Improving the operation process of a vane type vacuum pump for milking machines

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Abstract. A description is given of the improved design of a pump with a rotating casing and flexible plates, used to create vacuum in milking machines. As a result of theoretical and experimental studies, the influence of its main parameters and operating modes on the volumetric flow was revealed. The most significant factors under consideration include: the rotation speed of the rotor and pump housing, the eccentricity of the rotor installation in the housing, the ratio of the width and diameter of the rotor, the size of the gaps at the ends. An analysis of the dynamics of air pressure in the working cell of the vane pump under consideration allowed us to conclude that the proposed modernization has a small impact directly on its distribution. It has been established that the most rational value for the end gaps is 70...90 microns. Within the given dimensions of the installation, the maximum of its specific productivity was achieved at a rotation speed of the working pair of about 1750 rpm, an eccentricity of about 23 mm and a ratio of width to rotor diameter of about 1.5.

1 Introduction

The efficiency of milk production depends on many factors - the genetic potential of cattle, the quality and quantity of feed, water supply to animals, manure removal and other conditions of their keeping. A less obvious, but no less significant factor that determines the efficiency of dairy production is the organization of machine milking of cows and the level of technical equipment for this process.

One of the main directions for improving milking machines, as well as other industrial technical means, is to increase their productivity. However, the components of such installations directly interact with animals, which imposes, a number of special requirements on them. For example, both foreign and domestic researchers [1–6] have reliably established that the productivity of a dairy herd significantly depends on the vacuum operating modes of

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milking machines and installations, on the stability of the vacuum value in the cavities of the working units of such installations. Thus, it can be argued that the magnitude and stability of the created vacuum are important factors ensuring fast and high-quality milking of cows.

To create vacuum in milking machines, various vacuum pumps (VP) are used, which can differ significantly in design features, parameters and operating modes that determine the stability and magnitude of vacuum in milking machines. In practice, it has been established [6] that the rate of milk flow directly depends on the depth of vacuum created in the cups of milking machines. It is believed that, in general, for the health of the udder of animals, a vacuum value of up to $40 \cdot 10^3$ Pa is safe, but such a vacuum is not enough to ensure high-quality milking of low-milking cows. On the other hand, when the vacuum in the nipple chambers is below $30 \pm 3 \cdot 10^3$ Pa, the sphincters of the animal's nipples do not open completely, which is why the rate of milk flow and the fat content of the milk decrease, and in some cases its flow may be completely interrupted. Ultimately, all this affects the labor efficiency of machine milking operators.

In general, the issue of determining the rational vacuum during the operation of milking machines still remains relevant, for example, physiologists believe that during milking a vacuum depth of more than $50.5 \cdot 10^3$ Pa is unacceptable, since it can lead to injury and inflammation of the animals' teats, and the technological process at a large vacuum depth is difficult due to the fact that the milking cups will creep onto the teats. On the other hand, a vacuum value of more than $50 \cdot 10^3$ Pa allows for guaranteed opening of the nipple sphincter. For example, it was experimentally established [2] that the use of a three-stroke milking machine AD-01 "Farmer" in a vacuum system produces a vacuum of about $60 \cdot 10^3$ Pa provided a significant increase in the rate of milk production and milk fat content.

Be that as it may, both domestic and foreign modern milking machines operate in a fairly large range of operating vacuum values - from 42 to 53 kPa [4, 5], and some companies produce equipment that operates in a significantly wider range - from 33 up to 91 kPa [7].

When analysing the influence of vacuum values in the teat cup on the speed and quality of milk release, we must not forget about the aspect of the constancy of the value of this vacuum. Its fluctuations negatively affect the implementation of the milk ejection reflex, delay the milking process, and reduce the overall productivity of the dairy herd. Thus, a number of studies [3, 4, 8] have shown that fluctuations in the working vacuum in milking cups in the range of 9.7...19.8 kPa lead to a decrease in the milk flow rate by 105 ± 45 ml/min, and a general decrease milk yield by approximately 2.2%, in addition, they increase the likelihood of subclinical mastitis. In general, it was established [3, 4, 8] that the magnitude of vacuum fluctuations in milking cups should not exceed 7.3 kPa. In domestic milking machines, a working vacuum value from 34.6 to 50.6 kPa is used (in some cases -up to 53.3 kPa), while the technical conditions usually stipulate that its fluctuations should not exceed 6.7 kPa.

