N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 421 (2017), 177 – 185

UDC 658.52.011

O. V. Zhirnova[3], B. A. Suleimenov[3], A.Zh. Toigozhinova[1], W. T. Wojcik [2]

[1]Almaty University of Energy and svyazi, Kazakhstan,
[2]Lublin University of Technology, Poland,
[3]Kazahsky National Research Technical University after named K. I . Satpayev, Almaty, Kazakhstan.
E-mail: oxana_fedoseyeva@mail.ru

CONSTRUCTION OF MATHEMATICAL MODEL THE COMBUSTION OF BIOGAS TO REDUCE GREENHOUSE GAS EMISSIONS

Abstract. This paper shows the environmental and economic efficiency of biogas. An analysis of the prospects for world energy development shows a marked shift of priority issues in a comprehensive assessment of the possible side effects of the impact of major sectors of energy on the environment, the life and health of the population. Energy conservation measures and environmental security are aimed at increasing the use of CHP and renewable energy sources. The main advantages of CHP are: low cost of energy, low return on investment, the ability to quickly build, and reducing environmental pollution. The main advantage of renewable energy sources is the use of the inexhaustible source of energy, such as solar, wind and biofuels. The paper discusses the various sources of energy capacity of 1 MW mini-thermal power station with diesel, gas piston and turbine engines, as well as renewable energy-generation plant with a gas-piston engines running on biogas, solar and wind power. It was found that all sources participate in the emission of greenhouse gases. Gas turbine engines emit more greenhouse gases than other motors. The most environmentally friendly way to produce electricity is solar panels. This paper shows the environmental and economic efficiency of biogas in the brewery. The article used the standard method for determination of greenhouse gas emissions through the levels. Calculations for natural gas and biogas were made. The results of the calculations showed that the amount of greenhouse gas emissions from the combustion of natural gas and biogas in the boilers reduced. The efficiency of co-combustion of these fuels was determined. It is shown that co-combustion of natural gas and biogas will reduce the emission of gases by 10%.

Keywords: bioreactor, biogas, bacteria, adjusting, mathematical model, distributed system, optimal control, integration, aggregation, computer simulation.

Introduction. Improvement of the efficiency of heat sources is one of the main priorities in the development of new and modernization of existing heat-generating devices. The deteriorating ecology, as well as the global crisis leads to a search for new methods of heat supply management that would ensure ecological and economical heating. In order to develop new, environmentally friendly technologies for the production and processing of biomass we must develop a basis of these processes. Although biogas as an energy source is known for many centuries, it remains a matter of concern of engineers and scientists in both experimental [1-3] and theoretical studies. Therefore, the development of mathematical models and biogas combustion process is an interesting task carried out by researchers. Numerical simulation is an intersting, inexpensive and rapid method for analyzing problems and leads to understanding of the mechanisms in this process. But the numerical simulation should be preceded by the creation of a mathematical model which describes the phenomena. Depending on the complexity of these problems, the mathematical model can describe the monitoring process with various degrees of certainty. Thus, numerical simulation should be combined with experimental studies in order to compare and assess the validity of the model. The mathematical model of biogas combustion will be presented below. Then, on the basis of the results of experimental studies in order to validate the developed mathematical model there

will be conducted numerical simulation of biogas combustion. The process of biogas burning is complex heterogeneous and homogeneous combustion. Combustible gases – mainly CO, H_2, CH_4 – together with other non-combustible gases such as CO_2, H_20, N, particles are emitted during degasification – are subject to homogeneous combustion. Combustible components of solid material, mainly carbon in particle, so called carbonated coal, after degasification are suspectible to the heterogeneous combustion. Due to the complexity of the processes in homogeneous-heterogeneous combustion, it is assumed that the mathematical model of biogas combustion process will describe the process in a simplified form, in other words, using Euler-Lagrange method, which is the standard method used for numerical simulation of combustion of biogas and particles or droplets of combustible material [2-5]. The model assumes that the biomass particles will be considered as a discrete Lagrangian particle that creates the boundary conditions for the gaseous medium, viewed as Euler Wednesday. On the basis of analogy with the gaseous medium, the evolution of the particle is described by the equations of conservation of mass, momentum and energy. Thus, the aim of this work is the adaptation of a mathematical model of the combustion process, based on the theory of I. Wiebe to the process of combustion of biogas.

