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INVESTIGATION OF A SWITCH WITHOUT MOVING PARTS FOR AN EJECTOR OPERATING IN A PULSATING MODE

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The interest in the research of jet pumps is caused by their wide application in various industries; from automotive to oil refining. In oil refining, jet pumps are most often used in vacuum systems in various capacities and apparatuses, as well as for transport of various media. However, in the course of using jet pumps, a number of problems arise, for example as the need to treat wastewater in large quantities (with the use of vapor-jet systems for creating a vacuum), which is caused by the relatively high consumption of the ejecting agent due to the rather low efficiency of this type of pump. Consequently, research into the operation of jet pumps to increase their efficiency plays a very important role.

Hydro-jet pumps are devices designed to perform the process of mutual mixing of streams of active medium flow with a passive medium flow and their subsequent transportation. The passive medium can be a liquid, a gas or a slurry containing, in addition to the liquid, gaseous or solid dispersed impurities. Therefore, the external energy to hydraulic jet pumps is supplied by the working fluid.

In addition to the fact that jet pumps are characterized by high self-priming capacity, they can also pump liquids, gases, gas-liquid mixtures, slurries that can have solid impurities, aggressive media. The design itself is distinguished by the absence of movable parts, it is simple in the device, has small overall dimensions and weight and allows to be placed in hard-to-reach places, which is reflected in the operation and simplicity of feed and pressure control.

However, jet pumps, as a major problem, have a significantly lower efficiency than other types of pumps, they do not have a self-contained drive and require an extraneous source of pressure fluid to operate. In the course of operation, the jet pumps are irretrievably dumped large quantities of liquid used as an active medium.

These disadvantages can be solved by creating and using installations in which centrifugal and jet pumps are used together. Such facilities will have a set of indicators, which do not have a separate jet or centrifugal pump. This will expand the possibility of using centrifugal pumps.

Therefore, on the basis of joint application of jet and centrifugal pumps, installations can be created that will allow to change the range of performance of centrifugal pumps (that is, to increase several times the pressure or supply they create); increase the depth from which the liquid can be lifted by centrifugal pumps located above the reservoir (source); pumping slurries with solid or gaseous inclusions; create vacuum or pump out gases (jet vacuum pumps); create a gas pressure (jet compressors); to mix and dissolve liquid, solid and gaseous media and perform many other functions.

This versatile installation with jet paddle pumps will not only make full use of the advantages of jet pumps, but also will provide an opportunity to increase the efficiency of installations in comparison with the efficiency of jet pumps.

The efficiency of jet pumps has a limit, since it has losses when mixing active and passive streams. Therefore, an increase in the efficiency of installations with jet and centrifugal pumps can be achieved if a high-efficiency centrifugal pump performs a large amount of pumping work, and the jet pump performs only those technological functions that a centrifugal pump can not perform (self-priming, pumping gases or solid particles) [1].

However, there are scientific works that describe the functioning of the pumping unit in the regime of intermittent (periodic) supply of the active medium, which was air. When studying the operation of a jet pump in pulsation with liquid-gas media, the following results were obtained, namely the dependences, from which it can be seen that when pulsations are applied, the productivity by passive flow rate of the medium (air) increases. At the same time, the performance relation with different frequencies is not visible, but with a decrease in the ripple coefficient, the performance rises [2].

There was a need for a number of experimental studies, as well as a study of the effect of pulsations of jet pumps, which would reflect the confirmation of the positive results obtained, but liquid would be used as a passive medium.

The discovery in the history of the jet pump is attributed to the time of the first application of James Thompson in 1852 and the first theoretical development when mixing two Rankin fluxes in 1870 and Lorentz in 1910.

Transportation of media in various aggregate states is used more and more in industry.

In recent years, the jet pump, shown in the figure below, also known as the ejector, has grown in popularity as a different source for transportation systems. For example, hundreds of jet pump systems have been installed in industry around the world since the early 1970s [3]. The figure below shows the design of the ejector.