It is obvious that in this aspect, the incomplete realization of the biological potential of animals can be due not only to the design imperfections of milking cups and installations in general, but also to the low performance of vacuum stations.

The magnitude of the created working vacuum and the range of its fluctuations depend on the design and parametric features of the vacuum systems used. To ensure stability of the vacuum value in the system, designers, as a rule, during the design process include a performance reserve (supply reserve) of the HV, which is defined as the difference between their maximum and technologically required performance. The supply reserve is an important factor influencing the operation of milking plants, the value of which must be taken into account when designing and selecting power pumping stations. Data on the ratio of productivity and supply reserve of some VN, typical for individual countries, are presented in Table 1.

Table 1. Values of supply and its reserve for HV in various countries.

Indicator / A country	Russia	Sweden	Germany
HV supply, dm^3/min	95	80–110	70–85
HV supply reserve, dm^3/min	50	43–47	20–25

The supply reserve is necessary in order to, in addition to creating a technologically sufficient vacuum, compensate for possible accidental air suction. Some researchers [9], based on empirical studies, argue that at optimum, the performance of the high pressure pump should exceed the operating air flow rate by 2.25 times, taking into account the air flow rate for the drive of the milking unit units.

In the design of modern milking machines, rotary vane-type VNs (hereinafter referred to as RVNPT), which are characterized by an eccentric placement of the rotor in the housing, are widely used. Compared to analogues, they are simpler in design and operation, and at the same time provide fairly stable operation. However, RVNCT is also characterized by a number of disadvantages, such as relatively low reduced productivity, energy losses due to the frictional interaction of the plates with the elements of the housing and covers, a significant decrease in performance with increasing gaps at the junction of the plates, rotor, housing and its sides.

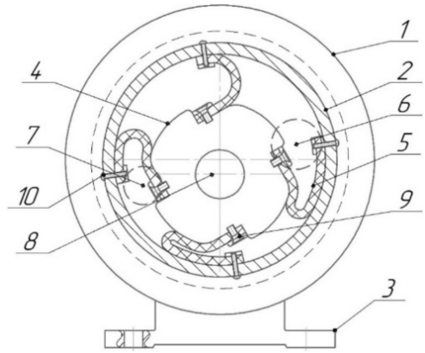
Some researchers have proposed various improvements to the design of high-voltage low-voltage propulsion systems [1], but in the overwhelming majority they did not reach industrial implementation and were “frozen” at the project stage. These projects provide for the presence of a fixed housing, which leads to a high level of friction of the plates against the elements of the HV housing. Design solutions that could provide a combination of the given second feed and a reduction in the energy intensity of the process implementation [2, 7] are quite rare.

In this regard, a VN with a movable (rotary) body was developed at the Azov-Black Sea Engineering Institute [10]. The design of such a pump allows us to significantly reduce the friction forces of the plates on the elements of the casing and side covers, this, in turn, allows us to reduce the specific energy consumption per unit of pump performance and stabilize the value of the generated vacuum.

As disadvantages of the pump of the described design, it can be noted that it operates with a certain tangential displacement of the plates, due to which air can flow from one cell to another through leaks between the plate and the housing, and also, as a disadvantage, oscillatory movements of the plates can lead to to their breakdown. In addition, this design is more complex than the classic one; it becomes necessary to install a large-diameter rotor, which occupies almost the entire useful volume of the stator, which leads to a decrease in pump flow.

In this regard, within the framework of the study, a HV design with a rotating casing was proposed in which flexible plates are rigidly fixed at their ends to the rotor and pump housing. In this design, there are no air leaks between the housing and the plates, and also, due to the flexibility of the plates, a rotor of a smaller diameter is used.

The diagram of such a pump is shown in Figure 1.



1 – protective casing; 2 – stator; 3 – base; 4 – rotor; 5 – plate; 6 – suction cavity; 7 – discharge cavity; 8 – axis; 9 – bar with rotor screw; 10 – strip with housing screw

Fig. 1. Schematic of a rotary vane pump with flexible vanes.

