RESEARCH OF VERIFICATION DESCRIPTIONS OF MANUFACTURING MECHANISMS

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Abstract

In this article, the description of the adjustment of the production mechanisms of the change of the technological parameters of the wastewater on the example of the pump devices used in the regenerator aerotank is considered. Descriptions of speed adjustment of existing mechanical transmission indicators of pumps by changing the frequency of the mains voltage to which the asynchronous motor is connected have been studied.

Keywords: Wastewater, air tank, pumping device, asynchronous motor, power, mains voltage frequency, adjustment specifications.

Currently, as a result of the development of energy, transport, industry and other sectors of the economy, special attention is paid to the rational use of water resources and the improvement of wastewater treatment and use in wastewater treatment systems.

It is promising to adjust the frequency of the asynchronous motor by controlling the technological parameters of the wastewater in the pump device that circulates the wastewater in the aerotank in the biological treatment facilities. The article describes the calculation and analysis of the characteristics of changes in electrical, energy and mechanical indicators depending on the level of loading for different values of the frequency.

For this, the mechanical power of the pumping device is determined [1,2].

$$N_P = \frac{Q_P \cdot H_P}{367{,}2 \cdot \eta}$$

where:

H_P – regerator height, m;

η – coefficient of efficiency of device;

Q_P – circulating active sludge consumption, m^3/h.

$$Q_P = R \cdot Q$$

where:

Q– consumption of wastewater entering the aerotank, m^3/h;

R— share of circulating active turbidity in the calculation flow of water;

$$R = \frac{x_O}{(1000/J) - x_O}$$

where:

x_O − dose of active turbidity in the aerotank, mg/l;

J − active fuzzy index, sm^3/g.

The change of the static torque of the pump device depending on the frequency is calculated by the following formula [3].

$$M_s = 0{,}1 \cdot M_n + (M_n - 0{,}1 \cdot M_n) \cdot \alpha^2 \cdot (1 - s)^2$$

where:

M_n − initial static torque of device, N·m;

α − relative frequency;

s− nominal slip;

The nominal static torque of the pumping device is calculated as follows.

$$M_n = \frac{N_p}{\omega_n}$$

where:

ω_n − nominal angular frequency of the motor, 1/s.

The relative static torque of the pump unit is found from the following formula [4,5,6,7,8].

$$\mu = \frac{M_s}{M_n}$$

Based on these, a working description of the pump device was built in Fig. 1.

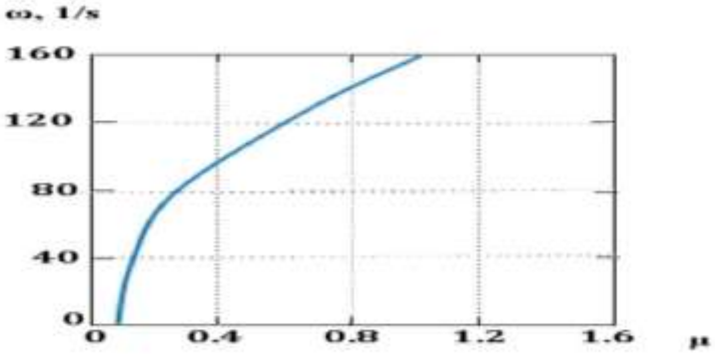

Figure 1. Operating description of the pumping device.

The natural mechanical description of the asynchronous motor is created based on the nominal indicators given in the reference book. For this, the values characterizing the following operating modes of the motor are considered, which are:

1) $s = 0, \omega_o$ and $M = 0 -$ idle running point;

2) s_n, ω_n and $M_n = \frac{P_n}{\omega_n} -$ nominal point;

3) $s_{kr} = s_n\sqrt{{b_n}^2 - 1}, \omega_{kr} = \omega_o(1 - s_{kr})$ and $M_{kr} = b_n \cdot M_n -$ critical point;

4) $s = 1\,, \omega = 0$ and $M_{it} = b_{it} \cdot M_n -$ short circuit point [14,15,16,17,18].

The nominal parameters of the asynchronous motor are as follows: $P_n -$ power on the motor, kW; $U_l/U_f -$ nominal voltage, kV; $cos\ \phi_{\text{п}} -$ nominal power factor; $\eta_{\text{п}} -$ nominal coefficient of efficiency; $b_{it} -$ multiple value of starting torque; $b_{\text{п}} -$ maximum load by torque; $d_{it} -$ multiple value of starting current; $\omega_n -$ nominal angular frequency, 1/s; $\omega_0 -$ idle running angle frequency, 1/s; $\mu -$ nominal relative static moment; s_n- nominal slip.

The characteristics of adjusting the frequency of the network voltage to which the asynchronous motor is connected are created as follows. If the relative static torque of an asynchronous motor at arbitrary load $\mu_S = \frac{M_S}{M_{\text{п}}}$. ($M_s$ – static torque on the shaft of an asynchronous motor), where the multiplication of the maximum and current static moments is calculated by the following equation:

$$b_S = \frac{M_{max}}{M_S \frac{b_n \cdot \gamma^2}{\mu_S \cdot \alpha^2}}$$

where:

$\gamma -$ relative value of voltage.

