the motor torque *Md* to the load torque *Mn* by the formula:

$M_n=K_p \cdot M_d$, (2)

where Kp is the coefficient of transmission reduction gear.

In this case, the rotation speed of the motor *ωd* and the shaft of the kinematic mechanism *ω* are connected by the ratio:

$\omega_d= K_p \cdot \omega$. (3)

The model of the electric motor is given by the torque characteristic:

$M_d=C_м \cdot I_я$, (4)

where $I_я$ - is the armature current; $C_м$ - is the mechanical constant.

The equation of the anchor chain:

$$U = E + R \cdot I_я + L \cdot \dot{I}_я; \quad (5)$$

where U is the voltage applied to the electro motor armature (power amplifier output); E is the counter EMF; R and L are the resistance and inductance of the anchor circuit.

Equation (5) can be written as follows:

$$T_d \dot{I}_я + I_я = K_d(U - E) \quad (6)$$

where Td=L/R is the time constant; Kd=1/L is the transmission coefficient of the anchor chain.

Contra EMF is defined by the formula:

$E= C_e \cdot \omega_d=C_e \cdot K_p\omega$, (7)

where C_e is the electrical constant.

The power amplifier is the aperiodic link:

$$T_y \cdot \dot{U} + U = k_d \cdot U, \quad (8)$$

Taking into account these expressions, we make a block diagram of the ARS with valve position.

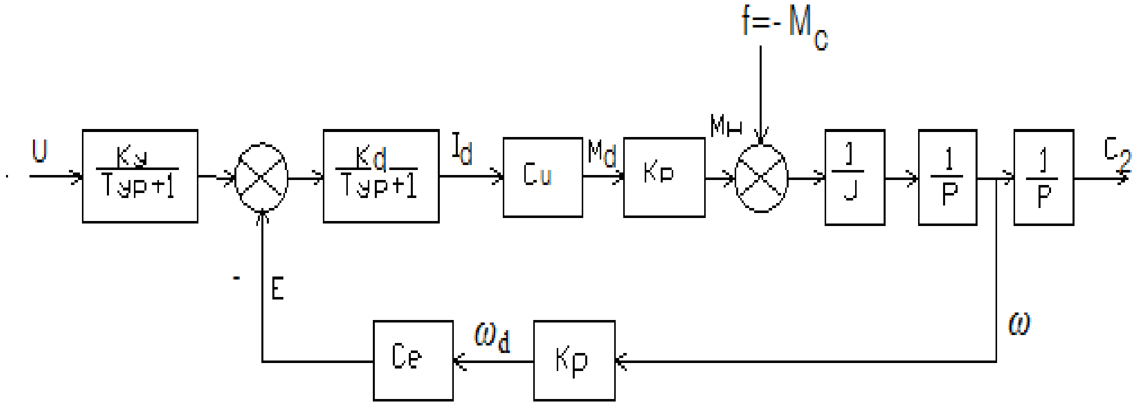

Fig.4. Block diagram of ARS by valve position.

With MATLAB you can build the dynamics of the process from changes *f* and *U*.

In production conditions, with frequent changes in loads and the influence of uncontrolled disturbances on the controlled object, the values of its parameters are subject to dynamics, which requires at the adjustment of the system, automatic control of the technological process, manual installation of new values of the settings of the PI controller or its adaptation. Adjustment of regulators in traditional ARS is a very time-consuming task that requires detailed adjustment of the parameters of the *Kp* transmission coefficient and the constant integration of the *Ti* object.

The calculation of parameters by formulas can not give the optimal setting of the regulator, since the analytically taken results are based on highly simplified models of the object. In particular, they do not take into account the nonlinearity of the type “restriction” always presents in the control action. In addition, the model uses *Kp* and *Ti* parameters identified with some error.

Taking into account the above disadvantages of the traditional system of PI-regulation at the introducing extraction process, it is proposed to implement a control system using fuzzy logic methods with the formation of corrective amendments in the work of the PI-regulator. In the proposed PI controller with fuzzy control methods, the settings will not be static, their coefficients will be changed depending on the state of the system at the current time. Such a control system would represent a nonlinear system. This will allow to qualitatively change the control process without resorting to complex descriptions of the mathematical model of the extraction process and implicit dependencies of the system parameters, as well as to make the control process more adaptive.

The regulator with fuzzy control methods based on the traditional regulator will carry out the correction of the coefficients in the settings of the PI-regulator depending on the current value of the control parameter. In the base of the fuzzy controller algorithm will be a set of rules that are formed in the knowledge base block in accordance with the expert knowledge of the process.

Taking into account the above, the paper proposes a block diagram of an automated control system of actuators, which includes a block of adaptation, presented to correct not only the parameters, but also the structure of the control stages.

In the "adaptation block" not only correction of the parameters is carried out, but also the structure of the control stages, that is, the entire control system as a whole. Adaptation block consists of the following blocks “input Mechanism” [1,2]; “evaluation of the state of the CO” [3]; “knowledge Base” [4]; “adaptation Mechanism” [5].

