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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 involves 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).

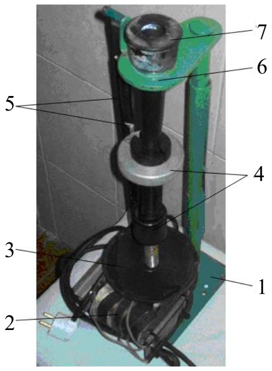

Fig. 1. Milking rubber fault detection device based on its elongation: 1 – bed; 2 – electromagnet; 3 – plate; 4 – rubber fixation unit; 5 – node for acquiring readings; 6 – rack with a support; 7 – milking rubber (which is being tested)

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.

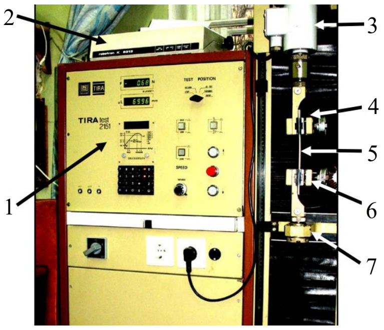

Fig. 2. General view of the TIRAtest machine:
1 — control panel; 2 — ROBOTRON K6313 printing device; 3 — dynamometer; 4 — stationary (upper) clamp; 5 — test sample; 6 — moving (lower) clamp; 7 — moving traverse

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):

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

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).

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

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:

$$M = 2.82909 - 4.49291\,x_1 - 0.422701\,x_1^2 + \\ + 2.70899\,x_1^3 - 1.78642\,x_2 - 1.06308\,x_1x_2 - \\ - 0.03114\,x_1^2x_2 - 0.721989\,x_2^2 + \\ + 1.49473\,x_1x_2^2 + 3.18519\,x_2^3. \qquad (3)$$

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:

$M=-11.2397+0.0417957t-0.000057436t^2+$
$+2.54815\cdot10^{-8}t^3+0.627032T-0.000295379tT+$
$+1.83967\cdot10^{-7}t^2T-0.0124291T^2+0.0007891 47T^3.$

$$M = -11.2397 + 0.0417957t - 0.000057436\,t^2 + \\ + 2.54815\cdot10^{-8}t^3 + 0.627032T - 0.000295379tT + \\ + 1.83967\cdot10^{-7}t^2T - 0.0124291\,T^2 + 0.0007891 47T^3. \quad (4)$$

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).

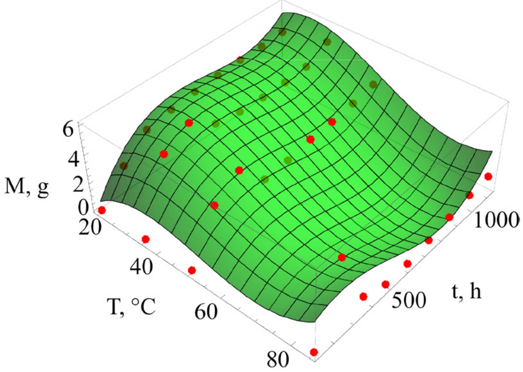

Fig. 3. Dependence of the swell mass of milking rubber M on the temperature of the detergent solutions T and the duration of operation t as a result of saturation with milk fats

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:

$$V = 0.0037F + 0.9841,\ R^2 = 0.9321. \tag{3}$$

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

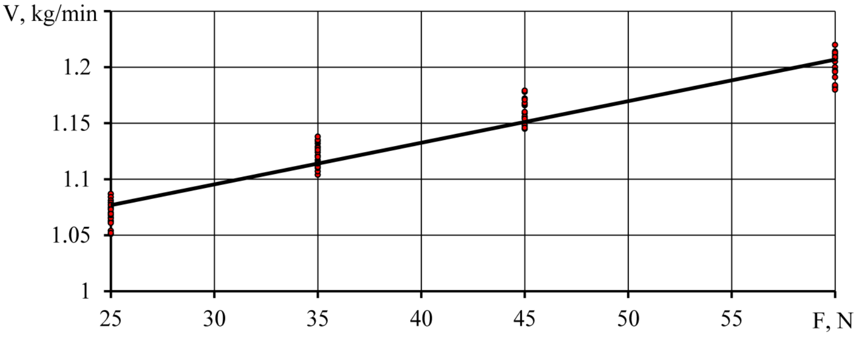

Fig. 4. Dependence of milk yield rate V on the tension force of milking rubber F of teat cups

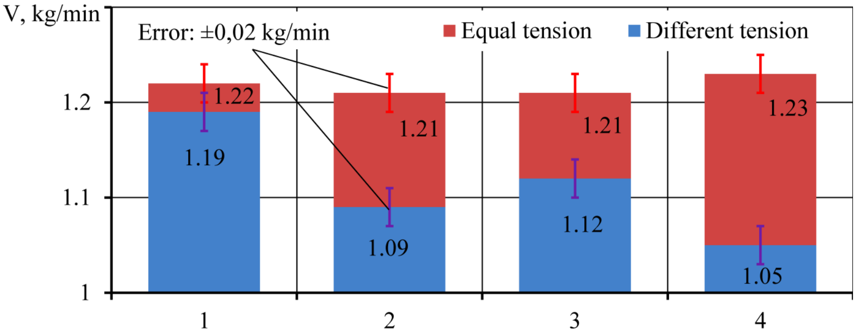

Fig. 5. Milking rate for various quarters of cows' udders: 1, 2, 3, 4 — milking rubber of the milking machine, which is put onto the corresponding quarter of the udder

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.

