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“QURILISHDA YASHIL IQTISODIYOT, SUV VA ATROF-MUHITNI ASRASH TENDENSIYALARI, EKOLOGIK MUAMMOLAR VA INNOVATSION YECHIMLAR” MAVZUSIDAGI RESPUBLIKA MIQYOSIDAGI ILMIY-AMALIY KONFERENSIYA TASHKILIY QO‘MITASI

VI-SHO‘BA. MUHANDISLIK MASALALARINI YECHISHDA MATEMATIKANING ROLI

Determination of the constructive sizes of cavitation mixers

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Abstract: Studies have shown that the mixing device uses hydrodynamic cavitation principle of the greatest interest from the point of view of obtaining a highly dispersed finished product, with large – scale production of low – power consumption and high reliability of operation of the mixing device. Implemented definition of physical modeling and mathematical model of the process. Defined the optimal basic geometric characteristics of the hydrodynamic jet dispersants – cavitators.

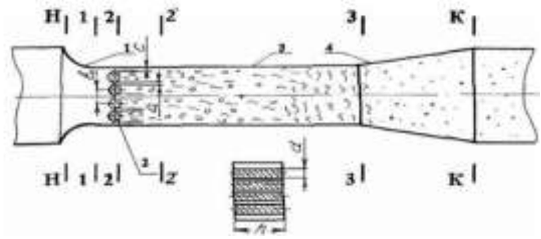
Keywords: cavitation technologies, emulsion, suspension, dispersion, enzyme, flow hydrodynamics, two-phase flow, lattice mixer, schematic diagram, turbulent, vapor condensation, subsonic flow, minimum energy.

1. Introduction

At present, cavitation technologies provide excellent results of transformation of gaseous, solid and liquid media. These technologies are used to prepare mixtures resistant to stratification (also for mixing difficult-to-mix or immiscible media), homogeneous solutions, emulsions, suspensions and dispersions from various products, to activate enzymes and accelerate processes by maintaining catalytic reactions, for sewage treatment, and for purification of water in water treatment systems [1].

2. Methods

The working process of the cavitation mixer is based on the phenomena occurring during the combined flow of the liquid and vapor-gas phases, and in general the velocities of the fluid and vapor (gas) are different [2-4]. Consequently, data on the flow rate of the medium, the geometry of the channel, and the physical properties of the liquid and gas (vapor) do not yet give a sufficiently complete idea of the hydrodynamics of the flow. Therefore, in order to characterize the two-phase flow, it is necessary to introduce quantities that take into account the particular motion of the individual phases.



1 – confusor; 2 - lattice; 3 - working chamber (neck); 4 - diffuser

Fig. 1. Schematic diagram of a mixer with a hydrodynamic cavitation grating

The mathematical model of the working process, compiled on the basis of the material, energy and heat balance of the flow in continuous mixers is a closed [3]. It makes it possible to calculate the transverse dimensions of mixers with cavitation stimulators in the flow in the form of a multi-jet nozzle or hydrodynamic cavitation grating, and also to determine the coordinates of the mixing jump and, thus, the longitudinal dimensions of the mixer. Providing operating modes of an emulsifier with a high slip coefficient will increase the efficiency of the mixing process. This can be achieved by using a multi-jet nozzle device, which will ensure uniform formation of the components of a two-phase flow in a living section. The fluid and vapor velocities can be assumed to be approximately the same, since, firstly, vapor evolution occurs from a moving fluid without additional heat input, and it is obvious that the rates of the vapor and liquid phases are close. Secondly, the interaction surfaces of liquid jets with evolved vapor are numerous. Therefore, both phases are uniformly distributed over the flow cross-section and are in thermal and mechanical equilibrium with each other. Under these conditions, a two-phase flow can be regarded as a flow of a quasihomogeneous isothermal (homogeneous) medium with an average density [2]. The task of calculating the mixer is as follows: with known physical properties of the components of the mixture (carrier medium and liquid additive), their content in the mixture stream, initial pressure and temperature, the regime and geometric parameters of the mixer are determined, realizing the flow of the working process with minimal energy consumption. Calculation of the mixer with minimum energy consumption and optimal workflow is performed by the method of successive approximations. In each approximation, the optimal transverse dimensions of the cavitation and working chamber drivers, corresponding to the minimum losses in the mixer, are determined from the initial data and the selected hydraulic cavity resistance coefficients (the nozzle or hydrodynamic grid) and the elements of the flowing part of the working chamber, then the steam flow and then the flow temperature are calculated mixture in the initial section of the working chamber T_2

3. Results and Discussion

The calculation is considered reliable if the flow parameters of the mixture of components in the last two approximations differ by not more than (2 – 5) %. After finding the temperature of the mixture in the initial section working chamber T_2 and vapor content in the flow, the longitudinal dimensions of the flow part of the mixer are determined. In this case, the total axial length of the working chamber is composed of sections:

- Formation of supersonic vapor-gas-liquid flow l_{form} ;
- Turbulent supersonic flow l_{course} ;
- Hopping mixing l_{trans} , where there is a jump like transition from supersonic to subsonic flow and condensation of vapors of liquid additive;
- Soothing flow l_{establ} ;

$$L_{friction} = l_{form} + l_{cours} + l_{trans} + l_{establ} \quad (1)$$

According to the recommendations [5], the region of formation supersonic vapor-liquid flow

$l_{form} = (1...2)$ D_3, where D_3 - diameter of the working chamber.