This network works as follows.

During the control process, information from the sensors enters the output block and the status evaluation block. After that, from the output block and the status evaluation block, the obtained values of the control parameter enter the "adaptation" block, in which, in turn, reference value of the control parameter is set. The adaptation block calculates the control parameter in real time and compares the calculated and reference values. And if they do not match, it creates adaptation of the obtained results to the reference values, and then produces control signals. A neuro-fuzzy network based on a fast operating fuzzy inference algorithm is shown in figure 5.

A neuro-fuzzy network

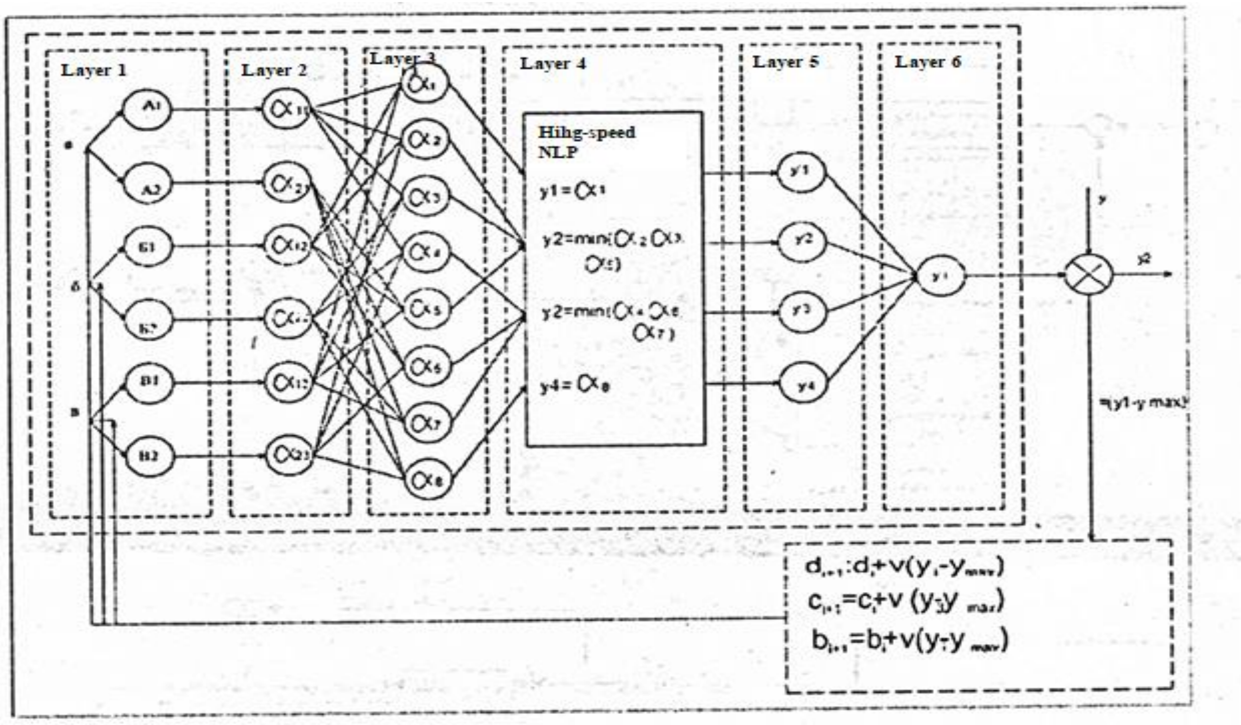

Fig.5. Scheme of neuro-fuzzy network based on high-speed logically fuzzy inference algorithm.

III. RESULTS AND DISCUSSION

Let the dynamics of the oil extraction process as an object of control via the G2-C channel be described by the transfer function as

$$W(P)=\frac{6}{13p^2+2p+1}$$

Determining the value of the error signal E and its integral $\int Edt$, the adaptive settings for the PI-regulator are calculated: K_p=0.42 and $T_и$=50. As a result of simulations of the process at the output of the adaptive ARS, a damped adaptive transition process Y(T) was observed. (Fig.6.)