The pump, the suction cavity 6 of which is connected to the branch pipe of the vacuum system of the milking station, and the discharge cavity 7 is connected to the atmosphere, functions as follows. With the simultaneous rotation of stator 2 and rotor 4, due to their eccentric location, the volume between the plates changes. When this volume coincides with the suction cavity 6, air is sucked in, since the volume of the cell between adjacent plates increases. At a certain stage of rotation of the stator 2 and rotor 4, the air suction ends, its compression stroke begins, followed by release into the cavity 7.

As in the prototype pump, the joint rotation of the rotor 4 and stator 2 in the proposed VN leads to minor tangential displacements of the plates 5, which are compensated by their flexibility, and the fastening of the plates 5 to the rotor 4 and stator 2 eliminates their joint friction against each other.

Figure 2 shows a diagram of the operation of the HV of the proposed design, equipped with four flexible plates. When the rotor and stator rotate simultaneously, due to their eccentric location relative to each other, the radial size of the working plate changes in the current mode.

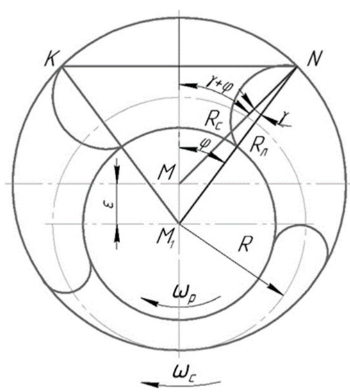


Fig. 2. Scheme for calculating the dimensions of the HV working cell of the proposed design.

During suction, the air flow ends at the maximum area of the end of the working cell in the area of the stator perimeter along an arc *KN* (Fig. 2). The total deployed length of the blade $R_л$ for this moment will be determined from the ratio of the main dimensions of the triangles M_1KN and MKN [11]:

$$R_л \times \cos\varphi = R_c \times \cos(\gamma+\varphi) + \varepsilon \text{, then } R_л = \frac{R_c \times \cos(\gamma+\varphi) + e}{\cos\varphi} \times \varepsilon \text{,} \tag{1}$$

where R_c – stator radius, m; ε – eccentricity MM_1, m;

γ – the angle of the current position of the blade relative to the rotor radius at a given point,

$$\sin\gamma = \frac{\varepsilon + \sin\varphi}{R_c};$$

φ – half the angle between flexible blades, rad; φ = 180/z; z – number of flexible blades, pcs.

The suction of air into the pump ends at the moment when the area of the working cell on the AC arc (Fig. 2) reaches its maximum value. The value of the current radius of the blade in this case will be determined from the ratio of the sides of triangles O1BC and OBC [11]:

$$\rho \times \cos\beta = R \times \cos(\alpha+\beta) + e \text{, тогда } \rho = \frac{R \times \cos(\alpha+\beta) + e}{\cos\beta}, \tag{2}$$

where R – body radius, m; e – eccentricity OO_1, m;

α – angle between the current plate position radius and the rotor radius, $\sin\alpha = \frac{e + \sin\beta}{R}$;

β – half the angle between the plates, rad; β = 180/z; z – number of plates, pcs.

To determine the flow rate of a flexible vane vacuum pump with a rotating casing, consider the maximum cross-sectional area of the cell formed by two adjacent vanes, a rotor and a casing (Fig. 2).

The value of the cell end area will be maximum when the axes of symmetry and the body coincide. Therefore, the cross-sectional area of the pump working cell can be determined

$$S_{\max} = S_1 + S_2 - S_3, \tag{3}$$

where S_1 – area of the triangle M1KN formed by the segment KN between the points of contact of the plates with the inner surface of the body and the current radii of the position of the plates, m^2.

The area of the cell will have an extremum at the moment when its axis of symmetry passes through the axis of the body. Then, its cross-sectional area will be

$$S_{\max} = S_T + S_{CM} - S_{CK}, \tag{4}$$

where S_1 – area of the triangle M1KN formed by the segment KN between the points of contact of the plates with the inner surface of the body and the current radii of the position of the plates, m^2.

$$S_1 = R_л \times \cos\varphi \times R_c \times \sin(\gamma+\varphi), \tag{5}$$

or

$$S_1 = \sin(\gamma+\varphi) \times \left[R_c \times \cos(\gamma+\varphi) + \varepsilon\right], \tag{6}$$

where S_2 – area of the sector formed by the stator radius Rc and the segment KM between the points of contact of the plates with its inner surface, m^2,

$$S_2 = \frac{1}{2} R_c^2 \left[2(\gamma+\varphi) - \sin 2(\gamma+\varphi)\right], \tag{7}$$

S_3 – area of the sector formed by the rotor radius R and the angle between the plates (2φ), m^2,

$$S_3 = \frac{\varphi}{180} \pi R^2 = \frac{\pi R^2}{z}, \tag{8}$$

where R_p – rotor radius, m.

