



ENERGY SAVING IN COMPRESSOR DEVICES IN WASTEWATER TREATMENT FACILITIES

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ABSTRACT

The article discusses the issues of energy saving of compressor units of treatment facilities. The main parameters of the aeration system compressor were calculated by determining the flow rate, temperature, and dissolved oxygen concentration of wastewater in the aeration tank. The possibilities of energy saving by changing the frequency of an induction motor are determined depending on the load on the device. The results of the study are presented in the form of tables and graphs.

In recent years, the development of energy, transport, industry and other sectors of the economy has had a significant negative impact on the environment. As a result, along with the rational use of water resources, special attention is paid to energy saving in wastewater treatment systems and the improvement of wastewater treatment and utilization systems. Due to the fact that biological treatment of wastewater is almost harmless to the environment, such projects are increasingly being implemented, large investments are being made in them, and promising developments and research are being supported. In particular, in 2020, the Asian Infrastructure Investment Bank (AIIB) has allocated a loan of \$ 385.12 million for the development of drinking water and sanitation infrastructure in Bukhara region.

Today, one of the important tasks is to control and manage the parameters of the technological environment in the systems of treatment and use of industrial wastewater. The use of biological treatment methods in aeration processes in standard wastewater treatment plants through the introduction of modern processes, methods and equipment reduces electricity costs. Aeration of turbid mixture (65% or more) accounts for the bulk of electricity costs in a standard wastewater treatment process [1].

In this study, the possibilities of energy saving in the asynchronous motor of compressor units by controlling the air driving depth, dissolved oxygen concentration and temperature of the aerator in the aerotank at the wastewater treatment plant of Bukhara region "Suv Taminot" LLC were studied. The daily flow of wastewater was calculated and

analyzed. Using the temperature of the effluent, the solubility of oxygen relative to the daily flow and the specific air consumption in the aeration process depending on the concentration of dissolved

oxygen in the effluent in the aeration tank were determined. Figure 1 shows the daily graph of wastewater flow. The estimated consumption of wastewater is 2770 m³ / h.

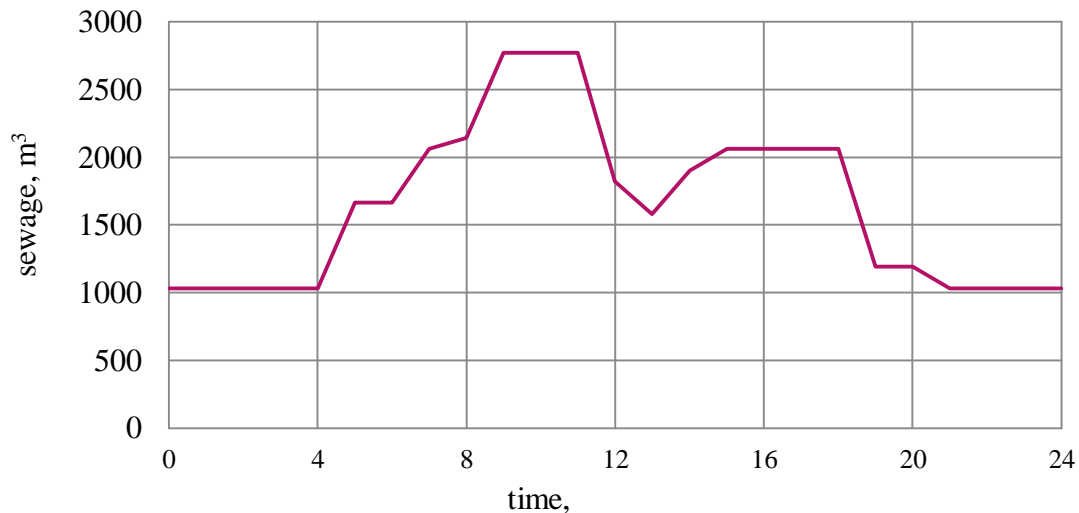


Figure 1. Daily graph of sewage flow

The specific air consumption during aeration is determined as follows [2,3]:

$$q_{air} = \frac{q_o(L_{en} - L_{ex})}{K_1 K_2 K_m K_3 (C_a - C_o)}$$

where: L_{en} and L_{ex} – the complete biochemical demand for oxygen of the treated wastewater entering the biological treatment system (BNFO_{complete}), mg/l; q_o – specific oxygen consumption, mg / mgBNFO_{complete} ; C_a – water solubility of oxygen in air, mg/l; C_o – concentration of dissolved oxygen in aerotank, mg/l; K_1 – coefficient taking into account the type of aerator; K_2 – coefficient taking into account the air driving depth of the aerator; K_m – coefficient taking into account the temperature of wastewater; K_3 – the coefficient taking into account the ratio of the rate of oxygen transfer in the active turbid mixture to fresh water.

The solubility of atmospheric oxygen in water and the concentration of dissolved oxygen in the aerotank are determined from the following formula [2].

$$C_a = C_T \frac{10,3 + \frac{h}{2}}{10,3}$$

$$C_T = 0,0043 \cdot t_w^2 - 0,358 \cdot t_w + 14,5$$

where: C_T – solubility of atmospheric oxygen in water depending on temperature and pressure, mg/l; t_w – sewage temperature, °C; h – aeration depth of the aerator, m.

Figure 2 shows a graph of the solubility of oxygen in wastewater at different temperatures depending on the air driving depth of the aerator in the program MatLab. Due to the fact that the aeration depth of the aerator in the effluent at the enterprise is 4.5 m and the temperature is 20°C, the water solubility of oxygen in the water was 11.2 mg/l.

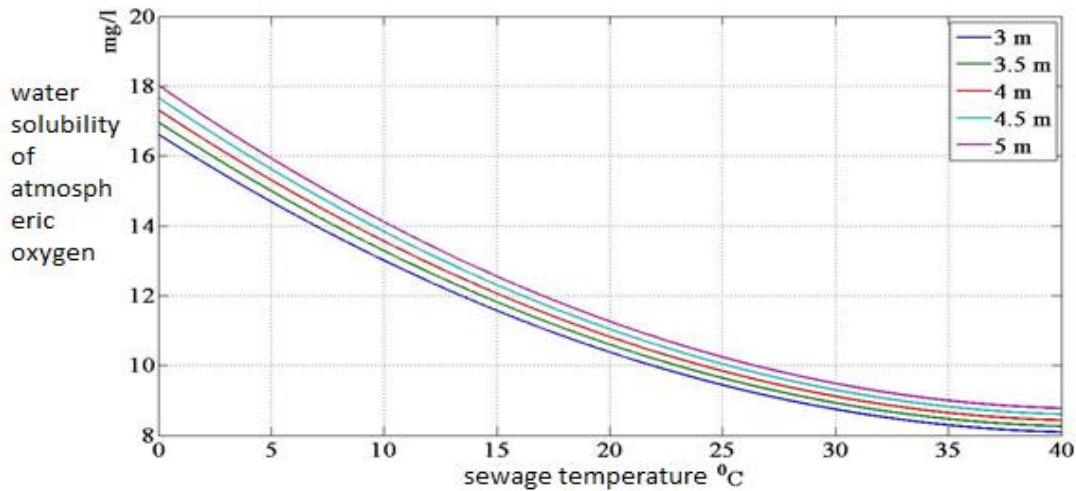


Figure2. Oxygen solubility in wastewater at different temperatures depending on the air driving depth of the aerator

We determine the efficiency of the compressor station from the following formula [2]:

$$Q_{air} = q_{air} \cdot q_w$$

where: q_w – estimated consumption of wastewater entering the treatment system, m^3/h .

