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THE RESULTS OF RESEARCH PNEUMATIC ELECTROMAGNETIC  
PULSATOR COMBINED WITH COLLECTOR

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**Abstract.** This article demonstrates the results of experimental research one of the pulsators. Its main difference from others is a pneumatic electromagnetic pulsator in combination with a collector. Therefore, this article describes in detail the process of studying the pulsator. The planned experiment was carried out on by Factorial experiments with multiple factors. The influence of factors (the ripple frequency  $n$ , the milk ejection  $q$  and the ratio between strokes  $t/T$ ) on the vacuum pressure in the inter wall chamber of teat cups was studied. The regression equation of the dependence response criterion on factors is modeled. This dependence is demonstrated graphically. Also there is a contour graph which is for more detailed information.

**Keywords:** milking machine, pulsator, electromagnetic pulsator, collector, vacuum pressure, ripple frequency, milk ejection, factors.

## Introduction

To date, one of the major innovations on dairy farms around the world is the provision of adaptive milking (De Koning, 2010). But we also need to pay attention to the automation of individual components that are included in the general milking system. Automatic control milking equipment is quite favorable for cows (Pastell et al., 2006). The use of an automatic milking system saves labor (Floridi et al., 2013).

Alternate impact on the teat of the udder animal by mechanical compression and vacuum pressure is provided by a pulsator. The main criterion of researchers is to adapt the milking process to the animal as much as possible. The adaptation of the system to the animal is particularly influenced by vacuum pressure and ripple frequency, they determine the softness and speed of milking (Penry et al., 2016). The duration of milking time will decrease by 25% when changing the ratio between strokes from 50:50 to 70:30 with a constant ripple frequency of 1 Hz and the vacuum pressure in the system 42 kPa, but at a vacuum pressure of 51 kPa milking time is reduced by only 5% (Thomas et al., 1993). When conducting an experiment

of certain components, the milking machine, the main attention is paid to the curve of milk ejection (Tancin et al., 2006). The pulsation coefficient of the milking machine affects the time of milk flow, milking time and the state of sucking (Ferneborg & Svennersten-Sjaunja, 2015). Researchers (Mein & Reinemann, 2007) state that the ripple frequency, the ratio between the strokes and vacuum level affect dominant on the milk ejection.

Therefore, in this research of a pneumatic electromagnetic pulsator combined with collector there are corresponding parameters. The values of these parameters were taken from the above-mentioned sources of reference and from the real operation of milking equipment.

## 1. Methodology

The purpose of this study is to determine the rational parameters of this pulsator. Investigate the main factors influencing its technological parameters. Conduct experiment planning. Make statistical processing over the results of the experiment. A second-order mathematical model must be constructed.

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Studies of the technological parameters of the pneumatic electromagnetic pulsator combined with collector were performed using a complete Factorial experiments. The response criteria is the vacuum pressure in the inter wall chamber of teat cups. The factors influencing the vacuum pressure in the inter wall chamber of teat cups are analyzed: the ripple frequency  $n$ , the milk ejection  $q$  and the ratio between the strokes  $t/T$ .

Based on research (Dmytriv et al., 2019), possible levels variation of factors will take the form:

- $n$  – the ripple frequency, 0.67–1.33 [Hz];
- $q$  – the milk ejection, 33–45 [g/sec];
- $t/T$  – the ratio between the strokes 0.67–2.33.

Accordingly, the maximum values correspond to the mark “+”, the minimum markings “-” and the average values, respectively, “0”.

To study the influence of these factors, according to the matrix of the experiment (Table 1), their study was performed in triplicate. The experiment was performed on a developed stand for experimental research (Dmytriv et al., 2020).

The matrix of the experiment includes all possible combinations of levels variation of factors.

