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Regime Characteristics of Vacuum Unit With a Vortex Ejector Stage With Different Geometry of Its Flow Path

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Abstract

The results of experimental researches of vortex ejector stage vacuum unit on the basis of liquid-ring vacuum pump are presented in the paper. Influence of geometry of the vortical chamber on regime characteristics of the vacuum unit is defined Recommendations for choice of the optimum geometrical parities of the flowing chamber depending on problems of designing of the vacuum unit are made.

Keywords: Ejector; ejector stage vortex; vortex ejector; vortex devices; liquid ring vacuum pump; operating characteristics.

1. Introduction

Vortical devices have received wide application in the diversified processes in which they can play as a key role: processes of the separation, rectification, cooling and heating, forcing and suction; and auxiliary: in processes of an intensification of heat exchange, mass exchange [1]. To one of possible directions of application of effect of Rank-Hilsh are vortical ejectors, applied in quality as autonomous suction devices, and devices integrated with forevacuum pump. In given article it is a question of the second type of vortical devices such as preincluded vortical ejector stages (VES) which are intended for increase of level of extremely achievable vacuum of the vacuum unit on base liquid-ring vacuum pump (LRVP). Generally VES are capable to work as a part of vacuum units and other types (piston, rotational etc.). But unitization with LRVP allows to expand their range of applicability on pressure of suction. Such units possess a number of conclusive advantages in comparison with other systems of the oil-free

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pumpings out is possibility of pumping out of the polluted, easy-polymerizing, explosive, toxic gases and steam-gas mixes etc.

Basic difference of the ejector stage of the vacuum unit from autonomous working ejector of any type consists in existence of compulsory pumping out of streams through provided by a design nozzle inputs or channels. In most cases as a working environment of an active stream in ejector stage the atmospheric air without external influences on its thermal parameters is used. For similar conditions, at maintenance in the chamber of mixture of pressure below atmospheric at the expense of vacuum pump work, through an active nozzle there will be an expiration of air from environment in the jet device. The mass expense of such stream depends on productivity of the vacuum pump and is limited by conditions of achievement of critical parameters.

For current occurrence through a nozzle of a passive stream it is necessary, that the mass expense through the vacuum pump exceeded as much as possible achievable meaning of the mass expense through a nozzle of an active stream.

At set geometry of the nozzle channels, parameters of active and passive streams depend on the mass expense and pressure of a stream of mixture which are in turn connected functionally in the form of the vacuum pump characteristic $V_{suct.of\ unit} = f(P_{suct.of\ passive})$. The important conclusion from this follows: everything that influences the vacuum pump characteristic is reflected in level of the parameters describing regime correlation of the ejector stage of the vacuum unit, such, as ejection coefficient and working pressure of suction.

Limiting modes VES describe behavior of a passive stream: or its mass expense is equal to zero ($\dot{m}_{of\ passive} = 0$), or it is equal maximum possible ($\dot{m}_{of\ passive} = \dot{m}_{of\ mixing}$). Certainly that the first mode with the expense of a passive stream $\dot{m}_{of\ passive} = 0$, and as consequence and with meaning of ejection coefficient $U = \frac{\dot{m}_{of\ passive}}{\dot{m}_{of\ active}}$, can't be concern to the category of workers, but it characterizes an attainment of the minimum meaning of pressure on an input in a nozzle of a passive stream of the vacuum unit or ejector which is working on pumping out of some technological system. Thus, at $U = 0$ the limiting maximum of vacuum, for the chosen geometry of the vortical ejector stage is reached. In other words, the mode outlines border of possibilities of ejector or the unit as a whole on pressure of suction. The second mode not is calculated, in designing ejector stage, and only is a starting point of a variation in the size of a passive nozzle for the purpose of achievement of the maximum ejection coefficient [2].

Ways of perfection of working process VES at the expense of change of geometry of a flowing part can be divided element-wise: nozzle devices, the reception chamber, target devices. As a result of preliminary computing experiment for the vacuum pump of type «VVP-1,5» have been defined optimum (from a position of achievement of the maximum ejection coefficient) geometrical parameters nozzle and target devices. Thus, the further perfection of working process vortical ejector consisted in an experimental research of influence of a configuration of a flowing part of the reception chamber on regime characteristics of the vacuum unit. Updating of a flowing part of the reception chamber can be spent not only at the expense of change of its geometry, but by a variation of an external surface of a nozzle of a passive stream. The general view and the sketch of geometry of performance of nozzle of passive stream are presented in figure 1. The basic geometrical parameters of a nozzle are D and L. Thus D is diameter of an external surface of a nozzle, from its fixing part, together with a surface of reception chamber VES forms the ring channel of a supply of an active stream of its long L.

