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INVESTIGATION OF THE SOLUBILITY OF OXYGEN IN WATER-JET EJECTORS

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Abstract: *This paper investigates a simple design of the wide used three water-jet ejectors. It was found that aerators with vortex flows increase the oxygen solubility in the water compared to the classic design Venturi pipe. Water-jet ejector with vortex flows creates optimal conditions for fluid aeration.*

Key words: *water-jet ejector, air solubility, fluid aeration.*

1. INTRODUCTION

During the change process of iron particles from divalent iron ions to trivalent insoluble ferric compounds, the water is always in need for additional oxidation, that is why it needs to be aerated. It is common to use a classical ejector the Venturi tube for air aeration. [1]
Ejector‘s work is based on the working flow of kinetic energy transfer to the ejected flow maintaining uninterrupted contact mode. Operating flow is supplied by the pump for such a construction of the aeration in the ejector. The out taked working flow ejected through the ejector nozzle creates a vacuum because of which the air through the nozzle is inhaled, which is mixed in the mixing chamber with the working flow. The resulting liquid mixture is discharged through the diffuser, there oxygen is dissolving in the liquid. The main purpose of mixing is to increase mixture‘s components‘ phases contact surfaces, thus the intensity of the reactions between them increases. [2]
The oxygen solubility in the liquid is a diffusion process, which is expanding in two-phases system: in gas and in liquid. Diffusion process review pioneer was Fik.He found a physical analogue of the heat transfer process and diffusion, which allowed him to use the Fourier equation to solve oxygen diffusion rates in the liquid from the air bubbles. Therefore, the mass exchange rate is indicated by Fiko law [3].

$$\frac{dM}{dt} = -DA\frac{dC}{dy}. \quad (1)$$

where: dM / dt - mass exchange speed rate;
D - diffusion coefficient;
A - the area through which the gases diffuse into the liquid;
dC / dy - concentration gradient, i.e., concentration changes according to the distance.

Mass transfer basis shall be the diffusion of oxygen molecules from the gaseous aggregate state to the liquid . It may be molecular, convectiv and turbulent. [4]
Diffusion rate speed is determined by these key factors: molecular size, concentration, electrical potential difference, the pressure difference inside and outside the cell, temperature, and surface area. [5]
The main criteria describing work efficiency of the construction of jet aeration is the amount of oxygen dissolved in the liquid. Having an intention to create a more efficient liquid aerator it is necessary to analyze the oxygen solubility concentration in the liquid.

2. OBJECT OF INVESTIGATION

To investigate the wide use of liquid aeration chosen - a classic Venturi tube (Fig.1). [6]
Investigation of alternative to increase water aeration efficiency using two created newly developed ejectors (2 – 3 fig.). [7]
All this aerator constructions is made up of: stream inlet, air intake, mixing camera, diffuser.

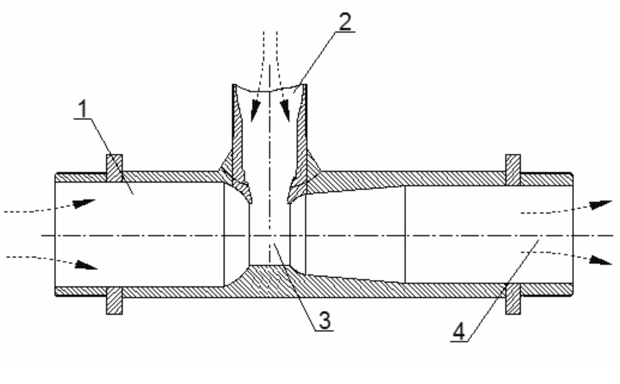

Fig.1. The clasic Venturi pipe: 1 – stream inlet; 2 – air intake; 3 – mixing camera; 4 – diffuser

Classical construction Venturi tube principle of operation (Fig. 1).: working flow enters in through device socket 1 enters the nozzle, in which the flow rate is increased but the pressure drops - potential energy changes into kinetic energy. Sprayed flow is ejecting the entering working flow through the device socket 2 and directs it to the mixing chamber 3, later it is directed to diffuser 4.
In the mixing chamber the pressure of the mixture begins to rise and the speed is falling down, the exchange of working flow’s mass is happening.

