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MATHEMATICAL MODEL OF A HYDRODYNAMIC CAVITATION DEVICE USED FOR TREATMENT OF FOOD MATERIALS

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ABSTRACT

The article analyzes the physicochemical effects during cavitation action on the liquid medium. The characteristic of ultrasonic and hydrodynamic cavitation is presented. Particular attention is paid to the use of cavitation technology in the food industry. A review of the latest research is presented showing that hydrodynamic cavitation is not only an alternative to acoustic cavitation for the management of chemical, biochemical, physical processes, but also a priority in the processing of large volumes of liquid process media, which determines its industrial application. A hydrodynamic cavitation device is proposed, the working process of which is fundamentally different from traditional cavitation devices, namely: the formation in the cavitation area of a supersonic flow in a homogeneous two-phase medium, which under conditions of friction of the working chamber (throat) passes into a subsonic flow through a pressure jump. Thus, the cavitation effect on the flow is amplified by the shock action of the pressure jump when the supersonic flow transfers into subsonic flow, which is a powerful intensifying factor at an energetically higher level when the liquid medium is transformed. The working process of a hydrodynamic jet cavitation device and a cavitation device with a hydrodynamic grid is described in detail. A mathematical model is developed for calculating the transverse and longitudinal dimensions of cavitation devices, in the compilation of which, the fundamental laws of conservation of mass and energy, the basic equations of hydrogasdynamics in their generally accepted mathematical form, and reliable semi empirical data are used.

Keywords: cavitation, hydrodynamic device, food environment, works process.

INTRODUCTION

The steady growth of the population of the earth urgently requires an increase in the volume of food production. Known modern storage technologies do not guarantee the complete preservation of food raw materials or products. Qualitative changes in them occur not only because of added food additives, microbial toxins or improperly selected storage regimes, but primarily because of the loss of natural moisture contained in raw materials or products. Since in the course of storage the natural properties of raw materials inevitably change, in this connection the task of restoring the qualities lost during storage is actual. Consequently, one of the priority tasks of the food industry is the development of new technologies for processing raw materials for obtaining high-quality and safe food (Velazquez, 2011).

The solution of this problem can be carried out in two ways: 1) the use of various food additives in the process of storage and recovery of natural properties of raw materials; 2) application of physical methods of processing food raw materials.

The second way seems preferable, since the current practice of using food additives in food production is not always harmless for human health. Therefore, the application of not only existing physical methods of processing food raw materials, but their improvement, as well as the introduction of progressive innovative technologies for food production, is an urgent task (Velazquez, 2011).

Of the known physical methods, the most interesting is cavitation technology. Cavitation is a physical phenomenon that occurs in a power fluid at the moment of a rapid change in pressure. A fluid changes its state from liquid to gas due to the vapour pressure of a fluid (Cvetković *et al.*, 2015). Modern scientific research is carried out both in search of new solutions and optimization of the cavitation technology itself, as well as in improving the devices implementing this technology (Long *et al.*, 2017).

During cavitation, a vapor-gas-liquid mixture is formed, consisting of a liquid medium and vapor-gas bubbles, the ratio of the gas-vapor content in the cavities of which can be different - theoretically from zero to one. Depending on the concentration of steam or gas in the cavity, they are called steam or gas (Zemenkov *et al.*, 2016).

Until recently, such negative consequences of cavitation as erosion of surfaces, noise and vibration in hydraulic systems, deterioration of energy characteristics of hydraulic equipment and, as a result, reduction of its resource were mentioned (Cvetković *et al.*, 2015; Long *et al.*, 2017). In the study of these negative phenomena, certain progress has been made. The useful effect of cavitation phenomena in the scientific world began to be mentioned only at the end of the last century. The first to use these modern technologies were heat power engineering, petrochemistry, metalworking industry, etc. Improvement and development of technologies associated