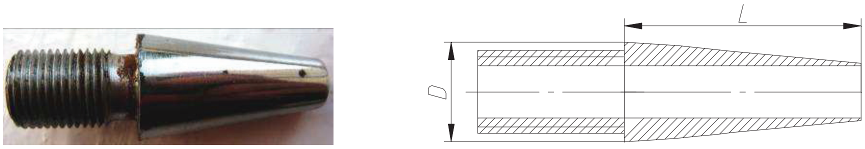

Fig. 1. The general view (at the left) and the sketch of performance of nozzle of passive stream of various geometry (on the right)

In Table 1 variants of geometry of performance of nozzle of passive stream of various geometry are presented (all sizes are specified in millimeters).

Table 1. Geometrical parameters of the nozzles of passive stream

D1=14,8			D2=16,8			D3=18,8		
L1	L2	L3	L1	L2	L3	L1	L2	L3
13,2	26,8	40,3	13,2	26,8	40,3	13,2	26,8	40,3

2. Results of the experimental research of regime characteristics of the vacuum unit with nozzles of the passive stream of various geometry

For vortical ejector, as well as for ejector devices of other type, the basic regime parameters are: ejection coefficient $U = \frac{\dot{m}_{of\ passive}}{\dot{m}_{of\ active}}$, degree of increase of pressure of a passive stream $\varepsilon = \frac{P_{suct.of\ mixing}}{P_{suct.of\ passive}}$, degree of expansion of an active stream $\pi = \frac{P_{suct.of\ passive}}{P_{suct.of\ passive}}$. Thus the coordination of work VES with LRVP is defined by character of dependence of the above mentioned parameters of a stage from volume productivity, pressure of suction of a passive stream of the vacuum unit and capacity expenses.

In figures 2, 3, 4 regime characteristics of the vacuum unit with preincluded VES are presented for nozzles with $D_3 = 18,8\,mm$, $D_2 = 16,8\,mm$, $D_1 = 14,8\,mm$ accordingly. For the assemblage of the curves designated in these figures «a», «b», «c», «d» there correspond dependences:

a) Dependence of volume productivity of the vacuum unit with VES on relative pressure of suction;

b) Dependence of volume productivity of the vacuum unit with VES on ejection coefficient;

c) Dependence of volume productivity of the vacuum unit with VES on degree of compression of a passive stream;

d) Dependence of capacity on a shaft «VVP-1,5» on volume productivity of the vacuum unit with VES.

For the various lengths of nozzles of passive stream on schedules of regime characteristics (figures 2, 3, 4) correspond designations:

□ – long (length of the nozzle of passive stream $L_3 = 40,3\,mm$);

Δ – middle (length of the nozzle of passive stream $L_2 = 26,8\,mm$);

○ – short (length of the nozzle of passive stream $L_1 = 13,2\,mm$).

Let's give the short characteristic to the received results.

By consideration of assemblage of curves «a» for nozzles of various geometry it is possible to draw a conclusion that with increase of length of nozzle of passive stream the area of achievable vacuum extends and volume productivity of the vacuum unit with VES (it is shown by a dotted line) raises at low pressures of suction in comparison with not aggregated «VVP-1,5» (is shown by a continuous line). Note that comparison of vacuum units with various geometry of flowing part VES is possible only on condition that the account characteristic «VVP-1,5» remains invariable. That's why for machines with the closed system of water supply it is expedient to use averaged the account characteristic for most severe conditions of operation of the vacuum unit when the temperature of circulating water reaches the maximum meanings (a summer mode) [3].

Let's estimate character of dependence of volume productivity of the vacuum unit with VES on ejection coefficient for nozzles of passive stream of the various geometry (the assemblage of curves «b»).

The ejection coefficient is one of main parameters VES defining expediency and efficiency of application of the vacuum unit. Thus, in spite of high meaning of ejection coefficient for the short nozzles, their application in VES isn't expedient, since volume productivity of such vacuum unit or below (nozzles with D=14,8 mm and D=16,8 mm), or slightly exceeds (nozzles with D=18,8 mm) volume productivity not aggregated LRVP in the area of considered pressures. It is possible to explain rather fast descent of a twisting active stream from a surface of a nozzle of a passive stream in a mixture zone, and also joint revolting influence on ejecting stream of an external surface of a nozzle of a passive stream and an end face of a wall of fixing cover VES. Therefore, the stream of an active stream hasn't time to be generated in a whirlwind with a sufficient gradient of static pressure and is carried away by more powerful stream of a passive flow. At the expense of it hydraulic losses in VES and turbulent viscosity of a stream increase, than deterioration of regime characteristics of the vacuum unit is decrease in extremely achievable vacuum, reduction of volume productivity and increasing of power consumption shaft of the vacuum unit.

