ГАЛУЗЕВЕ МАШИНОБУДУВАННЯ

УДК 631.563.4 DOI: 10.31388/2078-0877-2021-21-1-3-10

METHODOLOGY OF CONDUCTING STUDIES OF JET MIXING OF LIQUIDS

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*Formulation of the problem.*The technological purpose of mixing liquids is diverse. This process is widely used in the food industry to intensify chemical, thermal and mass transfer processes, as well as for the preparation of emulsions, suspensions and solutions. In particular, in the manufacture of soft drinks the main technological process is the mixing of liquids - water with blended syrup and water with a concentrate based on sweeteners.

Development and introduction into production of mixers which will provide high-quality mixing of liquids at the minimum expenses of energy and time is relevant. Mixers must be economical, reliable, and easy to manufacture and maintain, have simple schemes of inclusion in various installations.

Analysis of recent research and publications. These days, the most studied is the process of jet mixing in the tank. Experimental studies have been performed for different designs of jet mixers and a large number of dependences have been identified [1 – 10], but these dependences are not universal and cannot be used for any jet mixer.

Jet collision is one of the effective methods of intensification of various processes. The axes of the jets can be located on the same line or at an angle to each other. The change in the angle between the oncoming jets affects the intensity of the heat and mass transfer processes and it is greatest at the meeting angle of the jets 180°. Currently, there is no single approach to assessing the effect of colliding jets. This can be explained by the variety of initial conditions for the flow of jets, collisions and the formation of the resulting jet.

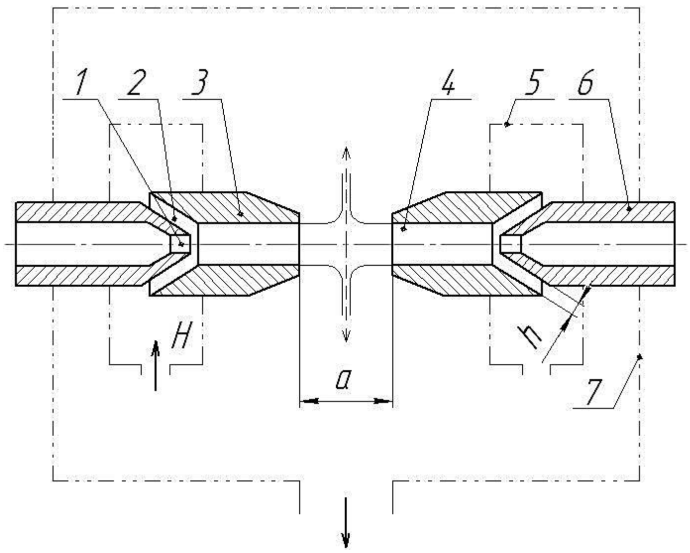
This work is part of a series of articles devoted jet mixing liquid components. In previous articles, the method of mixing [11], the design of the mixing apparatus [12] (Fig. 1), the method of assessing the quality of mixing [13] were substantiated.

Based on the analysis of literature sources, the following factors were identified that affect the process of mixing liquid components in the countercurrent-jet mixer:

– technological: water supply, Q; water supply pressure, p_w; feed pressure of the mixed component, H;

– constructive: distance between nozzles of injectors, **a**; nozzle diameter, d_n; the diameter of the working nozzle of the mixing unit, d; the value of the annular gap of the mixing unit, h;

– physicochemical properties of mixed components: density of blended syrup ρ_s, concentrate ρ_k, water ρ_w; temperature of syrup t°_s, concentrate t°_k, water t°_w; kinematic and dynamic viscosity of syrup, concentrate and water, respectively μ_s, v_s, μ_k, v_k, μ_w, v_w.



1 – working pipe; 2 – receiving chamber; 3 – injector; 4 – nozzle of the mixing chamber; 5 – input chamber of the mixed component; 6 – working pipe; 7 – liquid collection chamber; a – the distance between the nozzles; H – is the pressure of the concentrate; h – is the annular gap of the ejection chamber.

Fig. 1. Scheme of countercurrent-jet mixer.

The optimization criteria are the homogeneity of the mixture; the concentration of the mixed component in the resulting mixed product; power consumed P; specific energy consumption, E_{sp}.

The multiplicity of mixing water with blended syrup or concentrate (injection ratio) should be 1:4 – 1:5. The blended syrup-based product must contain 9 ± 2% of sugar. The product based on the concentrate should have an acidity of 3.5 ± 0.5 cm^3 [14, 15].