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with the processes of mixing difficult-to-mix or immiscible media led to the use of cavitation phenomena to obtain mixtures resistant to stratification. This served as an impetus for the development of cavitation mixing technology. At present, cavitation technologies provide excellent results of transformation of gaseous, solid and liquid media. These technologies are used to prepare mixtures resistant against stratification, homogeneous solutions, emulsions, suspensions and dispersions from various products, for mixing difficult-to-mix or immiscible media (Cvetković *et.al.*, 2015; Gaikwad *et al.*, 2008); in biotechnology - for activation (or deactivation) of enzymes and microbial cell disruption process (Balasundaram and Pandit, 2001; Gogate and Kabadi, 2009); in chemistry, petrochemistry and biotechnology - to activate and accelerate processes by maintaining catalytic reactions (Gogate and Kabadi, 2009); in the pharmaceutical industry and biotechnology - in the processes of crystallization and extraction of bioactive materials from herbs (Vinatoru, 2001); in ecology - for wastewater treatment by suppressing the growth of bacteria and reducing the level of bactericidal agents, as well as for purifying water in water treatment systems (Gogate and Kabadi, 2009; Gogate, 2002; Badmus *et al.*, 2018). It is important that the use of cavitation technology provides environmentally safe processes, since chemical additives are not used (Dular *et al.*, 2016).

Later, cavitation technologies began to be used in the food industry. Currently, there are known technologies for preparing edible water and water-in-oil emulsions (Cvetković *et al.*, 2015), extracting protein from soybeans (Preece *et al.*, 2017), improving the properties of meat raw materials (Alarcon-Rojo *et al.*, 2015), milk homogenization and improving the viscosity of yoghurt (Wu *et al.*, 2015), preserving vegetables and fruits (Seymour *et al.*, 2002).

Such an extensive field of application of cavitation is due to the multifunctionality of this complex wave hydrodynamic phenomenon. Externally, the cavitation process resembles the bubble boiling process. And although the liquid itself does not heat up, it acquires the properties of a boiling liquid. Such a liquid (in particular, water) dissolves salts well, intensively enters the hydration reaction of biopolymers of food raw materials, extracts vitamins and minerals from it, without destroying its natural structure. This is explained by the fact that in the conditions of cavitation the liquid acquires new qualities: when the pressure drops to the saturated vapor pressure, vapor or vapor-gas cavities are formed in the liquid, which quickly begin to form, and also collapse rapidly. When bubbles collide, a significant energy is released (Zemenkov *et al.*, 2016). It is noted that in the collapse of vapor bubbles intense cumulative jets are formed (the velocity of the cumulative jets is 300-500 m / s), which, when colliding, generate an oscillatory process and, as a result, sharp point increases in pressure and temperature (up to 1000-5000 atm and 500-15,000 K, respectively) (Gogate and Kabadi, 2009). Recent studies in (Long *et al.*, 2017) also show that the collapse of cavitation bubbles can cause an extremely high pressure and temperature rise. The liquid passes into the so-called thermodynamically nonequilibrium state, which determines the physico-chemical changes in its structure - the formation of a homogeneous two-phase medium and, as a consequence, the acquisition of new qualities due to high-frequency wave action.

Depending on the method of production, several types of cavitation are distinguished, but only acoustic and hydrodynamic cavitation are most effective for obtaining the desired chemical / physical changes in the liquid medium (Gogate and Kabadi, 2009; Badmus *et.al.*, 2018). Acoustic (ultrasonic) cavitation occurs in a fluid when it is exposed to a source of ultrasound - a cavitation generator. In the ultrasonic range, piezoelectric and magnetostrictive cavitation generators are most common.

Hydrodynamic cavitation is caused by hydrodynamic phenomena in liquid (Badmus *et al.*, 2018). Hydrodynamic cavitation is characterized by a change in fluid flow only due to geometric and, as a consequence, regime parameters. This change can occur both without the use of any moving parts and additional sources of energy, for example, using traditional hydrodynamic devices such as profiled nozzles (Sawant *et al.*, 2008), and when force is applied to the flow, for example, by rotating working elements, more often by paddle (Ashokkumar *et al.*, 2011). This causes hydrodynamic and acoustic effects on the liquid due to the developed turbulence, pressure and velocity pulsations, shock waves and secondary nonlinear acoustic effects (Cvetković *et.al.*, 2015; Long *et al.*, 2017; Mishra and Gogate, 2010; Ozonek, 2012). Recent studies show that hydrodynamic cavitation can be an alternative to acoustic cavitation for controlling the kinetics of chemical, biochemical, physical processes during the transformation of technological media (Gogate and Pandit, 2001), which is especially important when processing large volumes of liquid media in the food industry (Ashokkumar *et.al.*, 2011).