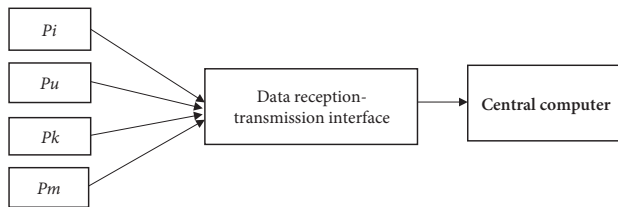


Figure 1. Scheme data transmission of vacuum pressure by digital signal:

- $P_i$  – vacuum pressure in the under teats space;
- $P_u$  – vacuum pressure in the wall chamber of teat cups;
- $P_k$  – vacuum pressure in the collector;  $P_m$  – vacuum pressure in the milk hose

Vacuum pressure values were recorded by intelligent pressure sensors. They were installed in the under teats space ( $P_i$ ), in the wall chamber of teat cups ( $P_u$ ), in the collector ( $P_k$ ) and the milk hose ( $P_m$ ). The digital code from the sensors is transmitted to the data reception-transmission interface. Then the signal is sent to the central computer. On which the further information processing was carried out.

A detailed signaling scheme is shown in Figure 1.

## 2. Results of the research

According to the procedure (Dmytriv et al., 2020), the real and natural values of the regression equation coefficients were calculated, which are given in Table 2.

Table 2. Results of calculating the coefficients of the regression equation of the vacuum pressure in the wall chamber of teat cups

Coefficient of the regression equation	Coded coefficient	Real coefficient
b0	55,193213	20,47540968
b1	-3,113375	14,10551173
b2	-1,054413	-0,555494176
b3	14,355110	10,14037511
b12	-0,287718	-0,153935518
b13	-9,738675	-5,503060346
b23	-0,358321	-0,123250093
b11	2,242115	-3,99579912
b22	0,014974	0,005817901
b33	-1,718252	-2,037063918
b123	0,265338	0,164173044

Table 1. Experiment planning matrix

Experiment №	Controlled factors			Response criteria	Experiment №	Controlled factors			Response criteria
	$x_1 (n)$	$x_2 (q)$	$x_3 (t/T)$	$y (P_u, \text{kPa})$		$x_1 (n)$	$x_2 (q)$	$x_3 (t/T)$	$y (P_u, \text{kPa})$
1	+1	+1	+1	14,75	15	-1	-1	-1	28,56
2	0	+1	+1	15,73	17	0	-1	0	24,90
4	+1	+1	-1	20,87	18	-1	-1	0	29,33
5	0	+1	-1	24,56	19	+1	0	+1	16,30
7	1	+1	0	17,73	20	0	0	+1	16,60
8	0	+1	0	19,54	22	+1	0	-1	22,15
10	+1	-1	+1	17,08	23	0	0	-1	25,04
11	0	-1	+1	22,41	25	+1	0	0	19,92
13	+1	-1	-1	23,78	27	-1	0	0	27,97
14	0	-1	-1	28,02					

The regression equation that models the change in the vacuum pressure in natural factors will look like:

$$Pu = 55,193217 - 3,113375 \cdot n - 1,054413 \cdot q + 14,355110 \cdot \left(\frac{t}{T}\right) - 0,287718 \cdot n \cdot q - 9,738675 \cdot n \cdot \left(\frac{t}{T}\right) - 0,358321 \cdot q \cdot \left(\frac{t}{T}\right) + 2,242115 \cdot n^2 + 0,014974q^2 - 1,718252 \cdot \left(\frac{t}{T}\right)^2 + 0,265338 \cdot n \cdot \left(\frac{t}{T}\right) \cdot q, \quad (1)$$

where  $Pu$  – vacuum pressure in the wall chamber of teat cups, [kPa];  $n$  – the ripple frequency, [Hz];  $q$  – the milk ejection, [g/sec];  $t/T$  – the ratio between the strokes.

This equation of the dependence of the vacuum pressure on the factors is presented graphically in Figure 2.

In the Figure 3 is a contour graph which is for more detailed information.

Figure 2 and Figure 3 graphically describe in detail the dependence of the regression model on the corresponding parameters of the pneumatic electromagnetic pulsator in combination with a collector. What is part of the milking machine.

