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IDENTIFYING CHANGES IN THE TECHNICAL PARAMETERS OF MILKING RUBBER UNDER INDUSTRIAL CONDITIONS TO ELUCIDATE THEIR EFFECT ON THE MILKING PROCESS

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Many years of experience in the operation of milking machines show that milking rubber was and remains a short-lived and unreliable link in the technological process of machine milking. During operation, rubber quickly loses its strength and elastic properties, becomes stiff and less elastic, deforms, and changes its shape.

The purpose of this study is to identify changes in the technical parameters of milking rubber under industrial conditions in order to establish their impact on the milking process. The obtained results could make it possible to rationally choose the milking rubber for teat cups, which would ensure an effective milking process.

During this study's initial stage, the physical and mechanical condition of milking rubber was experimentally established at steam disinfection and as a result of saturating the article with milk fats. The following stage implied detecting the effect of milking rubber tension in a teat cup on the speed of milking.

It was established that milking rubber during operation is actively exposed to milk fat, which leads to the loss of its weight relative to its original value. On day 1,000 of work, the weight loss relative to the initial value (100 g), under the washing regime temperature of 85 °C, 50 °C, 35 °C, and 20 °C, was 1 g, 3.3 g, 5 g, and 4.2 g, respectively. The dependences have been derived for the swell mass of milking rubber M on the temperature of washing solutions T and the duration of operation t as a result of saturation with milk fats.

The dependence of milk yield rate V on the tension force of milking rubber F in teat cups has been established. Thus, it was found that when the tension force of milking rubber changes from 25 to 60 N, the difference in the average intensity of milk yield is 0.13 kg/min (10.8 %). Regarding the amount of milk yield at the specified tension, the difference is 0.15 kg (2.5 %). At rubber tension from 60 to 25 N, the avere age milking time increases by 0.46 min (8.3 %). Thus, it was determined that a milking machine with milking rubber at different tension over a total milking time would unevenly milk different parts of the cow's udder.

The study reported here expands the idea about the technical and manufacturing characteristics of rubber articles, namely changes in them at steam disinfection and as a result of saturation with milk fats

Keywords: milking rubber, rubber operation, rubber parameters, milk fat, milking speed

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1. Introduction

Machine milking is a complex process of obtaining milk from cows and collecting it in a milk receiving container. In this case, the milking equipment is in direct contact with the cow's body. This process makes it possible not only to reduce the volume of manual labor but also to improve productivity by 2–5 times compared to milking by hand [1].

Analysis of numerous experiments [2–4] reveals that machine milking of cows occupies a special place in dairy cattle breeding as the most time-consuming and responsible process. The share of this technological process accounts for ≈50 % of the total labor costs for servicing milling herd [5]. As stated in [6, 7], unlike milking by hand, machine milking facilitates and simplifies the work of operators and significantly improves productivity. That requires ensuring a technical transition to a qualitatively new, more advanced technological level.

However, as practice shows [8, 9], the main issue related to executing the process of extracting milk from the udder is the negative effect of milking machines on the mammary gland of the animal. In this regard, there is a question about the possibility and necessity of milk production at dairy farms, the technical equipment of which is one of the most important tasks. This issue affects various areas of economic and research activities of specialists in the field of machine milking.

To a large extent, the parameters and characteristics of milking machine operation depend on the technical and technological condition of milking rubber. In the general milking system, this is crucial for implementing the algorithm to manage the milking process.

Milking rubber is an intermediate link between the cow and the milking machine. That is why strict hygienic requirements are put forward for this rubber article.

The technical characteristics of milking rubber are factors that exert a determining impact on the performance of rubber in the milking process, and, as a result, its effect on the animal's body. Therefore, rubber articles in milking machines must be given proper attention.

A range of operational tests and quality checks are carried out for milking rubber so that the article can withstand high levels of mechanical load and chemical action.

Thus, the need for our study is to identify changes in the technical parameters of milking rubber under industrial conditions involving the establishment of their impact on the milking process. That can be achieved through comparative technical tests of milking rubber at steam disinfection and as a result of saturation of the article with milk fats.

This approach would make it possible to expand the idea about the technical and technological characteristics of rubber articles. Along with this, that could reveal the mechanism of changes in the technical parameters of milking rubber in the process of its application, which is of practical importance.

2. Literature review and problem statement

One of the ways to improve the efficiency of livestock production is to improve such essential indicators as increasing animal productivity, reducing the cost of resources and labor. Thus, designers and manufacturers of equipment for dairy cattle breeding pay considerable attention to improving the structural execution of milking equipment, namely teat rubber for milking machines [10]. Along with this, as noted by the researchers in works [11, 12], improvement ine volves increasing the functional and technical-technological capabilities of milking equipment.

Work in this direction is constantly underway. Thus, the main idea of the research indicated in work [13] implies that any milking machine should have optimal parameters regarding the physiological needs of cows. In work [14], attention is paid to the fact that the milking equipment should ensure the complete extraction of milk from the udder of cows without having a harmful effect on the mammary gland. At the same time, the researchers in paper [15] emphasize the effectiveness of the use of milking machines in terms of productivity and functionality. However, there is no single opinion about this, which is explained by the complexity of comprehensive studies and the significant variability of the physiological state of animals.

A manufacturer of milking equipment offers its original technical solution. All units and parts of this equipment are typically tested multiple times. Milking rubber is one of the main elements of milking equipment and is also designed by taking into consideration the specific features inherent in a particular manufacturer. The load on the milking rubber is extremely high. This is a mechanical effect during the operation of the milking machine, the destructive effects of chemical components that are included in detergents, the influence of high temperatures during the washing process [16]. Therefore, each manufacturer of milking equipment tries hard to ensure that milking rubber lasts over a certain service life without degrading its original properties.