Methods such as hydrodynamic cavitation are gaining increasing importance for certain applications in food processing (Velazquez, 2011). Ashokkumar *et al.* (2011) noted that the acoustic cavitation reactors are not suitable for large-scale food processing. In comparison with ultrasonic cavitation in conditions of large-scale industrial production of food products, the principles and designs for conducting hydrodynamic cavitation are more applicable. The processing parameters can be optimized, and the design of the equipment is improved to maximize product quality (Knoerzer *et al.*, 2015). Gogate and Kabadi (2009) noted that the future of hydrodynamic cavitation reactors lies in the design of orifice plate type configuration.

The purpose of this work is the theoretical justification of a technical solution for the optimization of cavitation technology, including a description of the work process and the development of a mathematical model of a hydrodynamic device that implements this work process.

MATHEMATICAL FORMULATION

The flow in cavitation conditions can be regarded as a two-phase flow consisting of a vapor-gas and a liquid phase - a vapor-gas-liquid flow. The work process of the hydrodynamic cavitation devices that provide this mode of operation is based on phenomena occurring during the joint flow of liquid and gas in the flow part of the device and, in its physical essence, is close to the work process of two-phase jet devices (gas-liquid or liquid-jet devices operating under conditions of cavitation) operating in idle mode.

Literature review devoted to cavitation in jet pumps has shown that one of the most efficient ways to create emulsion is cavitation in the jet boundary layer. At the same time to increase emulsion dispersion degree it is necessary to equally distribute cavitation points along the standard cross-section of the flow, and to enlarge their number when possible. One of such devices - agitators of cavitation is a multiple-jet nozzle with equally spaced holes which form several high velocity jets in a flow-part of a mixer (Spiridonov, 2015).

Cavitation represents a set of complex fast flowing hydrodynamic phenomena in which the dynamics of free surfaces, turbulence, diffusion, phase transitions, etc. play an important role (Mishra and Gogate, 2010; Ozonek, 2012; Ji *et.al.*, 2016). Up to the present time, there are various points of view on the physical nature of the appearance, as well as the development of certain stages of cavitation, in the scientific world there is no doubt that: a) homogeneous two-phase media are characterized by increased compressibility - they are more compressible than even gases; b) the speed of sound in homogeneous two-phase mixtures is much less than the speed of sound not only in the liquid, but also in the gas.

In connection with the fact that cavitation leads to the formation of a two-phase medium, the achievement in which supersonic velocities does not cause any particular difficulties, the idea arises - to supplement cavitation with one more effect-the transition of a supersonic flow to a subsonic one. It is known that the flow of a supersonic flow under friction conditions leads to its inhibition and increase in pressure, and a continuous transition through the velocity of sound in an adiabatic channel of constant cross section is impossible. Therefore, during the flow of a supersonic two-phase flow, an isoentropic pressure jump occurs-the supersonic flow passes into subsonic flow. An additional powerful effect of the pressure jump causes a deeper physico-chemical transformation of its structure and the transformation of the flow itself is most fully realized.

WORK PROCESS AND SCHEMATIC DIAGRAMS

The flow state at which the flow regime changes occurs, is called critical, the pressure corresponding to this transition, is the critical pressure. If a cavitator (a nozzle or a hydrodynamic grid) uniformly distributes cavitation points along the normal flow cross-section, then at its exit the two-phase flow can be considered as a flow of a quasi-homogeneous medium with a minimum phase slip due to only near-wall friction (Spiridonov, 2015).

This work process can be carried out in a hydrodynamic cavitation device. A cavitation device is placed in the flow: it can be either a hydrodynamic grid (and then the device is called a cavitation device with a hydrodynamic grid), or a nozzle (in this case the device is called a hydrodynamic jet cavitation device), providing local acceleration of the flow to a rate at which the pressure decreases up to the saturated vapor pressure and cavitation occurs (Spiridonov, 2015). In the flow there occurs generation of gas-vapor bubbles which, with further acceleration of the flow, increase, and when they are transferred in the region of increased pressures they collapse. The work process of the hydrodynamic cavitation device can be arranged so that in the initial section of the working chamber behind the cavitation inducers a turbulent supersonic flow of the vapor-gas-liquid mixture is formed, which under friction conditions will inevitably pass into a subsonic flow through an isentropic pressure jump at the end of the working chamber. Figure-1 schematically shows the stages of the work process with the transition of supersonic flow to subsonic.