Figure 3 shows a graph of the concentration of dissolved oxygen in wastewater at different temperatures in the aerotank as a function of the specific air consumption during aeration. When the concentration of dissolved oxygen in the effluent was adjusted in the range of 2-4 mg /

l, the specific air consumption at a temperature of $20^{\circ}C$ averaged $3 m^3/m^3$. According to practical calculations, when the parameters of the technological environment of wastewater are not adjusted, this figure is $12 m^3/m^3$ [1].

We determine the capacity of the compressor from the following formula [3]:

$$N = \frac{13,1(p_2^{0,29} - 26,3) \cdot Q_{air} \cdot 0,278}{1000 \cdot \eta}$$

where: p_2 – air pressure, kPa; η – the efficiency of the device

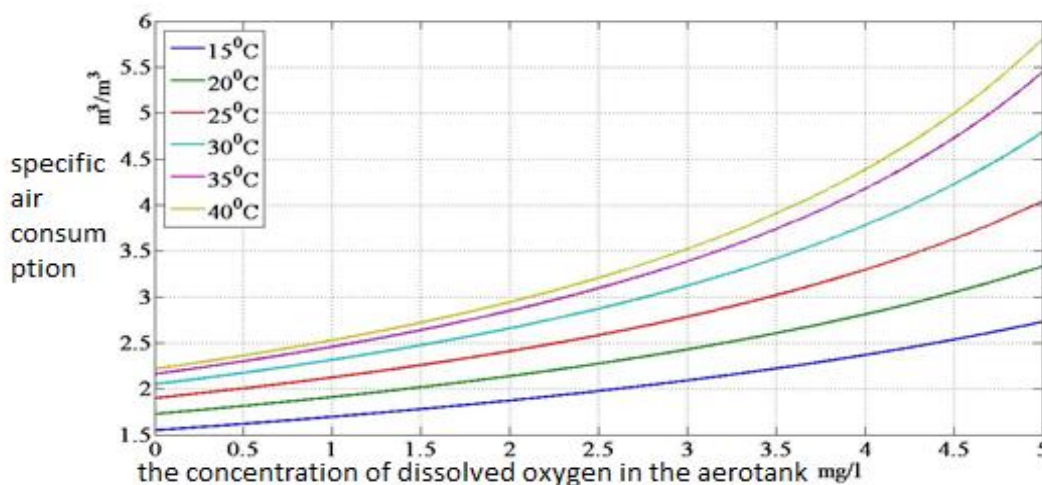


Figure3. Graph of the concentration of dissolved oxygen in wastewater at different temperatures in the aerotank as a function of specific air consumption during aeration

The compressor station of the enterprise is equipped with 2 200 kW devices. The tuning energy characteristics of an induction motor are constructed as follows [5,6,7,8,9,10]. Asynchronous motor frequency α static moment in relative value μ_s the relative value of the voltage for the relative value $\gamma = \alpha \cdot \sqrt{\mu_s}$ is equal to. Based on these parameters, we determine the maximum torque load of an induction motor:

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

We determine the rotor current using the following formula:

$$\frac{I_2}{I_{2n}} = \sqrt{\mu_s \frac{b_n + \sqrt{b_n^2 - 1}}{b_s + \sqrt{b_s^2 - 1}}}$$