Milking rubber works in an aggressive environment, being exposed to constant exposure to milk fat, hot water, and various detergents containing alkalis, acids, and chlorine. Penetrating rubber, fat molecules cause its swelling, thereby accelerating the aging process and the destruction of the polymer structure. Detergents remove most of the milk fat but also affect the inner surface of the rubber, leading to its aging.

During the milking rubber operation, its swelling is observed, which is associated with the absorption of fat by the rubber. Emulsifier fat is absorbed much more slowly by rubber. For this reason, milking rubber immersed in milk absorbs a small amount of fat. Fat must first be deposited on the rubber before it can be absorbed. This indicates the importance of regular washing and removal of a fat film, which is formed on the working surface of milking rubber [17, 18].

Works [19, 20] noted that fat has a dual effect on rubber – softens it. In terms of molecular aging, this is because fat molecules tear rubber molecules and especially easily penetrate the rubber when an article is under a strain. The main bonds in the milking rubber (sulfur – rubber) are not torn but the internal chains that contribute to stiffness are destroyed. In addition, rubber is oxidized faster in fat. Shorter chains of molecules that are formed during oxidation contribute to more intensive fat absorption. Thus, a circle forms: the absorption of fat causes accelerated oxidation of rubber while oxidation, in turn, opens wider access of the fat inside the rubber.

The heat treatment of insufficiently washed rubber leads to fat absorption, and the heat treatment of the rubber already impregnated with fat leads to its softening.

Work [21] emphasizes that the presence of two sets of milking rubber and using them, in turn, makes it possible to keep it bacterially clean and in an optimal physical condition. However, misunderstanding the value of milking rubber alternation leads to its accelerated wear. Along with this, insufficiently degreased rubber, put to rest, continues to collapse.

No information on how the milking rubber of modern production can withstand heat treatment was revealed.

Several researchers in their works [22–25] argue that all milking rubber in one milking machine should have almost the same rigidity. Thus, when the milking machine is equipped with milking rubber with varying degrees of rigidity, there is a non-simultaneous milking of udder parts. While other teats are milked, the so-called «dry» milking occurs in the already milked one, which could lead to udder disease.

The consequences of using milking rubber that does not meet the zootechnical, sanitary-hygienic, and international technical-technological requirements (ISO 3918, ISO 5707, ISO 6690) are a significant technological impact on the milk microstructure and the physiological state of animals [26].

There are two materials from which the milking rubber is made [27]. The most common commercially is black rubber. The product's popularity is due to its cheapness, which its only advantage [28]. The second type is made of silicone. One such milking rubber is many times more expensive than an analog made from rubber [29].

Earlier studies of the operational properties of milking rubber were carried out with a pre-known time of their operation. That excluded the possibility of establishing a change in the technical characteristics of articles at steam disinfection and as a result of saturation of the article with milk fats [30].

Studies into the design and operation of milking equipment are reported in [31–33]. However, the issues related to the establishment of the effect of milking rubber tension on milking speed remained unresolved. The reason for this is the cost of relevant research and observations.

Therefore, it is advisable to conduct a study to identify changes in the technical parameters of milking rubber under industrial conditions with the establishment of an impact on the milking process.

3. The aim and objectives of the study

The purpose of this study is to identify changes in the technical parameters of milking rubber under industrial conditions with the establishment of an impact on the milking process. The results to be obtained would make it possible to rationally choose milking rubber for teat cups, which could ensure an effective milking process.

To accomplish the aim, the following tasks have been set:

– to experimentally establish the physical-mechanical condition of milking rubber at steam disinfection and as a result of saturation of the article with milk fats;

– to detect the effect of milking rubber tension in a teat cup on the milking speed.

4. Materials and methods to study the technical parameters of milking rubber

4. 1. Procedure for studying changes in the physical-mechanical properties of milking rubber under industrial conditions

This study was carried out at the State Enterprise «Research Farm «Gontarivka», Vovchansky region, Kharkiv oblast (Ukraine) for the tethered maintenance of dairy cows of the Ukrainian black-and-white dairy breed. The cows are milked in the milk pipeline at the milking plant UDM-200 Bratslavchanka. The milking machines are equipped with the milking rubber DD 00.041A made from the material of rubber compounds produced by AO Bratslav, Bratslav settlement, Nemyriv region, Vinnytsia oblast (Ukraine). The total number of samples of milking rubber was 96. The total duration of the milking plant operation was 1,125 hours.

We studied changes in the physical and mechanical properties of milking rubber under industrial conditions in the following way. In the beginning, milking rubber was weighed with accuracy to a hundredth of a gram, mounted in teat cups, and the milking process was launched at the milking plant. The research implied the alternation of work and rest. When the milking rubber was taken off for rest, it was treated in one of the following ways: I – hot water (90 °C); 2 – hot water (90 °C)+once a day steaming for 3 minutes; 3 – hot water (90 °C)+*a* washing solution based on the detergent by the company «Ecolat» (Germany); IV – hot water (90 °C)+*a* washing solution based on the detergent by the company «Ecolat» (Germany)+once a day steaming for 3 minutes. In addition, the milking rubber was washed with sponges, rinsed in warm water, dried, and placed in the fume cabinet. During the removal of rubber, it was re-weighed, then we determined the weight gain to the initial weight, which is a swelling coefficient. Thus, the swelling coefficient reflects the extent of fat absorbing by the milking rubber.

To weigh the milking rubber in determining the mass of the sample, analytical electronic scales AS 60/C with an LCD indicator (Poland) were used, which are included in the State Register of Ukraine, No. 1821-09.

In addition, in the process of research, it was necessary to determine the dependence of the coefficient of swelling of milking rubber M (g) on the temperature of detergent solutions T (°C) and the duration of operation (t, hour) as a result of saturation with milk fats and present it as an equation of regression and a surface of response. The temperature of detergents ranged from 20 °C (coded to «–1») to 85 °C (coded to «1»). Measurements were carried out every 125 hours of operation of the milking plant. It is accepted that the operating time of 125 hours corresponds in a coded form to «–1», and the time of 1,125 hours corresponds to «1».