Conclusions about overall performance of the vacuum unit with VES for assemblage of curves «c» are in functional dependence with the data presented on the previous schedules. Thus, degree of compression of passive stream depends on maximum level of the vacuum created by the vacuum pump with VES which is in turn connected with ejection coefficient and is limited by conditions of limiting operating modes of the vacuum unit with VES.

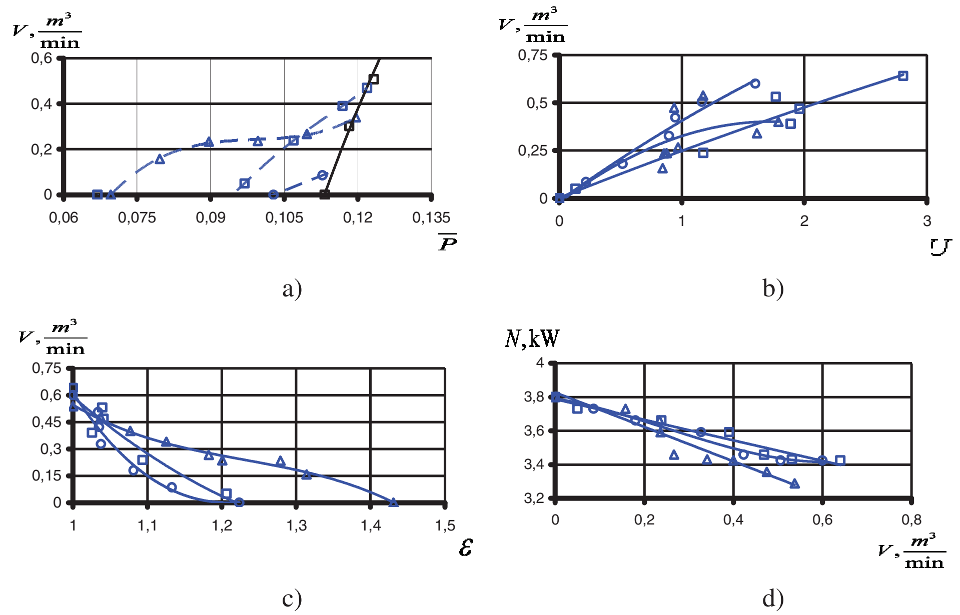

Fig. 2. Regime characteristics of the vacuum unit with VES for nozzles with D=18,8 mm

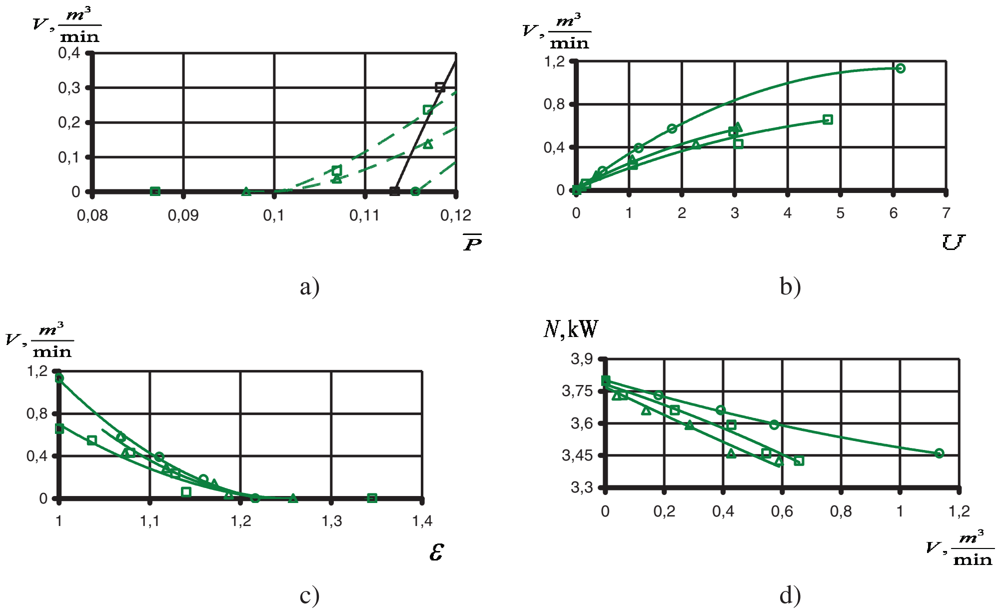

Fig. 3. Regime characteristics of the vacuum unit with VES for nozzles with D=16,8 mm

Thus, degree of compression of a passive stream is in inverse dependence to ejection coefficient and, accordingly, for the short nozzles accepts the minimum meanings.