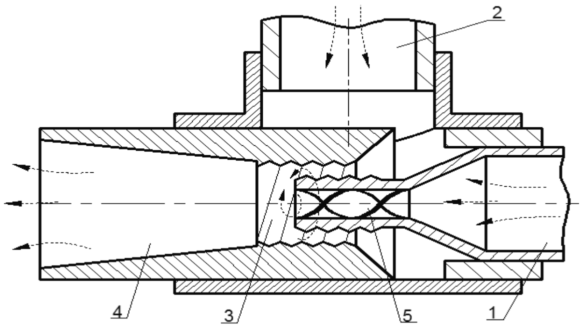

Fig.2. Scheme of blade jet pump: 1 – stream inlet; 2 – air intake; 3 – mixing camera; 4 – diffuser; 5 – twisted blades

In the construction of blade ejector (Fig. 2) the movement of opposite flows is used. To start a working flow helical vanes have been used 5. If the flows are given opposite movement, they face each other and that is how cavitation zone is formed in the mixing chamber 3, which activates the dispersion process, increasing the ejected flow's contact area and hence the solubility.

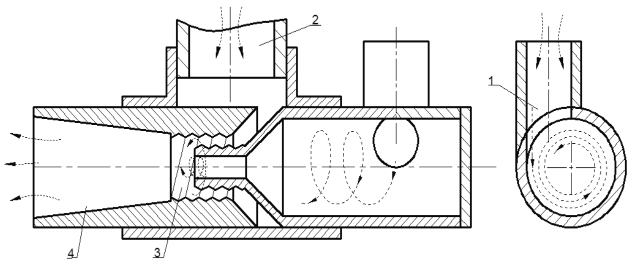

Fig.3. Scheme of the jet pump with the tangential stream inlet: 1 – stream inlet; 2 – intake; 3 – mixing chamber; 4 – diffuser

In this ejector's construction with the introduction of tangential flow (Fig. 3) working flow is introduced tangentially 1, for it to give vortex flow motion.
Working flow's direction of movement is installed on the contrary to the ejecting media flow, to form the cavitation zone in the mixing chamber 3.
Cavitation activates the dispersion process, which increases ejecting flow's contact area and hence the solubility.

3. EXPERIMENTAL STAND AND TECHNIQUE

Especially for this study purpose test stand was designed (Fig. 5)., which consists of a water tank 1 for primary water verification. From this capacity using the water pump 2 the fluid is supplied through the flow meter 3, adjustable valve 4, manometer 5 and fed to the study subjects 6 from which the water tank was filled 7. The water from the tank 7 was studied with oximeter 8 (inoLab Oxi 730).
The experiments were carried out in the following order:
The first test:

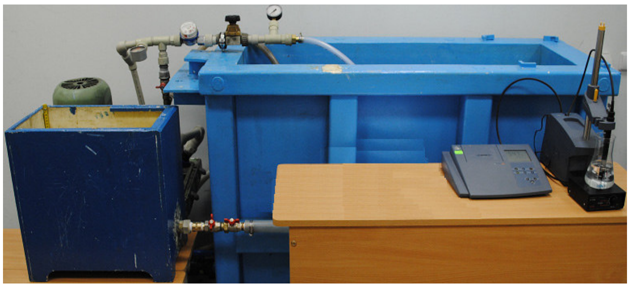

Fig.4. The experimental stand investigation on the solubility of oxygen in water-jet ejectors.

The supplying water dissolved oxygen quantity was fixed to O_2, mg/l (Fig. 5).
When the water pump was turned on, the valve was adjusted according to the flowmeter readings and the water flow rate was selected at Qs = 0,97 m^3/h (Fig. 5).
Using the oximeter dissolved oxygen quantity in the water was recorded O_2, mg/l (Fig. 5).
Water flow rate was selected Qs = 1.15 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig. 5).
Water flow rate was selected Qs = 1.31 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig. 5).

