DOI: 10.53360/2788-7995-2024-2(14)-8

ISTIR: 55.13.17

A. Sovetkanov[1], Y. Shayakhmetov[1]*, R. Sovetbayev[1], O.I. Morozov[2]
[1]Shakarim University of Semey,
071412, Republic of Kazakhstan, Semey, 20 A Glinka Street
[2]Ulyanovsk State Technical University,
432027, Russian Federation, Ulyanovsk, Severny Venets str. 32
*e-mail: shaiakhmeterzh@mail.ru

MIXING DEVICE DESIGN IN A BIOGAS PLANT: PROBLEMS AND PERSPECTIVES

Abstract: *The paper presents a review of stirring device designs used in biogas plants. The efficiency of a biogas plant depends on many factors, one of which is the agitation of the substrate to increase the efficiency of the biogas plant and provides: release of the biogas produced; agitation of fresh biomass and bacteria in the metatank; preventing the formation or destruction of crusts on the surface and minimizing sludge; providing uniform temperature throughout the bioreactor; and providing uniform distribution of the bacterial population. A well-mixed feedstock can yield up to 50% more biogas. Agitators operate in difficult conditions of aggressive and fire-hazardous environment, contributing to high corrosion of its elements. The design of agitators should not promote sparks or elevated temperatures to avoid explosive situations.*

Advantages and disadvantages of different types of agitators are discussed, as well as the problems encountered in their operation. Special attention is paid to the promising directions of development of agitators for biogas plants.

The design of agitator with float device, which allows mixing biomass throughout the entire volume of the bioreactor module, is proposed. The advantage of this design is the absence of an electric motor and electric cables (which of course increases fire safety), and the mechanical agitator is driven directly by a pneumatic motor operating from compressed air, while the compressor is located outside the bioreactor, and only compressed air supply hoses lead to the reactor.

Key words: *biogas plant, mixing device, substrate, biogas, alternative energy.*

Introduction

The emerging trends in the global energy sector show that the advanced mankind is doing everything to make the energy of future generations become «green» energy, which allows not to pollute air, water and soil, and thus restore, preserve and save the biological balance in the environment, flora and fauna. In addition, it will prevent global climatic changes on our planet, which can lead to catastrophic consequences for all life on Earth.

One of the types of RES is biogas (in purified form biomethane) produced by anaerobic methane fermentation of biomass, i.e. organic waste from agriculture and food processing plants, sewage and household waste, as well as energy crops and algae. The advantage of using biomass energy by methane fermentation (unlike solar and wind energy) is independence from weather conditions, i.e. continuity and stability in energy use.

Materials and methods

Biogas plants are systems that convert organic matter into methane-rich biogas. The efficiency of a biogas plant is directly dependent on many factors, one of which is the agitation of the substrate. The agitator ensures: homogenisation of the substrate (This leads to an even distribution of nutrients, microorganisms and waste products, which optimises the biogas production process), increase of the contact surface (Crushing of substrate particles increases the surface area available to microorganisms, which accelerates decomposition and increases biogas yield), prevention of crusting (Agitating prevents the formation of crusts on the surface of the substrate, which can hinder biogas production.

The main types of stirring devices.

The following mixing systems are used in biogas plants [1-2]: hydraulic, mechanical, bubbling, combined.

Advantages and disadvantages of stirrers

The hydraulic mixing method consists in recirculation of the fermentation mass from one part of the bioreactor to another (Fig. 1). The advantage of this system is the absence of moving parts inside the reactor, which simplifies the operating conditions. However, hydraulic systems are only effective in plants operating on very liquid substrates that are not prone to crusting and sludge accumulation.

