# INTENSIFICATION OF BIOGAS PRODUCTION BY MEANS OF MECHANICAL MIXING OF THE SUBSTRATE

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***Abstract***

**Usage of alternative sources of energy can improve the modern state of energy supply and reduce some ecological problems. To obtain high efficiency of bioreactors operation it is necessary to intensify the process of biogas production at the expense of substrate mixing. As a result of modeling of process kinetics of substrate mixing the interconnection of constructive-technological parameters of mixing device with physical characteristics of organic mass is determined.**

***Key words: biogas, bioreactor, kinetics, mixing, intensification***

## Introduction

Increase of conventional power resources cost and further technogenic impact on the environment specify comprehensive usage of renewable alternative energy sources. Up to 65 % of renewable energy resources, particularly biogas, can be obtained from organics of agricultural origin [1, 2].

Livestock waste, farm waste, food waste, domestic waste can be used as original raw material for biogas production. Output and composition of biogas is determined by considerable number of factors, but, in general, depends on the composition of original raw material and means of intensification of substrate anaerobic fermentation.

## Ease of Use

The efficiency of biomass processing in energy product is achieved only in case of rational parameters of technological processes and machines for processing enterprises, carrying out the substrate conversion. To achieve high efficiency of bioreactors operation and produce maximum output of biogas per unit of volume of the biomass it is necessary to create in bioreactor optimal technological parameters. We can intensify the process of biogas release as a result of substrate mixing, that is the precondition for free and efficient progress of fermentation process [3]. Substrate mixing in the bioreactor promotes contact between microorganisms and nutrient substances

prevents crust formation on the surface that leads to increase of biogas formation.

Parameters of mixing (propeller mixer rotation speed and substrate flow) as well as their interconnection with mixing time depend on physical properties of loaded substrate. Setting of optimal mixing parameters of the substrate in bioreactor to provide intensive formation of biogas is possible by the results of mathematical modeling of mixing process. Mathematical study of substrate mixing process in the bioreactor enables to define the dependences of fermentation process, parameters, particularly, substrate rotation speed, on agitation intensity. Depending on angular velocity of the substrate rotation in bioreactor agitation speed by propeller blade mixer changes, this, in its turn, influences thermostabilization of fermentation process and intensification of heat exchange processes in bioreactor.

According to mechanical diagram [3] general torque, emerging as a result of substrate mixing process in bioreactor, is determined by the relation

$$M_{gen} = M_{motor} - M_{cz}, \qquad (1)$$

where $M_{cz}$ – is blade torque of vertical propeller mixing device in bioreactor, N·m;

$M_{motor}$ – is the torque of the motor, actuating mixing device, N·m.

General torque of the blade of propeller mixing device we will define by means of differential equation of body rotation around axle

$$M_{gen} = J_{cz} \cdot \ddot{\varphi}, \qquad (2)$$

де $J_{cz}$ – is moment of inertia of blade rotation of mixing device;

$\ddot{\varphi}$ – is the second-order derivative of mixer rotation angle in bioreactor.

As a result of transformations mixer rotation acceleration in bioreactor is expressed by the expression

$$\ddot{\varphi} = \left( -\frac{1}{32} \alpha \cdot h \cdot \omega^2 \cdot l^4 + M_{motor} \right) / \frac{G \cdot l^2}{12g} = \frac{d\omega}{dt}, \qquad (3)$$

where $h$ – is the height of the mixer, m;

$\omega$ – is angular velocity of mixer blade rotation, rad$^{-1}$;

$l$ – is the distance of substrate particle from the centre of mixer rotation, m;

$G$ – is the weight of the substrate, kg;

$g$ – is free fall acceleration, m/sec$^2$;

$t$ – is the time of substrate mixing by the blades of the mixer, sec.

After the transformation of the equation (3), taking into account Reynolds number, determined by linear velocity of organic mass agitation $V$, distance of substrate particle from the centre of mixer rotation $l$ and viscosity ratio of the substrate, we obtain the equation

$$\frac{d\omega}{dt} = \left( -0{,}001125 \cdot \left( \rho_s \cdot \left( V \cdot l / \nu_c \right)^{-0.2} \right) \cdot h \cdot V^2 \cdot l^2 + M_{motor} \right) / \frac{G \cdot l^2}{12g},$$

where $\rho_s$ – is the density of the substrate, loaded in bioreactor for further fermentation, kg/m$^3$;

The analysis of the equation (4) shows that the angular velocity of vertical mixer rotation in bioreactor depends on physical

properties of the substrate, geometric dimensions of the mixer, mass of the substrate as well as torque of the motor that actuates mixing device. Varying these factors, as initial solutions of the equation (4), optimal values of substrate mixing speed at its different densities can be determined in order to obtain maximum output of bioreactor. Using the obtained mathematical model of substrate mixing in bioreactor by the vertical propeller mixer, numerical modeling of mixer operation at such initial conditions is performed: $\nu_s = 0{,}8 \cdot 10^{-6}$ m$^2$/sec; l = 1 m; h = 0,8 m; M = 10...50 N·m; $\varphi_0 = 0$; $\omega_0 = 0$ equation (5). Modeling is performed in mathematic package Matcad.

$$\frac{d\omega}{dt} = \frac{\left(-0{,}007 \cdot \rho_s + M_{motor}\right)}{0{,}083}. \qquad (5)$$

The results of modeling of vertical propeller mixer operation for the preset initial conditions are shown in Fig. 1.

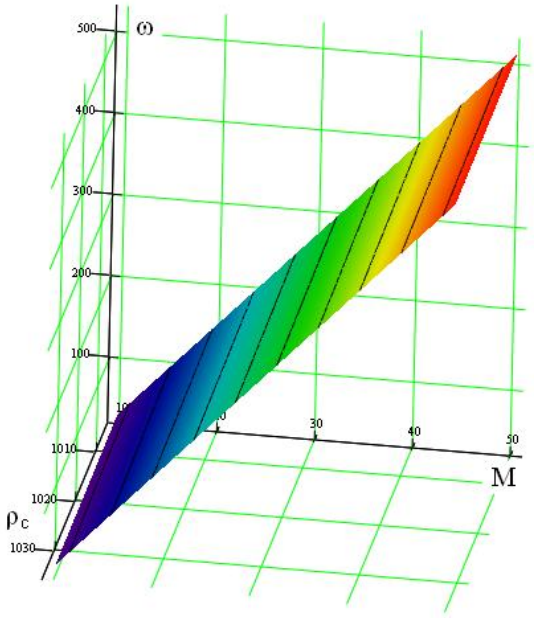


Fig. 1 The results of numerical modeling of mixing device operation in bioreactor

The analysis of numerical modeling result (Fig. 1) show that the blade of vertical propeller mixing device, rotating around the axle, supplies the environment inside bioreactor with necessary rotation speed to provide intensification to biogas release process. Since the substrate in non-uniform and organic environment, the torque of the motor of mixing device increases 5 times if substrate density changes from 1005 до 1035 kg/m$^3$. Increase of the torque leads to directly proportional increase of angular velocity.

## Conclusions

Interconnection of constructive-technological parameters of mixing devise and physical characteristics of organic mass has been determined.

By the results of modeling of mechanical process kinematics of organic substrate mixing in bioreactor with vertical propeller mixer it was determined that the acceleration to be provided to mechanical mixer in bioreactor for intensification of biogas formation process, depends on physical properties of the substrate, geometric dimensions of the mixer and the torque of the drive.

## References

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