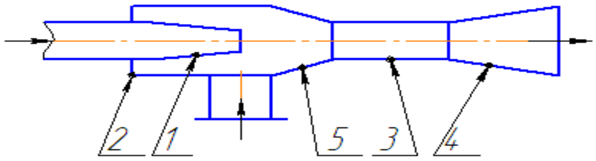

Fig. 1. General configuration of jet pumps:
1 – nozzle; 2 – the suction chamber; 3 – the suction chamber; 4 – diffuser; 5 – confuser

Jet pumps (ejectors) are among the most common. If we consider that ejectors, performing certain technological functions, and operate in hydraulic systems, as a rule, continuously and for a long time, even an insignificant increase in their efficiency leads to a significant saving of energy and the working environment.

The effective use of a jet pump in hydraulic systems requires a thorough knowledge of the hydrodynamics of the working process.

However, in most hydraulic systems, ejectors operate under non-stationary conditions, for example, when starting up the system or in the process of regulation.

For example, jet pumps use the driving flow of the active medium to increase the energy of the transported passive media. As shown in Figures 1 and 2, the jet pump consists of a nozzle to create a high-speed jet that feeds the active medium of the suction chamber associated with the raw chamber, the confuser and the mixing chamber (collector), the diffuser (sprayer) that communicate with the system [3].

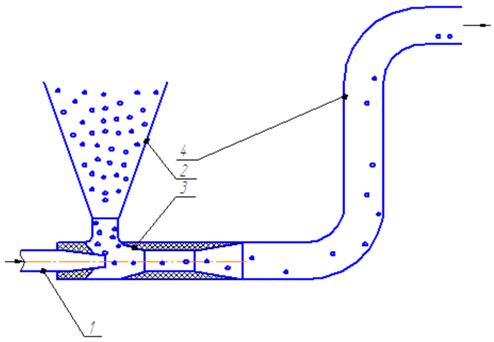

Fig. 2. Typical transmission scheme using a jet pump:
1 – supply of active medium; 2 – submission of passive medium; 3 – location of mixing flows;
4 – pipeline system of fluid motion

The principles of operation are based on fluid dynamics and are very different from other types of pumps (for example, a centrifugal pump): the jet of active (high-pressure) medium rushes from the nozzle into the working chamber and carries with it a passive (low-pressure) medium from the receiving chamber. In the working chamber, the active jet, mixing with the passive flow, transfers some of its energy to it. As a result, the total head (specific mechanical energy) of active molasses increases, while the active molasses decreases. In the diffuser, the dynamic head (velocity) is partially converted into static head. The diffuser reduces the speed and converts the kinetic energy, and at the output it provides less energy loss. Consequently, the flow is sucked out under the action of an active driving medium [4].

The jet - the working organ is the same as the piston in the piston pump and determines the processes occurring in the apparatus, as well as the efficiency of its operation. The peculiarity of the jet is its expiration into an air jet with a pressure below atmospheric pressure. This significantly affects the parameters of the jet (expansion angle, velocity distribution, length of the initial section).

The decisive role in the structure of the jet at the outlet from the nozzle is the air dissolved in it. Getting into the receiving chamber, where the pressure is much lower than the atmospheric pressure, the solubility of the gas in the liquid decreases, the compressed gas expands, which leads to the expansion of the jet - an increase in its diameter [4].

The passive medium can be a liquid, a gas or a gas-liquid mixture containing, in addition to the liquid, impurities of solid or gaseous particles. Mixed flows can be either phase-to-phase or single-phase, during the mixing process the state of media flows can remain unchanged, but it can also change. The flow entering the mixing process at a higher speed is called the working (ejecting) flow, and the flow entering the process at a lower speed is ejected [5].

The operating conditions of the ejectors depend also on the elastic properties of the interacting media. Under elastic properties, sills are understood as a significant change in the specific volume of the medium when its pressure changes.

