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THE USE OF GAS-LIQUID APPARATUSES IN INDUSTRY

B. K. Leont'ev, O. N. Korableva, E. A. Girba

Leont'ev V. K., Candidate of Technical Sciences, Associate Professor; Korableva O. N., Candidate of Chemical Sciences, Associate Professor; Girba E. A., Candidate of Technical Sciences, Associate Professor
Institute of Chemistry and Chemical Technology, Yaroslavl State Technical University, Moskovsky ave., 88, Yaroslavl, Russian Federation, 150023
E-mail: leontievvk@ystu.ru; korablevaon@yandex.ru; girbaea@ystu.ru

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We consider different designs of gas-liquid apparatuses in which the gas-liquid system receives a kinetic energy reserve via a stirrer or one of the contacting phases. We present some of the most typical ejection gas dispersant designs and analyze their efficiency.

Introduction

Sustainable production technologies of chemical, petrochemical, microbiological and other industries are closely related to the increasing efficiency of heat and mass transfer and intensification of the mixing process. The apparatuses design determines the efficiency and specific capacity of the machinery and depends on the way of energy injection into the medium and its distributing in the displacement [1-3]. Gas injected apparatuses, i.e., with mechanical energy input, are very common. These apparatuses should provide high gas charges per unit area of cross section of the apparatus. Also, they should have high specific surface area, simple design, manufacturability, serviceability, quick regulation of process flow rate [4, 5].

Study

High degree of dispersion while varying the raw material flow rate is providing by high efficiency of gas-liquid apparatuses [6].

Studies of the hydrodynamics of two-phase flow in gas-liquid apparatuses have shown that the pressure of the gas flow is the pacing factor of turbulence. The main hydrodynamic characteristic of the two-phase flow is the gas content [7, 8].

There are large varieties of turbulent gas-liquid apparatuses. The gas-liquid contact is implemented and the mixture is provided with a certain amount of kinetic energy by the mixer or one of the contacting phases [9, 10].

Fig. 1 shows some types of apparatuses belonging to this class.