Taking into account formulas (4), (5), (6), expression (2) can be written

$$S_{\max} = R_c^2 \times \left[(\gamma + \varphi) + e \times \sin(\gamma + \varphi) \right] - \frac{\pi R^2}{z}, \quad (9)$$

where e – relative eccentricity.

The cross-sectional area of the end of the working cell will actually have smaller dimensions, since part of it is occupied by a flexible blade

$$S_{\partial} = R_c^2 \times \left[(\gamma + \varphi) + e \times \sin(\gamma + \varphi) \right] - \frac{\pi R^2}{z} - \delta \times \left[\frac{R_c \times \cos(\gamma + \varphi) + \varepsilon}{\cos \varphi} - R \right], \quad (10)$$

where δ – flexible blade thickness, m.

The theoretical hourly flow rate of a vane vacuum pump is determined by the following relationship

$$Q = 60 S_{\partial} L \times n \times z, \quad (11)$$

where L – vacuum pump rotor length, m; n – vacuum pump rotor speed, min^{-1}.

The supply of a vacuum pump reduced to atmospheric pressure, taking into account the degree of filling of its cell, will be

$$Q_{н} = 60 \times \mu \times \frac{P_{атм} - P_{раб}}{P_{атм}} \times L \times n \times z \times S_{\partial}, \quad (12)$$

where μ – coefficient taking into account the degree of filling of the working cavity of the cell; P_{atm} – atmospheric air pressure, kPa; P_{work} – working vacuum in the vacuum system, kPa.

With an arbitrary position of the housing and rotor (Fig. 3):

$$S_T = \frac{1}{2} R_\alpha R_{\alpha+2\varphi} = \frac{1}{2} \left[\left(\sqrt{R_c^2 - \varepsilon^2 \sin^2 \alpha} - \varepsilon \cos \alpha \right) \times \left(R_c^2 - \varepsilon^2 \sin^2 (\alpha + 2\varphi) \right) \right], \quad (13)$$

where R_α, $R_{\alpha+2\varphi}$ – current radii of flexible blades forming the cavity of the working cell, m;

α – angle of the current position of the flexible blade,

$$S_{CM} = \frac{1}{2} R_c^2 \left[(2\varphi + \psi) - \sin(2\varphi + \psi) \right], \quad (14)$$

where ψ – additional angle depending on the angle of the current location of the flexible blade:

$$0 \le \alpha \le \frac{\pi}{2} \rightarrow \psi = \gamma_1 - \gamma_2, \ \frac{\pi}{2} \le \alpha \le \pi \rightarrow \psi = \gamma_1 + \gamma_2, \ \frac{\pi}{2} \le \alpha \le \pi \rightarrow \psi = \gamma_2 - \gamma_1;$$

$$\gamma_1 = \frac{\varepsilon \cos \alpha}{R_c}, \ \gamma_2 = \frac{\varepsilon \cos(\alpha + 2\varphi)}{R_c}.$$

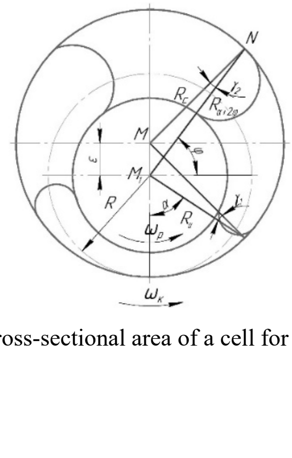


Fig. 3. Scheme for determining the cross-sectional area of a cell for an arbitrary position of the housing and rotor.