If we make a simplification without taking into account the active resistance of the stator, the frequency is inversely proportional to the critical value of the slip.

$$s_{krf} \approx \frac{s_{kr} \cdot f_{1n}}{f_1} = \frac{s_{kr}}{\alpha}.$$

Based on the above equations, the Kloss formula takes the following form:

$$\mu = \frac{2 \cdot b_n \cdot \frac{\gamma^2}{\alpha^2}}{\frac{s_{kr}}{\alpha s} + \frac{\alpha s}{s_{kr}}}$$

The energy characteristics of the asynchronous motor connected network voltage adjustment by changing the frequency are created as follows. For the relative value of the static torque of the pump load μ_S at the relative value of the frequency of the network voltage, the relative value of the voltage is equal to $\gamma = \alpha \cdot \sqrt{\mu_S}$. Based on the technical parameters of the asynchronous motor, its maximum torque load is calculated [9,10]:

$$b_s = \frac{b_n}{\mu_s} \cdot \frac{\gamma^2}{\alpha^2}.$$

The actual value of the rotor current is calculated using the following formula:

$$: \grave{I}_2 = \grave{I}_{2n} \sqrt{\mu_s \frac{b_n + \sqrt{b_n^2 - 1}}{b_s + \sqrt{b_s^2 - 1}}}$$

Nominal value of the rotor current:

$$I_{2n} \approx cos\varphi_n \cdot I_{1n} = \frac{P_n}{\eta_n \, cos\,\varphi_n \sqrt{3} U_l};$$

where:

I_{1n} – nominal phase current of the stator.

The nominal value of the magnetizing current:

$$I_{\mu n} = \sqrt{I_{1n}^2 - I_{2n}^2}$$

Calculates the sine and cosine values of the angle between the mains voltage and the stator current.

$$sin\,\varphi^{\backprime} = \frac{1}{\sqrt{2 \cdot b_s (b_s + \sqrt{b_s^2 - 1})}} \text{ and } cos\,\varphi^{\backprime} = \sqrt{1 - sin^2\,\varphi}$$

The stator phase current value is found.

$$I_1 = \sqrt{(I_\mu + \grave{I}_2 \cdot sin\,\varphi^{\backprime})^2 + (\grave{I}_2\, cos\,\varphi)^2}$$

Calculates the power factor of the asynchronous motor.

$$cos\,\varphi = \frac{\grave{I}_2 \cdot cos\,\varphi^{\backprime}}{I_1}$$

The total power consumed by the asynchronous motor from the network is determined.

$$S = \sqrt{3} \cdot \gamma \cdot U_l \cdot I_1$$

The active power consumed by the asynchronous motor from the network is determined.

$$P = S \cdot cos\,\varphi$$

The reactive power consumed by the asynchronous motor from the network is determined.

$$Q = S \cdot sin\,\varphi$$

The efficiency of the asynchronous motor is calculated [17,18,19].

$$\eta = \frac{\alpha \cdot \mu_s \cdot P_n}{S}$$

Based on the above, by measuring the technological parameters of wastewater at the wastewater treatment plant of Bukhara regional "Suvta'minot" LLC the issues of energy saving in pumping devices used in regenerator aerotanks were considered. 4A160S4U3 rotor short-circuited asynchronous motor is installed in the pump unit at the enterprise, and its nominal parameters: Pn = 15 kW; 380/220 V; $\eta_n = 88{,}5\%$; $\cos\varphi_n = 0{,}88$; $b_n = 2{,}2$; $b_{it} = 1{,}4$; $d_{it} = 7{,}0$; $\omega_0 = 157\ 1/s$; $\omega_n = 153{,}5\ 1/s$; sn = 0,02. Based on the nominal parameters, the natural and adjustment characteristics of the 4A160S4U3 asynchronous motor are built.

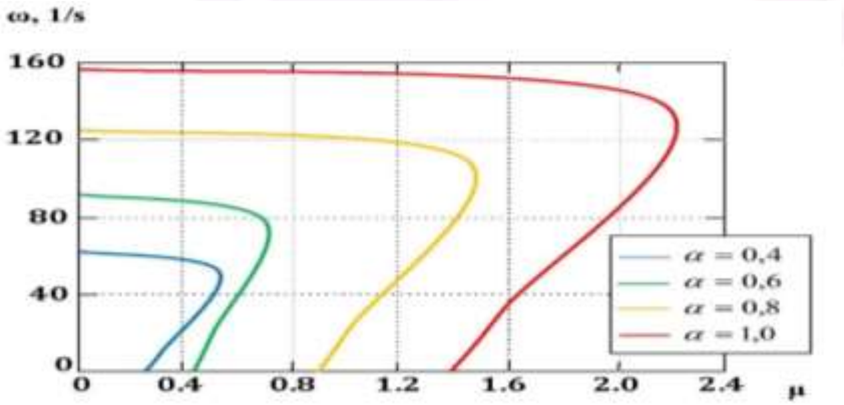

Figure 2. Natural and adjustment characteristics of the 4A160S4U3 asynchronous motor.

