ANNOTATION

of the dissertation work presented for the degree of Doctor (PhD)
on the specialty 6D070200 – Automation and control

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Research and development of an automated air ozonation unit

The relevance of the dissertation work theme.

Ozone, being a gas with unique bactericidal properties and having a high oxidative potential, found diverse and extensive application in various areas of human activity and in various industries, among which agriculture and food industry occupy a special place.

One of the ways to increase the efficiency of a number of technological processes in the food industry is the use of an ozone-air mixture. This is due to the participation of ozone in many biochemical processes that are the basis of metabolism and energy in agricultural biological objects. The result of such application of the ozone-air mixture is the increase in productivity, the reduction of energy intensity, the reduction of bacteriological and viral oppression, the increase of output, productivity and safety of agricultural products. One of the new directions of fruits, vegetables, grains and industrial crops storage is the use of ozone. Ozonated air is successfully used as a means for sterilization, for ensuring the safety of food products and for odor removing (deodorization) in refrigerators and vegetable stores. Ozone destroys the surface mold, foci of decay and kills bacteria on the surface of vegetables and fruits, that leads to an extension of the period of preservation and freshness. Oxidizing ethylene, ozone inhibits the ripening of fruits, destroys carbon monoxide and sharply reduces the content of harmful, toxic, foul-smelling substances in the air.

In connection with various fields of ozone use the most relevant are the tasks of development of a scientifically grounded technology for the application of electrozoning at the storage of agricultural products.

The development of high-efficiency ozone technologies and ozonizing devices has a great importance and requires the study of theoretical positions and analysis of experimental data, the totality of which would allow developing a scientifically grounded methodological apparatus for designing these systems, taking into account the requirements set by the food industry.

When ozone is used in the food industry great attention must be paid to the concentration of the treated ozone for products processing. It is also necessary to take into account the peculiarities of the technological process, species composition of the microflora, temperature, humidity and other parameters that may affect the effect of ozone. Moreover, the technological process of ozonization is a complex inertial system, characterized by non-stationary parameters, non-stationary nature of the properties of the initial products supplied for storage.

The change over time in the TP parameters is primarily due to the difference of the properties of the incoming fruits and vegetables, the multi-nomenclature of production, as well as to depreciation, aging and failure of the process equipment, sensors and actuators. The multi-nomenclature of the production leads to the fact that for the control of TP of ozonization it is necessary either to have a large number of control objects models or to build such models directly during the TP.

The main problem is that it takes some time to build the control object model. For a continuous TP of ozonization this means that at creation of an object model it is possible to escape controlled output parameters beyond the tolerance limits and, as a result, spoilage of products and not compliance with technical and customer requirements.

Therefore, researchers in recent years begin to develop an approach to adaptive identification of non-stationary TP with Markov parameters. TP of ozonization at the storage of agricultural products as an object with non-stationary parameters (of stored products) can be reduced to passive identification, that is, to the problem of stochastic control at the constructing of TP models in real time. In order to control such non-stationary dynamic objects one of the popular methods is the construction of adaptive control systems.

In this regard, the development of mathematical models and control algorithms which take into account the features of the ozonization process and which are oriented on the modern microprocessor-based real-time control tools, with the goal of creating an automated process control system, determines the relevance of the selected theme of the dissertation work.

The object of the research are the air ozonation regimes for ensuring the safety of agricultural products in the "ozonator-vegetable store" system.

The subject of the research are the methods and models for constructing an ozonizer with an automatic controlled frequency and an adaptive control system for the technological process of ozonization.

The purpose of the dissertation work is the study and development of an automated installation with monitoring and operational control of air ozonation for increasing the storage time of agricultural products in closed spaces on the basis of an improved design of the ozonizer.

The main tasks of the research:

1. to perform analysis and to identify scientific, technological and technical problems of automation and control of air ozonation processes at storing agricultural products in a closed space;

2. to develop an improved design of the ozonizer with an automatic controlled frequency based on methods of current amplification in ozonizers on the corona discharge, which provide an increase in ozone output (including the development of a methodology for calculating the pressure drop in an ozonator operating on the principle of an ion-convection pump);

3. to develop adaptive predictive models of the technological process of ozonization at the storage of agricultural products, as well as the conditions for the identifiability of the control object for the synthesis of the identification algorithm;

4. to propose and to investigate the functional diagrams of the control system of the automated installation with monitoring and operational control of the air ozonation processes at storing agricultural products in a closed space using the developed mathematical model.

5. to develop and to conduct tests of the control system of the automated installation with monitoring and operational control of air ozonation processes at storing agricultural products in a closed space.

The scientific novelty of the work:

– The developed mathematical model of ionization processes in the corona discharge and the calculated values of the dependence of the ozone density in the corona discharge zone on the magnitude of the discharge current and the configuration of the corona electrode.

– Justification of the presentation of the technological process of ozonization at the storage of agricultural products as a non-stationary dynamic multidimensional multiply-connected control object for which an analytical description was firstly proposed in the form of a system from q of difference equations, linear with respect to coefficients.

– For the first time the proposed method of obtaining adaptive predictive models of the technological process of ozonization at the storage of agricultural products for the synthesis of the identification algorithm and adaptive control system for TP of ozonization.

– Synthesis of control system of automated installation with monitoring and operational control of air ozonation processes during the storage of agricultural products in a closed space using the developed dynamic mathematical model.

The scientific statements of the work:

– mathematical model of ionization processes in the corona discharge and calculated values of the dependence of the ozone density in the corona discharge zone on the magnitude of the discharge current and the configuration of the corona electrode.

– the ozonizer on the corona-barrier discharge, operating under high-voltage impulse power supply with an automatically controlled frequency;

– mathematical model of the technological process of ozonization at the storage of agricultural products in the form of a system from q of difference equations, linear with respect to coefficients.