Then the current area of the working cell, taking into account the area occupied by the plates, will be:

$$S = \frac{1}{2}\left[\left(\sqrt{R_c^2 - \varepsilon^2 \sin^2 \alpha_1} - \varepsilon \cos \alpha_1\right) \times \left(\sqrt{R_c^2 - \varepsilon^2 \sin^2(\alpha_1 + 2\varphi)} - \varepsilon \cos(\alpha_1 + 2\varphi)\right)\right] +$$
$$+ \frac{1}{2} R_c^2 \left[(2\varphi + \psi) - \sin(2\varphi + \psi)\right] - \frac{\pi R^2}{z} - \frac{1}{2}\delta\left[\left(\sqrt{R_c^2 - \varepsilon^2 \sin^2 \alpha_1} - \varepsilon \cos \alpha_1\right) - R\right] +$$
$$+ \left[\left(\sqrt{R_c^2 - \varepsilon^2 \sin^2(\alpha_1 + 2\varphi)} - \varepsilon \cos(\alpha_1 + 2\varphi)\right) - R\right].$$

According to the obtained analytical dependencies, the flow of a rotary vane vacuum pump with flexible plates depends to the greatest extent on the dimensions of the housing and rotor, their rotation frequency, and less on the number of plates in the rotor.

The dependence of the change in the volume of the interplate chamber of the pump on the angle of rotation of the rotor is determined by the geometric ratios of the dimensions of the main parts of the vacuum pump.

2 Materials and methods

An experimental study of the RVN of the proposed design was carried out in laboratory conditions on a laboratory installation (Fig. 4).

The plates of the developed pump were made of ethylene-propylene rubber 6 mm thick, the rotor and the HV housing were made of steel, the number of plates was taken to be four.

When determining the parameters of the RVN, first of all, it was specified by its required volumetric supply, determined by the number, type and performance indicators of the milking machines used. After this, using expressions (8) and (9), the maximum required area of the longitudinal section of the RVN working cell was calculated. Knowing the working diameter of the rotor and setting the ratio L/D = 1.47...1.52, its width was determined. When using RVN as part of serial installations, a rotor speed of n = 1500 min^{-1} is most often used [12], which is also acceptable in this case. However, changing the stator design makes it possible to increase it to values n ≈ 1720...1770 min^{-1}.

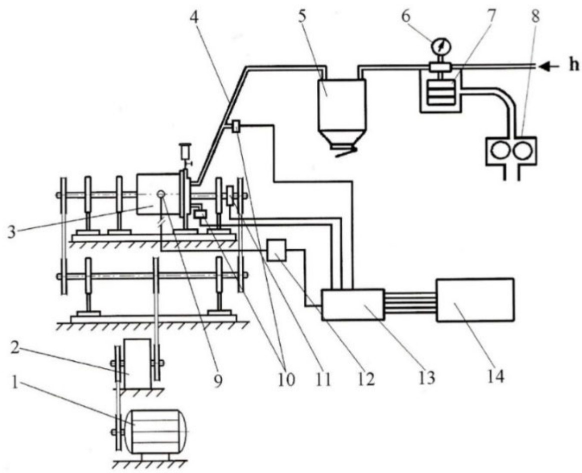
When projecting the developed RVN, the eccentricity value was specified e ≈ 0.02...0.025 m. This choice is the result of solving a compromise problem: on the one hand, an increase in the eccentricity value allows increasing pump performance; on the other hand, it increases the likelihood of wear of the plates under the influence of increasing bending influence, increases the tangential displacement of the plates, and leads to an increase in the dimensions of the RVN. In addition, there is an inverse relationship between the eccentric distance under consideration and the magnitude of the created vacuum; the deeper the planned value of the latter, the smaller the eccentricity should be [13].

The required power of the RVN drive was determined using data from [14] with the introduction of a correction factor of 1.17...1.25 into the known dependencies, which takes into account additional energy costs for the deformation of flexible plates.

Figures and tables, as originals of good quality and well contrasted, are to be in their final form, ready for reproduction, pasted in the appropriate place in the text. Try to ensure that the size of the text in your figures is approximately the same size as the main text (10 point). Try to ensure that lines are no thinner than 0.25 point.

During the experiments, using a gas meter RS-10 and a flow meter KI-4840M, the volumetric air supply of the developed RVNPT was determined with an accuracy of about 96%.

The pressure (vacuum) in the vacuum line 4 and the working cavities of the RVN was recorded by strain gauges 10, from which a pulse was fed through an ADC 12 and a fivechannel amplifier F-1510 to the input of a computer or an oscilloscope of the N-107 type. The required rotor (stator) rotation speed in the range from 1200 to 2700 rpm in increments of 300 rpm was set using variator 2 and a set of chain drives and measured with a tachometer (not shown in the diagram).