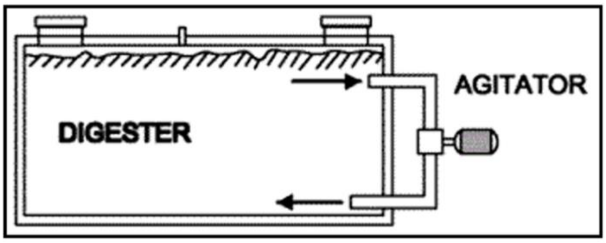
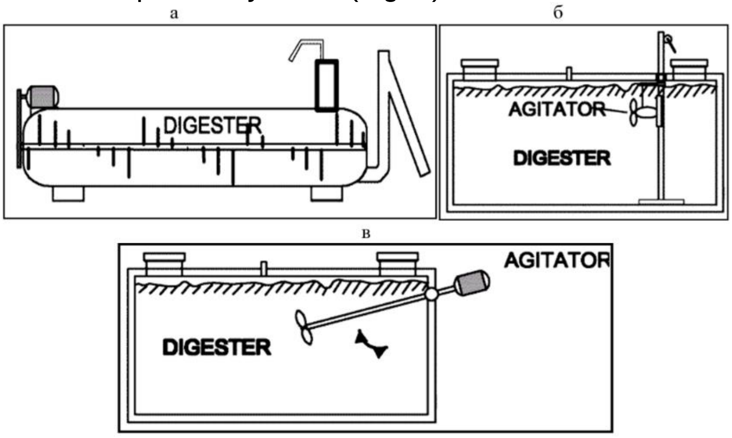


Figure 1 – Hydraulic mixing system

Mechanical mixing is performed by using agitators, whose working bodies are augers and blades driven by a motor or manually. The following systems are used for biomass mixing: multi-blade; propeller immersion and paddle systems (Fig. 2).



a – stirrer with many blades; b – propeller immersion; c – paddle stirrer

Figure 2 – Mechanical stirring systems

The agitator with many blades (Fig. 2, a) is used most often for mixing in horizontal reactors [3]. Structurally, they are a horizontal shaft with blades or bent tubes located along the entire length of the reactor. The rotation of the shaft agitates the feedstock, preventing the formation of crusts, while promoting the biomass to the outlet in the form of a plug (perfect displacement), which is effective in hygienising the process. The use of tubes with hot water flowing through them as working elements also makes it possible to heat the fermentation mass. Submersible propeller stirring system (Fig. 2, b) is mainly used in vertical cylindrical reactors [4]. It represents a propeller with a motor located in a waterproof shell and mounted on a tripod. During operation, vertical movement of biomass is carried out, and changing the height of the agitator arrangement avoids the formation of crust. The disadvantage of this system is the small mixing volume, which requires the installation of two or more agitators, and the application of submersible motors is limited to a temperature range of up to 40 0C. 445 The paddle stirring system (Fig. 2, c) consists of a motor placed outside the reactor and an elongated shaft with paddles. This system can be vertical, mounted on the top base of the reactor, but more commonly a diagonally arranged agitator is used, entering through the top of the reactor side wall. The agitator shaft can change the angle of inclination, which allows mixing a larger volume of biomass compared to a submerged system.

A significant disadvantage of mechanical mixing systems is the limited mixing zone, which requires the installation of two or more stirrers. Barbotage mixing is performed by feeding the biogas produced into the bioreactor using a draft inducer and a system of pipelines located in the lower part of the bioreactor (Fig. 3). Barbotage agitation separates small gas bubbles from methanogenic microorganisms, which facilitates their contact with the nutrient substrate [4]. In addition, according to [1], bubbling in the bioreactor increases the concentration of dissolved carbon dioxide, which, being a hydrogen acceptor, reduces its partial pressure and thereby improves the conditions for the life activity of acetate-degrading methanogens, resulting in an increase in methane yield.

Combined stirring systems contain two or more stirring methods that operate simultaneously, which leads to higher energy costs. However, the use of combined agitation systems allows for a more uniform distribution of biomass particles and temperature throughout the bioreactor volume and significantly increases the efficiency of specific biogas yield.

Barbotage mixing is carried out by feeding the biogas produced into the bioreactor by means of a draught inducer and a system of pipelines located at the bottom of the bioreactor (Fig. 3). Barbotage agitation separates small gas bubbles from methanogenic microorganisms, which facilitates their contact with the nutrient substrate [4]. In addition, according to [1], bubbling in the bioreactor increases the concentration of dissolved carbon dioxide, which, being a hydrogen acceptor, reduces its partial pressure and thereby improves the conditions for the life activity of acetate-degrading methanogens, resulting in an increase in methane yield.