$$\frac{\Phi}{\Phi_{nom}} \approx \frac{\gamma}{\alpha}$$

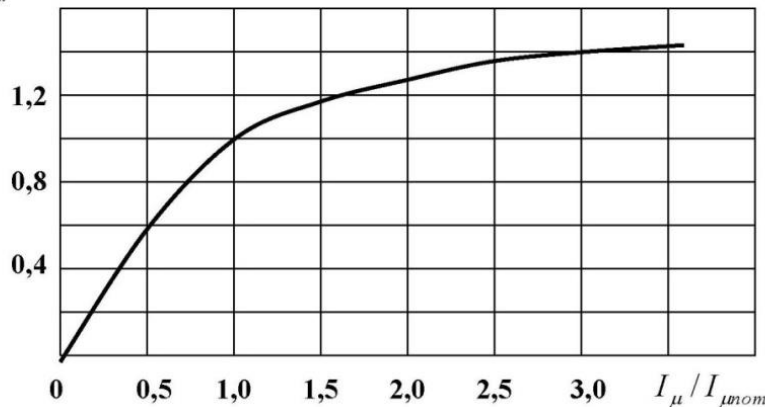


Figure4. Description of the universal magnetization of an induction motor ($I_{\mu n}$ – rated voltage and magnetizing current at frequency)

We determine the sine and cosine values of the angle between the stator current and the mains voltage:

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

Determine the value of the stator phase current: $I_1 = \sqrt{(I_\mu + I_2 \cdot \sin \varphi)^2 + (I_2 \cos \varphi)^2}$.

Determine the power factor of an induction motor: $\cos \theta = \frac{I_2 \cdot \cos \varphi}{I_1}$.

and actual value:

$$I_2 = I_{2n} \sqrt{\mu_s \frac{b_n + \sqrt{b_n^2 - 1}}{b_s + \sqrt{b_s^2 - 1}}}$$

Nominal value of rotor belt:

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

where: I_{1n} – the rated current of the stator winding phase.

In this case, the nominal value of the magnetizing current of the motor magnetic system is determined as follows:

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

The relative value of the magnetization current for different values of frequency and voltage is determined from the universal magnetization characteristic of asynchronous motors shown in Figure 4.

We calculate the total, active and reactive power consumption of an induction motor from the mains:

$$S = \sqrt{3} \cdot \gamma \cdot U_l \cdot I_1, \quad P = S \cdot \cos \theta, \quad Q = S \cdot \sin \theta.$$

We determine the efficiency of an induction motor:

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

Table1. Nominal performance of an induction motor in a compressor

P_n kW	ω_o 1/s	s_n (-)	b_n (-)	b_{it} (-)	d_{it} (-)	η_n (-)	$\cos\theta_n$ (-)
200	157	0,013	2,3	1,3	6,0	0,94	0,92

In Figures 5 and 6, the indicators with the sign (0) in the index of energy performance of the asynchronous motor in the compressor unit at different loads are

connected when the asynchronous motor is connected directly to the network, as well as the energy value without such index. The indicators are in the case of asynchronous motor adjustment.