As noted above, the efficiency of the jet devices increases significantly when they are operated in a pulsating mode, the pulsation mode can be realized by applying a unique switch without moving parts, which uses the Coanda effect as its operating principle.

The Coanda effect is a property of the jet to change the direction of motion due to adhesion to a nearby solid wall. The effect is as follows. A free jet, flowing out of the nozzle, carries with it particles of the environment, this leads to the formation of a secondary flow at the periphery of the jet, which additionally supports the trapped particles. If there are no walls near the jet, then the pressure throughout the stream flow region remains constant, and the jet does not change the flow direction. If a solid wall is placed near the jet, then the cross section of the jet from the side of the solid wall decreases. There is an increase in flow velocity and a decrease in static pressure near the wall. This leads to the deflection of the jet to the wall under the influence of atmospheric pressure, until the jet touches the wall and the equilibrium state arrives.

In the volume enclosed between the edge of the jet and the wall, a circulating region with a high secondary velocity and low pressure is formed. If a control signal is introduced into the low pressure region, this area begins to increase, the zone of sticking the jet to the wall will move along the stream, moving away from the additional channel.

When the control flow becomes equal to the switching rate, there will be a separation from the wall, which will ensure a change in the direction of its flow.

This happens as follows. In Figure 3, the jet Pn emerging from the nozzle 1 flows along the wall 4 in which there is a control channel 2. In the absence of a control pressure Py in the channel 2, the jet of air flows along the wall 4 and enters the channel 3. With a gradual increase in the pressure Py direction jet does not change. Then, at some increased value of Py, the jet breaks away from the wall 4 and jumps to channel 5 abruptly.

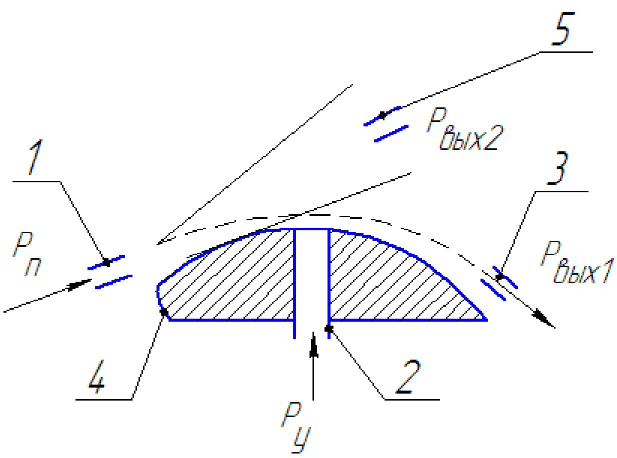

Fig.3. Jet Element with Jet Adhesion

Below is a simple description of the operation of a switch operating according to the Coanda effect principle [6]:

Step 1. The left channel is filled to the point 3, after which the flow switches to the right channel.

Step 2. Simultaneously, the following processes occur: the right channel is filled with liquid to point 2; liquid from the left channel during this time flows into the mixing chamber and creates a piston - call it a small piston; The liquid in the right channel continues to move to point 3 and switches to the left channel. While the liquid flows between points 2 and 3, an air bubble forms in the mixing zone.

Step 3. Simultaneously, the following processes occur: the left channel is filled to point 3, after which the flow switches to the right channel; the liquid in the right channel flows partially into the mixing zone, creating a regular piston; The previously created piston moves down. Between the pistons created by the liquid, air bubbles are created.

Step 4. Simultaneously, the following processes occur: the right channel is filled with liquid to point 2, the liquid from the left channel during this time flows into the mixing chamber, merging with the liquid from the right channel and creating a large piston; Previously created in the mixing zone, the pistons move lower; The liquid in the right channel continues to move to point 3 and switches to the left channel.

Next, steps 3 and 4 are repeated, creating a piston motion in the mixing zone. From the description it can be seen that the different lengths of the switch channels contribute to the formation of air bubbles in the mixing zone [6].