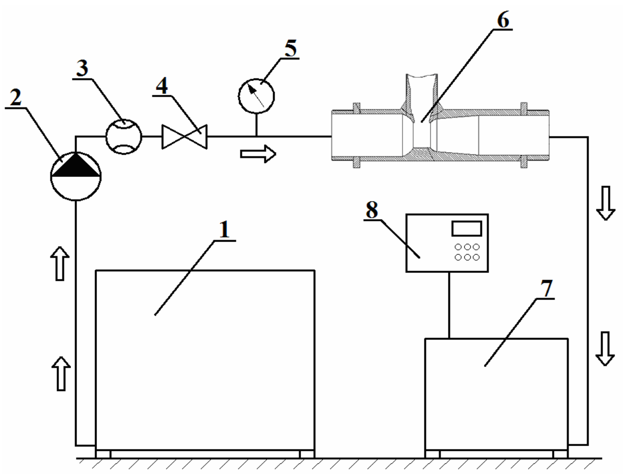

Fig.5. Experimental stand with Venturi pipe: 1 – water capacity; 2 – water pump; 3 – flow meter; 4 – adjustable damper; 5 – pressure meter; 6 – the clasic Venturi pipe; 7 – capacity; 8 – oksimeter

Second test:
When the water pump was turned on, the valve was adjusted according to the flowmeter readings and the water flow rate was selected at Qs = 0,97 m^3/h (Fig. 6).
Using the oximeter dissolved oxygen quantity in the water was recorded O_2, mg/l (Fig. 6).
Water flow rate was selected Qs = 1.15 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig. 6).
Water flow rate was selected Qs = 1.31 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig. 6).

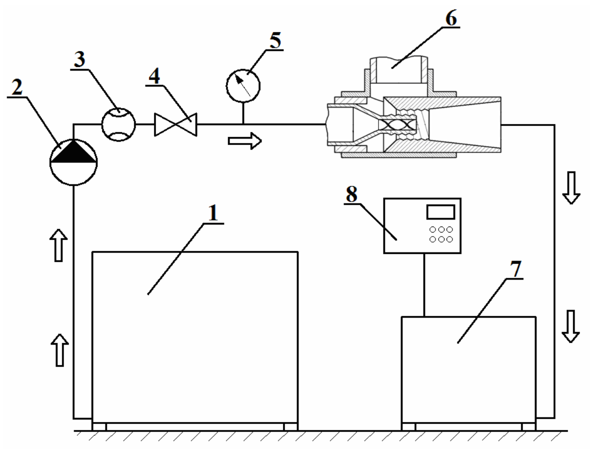

Fig.6. Experimental stand with blade jet pump: 1 – water capacity; 2 – water pump; 3 – flow meter; 4 – adjustable damper; 5 – pressure meter; 6 – the blade jet pump; 7 – capacity; 8 – oximeter

Third test:
When the water pump was turned on, the valve was adjusted according to the flowmeter readings and the water flow rate was selected at Qs = 0,97 m^3/h (Fig. 7).
Using the oximeter dissolved oxygen quantity in the water was recorded O_2, mg/l (Fig. 7).
Water flow rate was selected Qs = 1.15 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig. 7).
Water flow rate was selected Qs = 1.31 m^3/h, and again dissolved oxygen quantity in the water was fixed to O_2, mg/l (Fig.7).

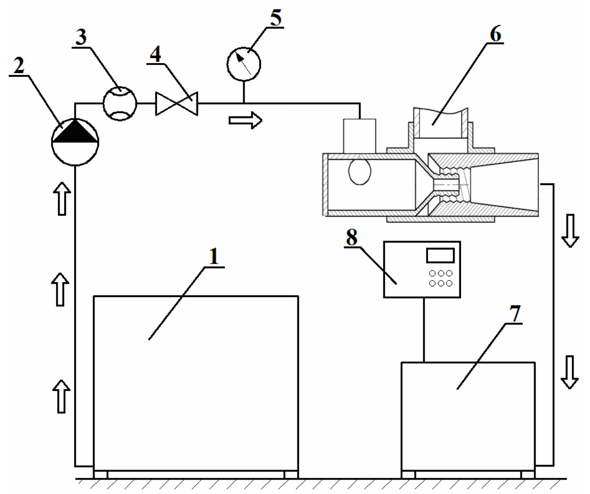

Fig.7. Experimental stand with modificated jet pump: 1 – water capacity; 2 – water pump; 3 – flow meter; 4 – adjustable damper; 5 – pressure meter; 6 – the jet pump with the tangential stream inlet; 7 – capacity; 8 – oximeter

4. RESULTS AND DISCUSSION

In test results (Fig. 8) of these three aerators: The CLASSIC venturi pipe (Fig. 1)., The jet pump blade (Fig. 2)., The jet pump with the tangential inlet stream (Fig. 3); Oxygen's concentration dependence from the water flow debit is shown.