1 – AC motor; 2 – variator; 3 – RVN under study; 4 – vacuum line; 5 – receiver; 6 – vacuum gauge; 7 – throttle; 8 – flow meter; 9 –electric thermocouple; 10 – strain gauges; 11 – current collector of sensors 10; 12 – ADC; 13 – amplifier; 14 – Computer or oscilloscope

Fig. 4. Study setup diagram RVN performance indicators.

An important characteristic of RVNTP, which significantly reduces their performance, is the flow of air from the discharge cavity into the suction cavity through the gaps between the plates and other elements of the pump. In general terms, this indicator, characterized by the leakage coefficient, is expressed as follows [15]:

$$G_n = \kappa_p \times f_t \times P_0 \times \sqrt{\frac{g}{RT_н}} \times \sqrt{\left(\frac{P_н}{P_0}\right)^2 - 1}\,, \tag{15}$$

where κ_p – air flow coefficient; f_t - gap area; P_0, $P_н$, $T_н$ – gas parameters before expiration (index n) and after (index 0).

The values of the considered gaps in the experiment were set artificially during the assembly of the VN.

The ranges of changes in the variable factors were established based on data from previous studies [2]. The volumetric air flow rate was determined within 30 minutes, after 15 minutes of preliminary operation to reach stable values.

3 Results and discussion

The volumetric supply of the RVN, which is one of its main characteristics, depends on various factors, but largely depends on the difference between the maximum and minimum volumes of the working cell (Fig. 2), formed by the surfaces of the rotor, stator and two adjacent plates.

A comparative analysis of the designs of various pumps confirms the benefits of using pumps with a movable casing, which makes it possible to achieve an increase in volumetric flow not by increasing their geometry and, therefore, material consumption, but by increasing the speed of the pump. This, in turn, imposes restrictions on the ratio of the width and diameter of the rotor; the fact is that when the L/D ratio is more than 1.6 [16] and at a high rotor (stator) rotation speed, part of the air compressed in the RNV working cell is not managing to escape into the discharge cavity, remaining in the cell, reducing the efficiency of the pump. Accordingly, an increase in the rotor rotation speed should be accompanied by a decrease in its width, however, it must be taken into account that the small width of the rotor will increase the proportion of air losses through the gaps between the plates and the sidewalls of the RVN housing.

Analysis of the dependencies presented in Fig. 5 allows us to conclude that the volumetric flow of the RVN under study linearly depends on the rotation speed (n) of its rotor, as in "classical" RVNs with a fixed body. But, at the same time, if serial pumps have limiting values of rotor speed, determined by the critical value of the speed of interaction of the working plates and the inner surface of the housing, then the pump of the design proposed as part of the study does not have such a limiting factor.

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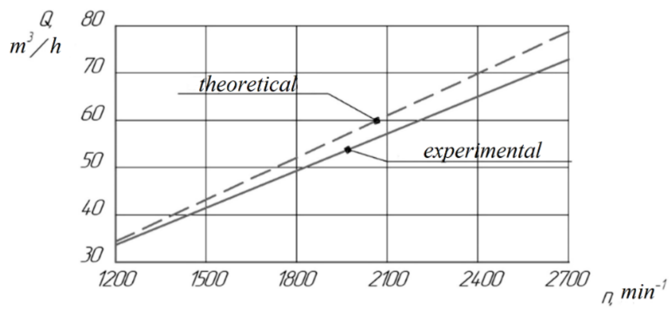

Fig. 5. Theoretical and experimental dependencies influence of rotor speed of the investigated RVN for its volumetric supply.

The actual volumetric flow of RVN is almost always lower than the theoretical one (see expression (10)) due to the flow of air from one working cell to another through the gaps δt between the plates and the sidewall of the housing. Moreover, in the proposed RVN, air leaks do not depend on the radial gaps δp between the plates and the inner surface of the stator. Figure 6 graphically displays the experimentally obtained dependences of the air supply by the developed pump on the end gaps δt between the plates and side covers.

