Секция IV

АППАРАТНОЕ ОФОРМЛЕНИЕ ПРОЦЕССОВ. СОВРЕМЕННОЕ ОБОРУДОВАНИЕ И АВТОМАТИЗАЦИЯ, ПУТИ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ХИМИЧЕСКИХ ПРОИЗВОДСТВ. ЦИФРОВЫЕ ТЕХНОЛОГИИ И ПРОЕКТИРОВАНИЕ. ПЕРСПЕКТИВЫ ВНЕДРЕНИЯ СИСТЕМ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА

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IMPROVEMENT OF THE DESIGN OF A HYDRODYNAMIC CAVITATOR FOR LIQUIDS HOMOGENIZATION

Producing liquid-dispersed media is a key stage in various technological processes in chemical and related industries (petrochemical, pharmaceutical, paint, food, etc.) [1]. In some technologies, hydrodynamic processing is relatively long, energy-intensive, and requires intensification. Reducing the energy and material consumption of equipment while achieving the required efficiency can be achieved by using unconventional technologies based on various physical phenomena. Special importance is given to the use of cavitation, as one of the simplest and most accessible methods of hydrodynamic material processing.

A significant effect can be achieved by using the phenomenon of supercavitation, i.e., the creation of cavitation cavities (supercaverns) that close beyond the working bodies without their cavitation destruction. The main cavitational destructive effect is due to the field of collapsing cavitation bubbles, generated mainly beyond the supercavern. Their micro-explosions, with local pressure changes in the liquid flow, lead to the destruction of particles of the processed material falling into the area of these micro-explosions. At the same time, the specific energy consumption can be significantly lower compared to traditionally well-established equipment (disk and conical mills, finger grinders, rotary-pulsating apparatuses).

Previously, we experimentally studied some designs of static supercavitating devices (SC devices) as relatively simple and effective for a number of technological processes, one of which is the homogenization of liquids. In addition, they can also be successfully used in combination with other devices (agitator devices, dynamic, jet, ultrasonic dispersers, etc.).

A water-oil emulsion was chosen as the basic model medium, due to its availability and prevalence. Such emulsions are used as lubricating and cooling technical means (LCTM), working fluids in hydraulic drives, are used in pharmaceuticals, cosmetology, etc. Depending on the properties and purpose, two types of emulsions are used: direct – O/W, when the oil (dispersed phase) is crushed in the form of separate small droplets in water (dispersion phase) and reverse – W/O. As a result of earlier experimental studies, semi-stable direct emulsions of various concentrations were obtained without the use of emulsifiers (Figure 1). Moreover, a static SC device was used, which was later taken as the basic version for computer modeling [2].

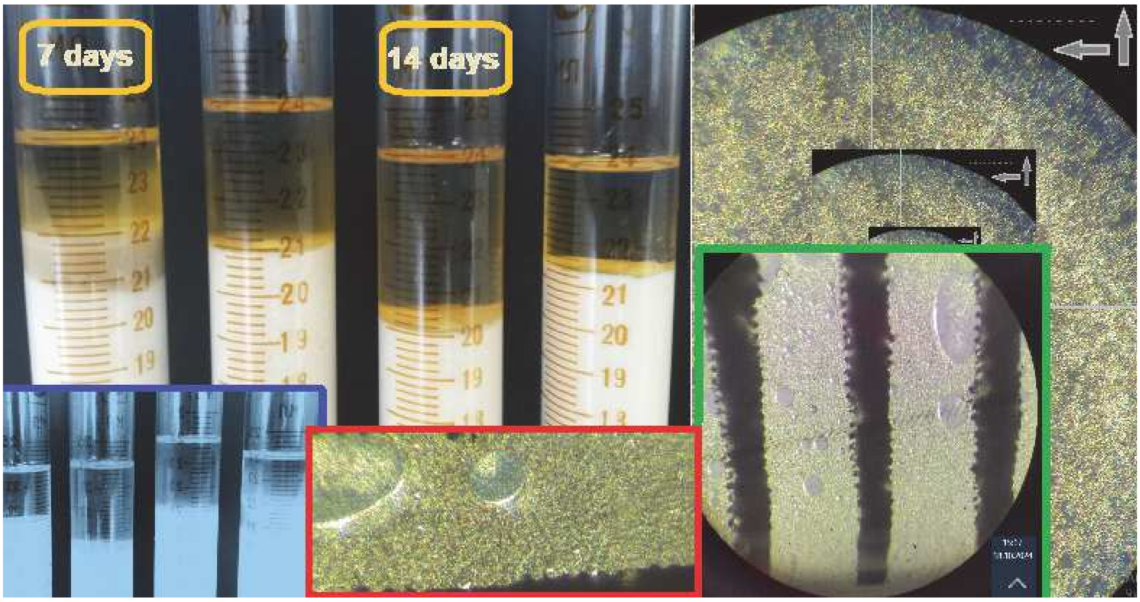

Figure 1 – Results of experiments

The simulation was conducted in the "Flow Simulation" module of the well-known CAD system "SOLIDWORKS" for hydrodynamics modeling, where the finite volume method is applied, using the physical interpretation of the studied quantities as its formulation.

