SAT-CR-P-2-CT(R)-14

LIQUID JET GAS EJECTORS: DESIGNS OF MOTIVE NOZZLES, PERFORMANCE EFFICIENCY

Assoc. Prof. Vitaly Ponomarenko, PhD
Department of Technological Equipment and Computer Technology Design
Educational-Scientific Engineering-Technical Institute named after Acad. I. S. Huly,
National University of Food Technologies, Kyiv, Ukraine
E-mail: vponomarenkov@ukr.net

Assoc. Prof. Tsvetan Dimitrov PhD
Department of Chemistry and Chemical Technologies,
University of Ruse "Angel Kanchev", Branch Razgrad
E-mail: tz_dimitrow@abv.bg

Postgraduate. Andrii Sliusenko
Department of Technological Equipment and Computer Technology Design
National University of Food Technologies, Kyiv, Ukraine
E-mail: andriy_slyusenko@ukr.net

Assoc. Prof. Dmytro Liulka, PhD
Department of Technological Equipment and Computer Technology Design
Educational-Scientific Engineering-Technical Institute named after Acad. I. S. Huly,
National University of Food Technologies, Kyiv, Ukraine
E-mail: lulkadm@ukr.net

Assoc. Prof. Inna Forostiuk, PhD
Department of Foreign Languages for Professional Purposes
Faculty of Hotel-Restaurant and Tourism Business
National University of Food Technologies, Kyiv, Ukraine
E-mail: ingaborge@ukr.net

Abstract: *Liquid jet gas ejectors are widely used to provide a variety of technological processes due to constructive simplicity, high intensity of the processes, and capability for installation in any location.*

However, the drawback of this equipment is a low efficiency coefficient which does not exceed 40%.

Taking into account the fact that jet apparatus design is a simple one, the role of each element and its set-down has a great impact. One of the ways to increase efficiency of this equipment is the choice of the motive nozzle's type. Known scientific data related to such a choice are very disputable and need further elaboration.

The purpose of this research is to study the work of ejectors with different types of the nozzles: jet nozzles, centrifugal-jet nozzles on the basis of injectors with the central insert and axial blind hole, as well as universal pulverizing jet with the inclined inlet channels. The pulverizing jet works in the range of centrifugal to jet streaming depending on the height of the open channel.

Conducted researches of the ejectors with the specified types of the active jets demonstrated a significant impact of the used jets on efficiency coefficient of the jet apparatus.

Keywords: *ejector, motive nozzle, ejection coefficient, efficiency*

INTRODUCTION

The widespread use of liquid jet gas ejectors in various branches of industry is determined by their constructive simplicity at high intensity of the exchange processes, possibility for installation in any position of the working area.

A significant drawback of this equipment is the low efficiency coefficient. Therefore, research aimed at improving their performance is being actively conducted around the world.

Since the jet apparatus design is quite simple, the role of each element and their relative position is extremely important. It should also be noted that the operation of the jet apparatus depends on the hydrodynamic regime of the flow of the working medium (liquid): if the working nozzle is designed in such a way that for supersonic flow mode it leads to a significant improvement in the efficiency of the ejector, then at subsonic speeds the operation of such an ejector deteriorates.

One of the main elements of the jet apparatus is a motive nozzle, which in the classical ejector is made in the form of a jet nozzle. The jet of fluid flowing from such a nozzle is compact, has a small torch opening angle, splits into droplets at a considerable distance from the nozzle (Ponomarenko, V., & Pushanko, N., 2015)

To improve the performance indicator of the ejector with such a motive nozzle, it is proposed (Filipovich, Yu. Yu., 2001) to perform it with an internal threaded spiral section. As the liquid passes through this sector, it acquires a rotational motion, which leads to an increase in its kinetic energy, and therefore increases the ejection capacity.

The paper (Spiridonov, E. K., 2005) presents data of studies of the effect of the nozzle openings number and their location on the characteristics of the nozzle pump. It is established that from a number of investigated ways of placement of nozzles in a disk (on concentric squares, circles, hexagons), the placement of holes on concentric hexagons and one hole inside was the most efficient.

In addition to the classic nozzle, a nozzle in which the jet of fluid is swirled was also studied (Cramers, P.H.M.R. & Beenackers, A.A.C.M., 2001), which allowed to increase the pressure drop across the gas phase. Similar results were obtained while investigating the operation of the ejector with different fluid jets: cylindrical swirling, cylindrical not swirling and conical (Tsegelsky, V. G., 2003).

