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MODELLING OF PROCESSES OF HEAT EXCHANGE AT VIBRATING INFLUENCE IN MULTICOMPONENT MIXTURES OF BIOREACTORS

The basic laws of thermal and hydrodynamic processes in multicomponent organic mixes are considered at vibration action. Results of research allow to define parameters of heat-exchange devices in reactors of food, processing, chemical areas and for biogas production.

Keywords: *vibration, intensification, reactor.*

Initial preconditions and research problem statement

Modelling of processes of heat exchange and hydrodynamics at vibrating influence in multicomponent organic mixes will allow to define optimum operating modes of industrial biogas reactors, to calculate the constructive dimensions heat-exchanging devices and to predict growth of reactors productivity. Operation of reactors without compaction activation leads to formation of stagnant zones, temperature stratifications, and reduction of productivity [1]. Washing of heating elements of reactors by vibrating waves will allow to increase heat emission, to improve mixing and to intensify technological process. Modelling of heat-exchange process requires carrying out of experimental research to reveal the laws of convective heat exchange factors changes depending on parameters of the environment that washes the heat exchanger.

The analysis of recent research and publications

In our technical literature separate problems dealing with intensification of convective heat exchange in industrial reactors have already been discussed. In latest research main attention is paid to the influence of substratum properties, forms of reactor, biogas bubbles, ribbing of heat exchanger on the flow of convective heat exchange process in multicomponent mixtures [1-3].

Part of general problem to be solved

In scientific literature the influence of vibrating processes on heat exchange in liquids is partially studied and heat transfer processes under the influence of vibration in multicomponent organic mixtures are not investigated.

The aim of the paper is to investigate, using the results of experiments, heat transfer and hydrodynamics processes under the influence of vibration in multicomponent organic mixtures and elaboration of mathematical models of these processes.

Results of research

Experimental research were carried out according to the developed plan at the installation present in Fig. 1. The plan of research comprises free convective heat transfer in suspensions experiments as well as heat transfer from heating element to substratum and water in conditions of vibrating medium. Borders of variation of initial parameters of researches: heat flux (500 … 15000 W/m2), temperatures (20... 55 °C), substratum motion rate (0... 0,7 m/s), frequencies of fluctuations (0... 5 Hz), amplitudes of fluctuations (0... 0,1), concentration of dry organic substance C = 8% (grain crumbs) – correspond to operation conditions of reactor of biogas installation for recycling of organic waste.

Installation is completely computerised and all recearch information was obtained and processed automatically according to the developed program. The algorithm of the program is realised in programming language Object Pascal using IDE Delphi 7.

In the course of research the following parameters were measured:

- temperature of the liquid by means of three thermoprobes on the basis of DS 1626S sensors;
-voltage and current supplied on the heater and thermal capacity was calculated;
- temperature on each temperature-sensitive elements, build in the wall of heating element;
-time of experiment was fixed by a chronometre.

By the results of research of temperatures distribution near heat exchanging surfaces on different distance from the wall in substratum (Fig. 2) the choice of defining temperature of the liquid and wall temperature at different ways of convection, organization was substantiated.

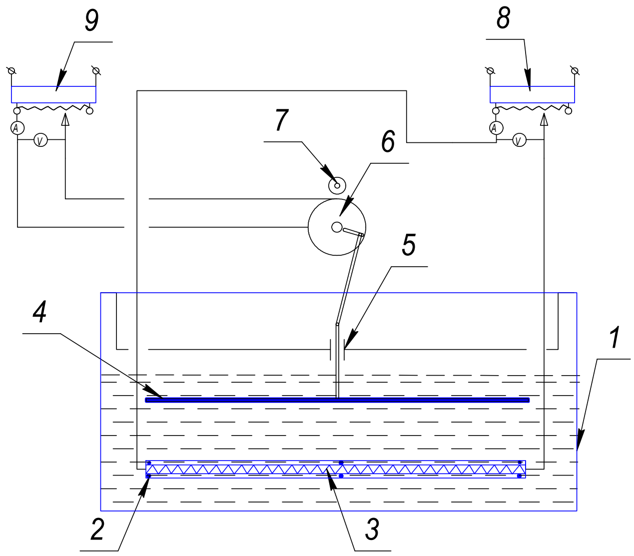

Fig. 1. Experimental installation for study of vibrations impact on intensity of convective heat transfer:
1 – transparent vessel; 2 – heating element with temperature-sensitive elements; 3 – electric heater; 4 – plate-activator; 5 – crank-and-rod mechanism; 6 – agitator; 7 – induction tachometre; 8 – power unit of heating element; 9 – agitator power unit.