Temperature measurement was carried out by the bimetallic thermometer with submersible sleeve T63/50 Watts F+R801 (T) (Italy). The measurement range varied from 0 °C to 120 °C. The accuracy class is 2.0.

In addition to the above, at the end of the experiment, for each sample of milking rubber, its residual and relative elongation was determined as a result of applying a force of 60 N, using the designed laboratory device (Fig. 1).

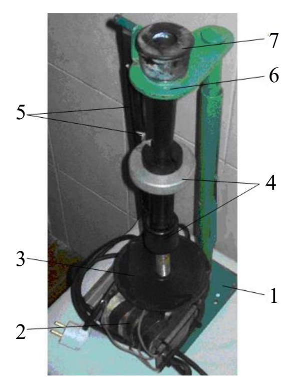

Fig. 1. Milking rubber fault detection device based on its elongation: 1 — bed; 2 — electromagnet; 3 — plate; 4 — rubber fixation unit; 5 — node for acquiring readings; 6 — rack with a support; 7 — milking rubber (which is being tested)

In addition, at the end of the experiment, the tensile strength limit for each sample of milking rubber was determined with the help of the testing machine TIRAtest made by VEB TIW Rauenstein betrieb des VEB Werkzeugmaschinenkombinat Fritz Heckert (Germany) (Fig. 2). The microprocessor K1520 of the TIRAtest machine with the help of the control unit adjusts the operation of the load unit (electromechanical reducer). The node through a mechanical link (a screw gear) moves the moving traverse together with a movable clamp attached to it and loads the sample.

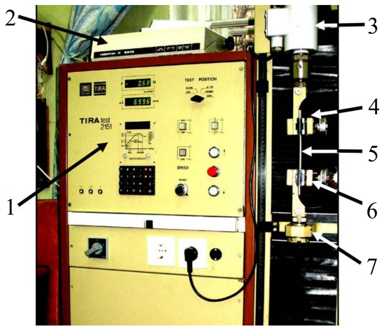

Fig. 2. General view of the TIRAtest machine: 1 – control panel; 2 – ROBOTRON K6313 printing device; 3 – dynamometer; 4 – stationary (upper) clamp; 5 – test sample; 6 – moving (lower) clamp; 7 – moving traverse

The issue of the acceptable, justified duration of operation of milking rubber and the importance of its rest value at steam disinfection is relevant. Thus, a parallel experiment was carried out, the research factors of which are the work of milking rubber (without rest and with the alternation of work and rest) and the mode of sanitary treatment of milking machines (at steam disinfection and without the use of steam). At the same time, the criteria for research, as well as in the previous experiment, were the swelling coefficient, residual elongation, and relative elongation, the tensile strength limit.

Based on the results of the acquired data, the absolute error of measurement according to the generally accepted procedure [34] was determined by each criterion.

4. 2. Procedure for studying the effect of milking rubber tension in a teat cup on milking speed

In order to assess the effect of milking rubber tension in a teat cup on milking speed, a group of 18 cows was formed. They were milked in shifts using the milking machines with a rubber tension in the cup equal to 25, 35, 45, and 60 N.

We determined the tension of milking rubber in the sleeve of a teat cup with the help of the device described in [16]. The device has a counting unit, a housing, a locking screw, a stop, a movable ferrule, a rotary lever, and a fixed insert.

Based on the data obtained (milk yield and milking duration), the average intensity of milk yield was calculated for various tensions of rubber.

The average intensity of milk yield (Q) in kg/min was calculated from the following formula (1):

$$Q=\frac{\sum(q_1+q_2)}{\sum(t_1+t_2)}, \quad (1)$$

where q_1 is the machine milking yield, kg; q_2 is the machine post-milking value, kg; t_1 is the machine milking duration, min; t_2 is the machine post-milking duration, min.

The average time of milk extraction was calculated according to the following formula (2).

$$T=t_1+t_2+t_3, \quad (2)$$

where t_1 is the time of machine milking (from the moment of putting on the fourth teat cup to reducing the intensity of milk production – less than 200 g/min); t_2 is the idle milking time (from the moment of a decrease in intensity to the beginning of machine post-milking); t_3 is the machine post-milking time (from the beginning of machine post-milking to the removal of teat cups).

Based on the obtained results, the absolute error of measurement according to the generally accepted procedure [34] was determined by each criterion.

5. Results of studying the technical parameters of milking rubber

5. 1. Studying a change in the physical and mechanical properties of milking rubber under industrial conditions

The results of studying a change in the physical and mechanical properties of milking rubber under different processing techniques under industrial conditions are summarized in Table 1.

The minimum value of the swell coefficient (3.34±0.21 g) was observed for the technique of treating milking machines with hot water (90 °C), and the largest – for treatment with hot water (90 °C)+*a* washing solution based on the detergent from company «Ecolat» (Germany)+steaming for 3 minutes once a day. The residual elongation was the lowest (6.16±0.28 %) for treatment technique II (hot water (90 °C)+steaming for 3 minutes once a day). The relative elongation was minimal (61.3±0.9 %) for treatment technique III for milking machines – hot water (90 °C)+*a* washing solution based on the detergent from company «Ecolat» (Germany). In turn, the tensile strength limit was maximal (162.4±2.8 kgf/cm^2) for hot water treatment (90 °C).

The results from studying the value of rest for milking rubber at steam disinfection during long-term operation are summarized in Table 2.

