

MODELING OF AIR TREATMENT PROCESSES IN ENERGY-EFFICIENT SYSTEMS FOR ENSURING ABIOTIC FACTORS IN ENTOMOCULTURE PRODUCTION

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Summary. The aim of the research is to develop methodological foundations for creating energy-efficient systems that ensure abiotic factors in adaptive technologies for cultivating uterine entomocultures. The relevance of the research lies in the need to create a mathematical description of the object to model air treatment processes in energy-efficient systems that ensure abiotic factors in adaptive technologies for cultivating uterine entomocultures. In this description, each state characteristic is presented as a function of input and control parameters, considering the objectively existing constraints on the range of changes in control parameters and process state characteristics. The task was to develop a mathematical model of an optimized air preparation system for the implementation of adaptive technologies.

Keywords: entomoculture production, air conditioning, air treatment process modeling, mathematical model, air humidification, polytropic processes.

Introduction

To develop the foundations of energy-efficient systems that ensure abiotic factors and to solve the tasks of optimizing air preparation technology for entomological production, it is necessary to create a mathematical model. It is known that the sequence of building a mathematical model begins with the formulation of the problem, selecting parameters, defining the goal, and identifying the efficiency criteria.

For solving optimization problems of air preparation technology for entomological production, it is necessary to develop a mathematical model. The sequence of building mathematical models is presented in Figure 1.

Formulation of the modelling problem	
Formulation of the problem, selection of parameters	Defining the goal and performance criteria
Drawing up a mathematical description of an object	
Statistical description	Deterministic description
Programming the task	
Choosing a numerical method	Creating an algorithm
Adequacy check	
Using a mathematical model to solve practical problems	

Figure 1. The Sequence of Building a Mathematical Model

Materials and methods

The task of the modelling is the development of a mathematical model of the air preparation system for implementing adaptive technologies. The method of analysing polytropic air humidification processes in dense regular packing layers with a crossflow scheme of contact between streams was chosen for the research.

Results and discussion

The description of the processes of cross-contact between water and air is based on an idealized model of flow structure - the model of complete displacement, which assumes the uniform distribution of flows and constancy of parameters across the width of the apparatus. However, the task of determining the average driving force of the process, unlike counterflow, is much more complicated. The crossflow process organization scheme in conditions of variable flow parameters along the height (Y) and length (X) of the apparatus necessitates solving a two-dimensional problem.

The physical foundations of air preparation processes are determined as follows:

The water vapor mass flow carried for a surface element dF is determined according to the Lewis equation at moisture content values d up to 20 g/kg, characteristic of contact apparatuses:

$$dW = \sigma \cdot (d'' - d) \cdot dF,$$

where σ is the moisture exchange coefficient, $\text{kg}/(\text{m}^2 \cdot \text{s})$.

The total heat flow, assuming the Lewis relation $le = 1$ holds true:

$$dQ_{\Sigma} = \sigma(h'' - h)dF,$$

where h – is the air enthalpy in kJ/kg ;

h'' – is the enthalpy of saturated air at temperature t_w , kJ/kg

$$le = \alpha / (\sigma \cdot c_v),$$

c_v – is the heat capacity of moist air, $\text{kJ}/(\text{kg} \cdot \text{K})$;

integral characteristic of the process intensity - Merkel number

$$Me = \sigma F / G_w = C_w \int d t_w / (h'' - h).$$

A classification of the processes of preparation of the air medium in contact apparatus with a cross-flow flow contact scheme is carried out: polytropic process of air cooling and dehumidification,

$$-Q_{\Sigma} = -(Q_{real} + Q_{hid});$$

humidity process of air cooling along the line $d = \text{const}$,

$$-Q_{\Sigma} = -Q_{real}, Q_{hid} = 0;$$

Polytropic air cooling and humidification,

$$Q_{\Sigma} = Q_{real} - Q_{hid};$$

Isoenthalpic air cooling and humidification along the line $h = \text{const}$,

$$Q_{\Sigma} = 0, Q_{real} = Q_{hid};$$

Polytropic air humidification and cooling,

$$Q_{\Sigma} = Q_{hid} - Q_{real};$$

Isothermal humidification along the line $t = \text{const}$,

$$Q_{\Sigma} = Q_{hid}, Q_{real} = 0;$$

Polytropic air humidification and heating,

$$Q_{\Sigma} = Q_{hid} + Q_{real}.$$

The next stage of the mathematical model development involved describing the processes in a crossflow apparatus for thermal-humidity air treatment.