Table 1 shows the electric parameters of the asynchronous motor for different values of the frequency and values of the corresponding static torque.

Table 1

Indicators of an asynchronous motor	Relative value of frequency			
	1,0	0,8	0,6	0,4
S, kVA	19,2	11,3	5,7	1,6
P, kW	17	8.9	4,8	1,2
Q, kVar	9,15	6,9	3,1	1,06
I_1, A	29,3	26	21,6	13,9
I_2', A	25,8	21,2	18,3	12
I_μ, A	13,9	11,1	8,8	6,3
$\cos\varphi$	0,88	0,79	0,84	0,75
η	0,885	0,7	0,64	0,79

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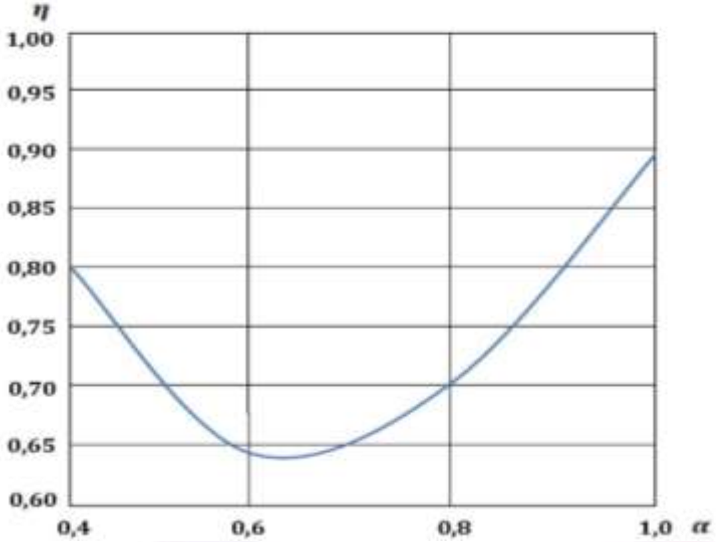

Figure 3. Description of the change of useful work coefficients of an asynchronous motor depending on the relative frequency.

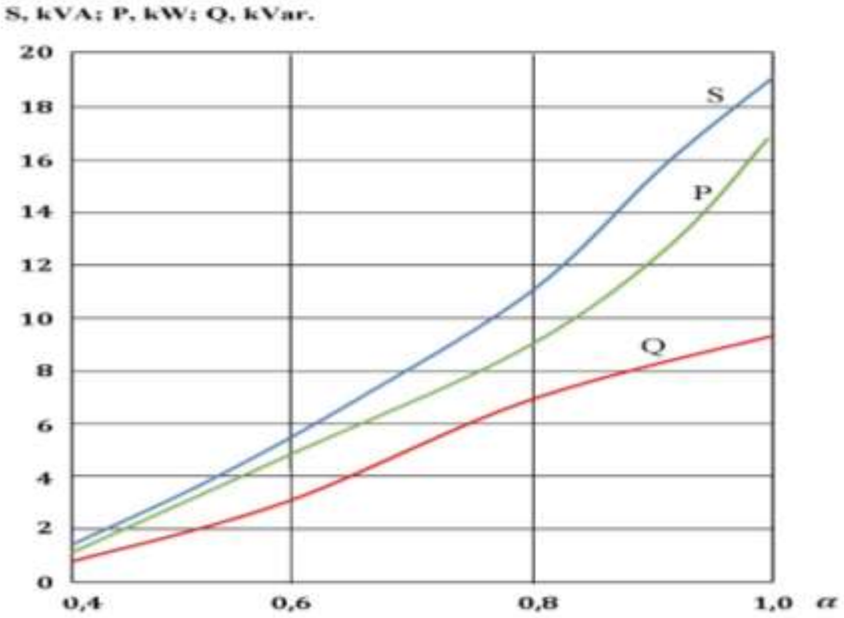

Figure 4. Descriptions of changes of the full, active and reactive powers of an asynchronous motor depending on the relative frequency.

The conducted research led to the following results:

1. First, a working description of the pumping device was built. Based on the working description, it was determined that the relative frequency of the mains voltage should be adjusted in the range of 0.4-1 so that the load of the device is mainly in the range of 30-100% compared.

2. The operating characteristic graph of the pumping device and the characteristics of the frequency adjustment of the asynchronous motor were constructed. When the relative frequency was 0.8, the relative static torque was 0.66, at 0.6 it was 0.42, and at 0.4 it was 0.24.

3. Descriptions of changes in the efficiency and power of the asynchronous motor depending on the relative frequency were constructed. When the frequency of the network to which the motor is connected changes from 40% to 100% compared to the nominal, its full power increases up to 12.0 times, correspondingly, the active power increases up to 14.2 times, the reactive power increases up to 8.6 times, and the useful work coefficient increases up to 1.38 times.

4. The results of the research showed that frequency adjustment of the motor of the pump device provides opportunities to save electricity in the device.

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