The paper (Yang, X., Long, X., & Yao, X., 2012) analyzes the effect of nozzles shape (conical, elliptical, square, rectangular, and cruciform), which are used to spray the working medium, on the performance of the ejector. It is established that when comparing the work of ejectors with rectangular and elliptical nozzles with the operation of the ejector with a conical nozzle, taken as the base, the ejection coefficient is lower by 7.1… 7.9%. While investigating the square and cruciform nozzle ejector, the ejection ratio increases by 2.0 to 9.1%, which is explained by the increase in vortices due to improved mixing and phase capture.

Numerical research of influence (Yinhai Zhu, Wenjian Cai, Changyun Wen & Yanzhong Li, 2009) of ejectors geometric parameters (position of the outlet nozzle of the active medium and the angle of the diffuser of the mixing chamber) on their performance showed dependence of the characteristics of the ejector on rational design dimensions.

An important condition for efficient operation of the jet apparatus is the reduction of backpressure, which is possible when installing behind the ejector a vertical drain pipe in which there is a column of liquid-gas mixture with a density less than the density of the liquid (Yatsenko, A. F. & Ustimenko, T. A., 2012, Spiridonov, E. K. & Ismagilov, A. R., 2012).

The submitted results of the experimental research of the ejectors operation prove the complex relationship of size, relative position, design features of the execution of individual elements of the ejector with the obtained final result. There is ambiguity in the results obtained. For example, the use of an ejector with a nozzle-swirler in one case leads to an increase in the coefficient of ejection, and in another - there is a decrease in efficiency. Such data require verification and theoretical explanation.

EXPOSITION

Ejectors in the food industry are used for various purposes, according to which they should be designed. When using jet apparatus for heat and mass exchange processes, in addition to a large contact surface, a sufficient amount of the gas phase with the active component is also required. Bringing it into the exchange zone should be provided by the ejection apparatus itself.

It is especially important to achieve the maximum ejection ratio when using jet technology for utilization of the large volumes heat of flue gas at a refinery and for absorption purification of industrial waste. The exchange processes in the jet apparatus occur at high intensity in a short phase contact time (Billerbeck, G. M., Condoret, J. S., & Fonade, C., 1999).

To establish the rational design of the motive nozzle which achieves the highest coefficient of ejection, comparative field studies of jet apparatus with cylindrical mixing chamber and different types of motive nozzles were carried out (Fig. 1).

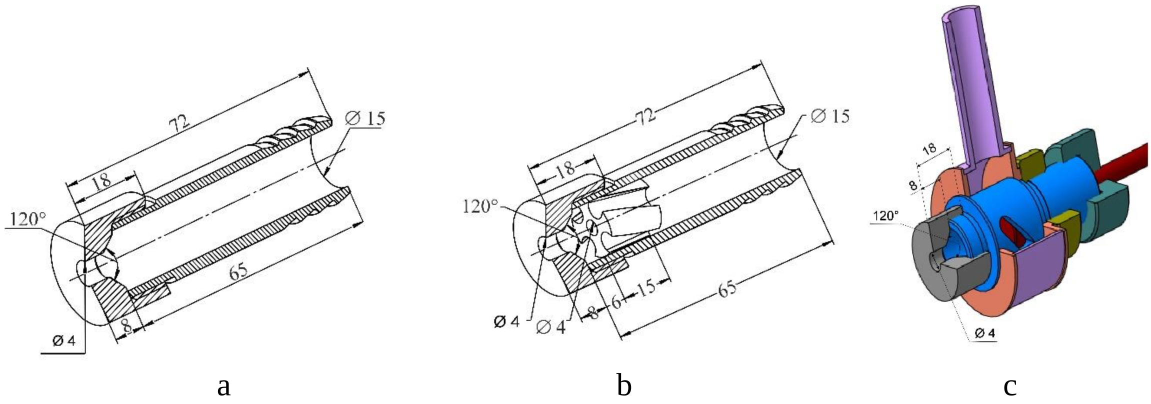

Fig.1. Motive nozzles: a - jet nozzle, b - centrifugal-jet nozzle with the central insert, c - universal nozzle with inclined inlet channels and adjustability

These nozzles were selected for research for the following reasons:

- jet nozzle is a motive nozzle of a classic jet apparatus;

- centrifugal-jet nozzle with central insert is especially effective in the case when heat and mass transfer processes occur in the jet apparatus. Comparative studies on the effectiveness of ejectors with such working nozzles are not enough;

- universal nozzle with inclined inlet channels as a motive nozzle for jet apparatus was not used. Its advantage is the ability to quickly regulate the flow of fluid, which is especially important for variable flows. The proposed nozzle allows maintaining the optimum pressure of the liquid at which it is dispersed. The design and description of the nozzle is given in the paper (Ponomarenko, V., & Pushanko, N., 2015). Stabilization of the nozzle allows achieving the constant coefficient of ejection of the jet apparatus.