It was been experimentally proved that the temperature at the distance of 1,5…2,0 of heating element diameter can be considered as defining temperature for suspension in case of vibroactivation, where as for suspension at free convective heat transfer this distance is 2,5…3,0 of the diameter. Hydrodynamic and heat exchange features in vibrating non-uniform viscous environment, flowing around heat exchanging surface are investigated.

The mathematical model is presented criterion by the equations which characterise dependence $Nu = f(\mathrm{Re}, \mathrm{Pr}, Gr)$. At the heart of developed and experimentally confirmed model (1,2) theory substantive provisions heat-mass exchange in multicomponent mixes [5,6] lay.

By results of the analysis experimental data are developed criterion dependences for intensity definition heat emission to a substratum under conditions of non-uniform vibrating washing of a surface (1) and at free convection in substrata (2).

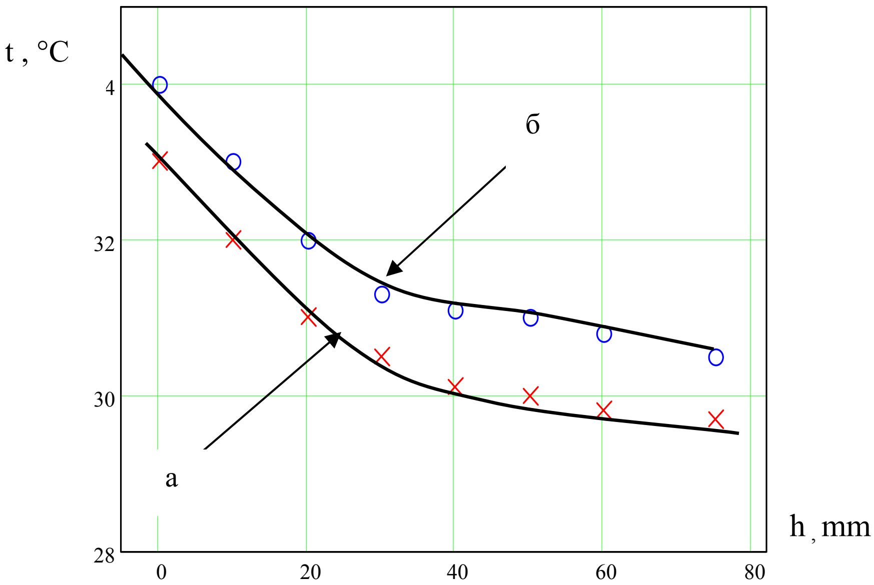

Fig 2. Distribution of temperatures near heat exchanging surfaces at distance h from the wall in substratum at vibroactivation:
a) in horizontal plane; b) in a vertical plane over heating element

Using the software package of statistical data processing Statistica 5.5, regression analysis of experimental data is carried out. By the result of analysis, applying Huk-Davis method, maximum value of determination factor R = 0,78 is achieved for dependences.

$$Nu = 40{,}48 \cdot \mathrm{Re}_{\Delta u}^{0{,}17} \cdot \mathrm{Pr}^{-1{,}01}, \tag{1}$$

$$Nu = 3{,}52 \cdot \left(Gr_p \cdot \mathrm{Pr}_p\right)^{0.1} \cdot \left(\mathrm{Pr}_p / \mathrm{Pr}_c\right)^{0{,}66}, \tag{2}$$

where Nu – Nusselt criterion, Pr – Prandtl criterion, Gr_p – value of Grasshoff criterion at liquid temperature; Pr_p – value of Prandtl criterion at liquid temperature; Pr_c – value of Prandtl criterion at temperature of heating element wall; $\mathrm{Re}_{\Delta u}$ – Reynolds vibrating criterion which is defined by the formula

$$\mathrm{Re}_{\Delta u} = 2 \cdot \pi \cdot f \cdot d \cdot A / \nu, \tag{3}$$

where f – frequency of fluctuations, Hz; A - amplitude of fluctuations, m; d – diameter of heating element, m; ν - factor of kinematic viscosity, m^2/s.