Table 1

Change in the physical and mechanical properties of milking rubber under different processing techniques

Milking machine treatment technique	Swell factor, g	Residual elongation, %	Relative elongation, %	Tensile strength limit, kgf/cm^2
I – hot water (90 °C)	3.34±0.21	6.80±0.24	68.6±0.8	162.4±2.8
II – hot water (90 °C)+steaming for 3 minutes once a day	3.42±0.26	6.16±0.28	69.9±1.2	161.6±2.2
III – hot water (90 °C)+washing solution based on the detergent from the company «Ecolat» (Germany)	6.71±0.24	8.20±0.35	61.3±0.9	148.1±2.2
IV – hot water (90 °C)+a washing solution based on the detergent from company «Ecolat» (Germany)+steaming for 3 minutes once a day	6.06±0.31	7.20±0.31	62.0±1.1	150.4±1.8

Table 2

Change in the physical-mechanical properties of milking rubber under different modes of operation and sanitation

Milking rubber operation	Milking machine sanitation mode	Swell factor, g	Residual elongation, %	Relative elongation, %	Tensile strength limit, kgf/cm^2
No rest	At steam disinfection	6.70±0.21	8.40±0.23	62.3±0.8	152.0±2.9
	No steam	8.02±0.34	8.90±0.24	63.6±0.9	160.2±3.1
Rest and work alternation	At steam disinfection	4.71±0.17	6.65±0.20	62.6±1.0	149.1±2.1
	No steam	6.51±0.31	7.91±0.21	60.3±0.9	142.3±2.2

The minimal swell factor (4.71±0.17 g), residual elongation (6.65±0.20 %) were observed when alternating the work and rest of milking rubber at steam disinfection. The relative elongation (60.3±0.9 %) and the tensile strength limit (142.3±2.2 kgf/cm^2) were minimal when alternating the work and rest of milking rubber without the use of steam. Table 2 demonstrates that the process of fat absorbing during the same working hours during the change-free operation of rubber occurs more intensively than when alternating work and rest.

The result shown by the acquired data and their subsequent treatment in the Mathematica software package (USA) using the function «NonlinearModelFit» is the dependence of the swelling of milking rubber M (g) on the temperature of detergent solutions T, x_1 (°C) and the duration of operation t, x_2 (h) as a result of saturation with milk fats, encoded in the following form:

$$M = 2.82909 - 4.49291\, x_1 - 0.422701\, x_1^2 + 2.70899\, x_1^3 - 1.78642\, x_2 - 1.06308\, x_1 x_2 - 0.03114\, x_1^2 x_2 - 0.721989\, x_2^2 + 1.49473\, x_1 x_2^2 + 3.18519\, x_2^3. \quad (3)$$

The results from the statistical treatment of the derived equation are given in Table 3.

Table 3

Results from the statistical treatment of the equation showing the dependence of milking rubber swell $M(x_1, x_2)$

Coefficient	Value	Error	Student's criterion	Probability
a_{00}	2.82909	0.447404	6.32334	$1.07487 \cdot 10^{-6}$
a_{10}	−4.49291	1.30737	−3.43661	0.00199186
a_{20}	−1.78642	0.769678	−2.32099	0.0283939
a_{12}	−1.06308	0.35488	−2.9956	0.00594871
a_{112}	−0.03114	0.601442	−0.0517755	0.959103
a_{221}	1.49473	0.619309	2.41355	0.0231419
a_{11}	−0.422701	0.459874	−0.919166	0.366458
a_{22}	−0.721989	0.469191	−1.5388	0.135937
a_{111}	2.70899	1.3239	2.04623	0.0509711
a_{222}	3.18519	0.854166	3.729	0.000943979

By comparing the calculated Student's criterion with the tabular one of $t_{0.05}(9)=2.26$, we reject the insignificant regression coefficients.

The result is the following equation:

$M = -11.2397 + 0.0417957t - 0.000057436t^2 + 2.54815 \cdot 10^{-8}t^3 + 0.627032T - 0.000295379tT + 1.83967 \cdot 10^{-7}t^2T - 0.0124291T^2 + 0.0000789147T^3$.

$$M = -11.2397 + 0.0417957t - 0.000057436\, t^2 + 2.54815 \cdot 10^{-8} t^3 + 0.627032T - 0.000295379tT + 1.83967 \cdot 10^{-7} t^2 T - 0.0124291\, T^2 + 0.0000789147T^3. \quad (4)$$

The graphical interpretation of the dependence of the swell of milking rubber M (T, t) is shown in Fig. 3 (red points correspond to the measured experimental data).

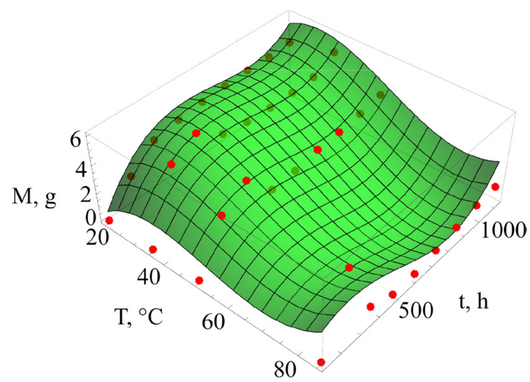

Fig. 3. Dependence of the swell mass of milking rubber M on the temperature of the detergent solutions T and the duration of operation t as a result of saturation with milk fats

As a result of oxidation, the molecular chains of fat disintegrate, thus joining even more molecules with the oxidation process increasingly accelerating.

Short molecular chains impair the reverse force of milking rubber and cause a softening effect. Subsequently, the process of rubber aging is accelerated by the high temperature and mechanical load.

Thus, when using detergent solutions at t=85 °C, it becomes possible to neutralize the effect of milk fat on milking rubber (Fig. 3). It was established that the weight of milking rubber under this temperature regime is lost only up to ≈80 hours of operation. Over the subsequent time periods of operation, the weight gradually returns to the primary value of 100 g. Subsequently, starting from ≈625 hours of operation, the rubber gradually loses weight, albeit not significantly (almost 1 g after 1,000 hours of operation).