Investigation of the jet apparatus with the proposed nozzles was carried out at a laboratory unit, which included a pump unit, an ejector, a system of pipelines with regulating valves and equipped with control and measuring facilities: fluid flow was measured by a rotary flow meter with an accuracy class of 1.5; the fluid pressure on the nozzle was controlled by a pressure gauge of accuracy class 1.5; gas consumption was measured by a volume type meter; the dilution in the mixing chamber was measured with a differential pressure gauge in mm. of water. col.; photographing the fluid flow in the mixing chamber was carried out with a digital camera.

The ejector with a cylindrical mixing chamber with a diameter of 19 mm and the specified types of sprayers with an outlet nozzle with a diameter of 4 mm in the range of fluid pressures at the inlet of the spray 0.005… 0.25 MPa was investigated. According to our studies, these dimensions are optimal in terms of achieving the maximum ejection coefficient (geometric characteristic of the ejector: $m = F / f = 22{,}56$, where F is the area of the mixing chamber of the ejector, f is the area of the motive nozzle).

Fig. 2 presents a graph of the dependence of the ejection coefficient on the pressure of fluid flow to the motive nozzle of the ejector for different types of nozzles. As follows from the graph, for the ejector with a geometric characteristic of 22.56 when used as an active nozzle of the jet nozzle, the lowest ejection coefficient, which reaches a numerical value of 1.8 at a fluid pressure P = 0.25 MPa, is obtained. The flow interaction occurs only on the outside of the spray torch.

A relatively small discrepancy between the volumetric ratio of the ejection is achieved when used as an active nozzle with a centrifugal-jet nozzle with a central insert as well as a nozzle with two inclined inlet channels, which are 1/2 open, that corresponds to the flow regime of the centrifugal jet nozzle. The angle of the spray torch is greater than 40 °, the droplets of liquid interact with the gas phase by a much larger surface, which clearly leads to an increase in the ejecting capacity of the jet apparatus. However, the impact of liquid droplets on the solid wall of the mixing chamber causes the return of fluid flows, especially in its lower part, the kinetic energy of the translational motion of the active stream decreases.

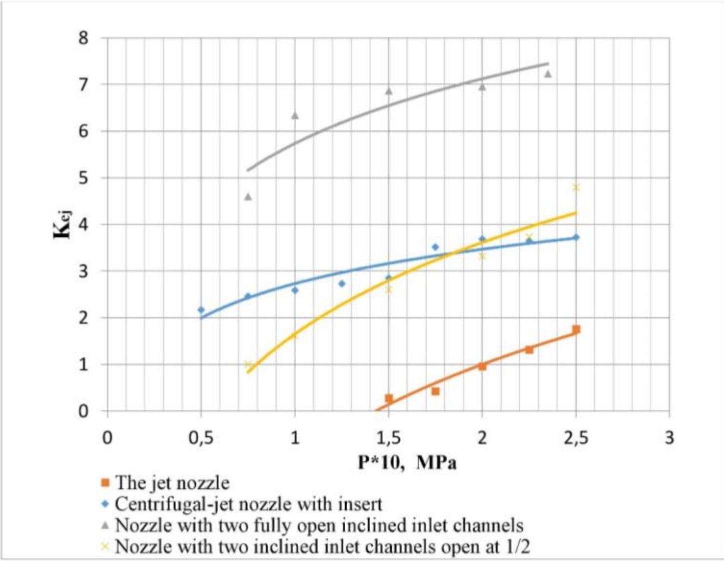

Fig. 2 Dependence of the volume ratio of the ejection on the fluid pressure in the nozzle for ejectors with d = 4 mm and D = 19 mm for different types of sprayers

The highest ratio of ejection is achieved when using a nozzle with fully open inclined inlet channels, which corresponds to the operation of the jet nozzle. In this position of the universal nozzle plunger the significant fluid turbulence in the nozzle is achieved, that results in the formation of droplets with a turbulated surface layer and a spray angle of up to 40 °, with the conservation of translational energy. The droplets of liquid, which are formed upon leaving the working nozzle of the jet apparatus, are unstable and constantly pulsate, that results in the formation of a new contact surface of the phases. Such phenomena cause an increase in the amount of ejected gas phase (the phenomenon of added mass).