Equations (1,2) are valid within the range of parameters variation: $\mathrm{Re}_{\Delta u}$: 0…4,08×10^4; $\mathrm{Gr_p}$: 2×10^5…2×10^6; $\mathrm{Pr_p}$: 5,45…6,85; $\mathrm{Pr_p/Pr_c}$: 1,04…1,15.

Active vibration allows to form environment in bioreactor with the minimum stratification.

Light particles in upper zone and water are easily subjected to active mixing. Heavy particles of bottom zone perform oscillations in the zone, that does not exceed the thickness of their sediment layer. Thus, two-phase environment is observed: the first phase – water – light particles, the second – heavy sediment the bottom of the reactor (Fig. 3, 4). In the cause of time, light particles are decomposed into smaller ones, and other phases are created in the environment: sediment, composed of tiny particles in the bottom part and water-alcohol mixture in upper part.

Fig. 3. Environment stratification of a reactor without vibroactivation

Fig 4. Vibrating intensification of heat exchange transfer in a reactor

According to suggested mathematical model it is experimentally revealed, that vibration of environment intensifies in aqueous environment free convection heat transfer 15.... 30 times, in suspension C = 8% – 1,3... 2,5 times. Thus, usage of vibroactivation of heat transfer in bioreactors gives thermo stabilization and intensifies the process of gas production as well as saves material resources at the expense of reduction of the surface of heat exchanging devices.

Conclusions

Modeling of heat exchange processe in multicomponent mixtures by means of developed empirical equations will allow to predict heat exchange intensification between a heater and environment in bioreactors, define the constructive dimensions of heat exchanging devices.

By the results of analysis of liquid vibration influence on the intensity of convective heat transfer from heating wall to wate and substrate the choice of determining temperature of the liquid and temperature of the wall at different ways of convection organization is substantiated.

It has been experimentally proved that the temperature at the distance of 1,5…2,0 of heating element diameter can be regarded as defining temperature for suspension at vibroactivation, where as for suspensions at free convection and vibroactivation in multicomponent organic mixtures are investigated.

By the results of modeling and analysis of experimental data received criterion the equation heat emission a heating element by Wednesday bioreactor, that are characterised by dependence of Nusselt’s criterion on Reynolds's criteria, Prandtl’s and Grasgof’s.

Critarial equations of heating element convective heat transfer to bioreactor are obtained. These equations are characterized by dependence of Nusselt criterion on Raynolds, and Grasshoff criteria.

REFERENCES

1. Ткаченко С.Й., Степанов Д.В., Джеджула В.В. Закономірності розподілу температурних напорів за умов локального газорідинного омивання поверхні //Вісник ВПІ, 2003, № 4. - С. 42-45

2. Баадер Б., Доне Е., Брендерфер М. Биогаз: Теория и практика. -М. : Колос, 1982. –148 с.

3. Г.С. Ратушняк, В.В. Джеджула Підвищення продуктивності біогазового реактору управлінням параметрами вільноконвективних процесів теплообміну//Вісник Хмельницького національного університету - Хмельницький, 2006, №2 – с 29-31

4. Ратушняк Г.С., Джеджула В.В. Енергозбереження в системах виробництва біогазу // Сотрудничество для решения проблем отходов. Материалы IV Международной конференции. Х.: ЭкоИнформ. 2007.– С. 180 – 182.

5. Галицейский Б.М., Рыжов Ю.А., Якуш Е.В. Тепловые и гидродинамические процессы в колеблющихся потоках – М.: Машиностроение. 1977.– 256 с.

6. Lemlich R., Chung–Kong Hwu. The effect of acoustic vibration on forsed convective heat transfer. // American institute of chemical engineering journal, USA – 1961 – vol. 7. – №1. – P. 102–106.

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