The length of the zone of supersonic flow l_{course} is determined by the critical length l_k of the section with a turbulent two-phase flow, at which the critical state of the flow $(P = P_k)$ is reached at the end section and is determined according to [6], that is $l_{course} = l_k$.

The length of the mixing jump is $l_{trans} = (2...4)$ D_3. The soothing zone can be recommended in the range $l_{establ} = (2...3)$ D_3. On the basis of the obtained mathematical model [3] and the method calculation, we perform the calculation of a mixer with a multi-jet nozzle, which serves to create a water-oil emulsion (WOE). Let's take the absolute value of the pressure before the mixer $P_{absolut} = 1000$ kPa, volumetric flow rate of the mixture flow (carrier medium + liquid additive) $Q_{carrier} = 120 m^3/hour = 3{,}33$ m^3/s, temperature of the water-oil mixture (WOM) $T_1 = 100^\circ C$, volume content of water in the water-oil flow (W O F) - 15%. In accordance with the tabular data [6] at $T_1 = 100^\circ C$ we have : water vapor density $\rho_{density} = 0{,}598$ kg/m^3, density of liquid additive (water) – $\rho_{trans} = 958{,}4$ kg/m^3, saturated vapor pressure $P_{sat.press} = 1{,}01 \cdot 10^5$ Pa, density of the carrier medium (fuel oil) – $\rho_{s.h} = 949$ kg/m^3, specific heat of liquid additive - $C_{trans} = 4220$ j/kg ⋅K, specific heat of the carrier medium – $C_{s.h} = 2008{,}32$ j/kg ⋅K, latent heat of vaporization $r = 2256{,}8$ kj/kg. Let us determine the density of the mixture:

$$\rho_s V_s = \rho_{trans} V_{trans} + \rho_{s.h} V_{s.h}$$

Here $V_s = 1$ - volume WOF;

$V_{s.h} = 0{,}85$ - volume of fuel oil in the WOF;

$V_{trans} = 0{,}15$ - volume of water in the WOF.

$$\rho_c = 0{,}15 \cdot \rho_{trans} + 0{,}85 \cdot \rho_{s.h} =$$
$$= 0{,}15 \cdot 958{,}5 + 0{,}85 \cdot 949 = 950 \text{ kg/m}^3.$$

Calculation of the emulsifier is carried out by the method of successive approximations. As a first approximation, we take the following values of hydraulic drag coefficients:

$\xi_{konfuser} = 0{,}15$;
$\xi_{resistance} = 0{,}10$;
$\xi_{diffuser} = 0{,}25$;
$\xi_r = 0{,}2$

The minimum relative pressure drop for the selected hydraulic resistance coefficients, and therefore the minimum loss in the mixer corresponds to $\Omega = 0{,}64$ With the relative nozzle area $\Omega = 0{,}64$, the cavitation number will be $\sigma = 0{,}41$. The minimum of the function corresponds to the minimum pressure loss in the mixer $\Delta P_{pressure\ loss} = P_{pressure} - P_k$.

At absolute pressure in the initial section $P_{pressure} = 1000$ kPa and saturated vapor pressure $P_{s.p} = 101$ kPa, the minimum pressure loss $\Delta P_{pressure\ loss} = P_{pressure} - P_k = 272\ kPa$.

Now determine the rate of IUD expiration from the nozzle V_{c2}:

$$V_{c2} = \sqrt{\frac{2(P_H - P_{H.\Pi})}{\rho_c (1 + \sigma + \xi_{KAB} + \xi_{KOH} \Omega^2)}}$$

Substituting in the last expression the received values of the coefficients resistance, the cavitation number σ, and also $\Omega = 0{,}64$, we find that in the first approximation, the exhaust velocity $V_{c2} = 34{,}71\ m/s$.