For dissolved oxygen quantity test measurement and analysis we have used oximeter inoLab Oxi 730, oximeter's measurement range is : (0 to 200)% O_2, (0 to 19.9) mg/l O_2 (0 to 90) mg/l O_2 and tolerances of ± 0 5%.
During the testing of aerators, it was assumed that the created new model ejectors will saturate water with oxygen better than the classic model - the Venturi tube, because the out taken working flow's aerator's torch shape is closer to the spiral form of the vortex, which creates a flow pulsations improving oxygen's solubility in the liquid. [9]
The results of the study research were to determine the most efficient ejector model which would improve the diffusion process in the two contact-phase system: gas and liquid.

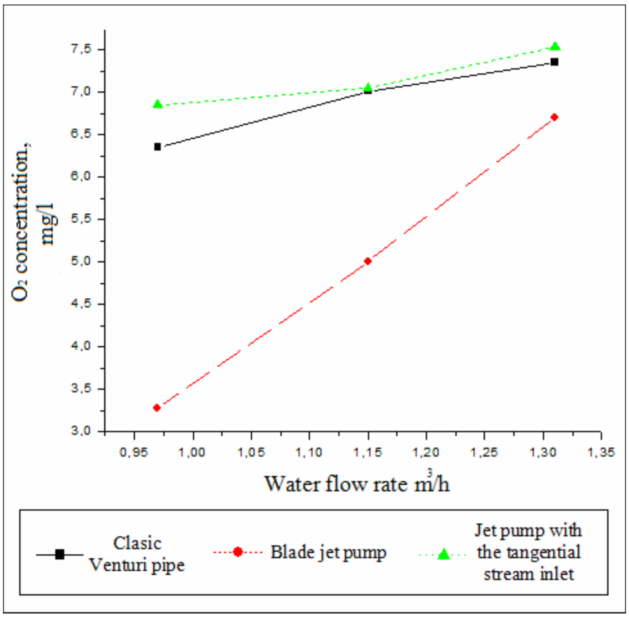

Fig.8. Solubility of oxygen in water-jet ejectors according to water flow rate

(Fig. 8) The data ejector oxygen solubility in water at three different water flow rates 0.97 m^3/h; 1.15 m^3/h and 1.31 m^3/h, this allows to see the most efficient aerator oxygen solubility dependence because of the water flow.

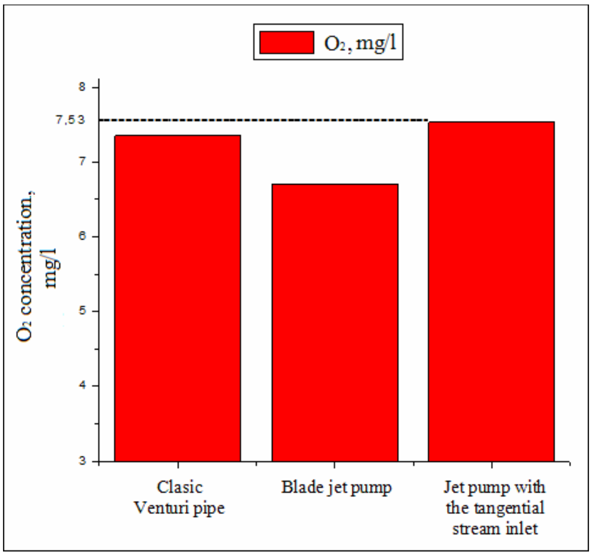

Fig.9. Solubility of oxygen in water-jet ejectors

From the charts we can see, that the aerator with the introduction of tangential flow reaches a maximum efficiency of oxygen solubility in water mg/l at the same liquid flow rate and compared to widely used, classic construction model - the Venturi tube.

5. CONCLUSION

It is shown that the aerator with the introduction of tangential flow reaches maximum efficiency for oxygen solubility in water.
From the obtained charts' we can conclude that the work of the investigated ejectors is more efficient operating at higher work flow rates up to 1.31 m^3/h.
It was found that the oxygen solubility in the liquid is improved by the aerator's spiral vortex form, which creates the flow pulsations.

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