Experimental analysis of microges installation for existing water flows in industrial plants

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Abstract. Calculation and analysis of the existing potential of low-pressure water flow at the engineering facilities of JSC "NGMK" (Joint Stock Company, Navoi Mining and Metallurgical Combine) is carried out, nomogram for determining the power of water flow based on the head and flow rate is created. The impeller design was analyzed by means of CAD (Computer Aided Design System) SOLIDWORKS software package, the optimal number of water impeller blades was revealed.

1 Introduction

The technological processes of production units of JSC "NGMK" continuously use water resources that have a significant hydropower potential and move without the use of pumping units, i.e. gravity spillway lines. In order to determine the energy performance of some gravity spillway lines, we will make brief calculations.

2 Materials and methods

When calculating the energy index of the water flow of designed hydropower plants, the flow rate and head of water passing through the cavity where the turbine is installed, and in our case through the cross-section of the pipe, are taken into account. For this calculation the following formula is used [1-2]:

\[
\Delta Ni = (\gamma \cdot \Delta Qi \cdot \Delta Hi)/102 = 9.81 \cdot \Delta Qi \cdot \Delta Hi, \quad \text{(kW)}
\]

(1)

Where \(\gamma\) is the specific weight of water (kg/m\(^3\)), 9.81 is the acceleration of free fall, \(\Delta Qi\) is the water flow rate (m\(^3\)/sec), \(\Delta Hi\) is the spillway head (m). Flow rate refers to the amount of water passing through a given station in 1 sec. It can be determined by multiplying the average flow velocity \(\Delta vi\) (m/sec) by the cross-sectional area of the flow:

\[
\Delta Si \quad \text{(m}^2\text{):} \Delta Qi = \Delta vi \cdot \Delta Si, \quad \text{(m}^3\text{/sec)}
\]

(2)

Substituting into the calculation formula, we get:

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\[ \Delta N_i = \left( \gamma \cdot \Delta vi \cdot \Delta Si \cdot \Delta Hi \right) / 102 = 9.81 \cdot \Delta vi \cdot \Delta Si \cdot \Delta Hi \text{, (kW)} \] (3)

3 Results and Discussion

Having made calculations, having data on diameter, head and velocity, we obtain the following nomogram (Figure 1) of the area of water flow power values:

![Fig. 1. Nomogram for determining the power of water flow.](image)

The abscissa axis shows the flow rate Q in (m\(^3\)/sec), the ordinate axis shows the head H in metres. At the point of intersection of the perpendicular lines of these axes we obtain the gravity water power in kW. For example, at a flow rate of 0.04 (m\(^3\)/sec) and a head of 5 (m), the gravity water flow capacity is 19.6 (kW).

At large fluctuations of flow rate and head, the flow capacity varies accordingly [3-5].

Having requested the parameters of the self-pumping line of process water spillway from the NZR (Pressure Reserve Tank) into the process of GMZ-3 (Hydrometallurgical Plant No. 3) of the Northern Ore Department, we have a head of 65 (m) and a flow rate of 1600 (m\(^3\)/hour), further we calculate:

\[ N = 9.81 \cdot 0.44 \cdot 65 = 280.5 \text{ (kW)} \] (4)

We have the following range of data for the water flow of the process water discharge line in the technological process of GMZ-3:H=45-65 (m)

\[ \begin{align*}
Q &= 0.27-0.44 \text{ (m}^3/\text{sec)} \\
N &= 119-280.5 \text{ (kW)}
\end{align*} \]

Having modelled in SOLIDWORKS the principle assembly of the experimental installation for a pipeline with a diameter of 159 (mm), we will analyse the impeller. The diameter of the impeller is 560 (mm), the number of blades \(n=9\).

For example, let's perform SOLIDWORKS calculation for a water flow with a flow rate of 65 (m\(^3\)/hour). To do this, enter the condition of water leaving the pipeline, in the volume of 0.018 (m\(^3\)/sec), calculation time 10 (sec). Then start the calculation.
After completing the calculation, let's consider the water flow diagram in Figure 3.