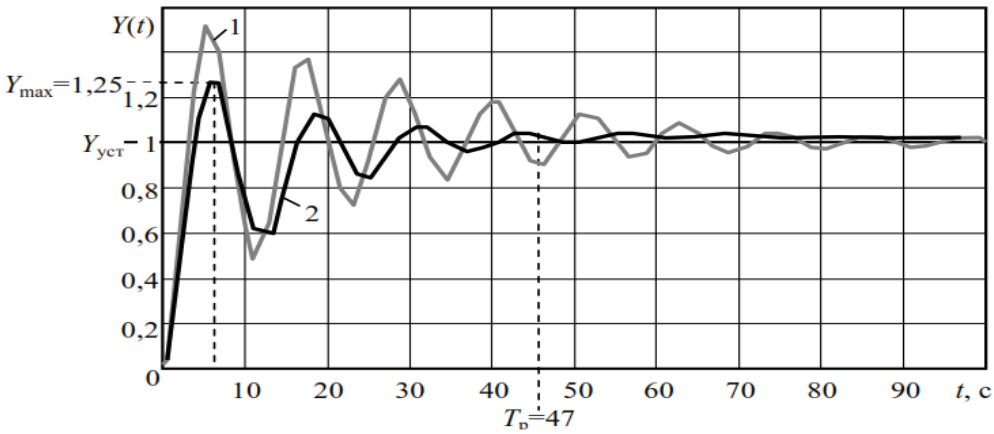

Fig.6. Transients y(t) ARS by the assignments channel 2: 1 - without adaptive settings, 2-with adaptive settings.

Thus, the adaptive algorithm of fuzzy-logical output successfully finds the optimal values of the settings of K_p, $T_и$ PI-regulator when controlling a complex object. The proposed tuning algorithm is effective and can be recommended for implementation in the production of the extract used in Pharmaceutics and food industry. The use of the algorithm improves the process of adaptation of ARS, so as it does not require special methods of active identification of object parameters that degrade the quality of control. The results of the carried-out experiments suggest that the mass introduction of adaptive neuro-fuzzy controllers will successfully manage complex technological processes that operate under uncertainty.

IV. CONCLUSION

In this paper, the simulation results show that in the control process, the developed adaptive fuzzy PI-controller system has a faster response, higher control accuracy, better performance in a stable state, which is difficult for a digital PI-regulator speed. One remarkable feature is that with the same accuracy, the transient timing system of the adaptive fuzzy PI-controller system is short, which is of great importance for the actual control of the process. Overall, the productivity of the control system of the adaptive fuzzy speed, PI-controller was a more significant improvement.

Adaptive fuzzy PI-control does not require a mathematical model of the controlled object and has real-time correction parameters, so the controller adapts to any changes in the parameters of the controlled object. To achieve the ideal control effect, the Proportional (P), integral (I), differential (D) coefficients were optimized in real time using fuzzy logic algorithm and some fuzzy rules.

REFERENCES

1. J. JOHNER, M. MEIRELES. Construction of a supercritical fluid extraction (SFE) equipment: validation using annatto and fennel and extract analysis by thin layer chromatography coupled to image // Food Science and Technology (Campinas). Volume 36.No2, 2016. pp.210-247
2. B. Pavlić, O. Bera, S. Vidović, L. Ilić, Z. Zeković. Extraction kinetics and ANN simulation of supercritical fluid extraction of sage herbal dust // The Journal of Supercritical Fluids. Volume 130. pp.327-336 (120)
3. Kurabachew Simon Duba, Luca Fiori. Supercritical CO_2 extraction of grape seed oil: Effect of process parameters on the extraction kinetics // Journal of Supercritical Fluids. Volume 99. pp.33-43 (March 2015)
4. Gholamhossein Sodeifian, Sajad Ghorbandoost, Seyed Ali Sajadian, Nedasadat Saadati Ardestani. Extraction of oil from Pistacia khinjuk using supercritical carbon dioxide: Experimental and modeling//Journal of Supercritical Fluids. Volume 110. pp.265-274 (April 2016)
5. Edgar Uquiche, Fabiola Garcés. Recovery and antioxidant activity of extracts from leptocarpha rivularis by supercritical carbon dioxide extraction //Journal of Supercritical Fluids. Volume 110. pp. 257-264 (April 2016)
6. *Omatu S., Khalid M., Yusof R. Neurocontrol and its applications.// B. M .: IPRZhR, 2000. 272 pages.*
7. A method of robustly, neuro-fuzzy and adaptive control // Under the editorship of Egupov. M.: MSTU named from N.E. Bauman, 2002. -744 pages.
8. V.S. Mikhailenko, R. Yu. Harchenko. Synthesis of an adaptive fuzzy regulator with a forecasting neuro-fuzzy net // SSU Bulletin. Technical Sciences Series. No3.2012. pp.30-37
9. Rotach V.Ya. Automatic control theory //M.:MEI, 2008. 396 pages
10. S. Kuvendziev, K. Lisichkov, Z. Zeković, M. Marinkovski, Artificial neural network modelling of supercritical fluid CO_2 extraction of polyunsaturated fatty acids from common carp (Cyprinus carpio L.) viscera, J. Supercrit. Fluids 92 (2014).
11. I.X.Siddikov, Sh.I.Fayziev. Synthesis of automatic control system for the concentration of ingredients from plant raw materials using liquefied CO_2//International scientific and technical journal. Chemical Technology. Control and Management. No4-5.2019. pp.113-118
12. Siddikov I.Kh., Fayziev Sh.I., Ismoyilov Kh.B., Uvayzov S.K. Synthesis of the neuro-fuzzy adaptive control system of a dynamic object// The Journal of Test Engineering and Management. Volume 83. pp. 11236-11246