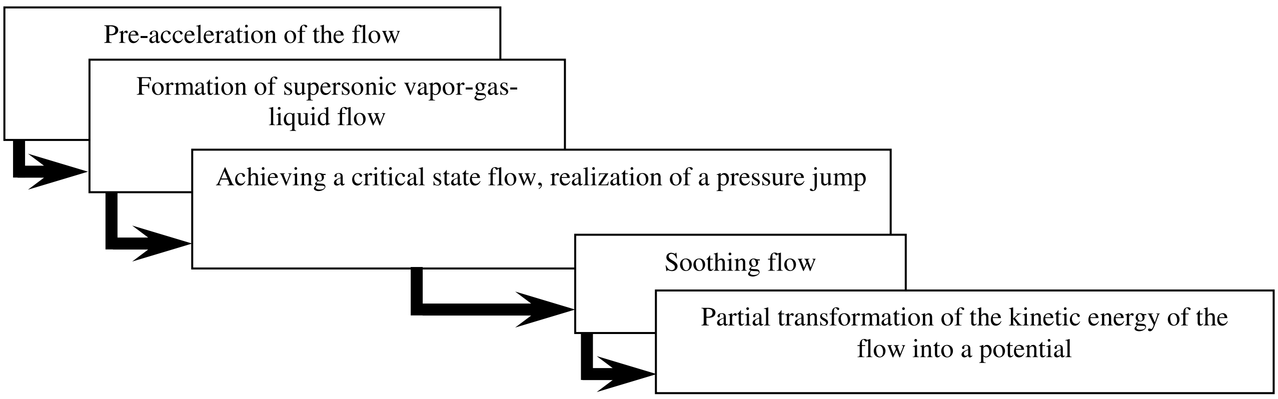

Figure-1. The work process of the hydrodynamic cavitation device.

The preliminary acceleration of the flow is performed by the confuser. A hydrodynamic grid or a nozzle accounts for the pressure drop to the saturated vapor pressure, the appearance of cavitation and the formation of a supersonic vapor-gas-liquid flow. Achievement of the critical state and the transition of the

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supersonic flow to subsonic flow through the pressure jump take place in the working chamber of the device (or throat). Damping of the flow and partial transformation of the kinetic energy of the flow into the potential flow takes place in the diffuser.

Figure-2 shows a schematic diagram of a hydrodynamic jet cavitation device that implements this work process, and Figure-3 shows a schematic diagram of a cavitation device with a hydrodynamic grid.