Analyzing character of dependence of assemblage of curves «d» it is possible to come to conclusion that the geometry of a flowing part of reception chamber VES makes considerable impact on the power characteristic of the vacuum unit. Increase of hydraulic resistance at use of the short nozzles of the passive stream involves additional expenses of capacity for maintenance of equal volume productivity. Rather low and moderate expenses of capacity characterize vacuum units in VES of which rather long nozzles of a passive stream are applied.

Influence of diameter of an external surface of the nozzles of passive stream on regime characteristics of the vacuum unit also it is possible to estimate under the presented schedules (figures 2, 3, 4). Having tracked character of change of assemblage of curves «a» it is possible to draw a conclusion that at increase in diameter of an external surface of the nozzle of a passive stream its effective length (at which the vacuum unit has the greatest volume productivity in area of pressure of suction more low, than for the unit not aggregated with VES) decreases and on the contrary grows with reduction of external diameter. Thus in figures 2, 4 «a» (for middle and long nozzle accordingly) it is possible to see sharp increase of account characteristics of the vacuum unit.

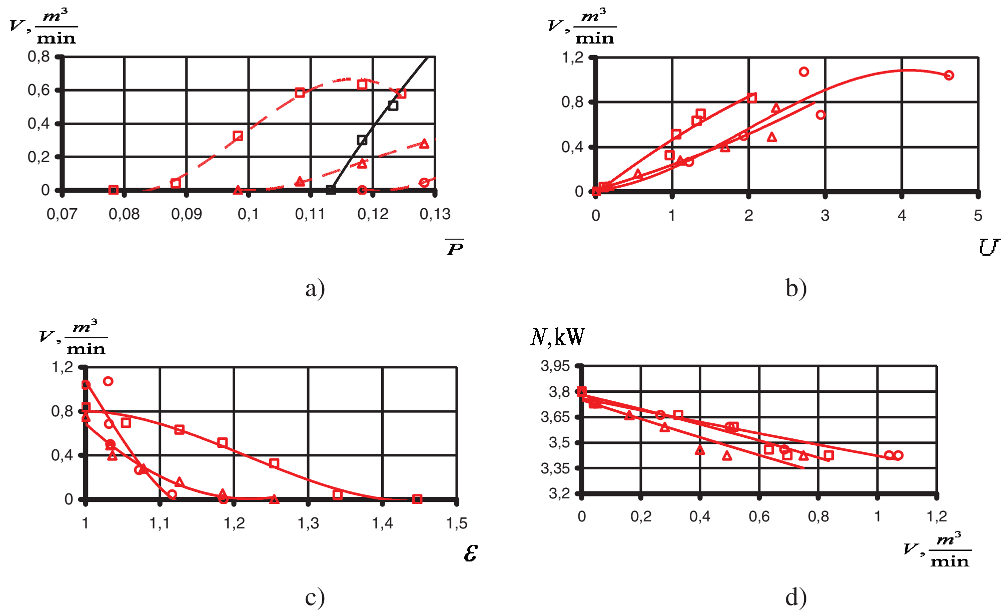

Fig. 4. Regime characteristics of the vacuum unit with VES for nozzles with D=14,8 mm

Influence of diameter of an external surface of the nozzles of passive stream on regime characteristics of the vacuum unit also it is possible to estimate under the presented schedules (figures 2, 3, 4). Having tracked character of change of assemblage of curves «a» it is possible to draw a conclusion that at increase in diameter of an external surface of the nozzle of a passive stream its effective length (at which the vacuum unit has the greatest volume productivity in area of pressure of suction more low, than for the unit not aggregated with VES) decreases and on the contrary grows with reduction of external diameter. Thus in figures 2, 4 «a» (for middle and long nozzle accordingly) it is possible to see sharp increase of account characteristics of the vacuum unit.

3. Conclusion

In work influence of geometry of a flowing part of reception chamber VES is experimentally researched. Dependences of regime characteristics of the vacuum unit with VES on geometry of a flowing part are established. As a result of the spent analysis of experimental curves following conclusions are drawn:

– With increase in length nozzles of the passive stream in area of achievable vacuum extends, volume productivity of the vacuum unit with VES raises at low pressure of suction in comparison with not aggregated «VVP-1,5»;

– Application of the short nozzles leads to deterioration of regime characteristics of the vacuum unit that is decrease in extremely achievable vacuum, reduction of volume productivity and increase power consumption on a shaft of the vacuum unit;

– At increase in diameter of an external surface of the nozzle of a passive stream its effective length (at which the vacuum unit has the greatest volume productivity in area of pressure of suction more low, than for the unit not aggregated with VES) decreases and on the contrary grows with reduction of external diameter.

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