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PRELIMINARY DESIGN OF BASIC PARAMETERS OF THE AERATOR

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Abstract: *The method of preliminary design of the basic runner parameters of the hydrodynamics submersible aerator is presented in this very brief paper. The problem of these parameters design is in the fact that flow rate (discharge) of the liquid (water) flowing through the aerator is unknown. The discharge is crucial parameter for a runner design. Therefore some basic ideas and basic expressions which can help with a preliminary design of the runner are outlined in this paper. After setting of the basic parameters of the aerator runner, this problem can continue with using some CFD code.*

Keywords: ***Submersible aerator, design of a runner, angle of a blades.***

1. Introduction

Aerators are used in waste water treatment plants, for adding the air to the lakes, in chemical industry and so on. The devices for the oxygen adding into the water, aerators, are based on different principles. Some of these different principles of aerators are described in papers (Baylar, A. 2003), (Pandit, A. B., et al. 1991), (Muller, G., Sell, G.1984), (Vandermeulen, H. 1992), (Zhu, J., et al.2007) and so on. Each of these aerators has some advantages and also disadvantages. One of aerator categories are submersible aerators. The aerator, which preliminary design will be presented in this paper, belongs to this category. This kind of aerator is designed as a centrifugal radial pump. The air is added to the water on the ejector principle behind of the runner. Similar aerator type is described in (Pandit, A. B., et al. 1991). The runner is designed as a double sided runner. The blades on one side are designed for the water and the blades on the other side are designed for the air inflow. Advantages of this aerator type are as follows:

- It is a very simple device.
- There is low level of noise because the aerator is submerged.
- Its installation is very simple. It is also easy removable.
- It can also work as a mixer after closing the inflow air pipe.
- There is no need any other device outside of tank (air pump).

Heart of this aerator is the runner. The Design of this runner is rather complicated because the aerator discharge is unknown. It is not also possible to measure it, because it is impossible to place there a flow-meter. Therefore it is a problem to design the runner blades. Now it is a question how to find basic parameters as the radius of the runner, inlet and outlet blade angles, the intake and outlet widths of the runner.

2. Design procedure

The basic idea of this design procedure is that flow rate (discharge) is unknown. Therefore the power transferred into the water is assumed instead of it. Then the basic parameters are designed in such a way to reach the maximal flow rate through the aerator. The power transferred into the water by aerator can be expressed this way

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$$P_h = \rho.Q.\Delta Y_{Run} \quad (1)$$

Where P_h is a power transferred to the water by the aerator, ρ is a density of water, Q is a flow rate (in our case it is an unknown value), ΔY_{Run} is a unit energy added to water by a runner.

The unit energy added to the water by the aerator in case of axial inflow can be expressed this way

$$\Delta Y_{Run} = v_{u2}.u_2 \quad (2)$$

The subscript 2 represents the parameters on the runner outlet. The velocity v_{u2} is a component of the absolute outlet velocity in the direction of the circumferential velocity u_2 on the runner outlet. All these velocities are outlined in the Fig. 1. These parameters can be expressed this way

$$u_2 = \pi.n.D_2 \quad (3)$$

$$v_{u2} = u_2 - \frac{v_{m2}}{tg\beta_2} \quad (4)$$

$$v_{m2} = \frac{Q}{\pi.D_2.b_2} \quad (5)$$

where π = 3.14, n is a speed of the runner [rev.s^{-1}], D_2 is the outlet runner diameter, v_{m2} is the meridional velocity on the runner outlet, β_2 is the blade angle on the runner outlet and b_2 is the width of the runner on the outlet.

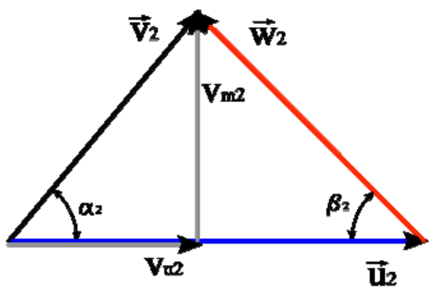

Fig. 1: The Outlet velocity triangle.

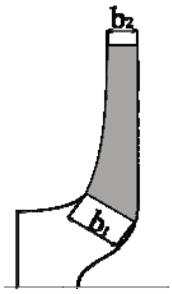

Fig. 2: Meridional cross-section of runner.