As a similarity criterion in cavitation flow studies, it is customary to use the cavitation number X, as the main cavitation parameter that allows explaining numerous and diverse characteristics of the cavitation phenomenon. In essence, the cavitation number represents the ratio of the pressure under which the cavity collapses to the pressure under which the cavity forms and grows. Depending on the value of X, five types of flows can be distinguished: from pre-cavitation continuous when $X > 1{,}05$ to supercavitation when $X < 0{,}5$.

Thus, the hydrodynamics of cavitation flows were simulated by varying different parameters (pressure, speed, temperature) with the improvement of the static cavitation emulsifier design to reduce the cavitation number. Subsequently, the dependencies of the cavitation number on fluid velocity, temperature, and Reynolds number were constructed, yielding the following results.

The basic version of the cavitation unit resembled a Venturi nozzle with a conical fairing placed on the rod in the diffuser. This is a well-known SC device design, which we have previously studied both experimentally and theoretically for various technologies [1, 2]. Despite its sufficient efficiency, the main drawback of this design is the high hydraulic resistance (50 kPa and more, depending on flow blockage).

To obtain the emulsion, the rod with the fairing is proposed to be made hollow, with the dispersed phase (oil) supplied into it. The results of computer modeling showed that the supercavitation mode starts at a liquid temperature above 60°C and a speed in the narrow section of the nozzle above 13 m/s.

To intensify the process and reduce hydraulic resistance, a design of the cavitation emulsifier with a hollow fairing and additional flow swirling is proposed. Swirled flows are characterized by a larger velocity gradient across the channel section, and a cavity almost always forms behind the swirlers.

Since the intensity of the destructive impact increases, the emulsification process can be carried out at lower liquid velocities, leading to reduced hydraulic resistance. The dispersed phase, moving at a certain speed, hits the blades of the swirler, where the flow is swirled. The swirled flow passes through the nozzle, increasing its speed due to the central constriction. The main component flows around the fairing at high speed, creating a low-pressure area, behind which a supercavern with a field of collapsing cavitation bubbles forms. As the fairing is hollow, there is continuous suction of the dispersed phase. The two liquids mix and disperse intensively, undergoing cavitation to form an emulsion.

The computer models showed that the supercavitation mode sets in much earlier, becoming stable at 20°C with an initial in pipeline speed of 5 m/s. Additional flow swirling, intensifying the process, and reducing hydraulic resistance can be achieved by tangentially introducing the dispersed phase into the main pipeline. The dispersed phase is also introduced into the flow through the hollow fairing. Hydrodynamic modeling of this cavitation emulsifier design demonstrated that the supercavitation mode occurs at a flow speed of 4 m/s.

Having gained some experience in computer modeling of static cavitation emulsifiers, it is planned to continue research in this direction, expanding the range of tasks to improve the design of such equipment.

REFERENCES

1. Petrov, O. A. Cavitation Technologies in Industry. Directions of Use / O.A. Petrov, V.S. Franckevich, V.I. Kozlovskiy // Petrochemical Complex. Scientific and Technical Bulletin. Supplement to the journal "Vestnik Belneftekhima". – 2018. – No. 1(17). – Pp. 5–8.

2. Petrov, O.A. Development of a Static Supercavitator with Minimal Cavitation Erosion / O.A. Petrov, V.I. Kozlovskiy, D.N. Borovskiy // Oil and Gas Chemistry – 2022: Proceedings of the V International Scientific and Technical Forum on Chemical Technologies and Oil and Gas Processing, Minsk, November 2-4, 2022. – Minsk: BSTU, 2022. – Pp. 238-242.

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АНАЛИЗ ТЕХНОЛОГИЧЕСКИХ ПАРАМЕТРОВ ЦЕНТРОБЕЖНО-УДАРНОЙ МЕЛЬНИЦЫ ДЛЯ ИЗМЕЛЬЧЕНИЯ ПОЛИМЕРНЫХ МАТЕРИАЛОВ В ПРОИЗВОДСТВЕ RDF-ТОПЛИВА

В настоящее время наблюдается тенденция роста потребления энергии в мире, характеризующаяся стремительным ростом глобального спроса. Согласно отчёту Международного энергетического агентства (МЭА), мировой спрос на энергоносители за 2022 год вырос на 1.2%, за 2023 – на 2.3%. Предполагается, что в 2024 году мировое потребление электроэнергии может вырасти на 4% и таким образом превысить отметку 29 трлн кВт·ч [1].

В настоящее время разрабатываются стандарты и технологии по получению альтернативных видов топлива. Одним из быстроразвивающихся видов альтернативного топлива является RDF-топливо. Данный вид топлива решает проблемы с постоянно увеличивающимся количеством отходов и с ростом потребляемой энергии. Наличие в RDF-топливе полимерных материалов ставит задачу по их измельчению.

На рисунке 1 представлен измельчительный комплекс, в основе которого стоит центробежно-ударная мельница с гибкими элементами.

Измельчение исходного материала происходит за счёт соударения с гибким элементом, закреплённым на вращающемся роторе. За счёт высокой скорости вращения гибкого элемента при соударении с кусками исходного материала и гибкого элемента происходит разрыв связей