As can be seen, at constant rotation only two blades will be completely submerged and under the influence of the flow. Next, let us consider the force exerted by the water flow on the blades.

Let us consider the velocity of motion in the blade region. Average linear velocity \( v = 1.5 \) (m/sec).
Using the obtained data, we calculate the power $N$ of the impeller arising under the influence of the water flow. For this purpose it is necessary to calculate the moment $M$ on the blade and the angular velocity $\omega$ of the impeller. The impeller power in this case is characterised by the following formula:

$$N = M \cdot \omega \text{ (W)}$$  \hspace{1cm} (5)

The torque depends on the radius and the force of water pressure on the blade:

$$M = F \cdot R \text{ (Newton-metre)}$$  \hspace{1cm} (6)

Angular velocity:

$$\omega = \frac{\vartheta}{R}$$  \hspace{1cm} (7)

Let's simplify the power formula:

$$N = F \cdot R \cdot \frac{\vartheta}{R} = F \cdot \vartheta \text{ (W)}$$  \hspace{1cm} (8)

It turns out that the power of the impeller does not depend on the diameter, but depends on the linear velocity of the blade and the force acting on this blade. Therefore, it is reasonable to manufacture a blade, on the surface of which the cross-section of the water flow will be completely affected by the cross-section of the water flow. Since the diameter of the pipeline and the maximum cross-sectional dimension of the water flow in height, and width is 159 (mm), the size of the blade should be a minimum of 159 (mm) in width and 159 (mm) in height [6-8]. It does not make sense to manufacture an impeller diameter that is too large as it will lead to bulky, weighty and increase the cost of the structure. It follows that the radius of the impeller should be at least 159 (mm), but it is necessary to take into account the location of the blades relative to each other, take into account the distance between them, which will create additional load on the blade, due to a certain mass of water between the blades, falling under the force of its own gravity [9-10].

Substitute the calculated values:

$$N = F \cdot \vartheta = 135 \cdot 1.5 = 202.5 \text{ (W)}$$  \hspace{1cm} (9)
Using the SOLIDWORKS software package, it was possible to calculate that the proposed plant produces the power of $N = 202.5$ (W).

Since the impeller power does not depend on the diameter, let us analyse the dependence of power on the number of blades.

At the same water flow rate and diameter of the pipeline and impeller, we reduce the number of blades to 7. Let's make calculations identical to the previous ones. The water flow diagram shows that with the number of blades equal to 7, only one blade is completely immersed in water.

**Fig. 6.** Water flow diagram.

Next, consider the force exerted by the water flow on the blades.

**Fig. 7.** Average value of force $F=81$ (N). Maximum value $F=82$ (N).

Linear velocity does not change $\nu=1.5$ m/sec.

**Fig. 8.** Velocity diagram.

Let's find the power:
Let us analyse an impeller with the number of blades equal to 11.
At the same water flow rate and diameter of the pipeline and impeller, we increase the number of blades to 11. The calculations are identical to the previous ones.
The water flow diagram shows that with the number of blades equal to 11, only three blades are completely immersed in water.

\[ N = F \cdot \vartheta = 81 \cdot 1.5 = 121.5 \text{ (W)} \]  

Fig. 9. Water flow diagram.

Next, consider the force exerted by the water flow on the blades.

Fig. 10. Average value of force \( F = 145.6 \text{ (N)} \). Maximum value \( F = 148.6 \text{ (N)} \).

The linear velocity does not change \( \nu = 1.5 \text{ (m/sec)} \).

Fig. 11. Velocity diagram.

Let’s find the power:

\[ N = F \cdot \vartheta = 145.6 \cdot 1.5 = 218.4 \text{ (W)} \]
Fig. 12. Graph of the force acting on the blades: a) number of blades 9; b) number of blades 7; c) number of blades 11.

4 Conclusion

When the number of blades is 7, the impeller power is 121.5 (W), which is less than 202.5 (W) when the number of blades is 9. When the number of blades is 11, the impeller power is 218.4 (W), which is not much more than 202.5 (W) when the number of blades is 9. But at the same time the mass of the impeller increases. Hence we conclude that the optimal number of blades is 9.

References


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