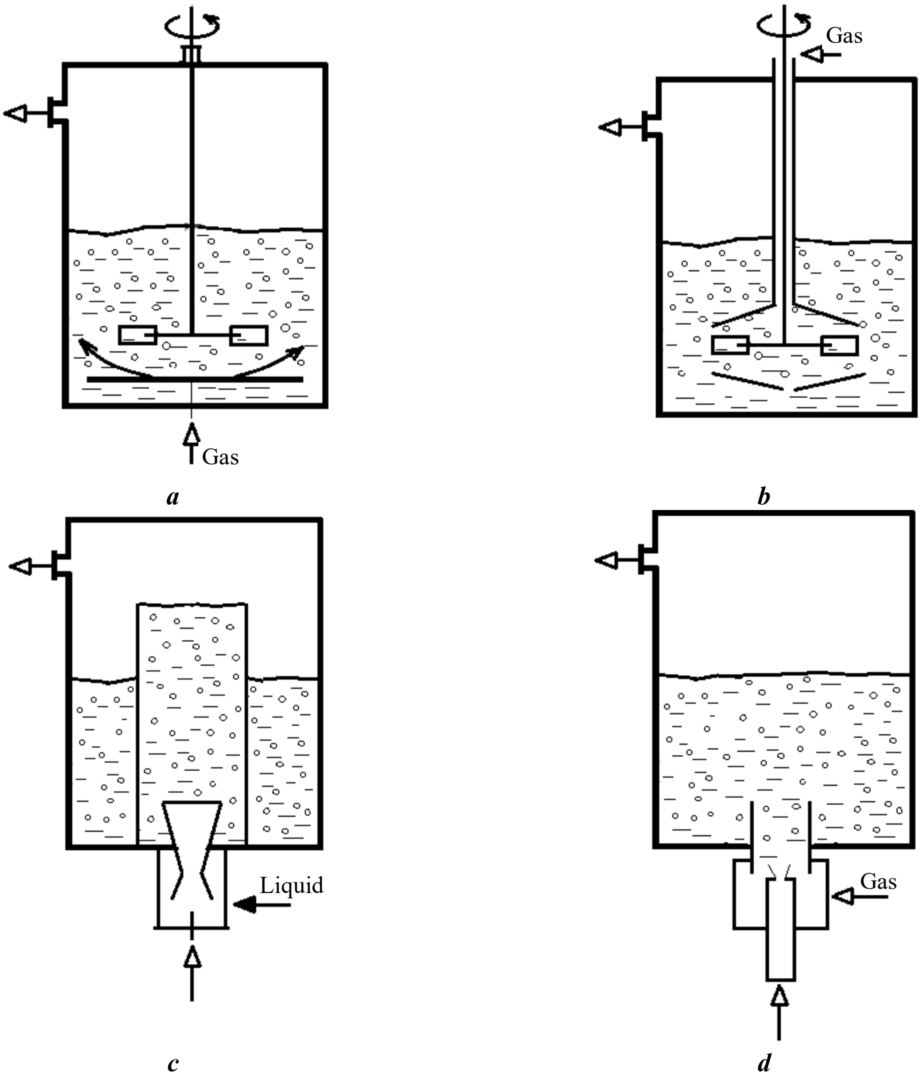

Fig. 1. Gas-liquid apparatuses with various dispersers:
a - open type turbine disperser; *b* - close type self-priming turbine dispersers; *c* - injecting and dispersing gas through the nozzle; *d* - hydrodynamic stirrer

Fig. 1, *a* shows an apparatus with an open turbine disperser. The gas is injected through a gas spray. By large shear gradient in the liquid layers, these apparatuses are more efficient in terms of creating a specific phase contact surface. They provide a higher gas flow rate per unit cross-sectional area ($q_{г} > 0.03$ m^3/m^{2}s) than apparatuses with other types of dispersers.

The main disadvantage of hollow tube type self-priming dispersers (Fig. 1, *b*) is the small injection ratio, which causes a low specific gas flow rate.

Fig. 1, *c* shows an apparatus diagram, gas-liquid dispersion is provided by an injector. The energy supplier is the gas, entering into the nozzle. The resulting gas-liquid mixture is routed into a cylinder where a foam layer is formed. This type of apparatus does not provide a large injection coefficient.

The use of liquid-gas injector, in which the energy carrier is a liquid flowing in the form of a jet from the nozzle, injecting gas (Fig. 1, *d*), provides a high mass transfer capacity and phase contact surface.

The typical gas-liquid apparatus designs analysis allowed to develop a more efficient gas-liquid apparatus with injected gas dispersion. The main advantages of the apparatus are: 1) high specific contact surface of the phases, 2) high specific flow rate of the gas flow, 3) the absence of dead areas, 4) simple design, 5) manufacturability, 6) ease of repair, 7) the possibility of rapid regulation of the process flow rate, 8) providing the necessary temperature conditions of the technological process.

Various theoretical and experimental studies of hydrodynamics and mass transfer allow developing a wide range of designs apparatuses of this type. Fig. 2 shows the most typical ejection gas dispersant designs [11].