Under the temperature regimes of 50 °C, the weight of the milking rubber decreases during the first 300 hours to

95.6 g (4.4 %). The weight is restored afterward, and, after 500 hours of use, it is 97.5 g (2.5 %). Over the following hours, its weight again undergoes a gradual change – it decreases; after 1,000 hours, it is 96.7 g (3.3 %). Thus, the loss of the mass of the milking rubber over 1000 hours of operation is, relative to the initial value of (100 g), 3.3 %.

As regards the results obtained with the use of detergent solutions at t=35 °C, then, before ≈320 hours of operation, the weight of the milking rubber is sharply lost – to 94.3 g (5.7 %), and, subsequently, the weight of the article is insignificantly restored to 95.8 g (4.2 %).

As regards the temperature regime of 20 °C, the mass of the rubber article is gradually lost during its entire service life. Thus, after 250 hours, the mass of the teat rubber was 97.6 g (3.4 %), after 500 – 96.4 g (3.6 %). After 1,000 hours of operation, the weight loss, relative to the initial value, was 4.2 %.

Based on the results of our study, it was established that milking rubber during operation is actively exposed to milk fat, which leads to a loss of its mass relative to its original value.

5. 2. Studying the effect of milking rubber tension in a teat cup on milking speed

After receiving the results on cows' milking yield and milking time, we calculated the average milking yield rate and the average milking time at various tension of the milking rubber (Table 4).

Thus, it was established that when the tension force of milking rubber changes from 25 to 60 N, the difference in the average intensity of milk output is 0.13 kg/min. (10.8 %). As regards the amount of milk yield at the specified tension, the difference is 0.15 kg (2.5 %). The difference in milk yield at rubber tension of 60, 45, and 35 N was not significant relative to the determined absolute measurement error of 0.32 kg.

At rubber tension from 60 to 25 N, the average milking time increases by 0.46 minutes (8.3 %).

In turn, the dependence of milk yield V on the tension force of milking rubber F of teat cups is shown in Fig. 4.

This dependence can be approximated in a linear form:

$$V=0.0037F+0.9841,\ R^2=0.9321. \quad (3)$$

When observing the process of milking cows at different forces of tension of milking rubber in a single milking machine, we detected the non-even rate of milking from different parts of cows' udders. This observation is represented in the form of a chart shown in Fig. 5.

For the above results, the different tension of the milking rubber was: teat cup 1 – 55 N; teat cup 2 – 35 N; teat cup 3 – 45 N; teat cup 4 – 25 N. The equal tension of the milking rubber in teat cups was 60 N. At the same time, a slight difference in milking rate (the rms deviation is 0.01 kg/min.) is explained by the physiological state of animals and the measurement error. It is this fact that underlies the controlling element of milking termination (for milking rooms – an automated manipulator of the milking machine), at which there is an automatic shutdown and removal of milking machines.

Table 4

Dependence of the speed of milking cows on the force of milking rubber tension

Indicator	Milking rubber tension force F			
	60 N	45 N	35 N	25 N
Average yield per group, kg	6.10±0.32	6.10±0.32	6.00±0.32	5.95±0.32
Average milking time, min.	5.10±0.18	5.25±0.18	5.50±0.18	5.56±0.18
Average milk yield rate V, kg/min.	1.20±0.02	1.16±0.02	1.12±0.02	1.07±0.02

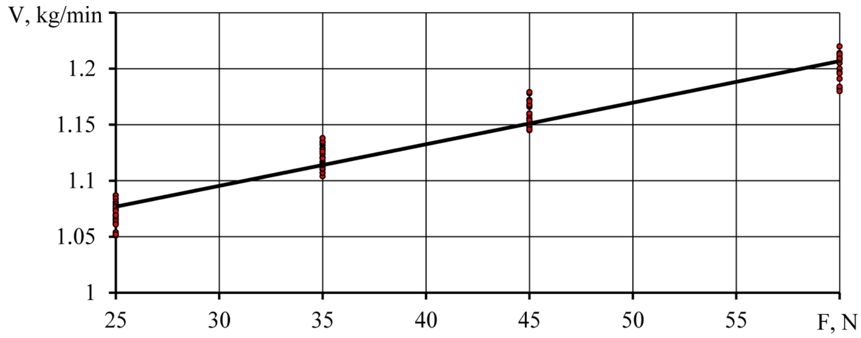

Fig. 4. Dependence of milk yield rate V on the tension force of milking rubber F of teat cups

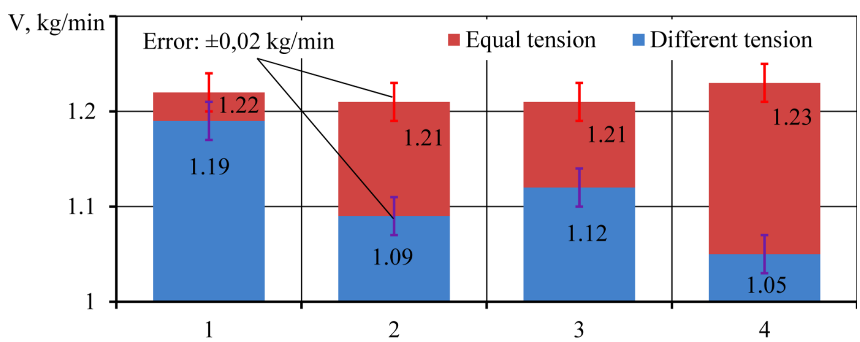

Fig. 5. Milking rate for various quarters of cows' udders: 1, 2, 3, 4 – milking rubber of the milking machine, which is put onto the corresponding quarter of the udder

It was established that a milking machine with milking rubber at different tension during the overall milking time would unevenly extract milk from different parts of a cow's udder. The rms deviation of the rate of milk output can equal, in this case, 0.07 kg/min. That leads to the «idle milking» of those parts of the udder that host the rubber with the greatest tension, which negatively affects the animal's body.

Thus, in order to evenly extract milk from udder parts, the tension of the milking rubber should be the same in all teat cups of the devices.