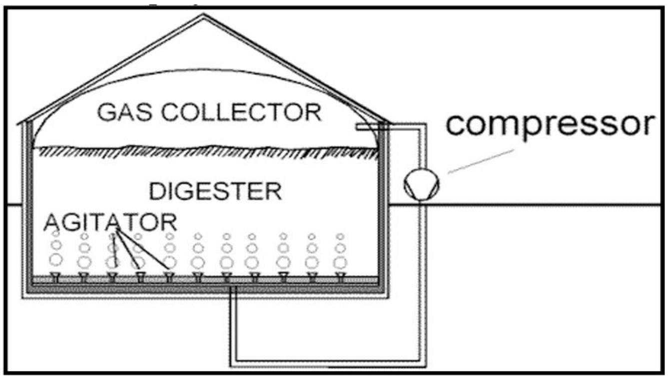


Figure 3 – Barbotage mixing system

Results and discussion

Prospects for the development of agitators. The development of agitators for biogas plants is aimed at increasing their efficiency, reliability and energy efficiency.

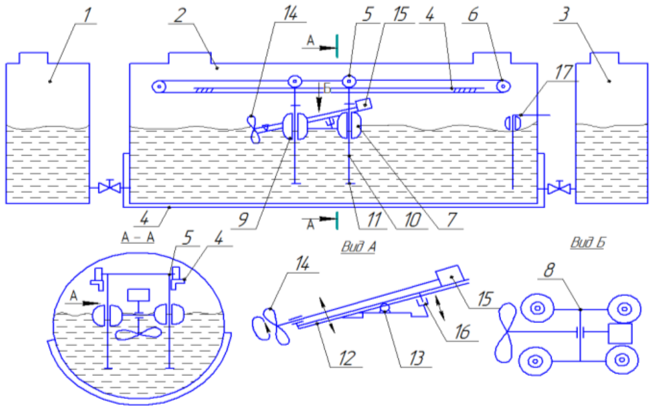
In order to equalise the temperature in the digestion chamber, all kinds of stirring devices are often installed. There are practically no recommendations on the choice of stirring methods, and the influence of stirring on the methane digestion of manure has not yet been sufficiently studied. There is every reason to believe that stirring to some extent should help to increase the contact area between microorganisms and substrate, i.e. multilevel stirring and forced degassing accelerates the digestion process. Stirring can achieve a uniform distribution of the feed manure and microorganisms in the reactor, and forced degassing can prevent the accumulation of intermediate and final metabolic products. Currently, the following methods of mixing manure in the digester are known: continuous mixing; mixing only at a certain time, immediately after loading the initial manure; periodic mixing, for example, 10 minutes in each hour, i.e. there is no unambiguous opinion in the application of mixing methods in methane digestion of manure. For example, a study on biogas production from liquid swine manure was conducted in France, where continuous anaerobic digestion with constant agitation of the substrate or "free cell" fermentation was applied. The experiments showed that this method is not reliable as fermentation does not always occur or takes a long time.

Further, an improvement of the continuous mixing system is the "contact method", which consists of capturing the active biomass in a sump at the reactor outlet to reintroduce it together with the feed manure (installation by the Belgian company Bioprocessing) [5-10].

Stirring can be constant or periodic depending on the reactor operation mode. Optimal stirring significantly reduces the digestion time of the feedstock and prevents the formation of crusts. Although partial stirring occurs due to the release of biogas from the feedstock, due to temperature movement and movement due to fresh feedstock, such stirring is not sufficient.

Stirring should be carried out regularly. Mixing the feedstock too infrequently will lead to stratification of the feedstock and crust formation, thus reducing the gas generation efficiency. A well-mixed feedstock can produce up to 50 per cent more biogas. Stirring too often can damage the fermentation processes inside the reactor, as the bacteria do not have time to "eat". In addition, it can lead to the discharge of incompletely processed feedstock. The ideal is to stir gently but vigorously every 4 to 6 hours.

The conducted analysis of designs of agitators of biogas plants allowed us to summarise the data and propose the design of the agitator (within the framework of the research conducted under the grant funded by the Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan, grant No. AP09259846) (Fig. 5).