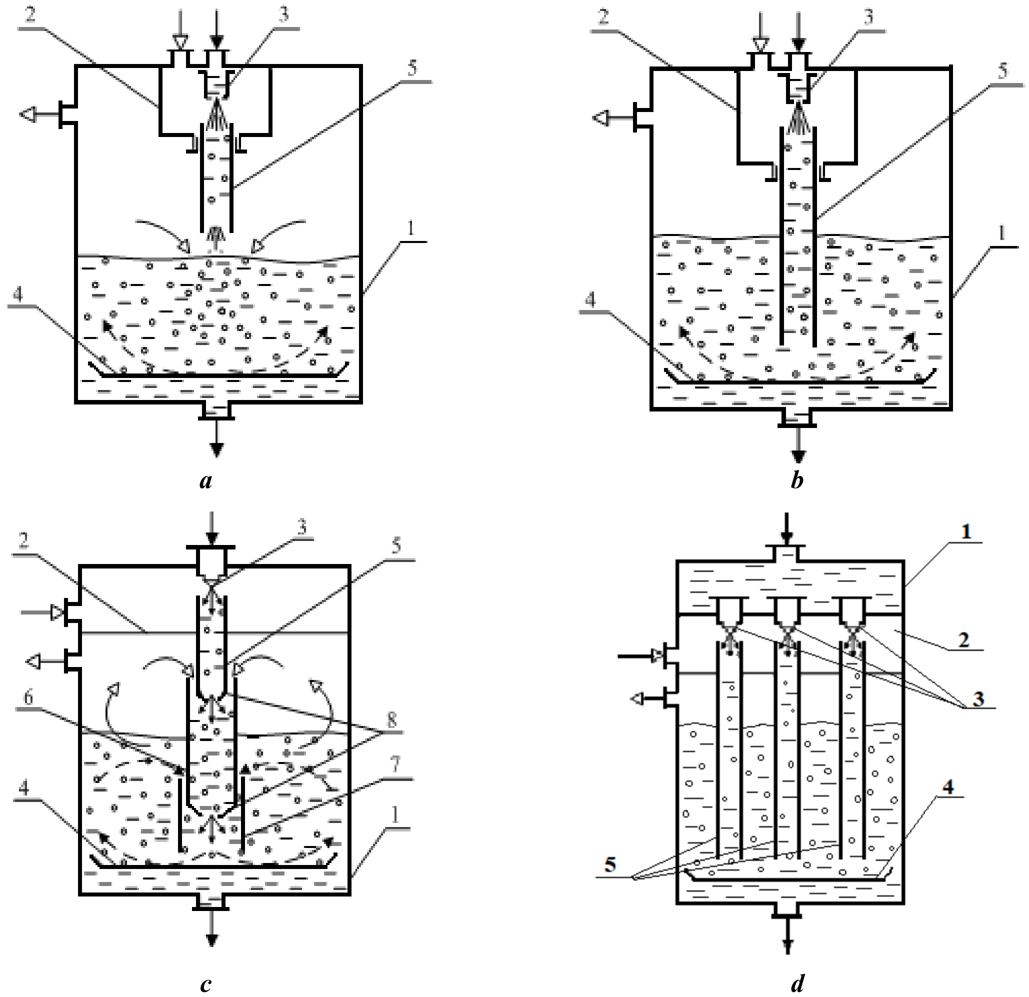

Fig. 2. Gas-liquid ejection apparatuses designs:
a - gas-liquid ejector with short ejector; *b* - gas-liquid ejector with long ejector; *c* - gas-liquid ejector with tiered ejector; *d* - multi-nozzle gas-liquid ejector;
1- cylinder; 2 - ejection chamber; 3 - liquid sprayer (flow nozzle); 4 - dispersant; 5, 6, 7 - ejectors-mixers; 8 - nozzles

The presented designs of gas-liquid-driven apparatuses use alternating change in the shape and direction of the flow, flow impact against solid countermeasure barriers, twisting, reciprocal ejection and phase injection, pulsation, effective liquid spraying for intensifying heat-exchange and mass-exchange processes.

The units work as follows: a pressurized liquid is fed into a nozzle, atomized and drawn into the induction chamber. The resulting gas-liquid mixture flows through the ejector mixer. The liquid-gas contact occurs with the surface of the atomized liquid. Depending on the ejector operating mode, its geometric parameters and the pressure drop across the nozzle, a gas-liquid two-phase flow with different liquid to gas ratios can be generated in the ejector. The two-phase flow can be as dispersed liquid or gas phase. By proper conditions, a phase inversion can occur. This mode is the most effective because the mass transfer coefficient is highest at the moment of inversion. Leaving the ejector, the gas-liquid flow strikes the disperser. When the gas-liquid flow hits the disperser, the gas bubbles are crushed and the next stage of gas-liquid contact occurs. The mixture is then distributed according to the apparatus reaction volume where another stage of contact of the gas-liquid contact takes place.

The characteristics of the presented designs.

The gas-liquid jet and short ejector apparatus (Fig. 2, *a*) has a gas-liquid jet that additionally captures gas from the reaction volume space, increasing the gas content of the apparatus.