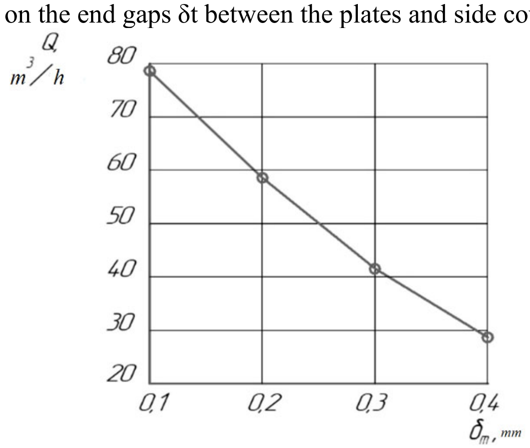

Fig. 6. Experimental dependence of the influence of rotor speed of the investigated RVN for its volumetric supply.

At the same time, the maximum volumetric air supply in the experiments was obtained with the minimum value of the end gaps achieved in practice δ_m = 70...90 microns.

Another significant characteristic of the operation of the RVN is the stability of the created pressure (vacuum). To assess the relationship between vacuum performance and RVN stability, an additional experiment was conducted to study the operation of the UDS-ZB-08 milking machine when milking in a bucket using a different number of devices. The diameter of the vacuum wire used in the experiment was one and a half inches; the design of the laboratory installation used a vacuum regulator with a throughput capacity of more than 70 m^3/h and a vacuum receiver cylinder with a volume of about 0.025 m^3. The data obtained from the results of the experiment, with a RVN productivity of 60 m^3/h and a working pressure of 53 kPa, are presented in Table 2.

Table 2. Data assessing the influence of the number of milking machines on fluctuations in the vacuum value in the UDS-ZB-08 installation when using the proposed RVN.

Number of milking machines used, pcs.	**1**	**2**	**4**	**6**	**8**
Maximum pressure fluctuations at the end of the line, kPa	0.22	0.54	0.81	1.33	1.82
Maximum pressure fluctuations in the nipple chamber, kPa	0.18	0.43	0.72	1.20	1.60
Pressure recovery period, s	0.2	0.5	1.2	1.9	2.7

From the data in Table 2 it is clear that an increase in the number of AD-01 “Farmer” milking machines leads to an increase in the magnitude of pressure fluctuations (vacuum) in the milking cups. In this particular case, the addition of one device led to an increase in pressure fluctuations in the sucking rubber by 0.2 kPa. The data presented in the table are averaged. If we consider specifically the glass farthest from the vacuum station, then the pressure drops in it were about 3.0 kPa when using eight devices. The reserve capacity of the RVN was about 11.2 m^3/h. In the case of a decrease in this indicator to 4.0 m^3/h, under the same operating conditions, fluctuations in the vacuum value in the nipple rubber of the outer cup increased to 6.0...7.0 kPa, and its recovery time - up to 7 seconds. This indicates the need to create a significant vacuum reserve during RVN operation.

A comparison of the performance indicators of the improved pump with the industrial RVN UVD 10.000 as part of the UVU-60/45V vacuum station showed that the use of the development at the same volumetric output allows reducing the required power for the drive by approximately 1.19 times. The given flow of the pump with a movable casing varied in the range of 17.6...18.0 m^3/kWh, while the productivity of the UVU pump is approximately 15 m^3/kWh.

4 Conclusion

Vacuum pumps with a housing rotating synchronously with the rotor, in which flexible plates are attached at their ends to the rotor and housing, are more promising compared to typical vane vacuum pumps with a fixed housing. In this design, there is virtually no air leakage between the housing and the plates, and also, due to the flexibility of the plates, a smaller diameter rotor is used.

The volumetric flow of the developed vacuum pump, as well as the serial one, linearly depends on the rotation speed of its rotor, but at the same time, the development does not have a limitation on the rotor rotation speed, due to the critical value of the speed of interaction of the working plates and the inner surface of the housing.

Within the given dimensions of the vacuum pump, its maximum specific performance was achieved at a rotor and housing speed of about 1750 rpm, their eccentricity is about 23 mm, the ratio of the width and diameter of the rotor is about 1.5 and the size of the end gaps is 70...90 microns.

A comparison of the performance indicators of advanced and industrial pumps showed that the use of the development makes it possible to increase the reduced flow rate of a vacuum pump from 15 m^3/kWh to 17.6...18.0 m^3/kWh.

The results of the study can be used for further improvement of vacuum pumps with a rotating casing as part of their use in the design of various milking installations.

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