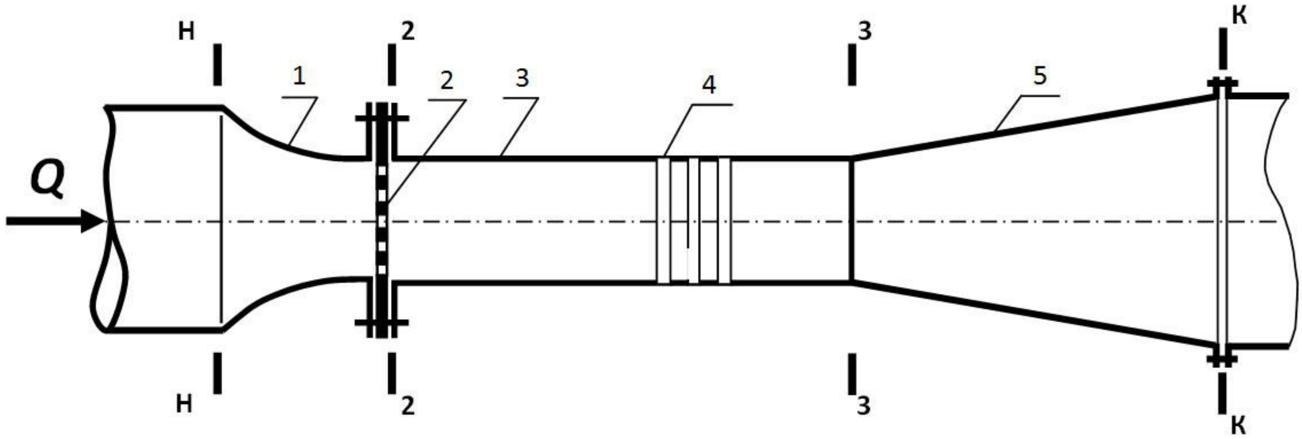

Figure-2. Principle diagram of hydrodynamic jet cavitation device: 1 - confuser; 2 - nozzles; 3 - working chamber (necktube); 4- flowing channel; 5- diffuser

The hydrodynamic jet cavitation device (see Figure-2), which realizes the above described work process, consists of a supply confuser 1, a cavitator (nozzle) 2, a working chamber (throat) 3, at the end of which flow grooves 4 and a diffuser 5 are provided. The flow enters in confuser 1, where it is accelerated and pressure reduced. The flow from the confuser 1 then flows to the nozzle 2, which ensures the formation of high-speed jets. At the outlet of the nozzle, there is a sharp drop in pressure to the saturated vapor pressure, which leads to the transfer of part of the liquid phase to the vapor phase and the formation, thereby, of a supersonic vapor-gas-liquid flow. In the working chamber 3, the supersonic vapor-gas-liquid flow decelerates and passes into subsonic flow in a pressure jump. The flow grooves 4 at the end of the working chamber are urged to initiate a pressure jump in the working chamber. After the working chamber, the stream enters the diffuser 5, where part of its kinetic energy is converted into a potential one. The pressure then rises to a value lower than before the cavitation device. This schematic diagram is similar to the device of a jet pump for studying the dynamics of cavitation bubbles within zero passive flow, as well as the cavitation mixer presented in (Spiridonov, 2015).

In a cavitation device with a hydrodynamic grid (see Figure-3), the pressure drop to saturated vapor pressure occurs in the vortex wake behind the grid, which actually acts as a cavitator. The designations in this figure are similar to those in Figure-2, except for the hydrodynamic grid at number 2.

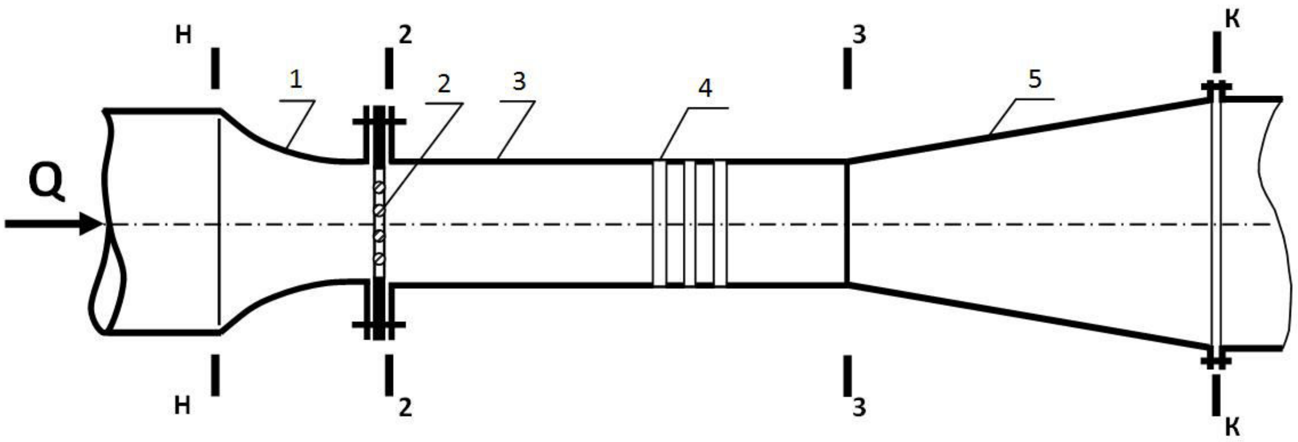

Figure-3. Principle diagram of cavitation device with a hydrodynamic grid: 1 - confuser; 2 - hydrodynamic grid; 3 - working chamber (necktube); 4 - flowing channel; 5 - diffuser

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The task of calculating the hydrodynamic cavitation device consists in determining the regime and geometric parameters of the device that realizes the flow of the working process through a pressure jump. The regularities of the flow of subsonic and supersonic two-phase flows can be fundamentally different because of the increased compressibility of the two-phase medium. On this basis, an important parameter of such flows is the speed of sound, which, in general, depends on the physical properties of the components of the mixture, the true concentration of them in the mixture, the heat exchange between the components.

