Conditions for the formation of cavitation

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Based on analysis of information sources was found that dimensionless complexes - numbers of cavitation, Reynolds, Weber - are used to characterize the intensity of the development of cavitation phenomena. It was established the critical value of the Reynolds criterion (Reqr = 32,500) in the case of the treatment of the aqueous medium in a hydrodynamic jet cavitator, which will enable to regulate the intensity of the development of cavitation and to avoid its negative consequences.

Keywords – cavitation, simplexes of geometric similarity, number of cavitation, Reynolds number, hydrodynamic jet cavitator.

Introduction

Cavitation is an effective method of intensification of hydromechanical, thermal and mass transfer processes, in particular processes: purification and disinfection of water; disinfection and shelf life in the food industry; purification of diffusion juices and increase of reactivity of slurry lime milk in the sugar industry; reduction of viscosity of petroleum products; receiving nanomaterials, etc. At the same time, the concentration of energy released as a result of the cavitation bubble splashing in small local volumes of the fluid causes the erosion of the surfaces of materials, accompanied by noise, vibration and causes a decrease in the efficiency of the hydro aggregates. That is, it is possible as a useful application of cavitation (innovative cavitation technologies in the chemical and food industries), as well as the emergence of negative effects as a result of cavitation phenomena. Therefore, it is important to analyze the conditions for cavitation and parameters for assessing the intensity of cavitation phenomena.

Parameters of estimation of intensity of development of cavitation phenomena

In accordance with the traditional definitions, "cavitation" is the phenomenon of formation in the liquid of cavities (cavitation cavities, bubbles), which is conditioned by local pressure reduction to the values of pressure of saturated water vapor under the given conditions.

The condition for the formation of cavitation in a liquid is written as follows [1]

$$f\left(\frac{l_1}{l},\dots,\frac{l_n}{l},k,\mathrm{Re},\mathrm{We}\right)=0, \tag{1}$$

where l, l_1, l_2, …, l_n – linear values that determine the size, shape, location of the working body, the state of its surface, as well as the size of microbubbles and solid particles forming the "core of cavitation"; $\frac{l_1}{l},\dots,\frac{l_n}{l}$ – simplexes of geometric similarity; k, Re, We – numbers (dimensionless complexes) of cavitation, Reynolds, Weber.

The number of cavitation (k) is the ratio of the pressure difference to the dynamic head

$$k=\frac{2(P-P_{нас})}{\rho w^2}, \tag{2}$$

where P – pressure in free flow, Pa; $P_{нас}$ – pressure of saturated water vapor at a certain ambient temperature, Pa; ρ – density of medium, kg/m^3; w – flow rate of liquid, m/s. It characterizes the distribution of cavitation bubbles in technological volume. Depending on the value of k, four types of streams are distinguished: 1) pre-cavitation (k> 1) - continuous (single-phase) flow; 2) cavitation (k≈1) - two-phase flow; 3) film (k <1) - a clear separation of the cavitation cavity from the continuous flow; 4) supercavitational (k << 1). In the case of supercavitation, noise and vibration significantly weaken, and erosion on the local support is practically absent.

The Reynolds and Weber numbers are similarity criteria of hydrodynamic processes that determine the ratio of inertia forces of a fluid to viscosity forces or surface tension, respectively:

$$Re = \frac{\rho w l}{\eta}, \tag{3}$$

$$We = \frac{\rho w^2 l}{\sigma}, \tag{4}$$

where η – coefficient of dynamic viscosity of the medium, Pa•s; σ – coefficient of surface tension, N/m. Often, for the characterization of the intensity of cavitation, a set of two dimensionless complexes - numbers of cavitation and Reynolds - are used. Cavitation occurs if $Re > Re_{кр}$ ($Re_{кр}$ is the threshold value of the Reynolds number).

For studies aimed at establishing parameters that correspond to the occurrence of cavitation, a hydrodynamic cavitator of the jet type (HCJT) with a system of profiled nozzles was used. The pressure at the entrance to the cavitator in the range 0,36 ... 0,60 MPa was changed by bypass [2]. Output water temperature is 291 ± 3 K. It was found that for cavitation numbers close to 1, $Re_{кр}$ = 32 500. In this case, the critical pressure value is 0.47 MPa. A photo of the cavitation area in the HCJT is shown in Fig.

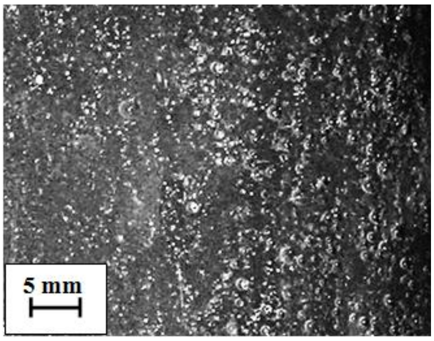

Fig. Photo of the cavitation area in the HCJT

Conclusions

Establishing the critical value of the Reynolds criterion will allow to regulate the intensity of the development of cavitation and minimize its negative consequences.

References

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