– a technique for obtaining adaptive predictive models of the technological process of ozonization at the storage of agricultural products for the synthesis of the identification algorithm and the adaptive control system for TP of ozonization.

– control algorithms that ensure optimal treatment mode of agricultural products by ozone.

The practical significance of the work:

1. As a result of the carried out researches there were obtained the current amplification conditions, which make it possible to obtain ozone from the non-dried air with an energy output of 40-50 grams per kWh, that makes it possible to

simplify the design of the ozonizer and to obtain a small specific energy consumption per 1 gr of ozone.

2. Developed, manufactured and tested an ozonizer of high-voltage impulses OVI-1 working in a corona-barrier discharge with a higher ozone output.

3. Developed the system of automatic regulation of ozone concentration in the working room.

The developed automated air ozonization unit has undergone scientific and experimental, production tests in:

- Lublin Polytechnic University;
- Vegetable storage of the food market "Arzan", Kyzylorda.

The scientific results of the dissertation work are implemented in the process of storage and preparation of products of the company "Herbapol" in Lublin (Poland).

Specific personal participation of the author in obtaining scientific results is following:

– setting research objectives and ways to implement them;

– development and manufacture of a high-voltage impulse ozonizer prototype for disinfection and sanitation of air operating under reduced atmospheric pressure;

– carrying out experimental researches and tests of the OVO-1 ozonizer.

– justification of the presentation of the technological process of ozonization at the storage of agricultural products as a non-stationary dynamic multidimensional multiply-connected object, described by a system from q of difference equations.

– development of a methodology for obtaining adaptive predictive models of the technological process of ozonization at the storage of agricultural products.

– development of technological scheme of ozonization and control system of automated installation of air ozonization for storage of agricultural products in a closed space.

Publications. More than 25 scientific works, including 1 book, 3 pre-patents and 3 innovative patents were prepared and published according to the main results of the research, 5 of them were published in the editions recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan.

Approbation of work: The main statements of the dissertation work were reported and approved at the international Satpaev Readings "The Role and Place of Young Scientists in Implementing the New Economic Policy of Kazakhstan", Almaty, 2015, at the Science conference. WD2016. Lublin, 11 - 13 Czerwca 2016, at the international Satpayev Readings "Competitiveness of Engineering Science and Education", dedicated to the 25th anniversary of the Independence of the Republic of Kazakhstan, 2016, at the Fifth National Congress of Environmental Engineering, Lublin, Poland, 29 may - 1 june, 2016.

The structure and volume of the dissertation work: Dissertation work consists of an introduction, four sections of the main content, conclusion and

applications, a bibliographic list of ___ nominations and contains 167 pages, 28 figures and 17 tables.

The first section describes the basic principles of ozone interaction with microorganisms and basic principles of the processes of bactericidal treatment of surface microflora and other pathogenic bacteria and microbes. There was revealed that at present time there are no industrial ozonizers used for ozonization of closed production facilities with the possibility of automatic regulation of ozone concentration. From the analysis of existing developments of automated systems and installations for the use of ozone, it has been shown that the development of automated control of ozone concentration in the vegetable store is characterized by the presence of many changing factors in the form of variety and form, maturity and fertility of processing products, which significantly complicates the optimization procedures for air ozonation modes in the vegetable store. Therefore, in order to optimize ozonization modes it is necessary to develop adaptive predictive models of the technological process of ozonization at the storage of agricultural products, as well as the conditions for the identification of the control object for the synthesis of identification algorithms and for adaptive control.

In the second section on the basis of current-voltage characteristics there were obtained the calculated values of the ion densities of ozone and oxygen at the boundary of the corona layer. On the basis of the continuity equation for ozone ions there was obtained an expression for the density of neutral ozone molecules in the discharge zone of the negative corona. A system of differential equations for corona discharge is solved with the aim of modeling the processes in the discharge zone and for determining the fraction of the diffusion component of the corona discharge current. The task of developing an ozonizer using the properties of electric wind arising in conditions of corona discharge was solved, that made it possible to simplify the design of the ozonizer and to obtain small specific energy inputs per weight unit of the produced ozone. In the sectio there is developed an ozonizing element on a corona-barrier discharge at small interelectrode distances, which will ensure its small size and lead to a significant decrease in the magnitude of the supply voltage. Also there was developed an improved design of the ozonizer operating in a semi-closed mode and consisting of separately located ozonizing elements and corona electrodes for creating an electric wind.

In the third section there is given the justification of the presentation of the technological process of ozonization at the storage of agricultural products as a non-stationary dynamic multidimensional multiply-connected control object with inputs p and outputs q, for which an analytical description is proposed in the form of a system from q of difference equations, linear with respect to coefficients. Obtained the adaptive predictive model of the TP of ozonization, as well as the conditions for the identifiability of the control object, with respect to which the identification algorithm is synthesized. Compiled an algorithm for the synthesis of an adaptive predictive control model for the TP of ozonization. Conducted the synthesis of the optimal regulator of the adaptive control systems of the TP of ozonization. Developed a system of automatic regulation (SAR) of ozone concentration in the working room. Compiled an algorithm and control program

for the main operating mode based on simulation results. On the basis of the obtained data there was developed an automated ozonization unit for disinfection and sanitation of atmospheric air in the production premises.

In the fourth section there are presented experimental researches of an automated air ozonization unit. The productivity and the specific energy output of ozone are determined experimentally. Evaluated the structure and parameters of the adaptive predictive model of TP of ozonization using the active identification. Estimated the adequacy of the adaptive predictive model and the non-stationary dynamic technological process of ozonization. According to the proposed technological scheme of ozonization there were carried out tests in production conditions.