INITIAL EQUATIONS OF THE WORK PROCESS

When compiling the physical and mathematical model of the work process, the fundamental laws of conservation of mass and energy, the basic equations of hydrogasdynamics in their generally accepted mathematical form, as well as reliable semiempirical data were used. This, as well as satisfactory correspondence of the calculation of the industrial sample of the hydrodynamic cavitation device of the developed mathematical model and the calculation method is a condition for the reliability and validity of the theoretical propositions, conclusions and recommendations obtained in this paper.

The development of a mathematical model consists in determining the dimensions of a cavitation device in which the above described working process is carried out with a minimum pressure loss on the device (P_n-P_k) (see Figures 2, 3) and, therefore, minimal energy consumption. It is necessary to determine both the transverse and longitudinal dimensions of the device, since this calculation of transverse dimensions ensures the formation of supersonic vapor-liquid flow and its acceleration to critical velocities in the working chamber and transition through a pressure jump. The choice of longitudinal dimensions is predetermined by the position of the pressure jump in the flowing part of the working chamber of the device.

The initial equations describing the work process in a cavitation device are the following equations: equation of balance of mass expenditures; D. Bernoulli Equation for the flow with the drip state of the mixture at the section between the normal sections H-H and 2-2, 3-3 and K-K (see Figures 2, 3); the amount of movement for the control compartment, limited by sections 2-2 and 3-3 and the inner surface of the working chamber. This system of equations is supplemented by cavitation numbers or the Euler's number, establishing the relationship between local pressure drops behind cavitators and regime and geometric flow parameters (Spiridonov, 2015).

THE BASIC EQUATION OF A CAVITATION DEVICE WITH A HYDRODYNAMIC GRID

For a cavitation device with a hydrodynamic grid, the system of basic equations, supplemented by an analytical expression for the cavitation number in the vortex wake σ', has the following form:

$$\frac{P_н - P_к}{P_н - P_{н.п.}} = \frac{\zeta_\Sigma}{\frac{(1+\sigma' + \zeta_{кав})}{\Omega^2} + \zeta_{кон}} \tag{1}$$

Where $\sigma' = (P_2 - P_{н.п})/(\rho \cdot V_2^2/2)$ is cavitation number; V_2, P_2 and ρ are speed, pressure and the flow density of the mixture at the outlet of the hydrodynamic grid in section 2 - 2 (see Figure 3); Ω – the relative area of the cavitator; $P_н$, $P_к$, $P_{н.п}$ the pressure in the sections H-H, K-K, and the saturated-vapor pressure respectively; ζ_Σ, $\zeta_{кав}$, $\zeta_{кон}$ – the total hydraulic resistance coefficient of the flowing part of the device, the hydraulic coefficient of resistance of the cavitator (grid) and the resistance coefficient of the confusor respectively.

THE BASIC EQUATION OF A HYDRODYNAMIC JET CAVITATION DEVICE

In the derivation of the calculated equation of the jet cavitation device, the system of basic equations is supplemented by an empirical formula that establishes the dependence of the cavitation number σ_0 (or the Euler's number Eu characterizing the cavitation phenomena in the boundary layer of the jet) with the relative area of the nozzle Ω_0 [22]:

$$\text{at } 0 < \Omega_0 \le 0{,}5 \quad \sigma_0 = 0{,}07 + 1{,}36 \cdot \Omega_0 \cdot (1 - \Omega_0),$$
$$\text{at } 0{,}5 < \Omega_0 < 1{,}0 \quad \sigma_0 = 0{,}41 \tag{2}$$

where $\sigma_0 = (P_2 - P_{н.п})/\rho V_2^2/2$ is cavitation number ($\sigma_0 = Eu$); Ω = A_2/A_3 –relative area of the nozzle (A_2 is the area of the exit section of the nozzle or the normal section of the jet immediately behind the nozzle in the section 2-2, A_3 is the area of the normal section of the working chamber 3 - 3 - see Figure-2).