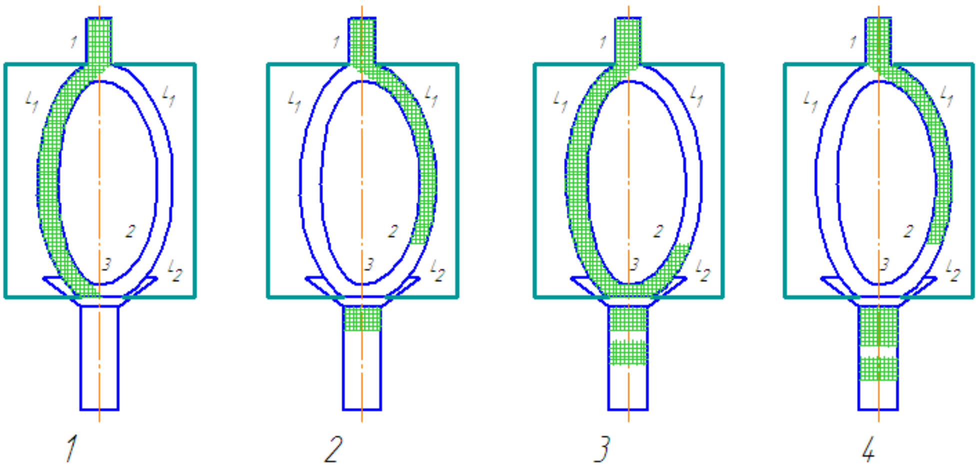

Fig.4. The simplest model of operation of the jet switch

Efficiency of the ejector is estimated mainly by means of the ejection coefficient, which is calculated by the following formula:

$$K_э = \frac{Q_П}{Q_А},$$

where $Q_А$ is the volumetric flow rate of the ejecting flow (active), m ^ 3 / c;

$Q_П$ - volumetric flow rate of the ejected flow (passive), m ^ 3 / s.

The efficiency of the application of the pulsation regime in the process of ejection is described in the source [5]. The organization of the pulsation regime allows to increase the ejection coefficient by reducing the flow rate of the ejected flow at a constant flow rate of the ejecting flow, however, the complexity of the flow and the appearance of phase transitions due to physical processes during the ejection process complicates a fairly accurate simulation of this process.

In consequence of the above, it should be concluded that it is useful to study the application of the pulsation regime for the ejection process. The organization of the ejection process thus allows not only to reduce the consumption of sewage generated during the operation of vacuum-creating systems, but also to reduce the power of pumps used in conjunction with ejectors in the organization of technological processes. The use of such a switch has a wide practical significance, both from the ecological point of view and from the technological point of view.

REFERENCES

1. Лямаев, Б.Ф. Гидроструйные насосы и установки / Б.Ф. Лямаев. – Л. : Машиностроение. Ленинград. отд-ние. 1988. – 256 с. : ил.
2. Зинькевич, К.А. Оценка возможности увеличения производительности струйного водовоздушного насоса за счет организации пульсационной подачи воды / К.А. Зинькевич, Е.М. Шестопалов // Вестник Полоцкого государственного университета. – № 16. – С. 66–69.
3. Wang, D. Analysis and design of air – jet pumps for pneumatic transportation of bulk solids in pipelines / D. Wang. – University of Wollongon Departament of Mechanical Engineering, 1995.
4. Спиридонов, Е.К. Характеристики нестационарной эжекции в жидкостном струйном насосе / Е.К. Спиридонов, А.А. Дурасов // Вестник ЮУрГУ. Сер. «Машиностроение». – 2007. – Вып. 10, № 25. – С. 35–43.
5. Чабурко, П.С. Численное моделирование течения жидкости в струйном насосе / П.С. Чабурко, В.О. Ломакин // Машиностроение : сетевой электронный научный журнал. – 2014. – Т. 2, № 3. – С. 55–58.