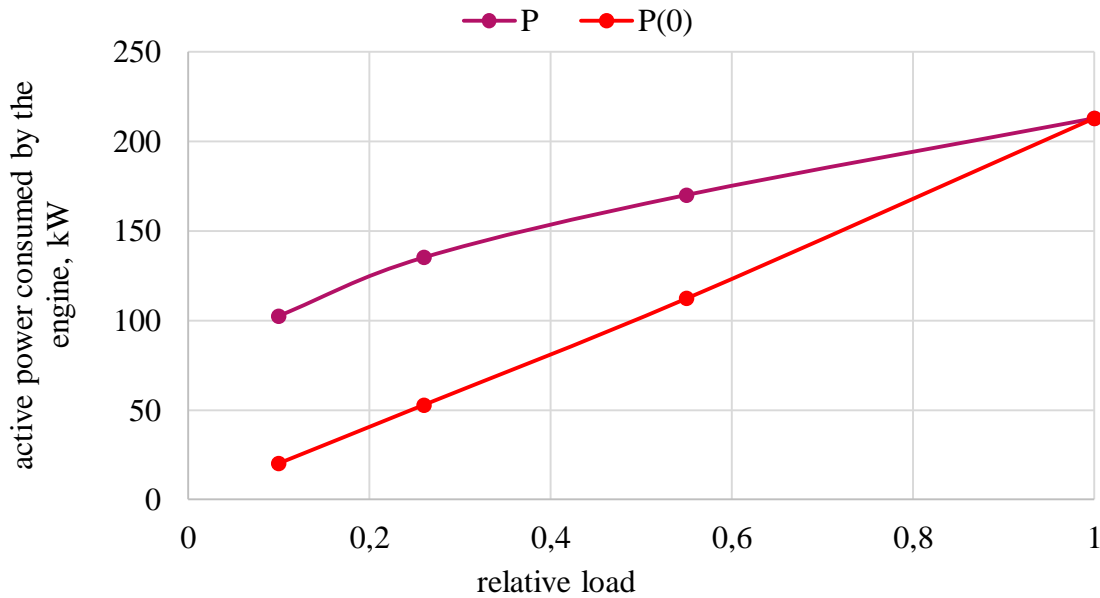


Figure5. Comparative characteristics of the active power consumed by an induction motor

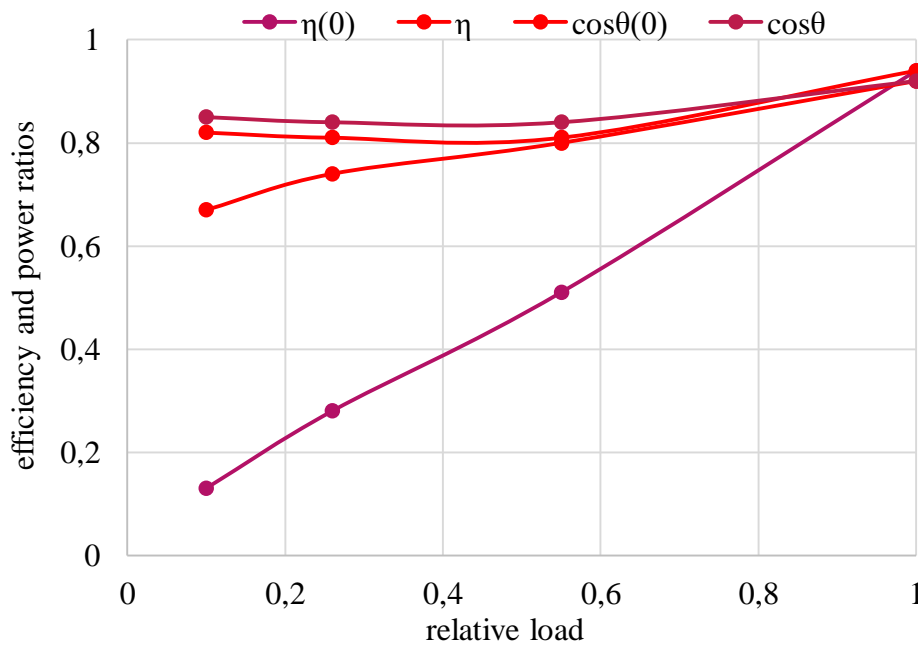


Figure6. Comparative characteristics of efficiency and power coefficients of asynchronous motors



The results of the study led to the following conclusions:

1. Data on the flow of wastewater in the aerotank, the concentration and temperature of dissolved oxygen from the treatment plant were obtained and analyzed. Since the aeration depth of the aerator is mainly 4.5 m and the temperature is 20 °C, it was found that the water solubility of oxygen in the air is 11.2 mg/l;

2. In the MatLab program, a graph of the concentration of dissolved oxygen in wastewater at different temperatures in the aerotank as a function of the specific air

consumption during aeration was constructed. When the concentration of dissolved oxygen in wastewater was adjusted in the range of 2-4 mg / l, it was found that the specific air consumption at 20 °C is on average 3 m³/ m³;

3. When adjusting an induction motor, it was found that when its load changes from 55% to 100% of the nominal, its active power consumption decreases by 27%, respectively, the efficiency increases by 1.6 times and the power factor by 1.05.

4. It was found that the asynchronous motor of the compressor can save up to 610 kWh per day.

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