The combination of the above equations and a number of transformations lead to an expression that is basic for calculating the hydrodynamic jet cavitation device:

$$\frac{P_н - P_к}{P_н - P_{н.п.}} = \frac{\varsigma_{con} + (\varsigma_{кон} + \varsigma_{диф} + \varsigma_г) \cdot \Omega_0^{\,2} + (1 - \Omega_0)^2}{1 + \sigma_0 + \varsigma_{con} + \zeta_{кон} \cdot \Omega_0^{\,2}}, \tag{3}$$

Where $\zeta_{кон}$, ζ_{con}, $\zeta_г$, $\zeta_{диф}$ are coefficients of hydraulic resistance of confusor 1, nozzle 2, working chamber (throat) 3 and diffuser 5.

The analysis of expression (3) shows that the relative pressure drop on the device depends on its basic geometric parameter (the relative area of the nozzle) and the resistance coefficients of elements of the flow section. This dependence is illustrated in Figure-4 in the entire practical range of variation of the throat resistance coefficients $\zeta_г$ = 0, 08 ... 1,00 and hydraulically perfect profiling of other elements of the flow section ($\zeta_{кон}$ =

0,15; ζ_{con} = 0,1; $\zeta_{диф}$ = 0,25). It can be seen that there are extreme values of the relative area of the cavitator, at which the pressure drop across the emulsifier is minimal. Since the minimum of the function $(P_н - P_к)/(P_н - P_{н.п})$corresponds to the minimum of losses on the device, these extreme values of the relative area Ω should be considered optimal.

From the graphs it follows that the zone of optimum values of the relative area of the nozzle for the above-mentioned coefficients of resistance of the flow section of the mixer is Ω_{opt} = 0,45…0,70.

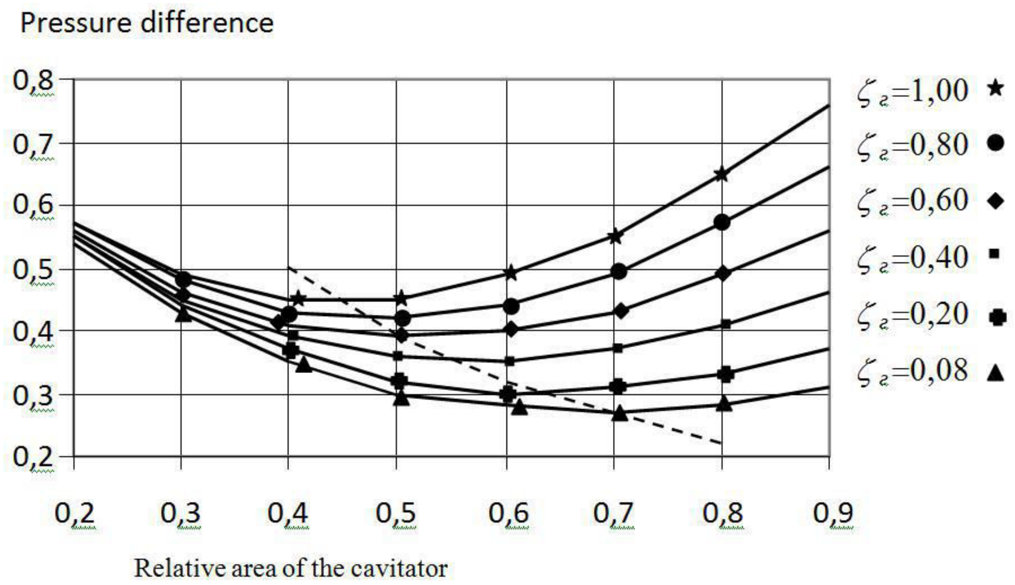

Figure-4. Nominal pressure difference on mixer to relative area of the nozzle dependency curve.

