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Simulation Model and Characteristics of the Cavitation Mixer with Hydrodynamic Grid

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Abstract

A promising method for obtaining homogeneous and high-dispersion emulsion is to create mixers with cavitation treatment of the mixed stream. The present research examines the hydrodynamic constant-flow mixer with a grid made of smooth cylinders as the agitator of cavitation. The authors offer a simulation model of a mixer based on hydrodynamic equations and experimental data of cavitation phenomena in the vortex wake of a cylinder. There has been considered and analyzed the characteristic of the cavitation mixer, which shows the relationship between relative loss of the total stream pressure, the grid geometrical parameter, the Reynolds number, and coefficients of hydraulic resistance of flow-part elements. It is shown that for every Reynolds number and a set of resistance coefficients there is optimum value of a grid geometrical parameter when losses of total pressure are minimum. The experimental characteristic of the mixer which shows correlation between minimum relative stream pressure loss and grid geometrical parameter is revealed. A simulation model and characteristics allow one to develop a hydrodynamic mixer with a minimum power consumption.

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Keywords: emulsion; cavitation; mixer; hydrodynamic grid; simulation model; characteristic; head losses.

1. Introduction

In many cases, cavitation causes damage to equipment (cavitation erosion, vibration, pulsation), reduces the machine performance sharply. Many studies [1-5] are focused on cavitation wear (erosion) of the flow part elements of hydraulic units and deterioration of their energy characteristics. This research aims at identifying destructive

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effect of cavitation via material removal by erosion; determination of operational conditions under which erosion reaches its maximum; development of measures to ensure cavitation-free work of hydraulic units. These studies can become the basis for the advancement of new technologies, where cavitation is a useful phenomenon, and its use is beneficial to the intensification of technological processes in various industries [6-9].

Mixing devices and systems based on them are widely used in many industrial sectors which respond to the need for such technological operations as mixing, dispersing, heat and mass transfer processes. The main direction of improvement of such devices is to increase the degree of dispersion of emulsions and suspensions. The literature review shows that one of the most promising ways to improve operating conditions of mixers and to increase dispersion degree of mixture is to use hydrodynamic cavitation. Information search revealed that a conventional agitator for hydrodynamic cavitation is either a multi-jet nozzle, and in this respect cavitation is generated in the jet boundary layer; or hydrodynamic grid made of bluff bodies. Hydrodynamic cavitation in the jet boundary layer is considered in the following works [10-12].

The goal of this work was to develop the theory of cavitation phenomena of high-velocity jets and to design an effective hydrodynamic mixer with minimum power consumption. While achieving this goal the following tasks were solved: to propose a scheme of a cavitation mixer; to develop its simulation model for obtaining a highly dispersed mixture; to determine characteristics of the mixer related to generation of intense cavitation and minimum head loss.

2. Design scheme of a cavitation mixer with hydrodynamic lattice in the form of a cylinder

Operating conditions of a cavitation mixer are based on the phenomena that occur during simultaneous flow of liquid and vapor-gas phases. Formation of a high-speed two-phase flow is organized by cavitators that provide local pressure drop reduced to saturated vapor pressure. In this case it is feasible for the operating conditions of a cavitation mixer to comprise the following stages: pre-acceleration of the flow; hydrodynamic grid wrap behind which the vortex wake with areas of cavitation is formed; formation of two-phase turbulent flow; dispersion of the mixture; transformation of excess kinetic energy of the flow to potential energy for further transportation of the mixture to the user.

Schematic diagram of the mixer is shown in Fig. 1. The basic elements of the mixer are: a confuser 1, a hydrodynamic grid 2 made of right cylinders, a mixing chamber 3, a diffuser 4. Confuser 1 pre-accelerates the flow of the mixture, which is supplied to the hydrodynamic grid 2 located in the mixing chamber 3. In the grid the mixture flow accelerates to reach critical velocity when the pressure in the vortex wake of a cylinder is reduced to saturated vapor pressure. Meanwhile, cavitation is initiated in the vortex wake, which results in formation of a turbulent vapor-gas-liquid flow. Then, in the mixing chamber a turbulent vapor-gas-liquid flow becomes laminar in mixing shock. The diffuser 4 reduces the rate of high-dispersion emulsion to the velocity appropriate for its movement by pipeline.

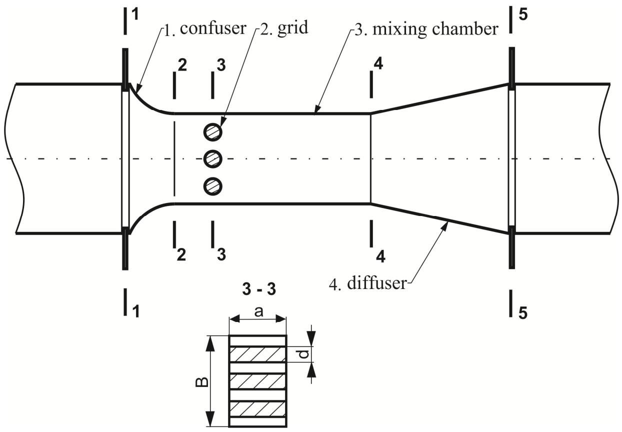

Fig. 1. Schematic diagram of the cavitation mixer with hydrodynamic grid