Air humidification processes in contact apparatuses are described by heat balance and heat transfer equations for the respective phases:

$$\begin{aligned} dQ_{\Sigma,i} &= \frac{c_w G_w}{m} dt_{w,i}, dQ_{\Sigma,i} = \alpha_w (t_w - t^*)_i dF_i, \\ \rightarrow N_w &= \alpha_w \frac{c_w G_w}{m F} = \int dt_{w,i} / (t_w - t^*)_i; \end{aligned}$$

$$dQ_{\Sigma,i} = -\frac{G_g}{n} dh_i, dQ_{\Sigma,i} = \beta_h (h^* - h)_i F_i, \rightarrow N_g = \frac{\beta_h G_g}{n F} = \int dh_i / (h^* - h)_i;$$

and the equation of the kinetics of the total heat transfer:

$$dQ_{\Sigma,i} = k_h (h'' - h)_i F_i, \rightarrow N_{\Sigma} = \frac{k_h G_g}{n F} = \int dh_i / (h'' - h)_i.$$

The empirical kinetic dependences were obtained:

$$Sh = c \cdot Re_g^n \cdot Re_w^m$$

Where c, n, m – proportionality factors;

$Re_g = w_g \cdot d_g / \nu_g$ – Reynolds number in the gas phase;

$Re_w = w_w \cdot d_v / \nu_w$ – Reynolds number in the liquid phase;

n_g, ν_w – are the kinematic viscosity coefficients of the gas and liquid phases, respectively, m^2/s .

The dependence of the aerodynamic drag ΔP of the nozzles on the air flow rate w_g at $q_g = 11 m^3/(m^2 \cdot год)$.

Conclusions

The results of the research work include transfer coefficients in the gas phase and empirical kinetic dependencies for the thermal resistance in the liquid phase based on studies of the model apparatus for thermal-humidity air treatment. The mathematical model of the optimized air preparation system for implementing adaptive technologies was developed.

References

1. Belchenko V., Pishchanska N., Krutyakova V., Dubrovina O., Trokhaniak O. Design development of a new unit for cassette-free breeding of grain moths in the production of trichograms for plant protection Volodymyr Bulgakov, International scientific journal "Mechanization in agriculture & conserving of the resources". 2024. YEAR LXX, ISSUE 1, P. 17-19.
2. Беспалов И. Н., Бельченко В. М., Лешишак А. В. Основные принципы создания энтомологических производств. *Сборник научных трудов «Защита растений»* / Научно-практический центр НАН Беларуси по земледелию, Институт защиты растений. 2015. № 39. С. 144–151.
3. Бельченко В. М., Гончарук О. І., Сенічев М. Ю. Вирощування комах – на промислову основу. *Збірник наукових праць* : матеріали Республіканської ентомологічної конференції, присвяченої 50-ій річниці Українського ентомологічного товариства. 2000. 89 с.
4. Krutyakova V., Pishchanska N., Bulgakov V., & Adamovics A. Investigation of the efficiency of adaptive technologies and technical means for growing entomocultures. Latvia University of Life Sciences and Technologies. Jelgava. 2020. DOI: 10.22616/ERDev.2020.19.TF284.
5. Belchenko V., Pishchanska N., Bulgakov V., Ivanovs. S. Experimental investigations of the operation of elements of the equipment for cassette-less breeding of the grain moth. INMATEH - Agricultural Engineering. 2022. 68(3), P. 543–548.