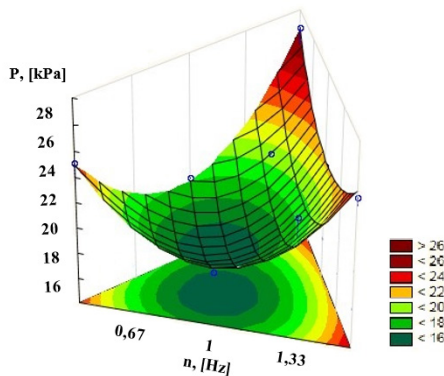


Figure 2. Dependence of vacuum gauge pressure in the inter wall chamber of the milking cup on the parameters of the technological process:  $n$  – the ripple frequency, [Hz];  $q$  – the milk ejection, [g/sec];  $t/T$  – the ratio between the strokes

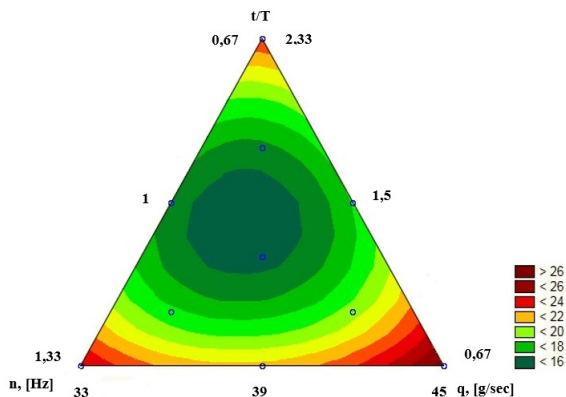


Figure 3. Contour plot:  $n$  – the ripple frequency, [Hz];  $q$  – the milk ejection, [g/sec];  $t/T$  – the ratio between the strokes

## Conclusions

This pulsator can work at the corresponding operating modes. During research the pulsator works at the set operating modes uninterruptedly. Operating modes and values of the main parameters can be changed during the experiment.

According to the regression model of vacuum pressure in the wall chamber of teat cups with respect to the studied factors (the ripple frequency, the milk ejection, the ratio between the strokes), it can be argued that this model is close to a linear form.

The vacuum pressure in the inter wall chamber of teat cups  $Pu$ , as the studied value, will acquire the lowest value ( $Pu \leq 16$  kPa) at the average values of three factors (the ripple frequency,  $n = 1$  Hz; the milk ejection  $q = 39$  g/sec and the ratio of strokes  $t/T = 1.5$ ). However, it will increase to the maximum value ( $Pu \geq 26$  kPa) when the milk ejection reaches the maximum scale  $q = 45$  g/sec, the ratio between the strokes (compression stroke to suction stroke) and the ripple frequency equal  $t/T = 1.5$ ;  $n = 0.67$  Hz.

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## PNEUMATINIO ELEKTROMAGNETINIO PULSATORIAUS SU KOLEKTORIUMI TYRIMO REZULTATAI

P. Yatsunskyi

Santrauka

Šiame straipsnyje yra pateikti vieno iš pulsatoriaus eksperimentinio tyrimo rezultatai. Esminis išskirtinis šio pulsatoriaus bruožas – kolektoriaus buvimas. Buvo atliktas išsamus faktorinis eksperimentas. Tiriamas tokių faktorių, kaip pulsacijų dažnio  $n$ , pieno išskyrimo  $q$  ir taktų santykio  $t/T$ , poveikis vakuuminiam spaudimui vidinėje melžimo mašinos kameros sienelėje. Buvo suformuluota regresinė lygtis, vaizduojanti faktorių priklausomybės atsako kriterijų. Ši priklausomybė pavaizduota grafiškai. Taip pat yra pridėtas kontūrinis grafikas detalesnei informacijai pademonstruoti.

**Reikšminiai žodžiai:** melžimo mašina, pulsatorius, elektromagnetinis pulsatorius, kolektorius, vakuuminis spaudimas, pulsacijos dažnis, išmesta pieno masė, faktoriai.