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Obtaining of the optimal speed of the centrifugal pump

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Abstract: The work is devoted to the finding of the formula for calculating the optimal speed of the centrifugal pump. The structure, applications and main types of this vertical tank and its advantages in comparison to the horizontal tank are described. The figuring out of the formula is based on the conditions of maximum pump efficiency and it allows us to quickly assess the degree of non optimality of the pump when its operating frequency differs from the optimal frequency.

Introduction

The concept of "house" efficiency as a characteristic of the most optimal operation of the centrifugal pump can often be found in the literature. However, how can you ensure optimal operation of the centrifugal pump [1–5] if it is already selected in a particular hydraulic system and does not fall into the necessary range? This can be achieved mainly by frequency regulator [6–12]. In this work the formula for calculating the optimal rotation frequency of the rotor of a centrifugal pump is obtained.

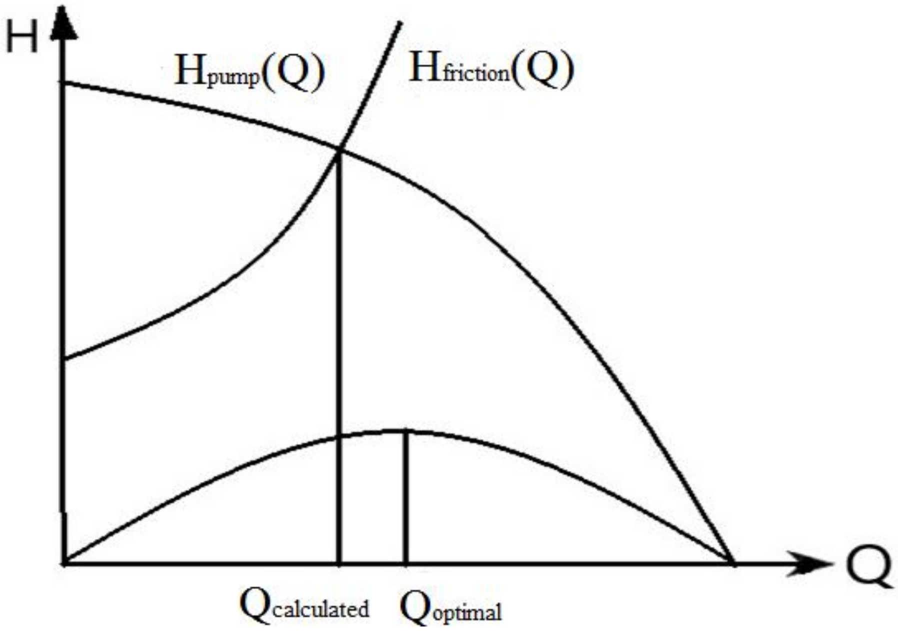

Figure 1. The "house" efficiency

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Mathematical model

$$H_{pump}(Q) = A + B \cdot Q + C \cdot Q^2 \tag{1}$$

where A, B, C — pump constants, obtained from the approximation of its hydraulic head characteristic.

Also the hydraulic head at the working point is equal to:

$$H_{friction} = H_{static} + \alpha \cdot Q^2 \tag{2}$$

where $\alpha = 0,0827 \dfrac{x \cdot l}{d^5}$ — the constant.

If we equate the above hydraulic heads and express flow rate Q, we get:

$$Q_{calculated} = \frac{-B \pm \sqrt{B^2 - 4(\alpha - C)(H_{static} - A)}}{2(\alpha - C)} \tag{3}$$

Analysis of the obtained formula for flow rate Q to the sign before the square root:

$$\alpha > 0,\ C < 0 \tag{4}$$

It means:

$$\alpha - C > 0 \tag{5}$$

$$H_{pump}(0) = A \tag{6}$$

$$H_{static} < A \tag{7}$$

Or:

$$H_{static} - A < 0 \tag{8}$$

Then:

$$\sqrt{B^2 - 4(\alpha - C)(H_o + y - A)} = \sqrt{B^2 + 4\left|(\alpha - C)(H_o + y - A)\right|} > |B| \tag{9}$$

$$Q(y) = \frac{-B + \sqrt{B^2 - 4(\alpha - C)(H_o + y - A)}}{2(\alpha - C)} \tag{10}$$

Similarly for the efficiency curve:

$$\eta(Q) = A_1 + B_1 \cdot Q + C_1 \cdot Q^2 \tag{11}$$

where A_1, B_1, C_1 — the constants of the approximately efficiency curve. Differentiate this expression:

$$\eta'(Q) = 2 \cdot C_1 \cdot Q + B_1 \tag{12}$$

Equate equation (12) to 0 to find the maximum efficiency, and we get the following formula:

$$Q_{optimal} = -\frac{B_1}{2 \cdot C_1} \tag{13}$$

We get following expression from the theory of similarity of centrifugal pumps:

$$\frac{n_2}{n_1} = \frac{Q_{optimal}}{Q_{calculated}} \tag{14}$$

where n_1 — frequency at optimal efficiency;

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n_2 — initial frequency;
$Q_{calculated}$ — calculated volume flow rate.
Then it turns out, taking into account the formulas (14), (10) and (13):

$$n_2 = n_1 \cdot \frac{-B_1 \cdot 2 \cdot (\alpha - C)}{2 \cdot C_1 \cdot \left(\sqrt{B^2 - 4(\alpha - C)(H_o + y - A)} - B \right)} \tag{15}$$

Conclusion

If the centrifugal pump is selected in a particular hydraulic system so that it is not in the range of the "house" of efficiency, but there is a possibility of frequency control, when the above formula (15) allows us to determine the optimal speed of the pump rotor, providing maximum efficiency.

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