The unit energy can be then expressed

$$\Delta Y_{Run} = \left(1 - \frac{\frac{v_{m2}}{u_2}}{tg\beta_2}\right).u_2^2 \quad (6)$$

The expressions (5) and (6) can be applied into equation (1). The equation (1) can be then modified to receive a quadratic equation for the flow rate Q.

$$\frac{\rho.Q^2.n}{b_2.tg\beta_2} - \rho.Q.(\pi.n.D_2)^2 + P_h = 0 \quad (7)$$

Previous quadratic equation can be rewritten in this way

$$A.Q^2 - B.Q + C = 0 \quad (8)$$

The solution can be found in a form

$$Q_{1,2} = \frac{-B \pm \sqrt{B^2 - 4.A.C}}{2.A} \quad (9)$$

Two solutions of the previous quadratic equation are available

$$Q_1 = \frac{1}{2}(\pi.D_2)^2.n.b_2.tg\beta_2 + \sqrt{\frac{1}{4}n^2.(\pi.D_2)^4.(b_2.tg\beta_2)^2 - \frac{b_2.tg\beta_2.P_h}{\rho.n}} \quad (10)$$

$$Q_2 = \frac{1}{2}(\pi.D_2)^2.n.b_2.tg\beta_2 - \sqrt{\frac{1}{4}n^2.(\pi.D_2)^4.(b_2.tg\beta_2)^2 - \frac{b_2.tg\beta_2.P_h}{\rho.n}} \quad (11)$$

The second solution is the right one, from the physical point of view, because when the power P_h is zero the flow rate is also zero. This is not true in case of first solution. So the solution for a flow rate is this

$$Q = \frac{1}{2}(\pi.D_2)^2.n.b_2.tg\beta_2 - \sqrt{\frac{1}{4}n^2.(\pi.D_2)^4.(b_2.tg\beta_2)^2 - \frac{b_2.tg\beta_2.P_h}{\rho.n}} \quad (12)$$

If the maximum flow rate is demanded then the argument under the radical has to be zero. It means that

$$b_2.tg\beta_2 = \frac{4.P_h}{\rho.n^3.(\pi.D_2)^4} \quad (13)$$

The maximal flow rate is given by the expression

$$Q_{\max} = \frac{1}{2}(\pi.D_2)^2.n.b_2.tg\beta_2 \quad (14)$$

The expressions (12), (13), (14) are derived for a case of an infinite number of the blades. There is possible introduce correction for finite number of blades into previous solution. The correction has to be introduced in expression (6) in this way

$$\Delta Y_{Run} = \left(\kappa - \frac{\frac{v_{m2}}{u_2}}{tg\beta_2} \right).u_2^2 \quad (15)$$

Correction factor κ can be expressed in a form taken from (Waisser, Z. 1976)

$$\kappa = 1{,}103 - \frac{0{,}523 + 0{,}582.\sin\beta_2}{\sqrt{z}} \quad (16)$$

Where z is a number of blades (3-16) and β_2 is an outlet blade angle. With the applying of this correction the expressions (12), (13), (14) are modified in the next way.

$$\frac{\rho.n.Q^2}{b_2.tg\beta_2} - \kappa.(\pi.n.D_2)^2.\rho.Q + P_h = 0 \quad (17)$$

$$Q = \frac{1}{2}(\pi.D_2)^2.\kappa.n.b_2.tg\beta_2 - \sqrt{\frac{1}{4}n^2.\kappa^2.(\pi.D_2)^4.(b_2.tg\beta_2)^2 - \frac{b_2.tg\beta_2.P_h}{\rho.n}} \quad (18)$$

The maximal flow rate will be in the case that the expression under the radical, in (18), will be zero. The only width of runner outlet can be expressed from this condition because correction factor κ also depends on the outlet blade angle β_2.

$$b_2 = \frac{4.P_h}{\rho.n^3.\kappa^2.(\pi.D_2)^4.tg\beta_2} \quad (19)$$

Then the maximal available flow rate then is

$$Q_{\max} = \frac{1}{2}(\pi.D_2)^2.\kappa.n.b_2.tg\beta_2 \qquad (20)$$

The expressions (18), (19), (20) are derived for a finite number of blades. There is introduced correction factor κ which is expressed in (16).

3. Conclusion

The equations (16), (18), (19), (20) can be used for a preliminary design of the basic runner parameters of the aerator in the case that the flow rate (discharge) through the aerator is unknown. The power which is transferred into the liquid is taken into consideration instead of it. Some parameters, as a outlet diameter of the runner, runner speed, number of blades, outlet blade angle, has to be chosen first and then the other, as the width of the runner outlet, flow rate, can be evaluated from the above equations. Next important parameters, as the inlet blade angle and inlet width of the runner and so on, can be then evaluated. The CFD computation of the flow inside of the runner or even the aerator has to come after this preliminary design to finish the hydraulic design of the aerator.

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