*Formulation of the purpose of the article***.** The purpose of this work is to develop a methodology for research of jet mixing of liquids in the developed countercurrent-jet mixer

*Presentation of the main research material***.** The main task of theoretical research is substantiation of parameters and modes of operation of countercurrent-jet mixer to obtain the necessary technological requirements of the concentration of the mixed component in the mixed product and the quality of mixing at minimum energy consumption.

The study of jet mixing of liquids is a complex process. Establishing the required physical values of the mixing process in the laboratory is very problematic. Obtaining some process data is not possible at all, so resort to computer simulation of the process.

These days there are a large number of programs and complexes that address various problems.The fluid dynamics calculation function is present only in such systems as COSMOSFloWorks, Ansys, SolidWorks, Gas Dynamics and FlowVision.Among them, the software complex of finite element analysis ANSYS stands out due to the ability to operate with a large number of parameters, as well as high accuracy of the results.According to the set parameters it is necessary to build a 3D-model of the mixing chamber of the countercurrent-jet mixer in the computer program SolidWorks and to integrate it into the ANSYS software package. The choice of the initial data of the process (temperature, density of liquids, mixing proportions, pressure at the inlet to the device) is due to the technological instructions for the production of soft drinks. As boundary conditions to set the walls, inlets and outlets, the parameters of the fluid medium on them, the parameters of the surfaces of solids in contact with the fluid medium. In fact, the boundary conditions determine the relationship of physical processes in the calculation area, which in our case coincides with the design grid, with physical processes outside it, and some wall surfaces can be considered as holes through which the design area connects with external cavities, filled with a fluid medium. All the conditions set at these limits are exactly fulfilled when solving the problem. To discretize the differential equations use the finite element method. The results of the calculation are displayed on the monitor screen in the form of a multi-colored image, which is analyzed by comparison with the appropriate scale.

As a result of modeling the mixing process in the ANSYS software package to create fields of kinetic energy of turbulence, its dissipation, velocities and pressure in the mixing chamber. Analytically determine one of the main parameters – the distance between the nozzles of the mixer's injectors.

The main task of experimental research is to substantiate the parameters and modes of operation of the countercurrent-jet mixer to obtain the required content of the mixed component in the finished solution and ensure the required level of mixing of components (mixing quality) with minimal energy consumption. To this end, it is necessary to check, refine and, if necessary, adjust the data obtained analytically.

Experimental studies should be performed according to the method described below.

The base, which is tap water, is fed into the ejector under pressure. When passing through the ejector, the kinetic energy of the water flow increases, and the potential decreases to create a vacuum that reaches its maximum value at the point of greatest narrowing of the flow, namely, at the outlet of the ejector. Blended syrup "Lemonade" based on sugar (concentrate based on aspartame and saccharin) under atmospheric pressure (0.1 MPa) is fed into the input chamber of the mixed component.

When a jet of water passes through the input chamber of the mixed component, blended syrup (concentrate) is ejected into the water flow. When the jet passes through the nozzle, the main component is pre-mixed with the admixture, and when the jets collide, the liquid components are finally mixed.

The size of the receiving chambers is changed by the axial movement of the working nozzles and during the research the dimensions of both chambers are fixed the same. The distance between the nozzles of the injectors is changed by the axial movement of the injectors in the guide bushings.

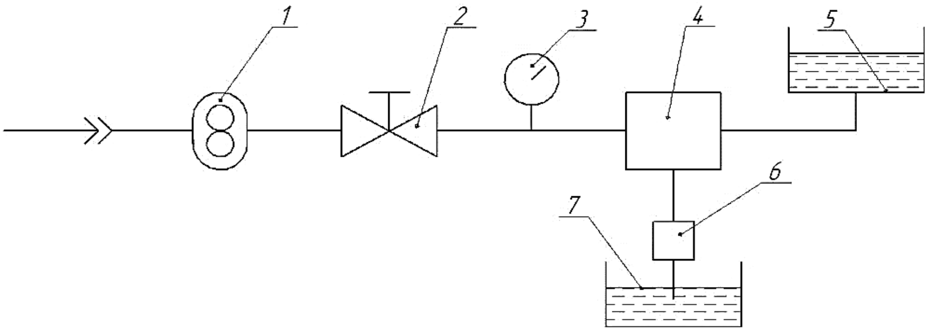
To conduct experimental research should be used: tap water DSTU 7525:2014 "Drinking water. Requirements and methods of quality control" at a temperature of 20°C (290°K) and a density of 982.3 $kg \cdot m^{-3}$, blended syrup "Lemonade" based on sugar at a temperature of 20°C (290° K) and a density of 1229.5 kg/m^3 and concentrate based on sweeteners (aspartame and saccharin) "Lemonade" at a temperature of 20°C (290°K) and a density of 1050 kg/m^3.