LONGITUDINAL DISTRIBUTION OF FLOW PARAMETERS IN A HYDRODYNAMIC CAVITATION DEVICE

The length of the working chamber of the device should be sufficient to carry out the transition from the rapid supersonic current to the quiet subsonic in the mixing jump. The total axial length of the working chamber is composed of sections:

- formation of supersonic vapor-gas-liquid flow l_{for};
- turbulent supersonic flow of the mixture l_{flo};
- pressure jump l_j where there is a jumplike transition from supersonic to subsonic flow;
- damping of the flow l_{dam}, that is

$$L_г = l_{for} + l_{flo} + l_j + l_{dam} \quad (4)$$

According to the recommendations of [24], the region of formation of supersonic vapor-liquid flow l_{for} = (1 ... 2) D_3, where D_3 - diameter of the working chamber (see Figure 2). The length of the supersonic flow zone l_{flo} is determined by the critical length l_c of the section with a turbulent two-phase flow, at which the critical state of the flow is reached at the end of the section, that is, $l_{flo}= l_c$ and $P = P_k$.

The length of the section with supersonic flow of gas-liquid flow can be found from the equation (Spiridonov, 1996):

$$\xi_{кр} = Z(X_{кр}) - Z(X_2), \quad (5)$$

where $\xi_{кр}= \lambda{\cdot}Y{\cdot}L_{кр}/8{\cdot}R$; $L_{кр}$ is the length of the section of the working chamber between section 2-2 and the critical section; R is the hydraulic radius of the chamber; λ - coefficient of hydraulic friction of the working chamber;

$$Z(X) = \gamma{\cdot}\ln{\cdot}X-(\gamma-1){\cdot}\ln{\cdot}(X+1)-(\gamma{\cdot}(X+\psi)/(X+1))-X; \quad (6)$$

$$\gamma = Y/\psi^2; \quad X = P/(\mu{\cdot}R{\cdot}T{\cdot}\rho); \quad Y= Q^2/(A^2{\cdot}\mu{\cdot}R{\cdot}T); \quad (7)$$

where μ - mass coefficient of gas content; R - the gas constant; T - the temperature of the liquid phase; ρ - the density of the liquid phase; Q - the volumetric flow rate of the liquid phase; ψ - the coefficient of phase slip; A - the area of the normal section of the flow.

The subscripts "2" and "kr" correspond to the flow parameters in section 2-2 and the critical section.
The critical state of the flow is described by the equation:

$$Y_{кр} = (\psi{\cdot}X_{кр})^2 (X_{кр}+1)/(\psi{\cdot}X_{кр}+1) \quad (8)$$

Solving together the system of equations (5) - (8), one can find the axial coordinate L_{kr} of the mixing jump and, consequently, the length of the working chamber.

CONCLUSIONS

Hydrodynamic cavitation has an undoubted advantage in comparison with acoustic cavitation, as it provides higher productivity in production scales with significantly lower energy inputs (Ashokkumar *et al.*, 2011, Gogate and Pandit, 2005).

In this work, the hydrodynamic cavitation device of the continuous principle of action is considered. Unlike traditional cavitation devices (Sawant *et.al.*, 2008; Ashokkumar *et al.*, 2011), the principle of operation of the proposed hydrodynamic device is based on a fundamentally new approach to the organization of the working process, namely, the cavitation effect on the flow is enhanced by the impact of a pressure jump in the transition of supersonic flow to subsonic flow. Initiation of the pressure jump in the flowing part of the device (the neck), which implements the impact effect on the flow, ensures the treatment of the latter at a qualitatively different, higher energy level. The developed mathematical model allows calculating longitudinal and transverse dimensions of hydrodynamic cavitation devices of continuous action with minimal energy consumption. The design of the hydrodynamic cavitation device was tested in industrial conditions, where it showed stable work on the creation of a high dispersion emulsion.

This method of cavitation effect on liquid can be used in technological processes of homogenization, dispersing and emulsification for obtaining higher quality food and biologically active solutions of extracts, fine emulsions and suspensions on an industrial scale. Compared with other methods of influencing food systems (Krasulya *et al.*, 2016; Jolhe *et al.*, 2017), this method allows not only intensifying the mixing processes, but implementing the process of disintegration of the food environment more profoundly.

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