6. Discussion of results of studying the technical parameters of milking rubber

Works [34–36] note that the milking rubber of milking machines is the only component that comes into close contact with a cow's udder during milking. The effectiveness of the milking process depends on its technical parameters. The advantages of our research compared to those above are the establishment of changes in the physical and mechanical properties of milking rubber at steam disinfection and as a result of saturating the article with milk fats.

When analyzing data given in Table 1, it can be argued that there are no changes in the physical-mechanical properties of milking machines when washing them with hot water and steaming them once a day for 3 minutes.

The milking rubber, which, in addition to steaming, was washed with a detergent solution from company «Ecolat», demonstrated somewhat better indicators than the rubber in control devices. Thus, the relative elongation was 1.1 times smaller. That also applies to the tensile strength.

As for the swelling coefficient, its value, in this case, was 1.8 times greater. The residual elongation – by 1.1 times.

It was established that the process of absorbing fat at the same operation time during the change-free work of rubber occurs more intensively than when alternating work and rest (Table 2). The duration of active operation was 20 hours. Thus, it makes sense to replace milking rubber not after 14–15 days but after 10. The process of rubber destruction with such a replacement would be slower.

The results obtained fully reveal the estimated technical indicators of milking rubber in milking machines. Along with this, we elucidated the mechanism of change in the operational characteristics of rubber articles. Given this, the task of the rational selection of milking rubber is resolved.

This research was made possible through the use of innovative equipment (Fig. 1, 2). That has allowed us to conduct a set of experiments with specific results.

The results of our research are consistent with those reported in earlier studies by other authors [20, 30, 37–41], and complement them. A significant difference in the methodological plan of the current research is that there was a possibility to examine a wide range of indicators – from technical to technological.

Along with this, given the extremely high variability of the structural parameters for milking rubber in milking machines, there are difficulties in fully resolving the issue of maximum compliance of the rubber article with the physiological needs of animals. That has remained an unresolved issue in the general technological link of milk production at dairy complexes.

The limitations of this research relate to the fact that our experiments were carried out using milking rubber made from only one material.

Research aimed at identifying the mechanism of influence exerted by the milking rubber of milking machines on cows during milking with the use of innovative approaches and methods appears promising.

7. Conclusions

1. It has been established that milking rubber during operation is actively exposed to milk fat, which leads to the loss of its weight relative to its original value. Over 1,000 hours of work, the weight loss, relative to the initial value (100 g), under the temperature regimes of washing at 85 °C, 50 °C, 35 °C, and 20 °C, amounted to 1 g, 3.3 g, 5 g, and 4.2 g, respectively.

2. It has been determined that when the tension force of the milking rubber changes from 25 to 60 N, the difference in the average intensity of milk output is 0.13 kg/min. (10.8 %). In order to evenly extract milk from udder parts, the tension of milking rubber should be the same in all teat cups of the machines.

References

1. Paliy, A., Nanka, A., Marchenko, M., Bredykhin, V., Paliy, A., Negreba, J. et. al. (2020). Establishing changes in the technical parameters of nipple rubber for milking machines and their impact on operational characteristics. Eastern-European Journal of Enterprise Technologies, 2 (1 (104)), 78–87. doi: https://doi.org/10.15587/1729-4061.2020.200635
2. Kuhnhenne, M., Pyschny, D., Kramer, L., Brieden, M., Ummenhofer, T., Ruff, D. C. et. al. (2019). Mechanical and thermal performance of new liner tray solutions. Steel Construction, 12 (1), 23–30. doi: https://doi.org/10.1002/stco.201800025
3. Palii, A. P., Kovalchuk, Y. O., Boyko, Y. A., Bondaruk, Y. V., Diachuk, P. V., Duka, T. M. et. al. (2020). Impact of various milking equipment on incidence of mastitis in dairy herd. Ukrainian Journal of Ecology, 10 (5), 160–165. doi: https://doi.org/10.15421/2020_224
4. Tse, C., Barkema, H. W., DeVries, T. J., Rushen, J., Pajor, E. A. (2018). Impact of automatic milking systems on dairy cattle producers' reports of milking labour management, milk production and milk quality. Animal, 12 (12), 2649–2656. doi: https://doi.org/10.1017/s1751731118000654
5. Dzidic, A., Rovai, M., Poulet, J. L., Leclerc, M., Marnet, P. G. (2019). Review: Milking routines and cluster detachment levels in small ruminants. Animal, 13, s86–s93. doi: https://doi.org/10.1017/s1751731118003488
6. Mishra, A., Khatri, S., Jha, S. K., Ansari, S. (2020). Effects of Milking Methods on Milk Yield, Milk Flow Rate, and Milk Composition in Cow. International Journal of Scientific and Research Publications (IJSRP), 10 (1), p9765. doi: https://doi.org/10.29322/ijsrp.10.01.2020.p9765
7. Aslam, N., Abdullah, M., Fiaz, M., Bhatti, J., Iqbal, Z., Bangulzai, N. et. al. (2014). Evaluation of different milking practices for optimum production performance in Sahiwal cows. Journal of Animal Science and Technology, 56 (1), 13. doi: https://doi.org/10.1186/2055-0391-56-13
8. Silva Boloña, P., Reinemann, D. J., Upton, J. (2019). Effect of teatcup removal settings on milking efficiency and milk quality in a pasture-based automatic milking system. Journal of Dairy Science, 102 (9), 8423–8430. doi: https://doi.org/10.3168/jds.2018-15839
9. Jacobs, J. A., Siegford, J. M. (2012). Invited review: The impact of automatic milking systems on dairy cow management, behavior, health, and welfare. Journal of Dairy Science, 95 (5), 2227–2247. doi: https://doi.org/10.3168/jds.2011-4943
10. Paliy, A. P. (2017). Study of the impact of milking systems on the teats of cow udder. Izvestiya natsional'nogo agrarnogo universiteta Armenii, 1 (57), 33–35.