Determination of the concentration of blended syrup in a mixed solution is carried out using a hydrometer-sugar meter AC-3, Ukraine (GOST 18481-81, 0-25%; 0.5%).The content of concentrate in the mixed solution is determined by the acidity of the mixed product. The acidity of the resulting solution is determined by titration with 0.1-n sodium hydroxide solution.

For experimental studies, a scheme (Fig. 2) was developed and a installation was built, the general view of which is presented in Figure 3. [16].

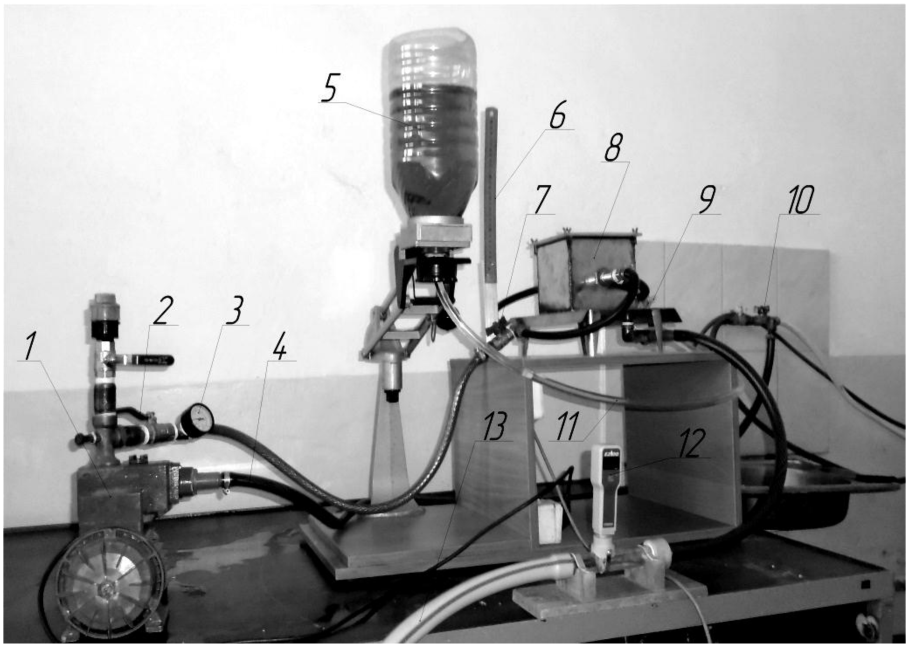
The water supply pressure is created by means of a vortex pump 1 (manufacturer KENLE, China, H_{max} = 50 m, Q_{max} = 50 $l \cdot min^{-1}$).The pressure is changed by means of a rotating valve 2. Control of water supply pressure in the mixer 8 is carried out by means of the manometer 3 (MP3 – U, Russia. According to ГОСТ 2405-88, the measurement range is 0–10 kgf/cm^2 (0–1.0 MPa), 0.2 atm).

Through the supply channel of the main component 4, water enters the countercurrent-jet mixer 8. The mixed component enters the mixer from the tank 5 through the supply channel 11. After mixing in the countercurrent-jet mixer, the mixed product is discharged through the channel 13.



1 – pump; 2 – rotating valve; 3 – manometer; 4 – countercurrent-jet mixer; 5 – container with a mixed component (concentrate); 6 – conductometer; 7 – receiving container for the mixed product.

Fig. 2. Scheme of the experimental installation.



1 – vortex pump; 2 – wraparound tap; 3 – manometer; 4 – feed channel for the main component (water); 5 – the number of food components (syrup); 6 – line; 7 – supply valve for the main component; 8 – countercurrent-jet mixer; 9 – valve for feeding a component; 10 – tap for water supply; 11 – channel for feeding a component; 12 – conductometer; 13 – channel for removal of the finished product.

Fig. 3. Experimental installation.

Determination of the dependence of the concentration of the mixed component in the mixed product:

– set the distance between the nozzles by moving them in the guide bushings. Control the distance with finite length measures

– connect the supply channel of the main component 4 to the water supply.

– set the container to collect the mixed product.

– fill container 5 with the mixed component.

– provide the required pressure of the mixed component by setting the tank 5 in the appropriate position (the distance between the surface of the blend syrup and the axis of the nozzles to control with a ruler 6).

– open the supply valve of the main component 7 and open the water supply valve 10 for 5 – 6 s (to fill the supply channel and pump cavities with water).