Then the speed Flow mixture in sections 1 -1 and 3-3

$$V_{c1} = V_{c3} = \Omega V_{c2} = 0{,}64 \cdot 34{,}71 = 22{,}21\ m/s$$

Perform a check of the pressure losses in the mixer:

$$\Delta P_{pressure\ los} = \xi_{cav.grat} \frac{\rho_c V_{c2}^2}{2} +$$
$$+ (\xi_{confuser} + \xi_{diffuser} + \xi_r) \frac{\rho_c V_{c3}^2}{2} +$$
$$+ \frac{(V_{c2} - V_{c3})^2}{2} \rho_c = 0{,}1 \frac{950 \cdot 34{,}71^2}{2} +$$
$$+ (0{,}15 + 0{,}25 + 0{,}2) \frac{950 \cdot 22{,}21^2}{2} +$$
$$+ \frac{(34{,}71 - 22{,}21)^2}{2} 950 =$$
$$= 2{,}7206 \cdot 10^5 \text{ Pa.}$$

Comparing the result with the one calculated earlier, we find that they are close. This indicates that the velocities V_{c2}

and V_{c3} found correctly. Knowing the velocity V_{c3} of the emulsion flow in the throat, determine its area A_3 and diameter D_3 in the first approximation.

The area of the normal section of the working chamber

$$A_3=\frac{Q_c}{V_{c2}}=\frac{3,33\cdot 10^{-2}}{22,21}=1,50\cdot 10^{-3}\ m^2$$

and the diameter

$$D_3=\sqrt{\frac{4A_3}{\pi}}=\sqrt{\frac{4\cdot 1,50\cdot 10^{-2}}{\pi}}=4,37\cdot 10^{-2}\ m=44\ mm\cdot$$

Area of jets

$$A=\Omega\cdot A_3=0,64\cdot 1,50\cdot 10^{-3}=0,96\cdot 10^{-3}\ m^2\cdot$$

Determine the amount of the released vapor, taking the value Slip coefficient $\psi=0,9$ and assuming that the steam occupies all The space free from jets in the initial section of the working chamber.

The velocity of the steam at $\psi=0,9$

$$V_{speed}=\psi\cdot V_{c2}=0,9\cdot 34,71=31,24\ m/s$$

Then the amount of steam

$$m_{speed\ 2}=\rho_{speed}V_{speed}\left(A_3\text{-}A_2\right)=$$
$$=0,598\cdot 31,24\left(1,50\cdot 10^{-3}\text{-}0,96\cdot 10^{-3}\right)\cong.$$
$$\cong 10^{-2}\ kg/s$$

Taking into account expression (1) and accepted recommendations, we define the length of the mixing chamber:

$$L_{friction}=l_{form}+l_{course}+l_{trans}+l_{establ}=$$
$$=2D_3+l_k+4D_3+3D_3=$$
$$=2\cdot 0,044+0,074+4\cdot 0,044+3\cdot 0,044\cong$$
$$\cong 0,47\ \ m.$$

The remaining dimensions of the mixer are defined and presented in the table. The number of jets is assumed to be $m=5$. To achieve minimum energy losses in the diffuser, it is assumed that the diffuser's opening angle is $\alpha=7^o$, and the degree of its expansion is $n=6$. Then the diameter of the outlet section of the diffuser is determined from expression $D_4=D_3\sqrt{n}$.

And the axial length of the diffuser –

$$L_{diffuser}=0,5\frac{\left(D_4\text{-}D_3\right)}{tg\dfrac{\alpha}{2}}.$$

Basic geometric dimensions of the mixer

Square,		Diameter, m			Length, m	
A_2	A_3	D_2	D_3	D_4	$L_{friction}$	$L_{diffuser}$
$9,6\cdot 10^{-4}$	$1,5\cdot 10^{-3}$	0,0156	0,044	0,108	0,47	0,523

Here D_2 is the diameter of the nozzle opening.

4. Conclusion

According to the proposed method, resource-saving industrial samples of cavitation mixers for various volume flows of water-oil mixtures of a new generation will be calculated in the future.

References

[1]. Кнэпп Р., Дейли Дж., Хэммит Ф. Кавитация. - М: Мир, 1994. -687 с.

[2]. Нигматулин Р.И. Динамика многофазных сред. Т.2, М.: Наука, 450 с., 2007.

[3]. Ходжаев Я.Д., Касимов Ш.А., Тохтахунов К.А. Основные соотношения рабочего процесса гидродинамических кавитаторов. Журнал ВЕСТНИК ТашИИТ, 2016г., № 2 /3 , с.70-74.

[4]. Уоллис Г. Одномерные двухфазные течения. - М. Мир, 1992. - 440 с.

[5]. Зысин В.А., Баранов Г.А., Барилович В.А., Парфенова Т.Н. Вскипающие адиабатные потоки. - М. : Атом.издат, 1976.- 152 с.

[6]. Спиридонов Е.К. Теоретические основы расчета и проектирования жидкостногазовых струйных насосов. М.: НПО "Гидромаш".-1996.

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