11. Enokidani, M., Kawai, K., Shinozuka, Y., Kurumisawa, T. (2020). A case study of improving milking cow performance and milking system performance with using a flow simulator. Animal Science Journal, 91 (1). doi: https://doi.org/10.1111/asj.13389
12. Drach, U., Halachmi, I., Pnini, T., Izhaki, I., Degani, A. (2017). Automatic herding reduces labour and increases milking frequency in robotic milking. Biosystems Engineering, 155, 134–141. doi: https://doi.org/10.1016/j.biosystemseng.2016.12.010
13. Aliev, E. B. (2010). Study of wear rubber nipple milкing machine based theory of aging. Zbirnyk naukovykh prats IMT NAAN «Mekhanizatsiya, ekolohizatsiya ta konvertatsiya biosyrovyny u tvarynnytstvi», 1 (5, 6), 233–242. Available at: http://aliev.in.ua/doc/stat/2010/stat_3.pdf
14. Penry, J. F., Upton, J., Leonardi, S., Thompson, P. D., Reinemann, D. J. (2018). A method for assessing teatcup liner performance during the peak milk flow period. Journal of Dairy Science, 101 (1), 649–660. doi: https://doi.org/10.3168/jds.2017-12942
15. Radu, R., Ioan, T., Petru, C. (2017). Assessment of the milking machine parameters using a computer driven test system. Journal of Agricultural Informatics, 8 (1), 32–44. doi: https://doi.org/10.17700/jai.2017.8.1.321
16. Paliy, A., Naumenko, A., Paliy, A., Zolotaryova, S., Zolotarev, A., Tarasenko, L. et. al. (2020). Identifying changes in the milking rubber of milking machines during testing and under industrial conditions. Eastern-European Journal of Enterprise Technologies, 5 (1 (107)), 127–137. doi: https://doi.org/10.15587/1729-4061.2020.212772
17. Bava, L., Zucali, M., Brasca, M., Zanini, L., Sandrucci, A. (2009). Efficiency of cleaning procedure of milking equipment and bacterial quality of milk. Italian Journal of Animal Science, 8 (sup2), 387–389. doi: https://doi.org/10.4081/ijas.2009.s2.387
18. Kukhtyn, M., Berhilevych, O., Kravcheniuk, K., Shynkaruk, O., Horyuk, Y., Semaniuk, N. (2017). The influence of disinfectants on microbial biofilms of dairy equipment. EUREKA: Life Sciences, 5, 11–17. doi: https://doi.org/10.21303/2504-5695.2017.00423
19. Verkholiuk, M. M., Peleno, R. A., Semaniuk, N. V. (2019). Development of a regime of disinfection of milking equipment and milk inventory with the acid detergent «Milkodez.» Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies, 21 (96), 153–157. doi: https://doi.org/10.32718/nvlvet9627
20. Hall, C. W. (2020). Dairy machinery. Access Science. doi: https://doi.org/10.1036/1097-8542.179900
21. Rasmussen, M. D., Frimer, E. S., Kaartinen, L., Jensen, N. E. (1998). Milking performance and udder health of cows milked with two different liners. Journal of Dairy Research, 65 (3), 353–363. doi: https://doi.org/10.1017/s0022029998002994
22. Paliy, A. P. (2016). Modern aspects of operation liner teat cups. Scientific Messenger of LNU of Veterinary Medicine and Biotechnologies, 18 (2 (67)), 159–162. doi: https://doi.org/10.15421/nvlvet6736
23. Antoshuk, S., Sorokin, E. (2014). Soskovaya rezina. Menyat' ili obsluzhivat'? Belorusskoe sel'skoe hozyaystvo, 3, 115–117.
24. Galitcheva, M. S., Golovan', V. T., Dakhuzhev, Y. G. (2009). Correlation between elasticity of mammillar rubber of milking machine and cow's lactiferous gland function. Novye tekhnologii, 1, 26–29.
25. Izmailova, N. O. (2005). Vplyv doilnoi aparatury na fiziolohichni i produktyvni pokaznyky koriv. Visnyk Sumskoho natsionalnoho ahrarnoho universytetu, 9-10, 63–66.
26. Shevchenko, I. A., Aliev, E. B.; Shevchenko, I. A. (Ed.) (2013). Naukovo-metodychni rekomendatsii z bahatokryterialnoho vyrobnychoho kontroliu doilnykh ustanovok. Zaporizhzhia: Aktsent Invest-treid, 156. Available at: http://aliev.in.ua/doc/knigi/kniga_1.pdf
27. Wiercioch, M., Luberański, A., Lejman, K., Fugol, M., Prask, H. (2019). Shaping Teat Suction Forces of Liners with Varied Structure of Rubber Core. Agricultural Engineering, 23 (1), 105–116. doi: https://doi.org/10.1515/agriceng-2019-0010
28. Il'in, V. M., Rezova, A. K. (2015). Styrene Butadiene Rubber: Production Worldwide. International Polymer Science and Technology, 42 (10), 35–44. doi: https://doi.org/10.1177/0307174x1504201008
29. Shit, S. C., Shah, P. (2013). A Review on Silicone Rubber. National Academy Science Letters, 36 (4), 355–365. doi: https://doi.org/10.1007/s40009-013-0150-2
30. Gálik, R., Boďo Š Staroňová, L. (2016). Monitoring the inner surface of teat cup liners made from different materials. Research in Agricultural Engineering, 61, S74–S78. doi: https://doi.org/10.17221/50/2015-rae
31. Palii, A. P., Handola, Yu. M., Shevchenko, I. O., Stotskyi, A. O., Stotskyi, O. G., Sereda, A. I. et. al. (2020). Assessment of cow lactation and milk parameters when applying various milking equipment. Ukrainian Journal of Ecology, 10 (4), 195–201. Available at: https://www.ujecology.com/articles/assessment-of-cow-lactation-and-milk-parameters-when-applying-various-milking-equipment.pdf
32. Fahim, A., Kamboj, M., Sirohi, A., Bhakat, M., Prasad, S., Gupta, R. (2018). Milking machine induced teat reactions in crossbred cows milked in automated herringbone milking parlour. Indian Journal of Animal Sciences, 88 (12), 1412–1415.
33. Xu, Y., Feng, L., Cong, H., Li, P., Liu, F., Song, S., Fan, L. (2020). Preparation of TiO2/Ser filler with ultraviolet resistance and antibacterial effects and its application in SBR/TRR blend rubber. Journal of Rubber Research, 23 (2), 47–55. doi: https://doi.org/10.1007/s42464-020-00035-x
34. Kyselov, O. V., Komarova, I. B., Milko, D. O., Bakardzhyiev, R. O.; Milko, D. O. (Ed.) (2017). Statystychna obrobka i oformlennia rezultativ eksperymentalnykh doslidzhen (iz dosvidu napysannia dysertatsiynykh robit). Zaporizhzhia: STATUS, 1181.
35. Dmytriv, V., Dmytriv, I., Lavryk, Y., Horodeckyy, I. (2018). Models of adaptation of the milking machines systems. BIO Web of Conferences, 10, 02004. doi: https://doi.org/10.1051/bioconf/20181002004
36. Paliy, A., Nanka, O., Ishchenko, K., Paliy, A. (2019). Research on high-yielding dairy cow treatment techniques during milking. ABAH Bioflux, 11 (1), 1–11. Available at: http://www.abah.bioflux.com.ro/docs/2019.1-11.pdf
37. Fenenko, A. I. (2015). Technical and technological parameters of the biotechnology system of cow. Mekhaniko-tekhnolohichni protsesy, vykonavchi orhany ta mashyny dlia tvarynnytstva, 1 (13), 111–120.