– connect pump 1 to the mains.

– open the water supply. After 1 – 2 s, switch on the pump. Using the rotary tap 2 to adjust the required water supply pressure according to the manometer 3.

– open the feed valve of the mixed component 9.

– after 4 – 5 s after opening the tap of the mixed component, take a sample (200 ml) in a separate container and sign it.

– repeat the experiment 3 times.

– determine the sugar content in the sample using a sugar hydrometer.

Conclusions. The proposed method of research of the jet mixing of liquids in the developed countercurrent-jet mixer will allow substantiating the parameters and modes of operation of the mixer to obtain the required technological requirements of the concentration of the mixed component in the mixed product and mixing quality at minimum energy consumption, as well as receive necessary data for construction of analytical model of countercurrent-jet mixers, homogenizers and other hydraulic devices.

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Summary

The process of mixing liquidsis widely used in the food industry. In particular, in the manufacture of soft drinks the main technological process is the mixing of liquids. Development and introduction into production of mixers which will provide high-quality mixing of liquids at the minimum expenses of energy and time is relevant.

As a result of the analysis of various methods of mixing of liquids countercurrent-jet mixing has been singled out as the most promising.The article presents a scheme of the developed countercurrent-jet mixer, a scheme of experimental installation and general view of installation. The factors that influence the process of mixing liquid components of the mixer and the method of analytical and experimental researches of the process of jet mixing of liquids in the developed countercurrent-jet mixer is described.

Key words: research, methods, liquid, mixing.

МЕТОДИКА ПРОВЕДЕННЯ ДОСЛІДЖЕНЬ СТРУМИННОГО ЗМІШУВАННЯ РІДИН

Самойчук К. О., В'юник О. В.

Анотація

Процес змішування рідин широко застосовується у харчовій промисловості для інтенсифікації хімічних, теплових і масообмінних процесів, а також для приготування емульсій, суспензій та розчинів. Зокрема, при виготовленні безалкогольних напоїв основним технологічним процесом є перемішування рідин – води з купажним сиропом і води з концентратом на основі підсолоджувачів.

Розробка і впровадження у виробництво змішувачів, які забезпечать якісне перемішування рідин при мінімальних витратах енергії і часу є актуальним. Змішувачі повинні бути економічними, надійними, простими у виготовленні та обслуговуванні, мати прості схеми включення в різні установки.

В результаті аналізу різних методів змішування рідин з'ясовано, що зіткнення струменів є одним з ефективних методів інтенсифікації різних процесів, тому протитечійно-струминне змішування було виділено як найбільш перспективне. Ця робота є складовою частиною циклу статей, присвячених струминному змішуванню рідких компонентів. Вона присвячена розробці методики аналітичних і експериментальних досліджень процесу струминного змішування рідин у протитечійно-струминному змішувачі. В статті представлено схему розробленого протитечійно-струминного змішувача та описано процес змішування рідин в ньому. Описано фактори, які впливають на процес змішування рідких компонентів у змішувачі. Окреслено задачі дослідження. Також в статті описано методику аналітичних досліджень струминного змішування рідин у розробленому протитечійно-струминному змішувачі. Представлено схему експериментальної установки та її загальний вид. Описано принцип роботи експериментальної установки. Вказано необхідне обладнання та засоби контролю для проведення досліджень. Представлено методику експериментальних досліджень з визначення вмісту підмішуваного компоненту в змішаному продукті.

Ключові слова: дослідження, методика, рідина, змішування.

МЕТОДИКА ПРОВЕДЕНИЯ ИССЛЕДОВАНИЙ СТРУЙНОГО СМЕШИВАНИЯ ЖИДКОСТЕЙ

Самойчук К. О., Вьюник О. В.

Аннотация

Процесс смешивания жидкостей широко используется в пищевой промышленности. В частности, при производстве безалкогольных напитков основным технологическим процессом является смешивание жидкостей. Таким образом, разработка и внедрение в производство смесителей, которые обеспечат качественное смешивание жидкостей при минимальных затратах энергии и времени является актуальным.

В результате анализа различных способов смешения жидкостей противоточно-струйное перемешивание выделено как наиболее перспективное. В статье представлена схема разработанного противоточно-струйного смесителя, схема экспериментальной установки и общий вид установки. Описаны факторы, влияющие на процесс смешения жидких компонентов смесителя, а также методика аналитических и экспериментальных исследований процесса струйного смешения жидкостей в разработанном противоточно-струйном смесителе.

Ключевые слова: исследование, методика, жидкость, перемешивание.