1 – loading sector; 2 – working sector (module); 3 – unloading sector; 4 – heat exchange jacket; 5 – cart; 6 – cart drive; 7 – float; 8 – horizontal rods; 9 – bushings; 10 – vertical rod; 11 – stops; 12 – lever; 13 – lever axis; 14 – agitator; 15 – agitator drive; 16 – hydro (pneumatic) cylinder; 17 – level sensor

Figure 4 – Diagram of bioreactor with float stirring device

This design can operate in horizontal tanks, can be underground (which is preferable for regions with sharply continental climate) and is powered by compressed air, which additionally increases fire safety.

The bioreactor is made tubular, located horizontally and divided into three sections: loading, working and unloading, the working section consists of one or more modules, in each module of the working section mounted agitators with a drive and heat exchanger. The technical result of the claimed technical solution is to increase the efficiency of mixing throughout the volume with low energy consumption. This is achieved due to the fact that an additional element in the design of the bioreactor is introduced in the form of a float device, in which the agitator with a drive is mounted, with the ability to move along the bioreactor and rotate relative to the horizontal axis in the vertical plane.

Conclusion

The agitator is an important component of a biogas plant. The correct selection of the agitator and its proper operation ensure efficient operation of the biogas plant and maximise biogas production.

The advantage of the proposed design is the absence of an electric motor and electric cables (which of course increases fire safety), and the mechanical agitator is driven directly by a pneumatic motor powered by compressed air. The compressor is located outside the bioreactor, and only compressed air hoses lead into the reactor

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А.Б. Советканов[1], Е.Я. Шаяхметов[1]*, Р.А. Советбаев[1], О.И. Морозов[2]
[1]Семей қаласының Шәкәрім атындағы университеті,
071412, Қазақстан Республикасы, Семей қ., Глинки к-сі, 20 А
[2]Ульяновск мемлекеттік техникалық университеті,
432027, Ресей Федерациясы, Ульянов қ., Северный Венеция к-сі, 32 үй
*e-mail: shaiakhmeterzh@mail.ru

БИОГАЗ ҚОНДЫРҒЫСЫНДАҒЫ АРАЛАСТЫРҒЫШ ҚҰРЫЛҒЫНЫҢ КОНСТРУКЦИЯСЫ: ПРОБЛЕМАЛАР МЕН ПЕРСПЕКТИВАЛАР

Мақалада биогаз қондырғыларында (БГҚ) қолданылатын араластырғыш құрылғылардың конструкцияларына шолу берілген. БГҚ тиімділігі көптеген факторларға байланысты, олардың бірі БГҚ тиімділігін арттыру мақсатында субстратты араластыру болып табылады және мыналарды қамтамасыз етеді: пайда болған биогаздың бөлінуі; метатенктегі жаңа биомасса мен бактерияларды араластыру; жер бетінде қыртыстың пайда болуын немесе бұзылуын болдырмау және тұнбаны азайту; биореактор бойынша біркелкі температураны қамтамасыз ету; бактериялар популяциясының біркелкі таралуын қамтамасыз ету. Жақсы араластырылған шикізат 50% көбірек биогаз бере алады. Араластырғыштар оның элементтерінің жоғары коррозиясына ықпал ететін агрессивті және өрт қауіпті ортаның қиын жағдайында жұмыс істейді. БГҚ араластырғыштарының дизайны жарылғыш жағдайларды болдырмау үшін ұшқындардың пайда болуына немесе жоғары температураға ықпал етпеуі керек.

Араластырғыштардың әртүрлі түрлерінің артықшылықтары мен кемшіліктері, сондай-ақ оларды пайдалану кезінде кездесетін мәселелер талқыланады. Биогаз қондырғыларына арналған Араластырғыштарды дамытудың перспективалық бағыттарына ерекше назар аударылады.

Биомассаны биореактор Модулінің бүкіл көлеміне араластыруға мүмкіндік беретін қалқымалы құрылғысы бар араластырғыштың дизайны ұсынылған. Бұл дизайнның артықшылығы электр қозғалтқышы мен электр кабельдерінің болмауында (бұл, әрине, өрт қауіпсіздігін арттырады), ал механикалық араластырғыш тікелей сығылған ауамен жұмыс істейтін пневматикалық қозғалтқышпен басқарылады, ал компрессор биореактордан тыс, ал реакторға тек Сығылған ауа беру шлангтары ғана жіберіледі.