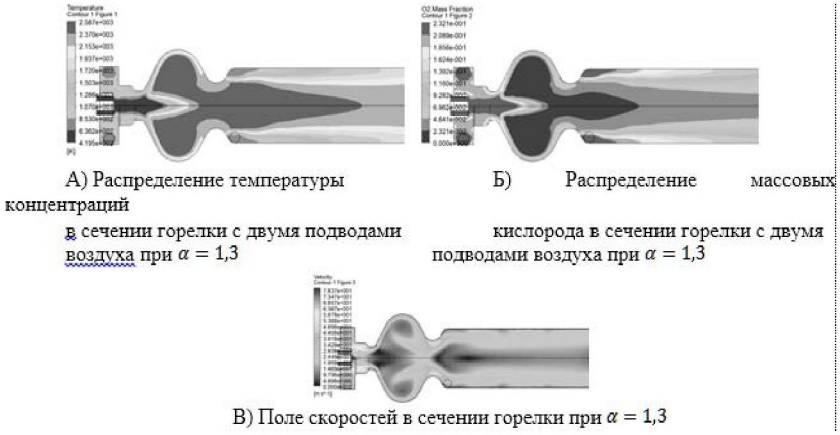
Research methods. Monitoring and control of the efficiency and emissions in industrial combustion of biogas is one of the greatest challenges faced by the society due to the use of fossil fuels and climate change.

There are different methods of adjusting the combustion of biogas:

- Preliminary determination of the heat capacity of the chemical composition of biogas and air-fuel ratio;
- Monitoring of biogas combustion in situ using optical sensors and timely control of air-fuel ratio;
- Measuring the concentration of gases such as oxygen, carbon monoxide or carbon dioxide in the exhaust and adjusting.

The measurement of oxygen concentration is most suitable for testing the efficiency of biogas combustion process because oxygen and excess air are almost independent of the fuel type. The method of adjusting the biogas combustion by measuring the concentration of gases in the exhaust is appropriate due to the development of modern sensors. Initially, different types of sensors have been developed for the control of biogas combustion efficiency and these technologies recently have been adapted for industrial furnaces, boilers and gas turbines. Organization of biogas combustion process is associated with permanent control. This is because the combustion of fuels with a large excess of air leads to unnecessary losses of heat consumed for warming the excess air and its emission into the atmosphere. Fuel combustion with air deficiency also causes high losses of energy due to chemical unburnt fuel, as evidenced by the CO in the flue gas. Optimal combustion conditions are achieved by some content of unused oxygen and CO in the flue gases. For one and the same furnace, depending on load, the minimum may be different. According to the research and calculations, 5-25% of CO and 3.2% of oxygen in the flue gases content is optimal. The CO content characterizes the quality of fuel combustion and the content of O_2 – the efficiency of furnace.

Automatic devices that support constant ratio of incoming air and fuel play major role in maintaining the optimal mode in the furnace. At biogas burning, the control of the combustion process and the maintenance of a regime is largely facilitated by using burners that have important property of automatically adjusting, maintaining a constant composition of the gas air mixture at changing the burner load (Figure 1).



А) Распределение температуры в сечении горелки с двумя подводами воздуха при $\alpha = 1{,}3$

Б) Распределение массовых концентраций кислорода в сечении горелки с двумя подводами воздуха при $\alpha = 1{,}3$

В) Поле скоростей в сечении горелки при $\alpha = 1{,}3$

Figure 1 – Temperature distribution in the cross section of the burner

The energy obtained in the process of biogas combustion can be used to heat water, heat generation for technological needs and heating, to provide autonomous power. Processed biomass can be used as an environmentally friendly fertilizer (Figure 2, 3).

Figure 2 – System of receiving and combustion of biogas

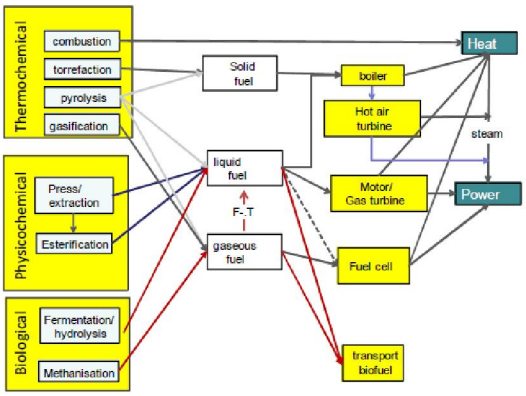


Figure 3 – Different ways to transform the energy of the biogas

This complicated problem can be solved by methods of mathematical simulation. The followings equations are sugessted as the initial equations of the study:

$$\left.\begin{aligned}
&U_e = r_e i_e + \frac{d\psi_e}{dt}\\
&M_e = \mathrm{Re}\, j(\psi_e i_e) + J\frac{d\Omega}{dt}\\
&U_f(t) = k_u U_e + k_i i_e\\
&n = f[\omega(t)]\\
&M_m = f[\omega(t), ЭВ]\\
&Z_э = \frac{Z_н(2^N - 1)}{2^N + Z_н(n-1)/n = 0 \div (2^N - 1)}\\
&U_e = (R_э + j X_э) i_e + x_e \frac{d i_e}{dt}
\end{aligned}\right\}$$

The proposed mathematical model of the combustion process involves the following assumptions:

– Fuel air mixture is divided into infinitely thin flame front in the zone of the burnt mixture and in the zone of the unburned mixture;

– The working medium in both zones is an ideal gas;

– The chemical composition of the working medium is different in the zones, so its thermal and physical characteristics are different;

– The pressure in both zones is the same;