The results of the research and given explanations lead to unambiguous conclusions about the significant impact of the type of used active nozzle on the operation of the ejector, and even minor changes in its design lead to considerable changes in the operation of the ejector.

CONCLUSION

The described research studied the liquid-gas jet apparatus and had the purpose of revealing the influence of the motive nozzle type on the efficiency of their work and establishing the regularity of the mixture flow in the ejectors mixing chamber. Jet apparatus were investigated with the following motive nozzles:

- jet nozzles,
- centrifugal-jet nozzles with a central insert,
- the nozzle with the inclined inlet channels opened at ½ (centrifugal-jet nozzle) and fully open (jet nozzle).

There was established the following:

- an increase in the fluid supply pressure to the jet nozzle of the jet apparatus results in a proportional increase in the ejection coefficient for all types of sprays;
- the highest coefficient of ejection is achieved when using a nozzle with inclined inlet channels, which are fully open, that corresponds to the flow of the jet nozzle. At the outlet of the nozzle, the fluid is artificially turbulated, which causes the formation of an unstable droplet with a pulsating outer surface. Its interaction with the gas phase is the highest and is shows itself in the increase of the ejection coefficient.

Further studies of the jet apparatus will be carried out in the direction of establishing the characteristics of the liquid-gas mixture flow in the mixing chamber at low pressures of fluid supply into the motive nozzle of the ejectors as well as theoretical description of these processes.

REFERENCES

Billerbeck, G. M., Condoret, J. S., & Fonade, C. (1999). Study of mass transfer in a novel gas-liquid contactor: the aero-ejector. *Original Research Article Chemical Engineering Journal*, 72, 185-193.

Cramers, P.H.M.R. & Beenackers, A.A.C.M. (2001). Influence of the ejector configuration, scale and the gas density on the mass transfer characteristics of gas-liquid ejectors. *Original Research Article Chemical Engineering Journal*, 82, 131-141.

Filipovich, Yu. Yu. (2001). Water-air ejector.UA Patent. № 34202.

Ponomarenko, V., & Pushanko, N. (2015). *Sprays fluid: an effective way to intensify the processes in the food industry*. Saarbrucken: LAP LAMBERT Academic Publishing istein Imprint der / is a trademark of OmnisScriptum GmbH & Co. KG, ISBN: 978-3-659-70944-9.

Spiridonov, E. K. (2005). Testing of SUSU water-air jet pump in steam turbine vacuuming systems. *Bulletin of South Ural state University. Series: Mechanical Engineering,* 6 (1), 120-125 (***Оригинално заглавие:*** *Спиридонов, Е. К., 2005. Испытание водовоздушного струйного насоса ЮУрГУ в системах вакуумирования паровых турбин. Вестник ЮУрГУ. Серия: Машиностроение, 6 (1), 120-125.)*

Spiridonov, E. K. & Ismagilov, A. R. (2012). On energy and resource saving in the operation of water-air jet pumps. *Bulletin of South Ural state University. Series: Mechanical Engineering,* 20 (33), 13-20 *(**Оригинално заглавие:** Спиридонов, Е. К., Исмагилов А. Р., 2012. Об энерго- и ресурсосбережении при эксплуатации водовоздушных струйных насосов. Вестник ЮУрГУ. Серия: Машиностроение, 20 (33), 13-20.)*

Tsegelsky, V. G. (2003). Two-phase jet apparatus. Moscow: State Technical University named after. N. E. Bauman *(**Оригинално заглавие:** Цегельский, В. Г., 2003. Двухфазные струйные аппараты, Москва: Изд-во МГТУ им. Н. Э. Баумана)*

Yang, X., Long, X., & Yao, X. (2012). Numerical investigation on the mixing process in a steam ejector with different nozzle structures. *Original Research Article International Journal of Thermal Sciences*, 56, 95-106.

Yatsenko, A. F. & Ustimenko, T. A. (2012). Theoretical and experimental studies of water-air ejector. *Scientific works of Donetsk national technical University. Series: Mining and Electromechanical*, 247-253 *(**Оригинално заглавие:** Яценко, А. Ф., Устименко, Т. А., 2012. Теоретические и экспериментальные исследования водовоздушного эжектора. Наукові праці ДонНТУ. Серія: Гірничо-електромеханічна, 247-253.)*

Yinhai Zhu, Wenjian Cai, Changyun Wen & Yanzhong Li (2009). Numerical investigation of geometry parameters for design of high performance ejectors. *Original Research Article Applied Thermal Engineering,* 29, 898-905.