Түйін сөздер: *биогаз қондырғысы, араластырғыш құрылғы, субстрат, биогаз, баламалы энергия.*

А.Б. Советканов[1], Е.Я. Шаяхметов[1]*, Р.А. Советбаев[1], О.И. Морозов[2]
[1]Университет имени Шакарима города Семей,
071412, Республика Казахстан, г. Семей, ул. Глинки, 20 А
[2]Ульяновский государственный технический университет,
432027, Российская Федерация, г. Ульяновск, ул. Северная Венеция, д. 32
*e-mail: shaiakhmeterzh@mail.ru

КОНСТРУКЦИЯ ПЕРЕМЕШИВАЮЩЕГО УСТРОЙСТВА В БИОГАЗОВОЙ УСТАНОВКЕ: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ

В статье представлен обзор конструкций перемешивающих устройств, используемых в биогазовых установках (БГУ). Эффективность БГУ зависит от множества факторов, одним из которых является перемешивание субстрата, с целью повышения эффективности БГУ и обеспечивает: высвобождение образовавшегося биогаза; перемешивание свежей биомассы и бактерий в метатенке; предотвращение формирования или разрушение корки на поверхности и минимизация осадка; обеспечение равномерной температуры по всему биореактору; обеспечение равномерного распределения популяции бактерий. Хорошо перемешиваемое сырье может дать на 50% больше биогаза. Мешалки работают в сложных условиях агрессивной и пожароопасной среды, способствующей высокой коррозии ее элементов. Конструкция мешалок БГУ не должна способствовать появлению искр или повышенной температуры во избежание взрывоопасных ситуаций.

Обсуждаются преимущества и недостатки различных типов мешалок, а также проблемы, с которыми сталкиваются при их эксплуатации. Особое внимание уделяется перспективным направлениям развития мешалок для биогазовых установок.

Предложена конструкция мешалки с поплавковым устройством, позволяющая перемешивать биомассу по всему объему модуля биореактора. Преимущество данной конструкции в отсутствии электродвигателя и электрических кабелей (что конечно повышает пожаробезопасность), а механическая мешалка приводится в движение непосредственно работающим от сжатого воздуха пневмодвигателем, при этом компрессор находится за пределами биореактора, а в реактор ведут лишь шланги подачи сжатого воздуха.

Ключевые слова: *биогазовая установка, перемешивающее устройство, субстрат, биогаз, альтернативная энергетика.*

Information about the authors

Yerzhan Shayakhmetov* – PhD, Professor of the Department of Technological Equipment and Mechanical Engineering; Shakarim University of Semey, Republic of Kazakhstan; e-mail: shaiakhmeterzh@mail.ru. ORCID: https://orcid.org/0000-0002-7986-0083.

Aslan Sovetkanov – Master's student of the Department of Technological Equipment and Mechanical Engineering; Shakarim University of Semey, Republic of Kazakhstan; e-mail: sovetkanov706@gmail.com. ORCID: https://orcid.org/0009-0009-1702-5590.

Rail Sovetbayev – Master, teacher of the Department of Technological Equipment and Mechanical Engineering; Shakarim University of Semey, Republic of Kazakhstan; e-mail: rsovetbayev@mail.ru. ORCID: https://orcid.org/0009-0007-3605-515X.

Oleg Morozov – Candidate of Technical Sciences, Acting Head of the Department Materials Science and Metal Forming, Ulyanovsk State Technical University, Russian Federation, Ulyanovsk; e-mail: olmorozov-rabota@yandex.ru.

Авторлар туралы мәліметтер

Ержан Ярнарович Шаяхметов* – PhD, «Технологиялық жабдықтар және машина жасау» кафедрасының профессоры; Семей қаласының Шәкәрім атындағы университеті, Қазақстан Республикасы; e-mail: shaiakhmeterzh@mail.ru. ORCID: https://orcid.org/0000-0002-7986-0083.