38. Artamonova, O. A. (2020). Studying sanitary and hygienic condition of delaval milking equipment units. International Research Journal, 6 (96), 184–187. doi: https://doi.org/10.23670/IRJ.2020.96.6.035
39. Leonardi, S., Penry, J. F., Tangorra, F. M., Thompson, P. D., Reinemann, D. J. (2015). Methods of estimating liner compression. Journal of Dairy Science, 98 (10), 6905–6912. doi: https://doi.org/10.3168/jds.2015-9380
40. Christine, O. (2018). Trends in Hand Milking and Machine Milking in Kenya. Journal of Engineering and Applied Sciences, 13 (14), 5655–5660. Available at: https://www.researchgate.net/publication/327682156_Trends_in_hand_milking_and_machine_milking_in_Kenya
41. Palii, A. P., Ishchenko, K. V., Bredykhin, V. V., Gurskyi, P. V., Levkin, D. A., Antoniuk, A. A. et. al. (2021). Effect of various milking equipment on milk ejection in high-yielding cows. Ukrainian Journal of Ecology, 11 (1), 18–24. doi: https://doi.org/10.15421/2020_303

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COMPREHENSIVE ASSESSMENT OF THE INFLUENCE OF STRUCTURAL FRICTION IN A VEHICLE SUSPENSION ON ITS PERFORMANCE

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Decision-making regarding the application of any new structure at the design stage requires in practice that it should be compared with the existing one by many indicators. A special feature of the new design of hydropneumatic suspension is the existence of movable connections (screw and splined) as parts of the hydropneumatic element. The presence of structural friction in movable connections requires, in particular, an assessment of the impact of this friction on the process of oscillations when moving through crossed terrain based on comparative analysis. The comprehensive estimate chosen for comparison includes operational properties in terms of ergonomics (smooth movement) and adhesion to the support surface (effort in the contact of wheels with the support surface).

The results of a theoretical study involving a vehicle with parameters (weight, dimensions) close to armored personnel carriers BTR70, BTR80, but with hydropneumatic suspensions, demonstrated that when driving on crossed terrain with speeds up to 65 km/h there is a significant reserve in terms of ergonomics. Regardless of the presence (absence) of structural friction, at friction coefficients of up to 0.085. When moving on the surface with large irregularities, the reserve for the maximum allowable (3 g) acceleration in a driver seat is 4.708 times (there is no structural friction) and 3.768 times (structural friction is present). When moving on the surface with small irregularities, the reserve for the maximum permissible (0.5 g) acceleration in a driver seat is 2.093 times (there is no structural friction) and 2.616 times (structural friction is present).

Under the most dangerous modes of movement (at the highest speeds) when driving over small irregularities, the presence of structural friction has a positive effect both in terms of ergonomics and stability. Thus, when driving at a speed of 65.679 km/h, the minimum clutch margin is 1.4 times greater, and the acceleration is 1.249 times smaller

Keywords: vehicle, operational properties, smooth movement, adhesion to the support surface, oscillations, suspension, structural friction

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1. Introduction

The construction (modernization) of wheeled and tracked machines for various purposes is typically accompanied by changes in the structure of existing samples. It is known that working processes involving the movement of ground vehicles are of an oscillation nature. It is also known that the parameters of the oscillation process depend, in particular, on the structural parameters of the running gear, road parameters, driving conditions. The parameters of the oscillating process of an object (movement, speed, acceleration) are predetermined by both the natural parameters of the object (weight, elastic, damping, dimensional, etc.) and the perturbation parameters (base surface profile, the presence of non-holding links, etc.).

The performance indicators of a vehicle directly depend on the parameters of the oscillation process of the object. Such indicators include smooth movement indicators (ergonomics) and indicators of adhesion to the support surface. These indicators affect the average speed, stability, controllability, safety, and, in general, the ability to move along a predefined trajectory.

Purposefully designed damping is executed in the form of separate structural elements (shock absorbers). Shock