The tiered ejector apparatus (Fig. 2, *c*) generates significant shear rates and multiple gas-liquid contact in the ejector-mixer.

The multi-nozzle apparatus occupies a special place among gas-liquid ejectors (Fig. 2, *d*). By the results of the experiments the efficiency of these units is 15-20% higher than that of a gas-liquid ejector with a long ejector (Fig. 2, *b*).

The chemical method based on determining the effective phase contact surface, i.e., the interfacial surface actually involved in the mass exchange process, is one of the most accurate way of assessing the efficiency of gas-liquid apparatus [11]. This method is based on the chemosorption of oxygen from air and identification of the "sulphite number". This allows us to determine the process speed.

Conclusions

By the results of the experiments the apparatus with a gas-liquid jet and a short ejector provides a higher (by 6-8%) mass transfer coefficient than the traditional apparatus with a long ejector. The gas-liquid apparatus with the multi-tier ejector has a complex design, but the "sulphite numbers" are considerably higher than the other apparatuses - by more than 15%, which allows us significantly intensificate the heat and mass transfer process. The multi-nozzle gas - liquid ejector has higher (by 15-20%) "sulphite numbers".

References

1. **Leont'ev V.K., Barasheva M.A**. Calculation of a gas-liquid ejection device for carrying out the absorption process. *Izvestiya vuzov. Khimiya i khimicheskaya tekhnologiya*. 2012. V. 55. N 12. P. 98-100 (in Russian).
2. **Basargin B.N., Galickij I.V., Gushchin Yu.I.** Mass transfer and heat exchange processes of chemical technology. *Sb. nauch. tr. Yarosl. politekhn. in-ta*. 1975. P. 39–44 (in Russian).
3. **Kan N.S., Nurgazizova T.T., Korableva O.N., Leont'ev V.K**. About the contact surface of the phases in the mixer of the gas-liquid ejection apparatus. *74 Vserossijskaya nauchno-tekhnicheskaya konferenciya studentov, magistrantov i aspirantov vysshih uchebnyh zavedenij s mezhdunarodnym uchastiem: sbornik materialov konferencii*. 2021. V. 1. P. 171-174 (in Russian).
4. **Ul'yanov B.A., Badenikov V.Ya., Likuchev V.G.** *Processes and apparatuses of chemical technology*. Angarsk: AGTA, 2005. 903 p. (in Russian).
5. **Frolov V.F.** *Lectures on the course "Processes and apparatuses of chemical technology"*. SPb.: Khimizdat, 2003. 608 p. (in Russian).
6. Patent RF N 2176929. Gas-liquid reactor / F.Sh. Hafizov, N.F. Hafizov, V.S. Andreev, V.A. Zyazin, YU.G. Moroshkin, I.F. Hafizov. 20.12.2001, Bul. N 35 (in Russian).

7. **Lepeshinskij I.L., Istomin E.L., Zarankevich I.L., Reshetnikov V.L.** Mixing device of an open-type bubble structure *Izvestiya vuzov. Aviatsionnaya tekhnika*. 2016. N 3. P. 71-75 (in Russian).
8. **Leont'ev V.K., Korableva O.N**. Calculation of the aeration energy of the working volume in gas-liquid ejection apparatuses. *Chemical and Petroleum Engineering.* 2021. N 4. P. 48 (in Russian).
9. Pat. RF № 167023 Apparatus for gas-liquid contact / V.K. Leont'ev, O.N. Korableva, O.V. Smirnova, I.A. Nevzorov, T.V. Pogodina. 20.12.2016, Bul. N 35 (in Russian).
10. Pat. RF № 152989 Apparatus for gas-liquid contact with a combined nozzle element / V.K. Leont'ev, O.N. Korableva. 27.06.2015, Bul. N 18 (in Russian).
11. **Leont'ev V.K., Korableva O.N**. Razrabotka konstrukcij gazozhidkostnyh ezhekcionnyh apparatov. *Chemical and Petroleum Engineering.* 2016. N 3. P. 8-10 (in Russian).

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