Аслан Бекжанович Советканов – «Технологиялық жабдықтар және машина жасау» кафедрасының магистранты; Семей қаласының Шәкәрім атындағы университеті, Қазақстан Республикасы; e-mail: sovetkanov706@gmail.com. ORCID: https://orcid.org/0009-0009-1702-5590.

Раил Аянович Советбаев – «Технологиялық жабдықтар және машина жасау» кафедрасының магистрі, оқытушысы; Семей қаласының Шәкәрім атындағы университеті, Қазақстан Республикасы; e-mail: rsovetbayev@mail.ru. ORCID: https://orcid.org/0009-0007-3605-515X.

Олег Игоревич Морозов – т.ғ.к., «Материалтану және металдарды қысыммен өңдеу» кафедра меңгерушісінің м.а., Ульянов мемлекеттік техникалық университеті, Ресей Федерациясы, Ульяновск қ.; e-mail: olmorozov-rabota@yandex.ru.

Сведения об авторах

Ержан Ярнарович Шаяхметов* – PhD, профессор кафедры «Технологическое оборудование и машиностроение»; Университет имени Шакарима города Семей, Республика Казахстан; e-mail: shaiakhmeterzh@mail.ru. ORCID: https://orcid.org/0000-0002-7986-0083.

Аслан Бекжанович Советканов – магистрант кафедры «Технологическое оборудование и машиностроение»; Университет имени Шакарима города Семей, Республика Казахстан; e-mail: sovetkanov706@gmail.com. ORCID: https://orcid.org/0009-0009-1702-5590.

Раил Аянович Советбаев – магистр, преподаватель кафедры «Технологическое оборудование и машиностроение»; Университет имени Шакарима города Семей, Республики Казахстан; e-mail: rsovetbayev@mail.ru. ORCID: https://orcid.org/0009-0007-3605-515X.

Олег Игоревич Морозов – к.т.н., и.о.зав. кафедры «Материаловедение и обработка металлов давлением», Ульяновский государственный технический университет, Российская Федерация, г.Ульяновск; e-mail: olmorozov-rabota@yandex.ru.

Received 28.05.2024
Revised 14.06.2024
Accepted 17.06.2024

DOI: 10.53360/2788-7995-2024-2(14)-9

МРНТИ: 65.13.19

Е.М. Ағзам[1*], А.К. Какимов[1], А.Е. Еренгалиев[1], Н.К. Ибрагимов[1] Б.А. Лобасенко[2]
[1]Университет имени Шакарима города Семей
071412, Республика Казахстан, г. Семей, ул. Глинки, 20 А
[2]Кемеревский государственный университет
650000, Российская Федерация, г. Кемерово, ул. Красная, 6
*e-mail: ektu2009@gmail.com

ВЫБОР ОПТИМАЛЬНОГО ОБОРУДОВАНИЯ ПРИ СУШКЕ КУРТА

Аннотация: *Сушка играет решающую роль в производстве курта, традиционного кисломолочного продукта. Она продлевает срок годности, улучшает структуру и вкус. Существуют различные методы сушки, каждый из которых имеет свои преимущества и недостатки.*

Солнечная и теневая сушка являются экономичными, но зависят от погодных условий и медленные. Инфракрасная сушка, быстрая и эффективная, но требует дорогостоящего оборудования. Вакуумная сушка обеспечивает наилучшее качество, но также является самой дорогой. Конвективная сушка быстрая и эффективная, но может привести к потере питательных веществ.

Выбор подходящего метода сушки зависит от масштаба производства, доступности ресурсов, требуемого качества продукции и стоимости. Для малых и средних производств конвективная или инфракрасная сушка могут быть оптимальными вариантами.

Независимо от выбранного метода, важно учитывать энергоэффективность, простоту эксплуатации и надежность сушильного оборудования. Правильный выбор сушильного оборудования гарантирует высокое качество и длительный срок хранения курта.

Данная статья подчеркивает необходимость разработки специализированного оборудования для сушки куртов, учитывая их уникальные характеристики и специфику производства. В контексте отсутствия подходящего оборудования на рынке, ученые адаптировали имеющиеся решения для этой цели. Однако, представленное в работе конвективное