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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

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ENGINEERING TECHNOLOGICAL SYSTEMS

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DEVISING MANUFACTURING TECHNIQUES TO CONTROL THE PROCESS OF ZONAL SEGREGATION IN LARGE STEEL INGOTS (p. 6–13)

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A method of physical modeling was applied to study the effect of external actions on the processes of crystallization and the formation of the structure of ingots. A brief review of existing hypotheses about the evolution of physical, structural, and chemical heterogeneities in large steel ingots is given. The parameters of the structure and the two-phase zone have been determined, as well as the nature of the distribution of segregated materials along the cross-section of ingots, depending on the conditions of their curing. The decisive importance of convective and capillary mass transfer in the interdendritic channels of hardening ingots on the formation of a zonal heterogeneity at their cross-section has been proven.

Experimentally, when crystallizing a model environment (camphene), it has been visually confirmed that the flow of segregated materials in interdendritic channels occurs when a certain amount of impurities accumulates in them. A clear dependence of the speed of this flow on the rate of melt crystallization has been established. With an increase of the hardened part of the melt, the rate of segregated material movement (V_l) increases while the rate of crystallization (R) decreases due to worsening heat release conditions. At a certain distance from the ingot's surface, these rates become equal, and impurities are carried to the curing border, which is the main cause of the formation of zonal segregation.

The results reported here show that the evolution of zonal segregation in ingots can be controlled using various techniques involving external influence on the hardening melt. This study has demonstrated that the adjustable intensity of heat removal from an ingot, as well as the addition of external excess pressure on the hardening melt, could be used as such tools. In the study, to obtain ingots with a minimum level of chemical heterogeneity, it would suffice to provide the following conditions for the curing of the alloy: a value of the alloy crystallization speeds at the level of $R_{cr} \geq 9 \cdot 10^{-2}$ mm/s, or external pressure on the free surface of ingots $P_{ext.} \geq 135$ kPa.

The industrial implementation of the reported results could make it possible to improve the technology of obtaining large blacksmith ingots, provide savings in materials and energy resources, increase the yield of a suitable metal, and improve its quality.

Keywords: physical modeling, large ingot, zonal segregation, convective and capillary mass transfer.

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DETERMINING THE WIDTH OF A LAYER CUT WITH SAWS WITH MULTIDIRECTIONAL TEETH (p. 14–20)

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To predict the workability of a tool structure at the design stage, it is necessary to calculate the parameters of the cut layer when this tool is used because the cut layer's size determines the strength and dynamic characteristics of the cutting process.

It is known that the size and shape of the cut layer are affected by the allowance cutting scheme embedded in the tool design. Therefore, the parameters of the cut layer with the tool must be investigated taking into consideration the actual shapes and location of the cutting edges of the tool teeth and the cutting scheme with individual teeth.

Existing analytical dependences on determining the thickness of the cut layer do not take into consideration the group arrangement of the teeth, which have a different shape and location of their cutting edges. Therefore, a procedure for determining the thickness of the cut layer analytically has been proposed, using the example of circular saws with multidirectional teeth while taking into consideration the patterns in the arrangement of the cutting edges of individual teeth and the real movements of the tool during its operation.

The proposed procedure makes it possible to determine the parameters of the layer cut with the tool at both constant and progressive allowance cutting schemes. One can also specify the parameters of the cut layer at any time of the tool's operation and analyze the change in the shape of the slice in time.

Based on the analysis of the parameters of the cut layer, it has been established that saws with multidirectional teeth do not work with the entire width of the cutting edge but only in its part, whose share does not exceed 55 % of the width of the tool.

The procedure reported here could be used to determine the loading of the cutting tool part with a more complex cutting scheme, which also includes tools that are operated by the form-generating method.

Keywords: thickness of the cut layer, circular saw, allowance cutting scheme, cutting edge, cutting edge shape, multidirectional teeth.

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IDENTIFYING CHANGES IN THE TECHNICAL PARAMETERS OF MILKING RUBBER UNDER INDUSTRIAL CONDITIONS TO ELUCIDATE THEIR EFFECT ON THE MILKING PROCESS (p. 21–28)

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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 average 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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COMPREHENSIVE ASSESSMENT OF THE INFLUENCE OF STRUCTURAL FRICTION IN A VEHICLE SUSPENSION ON ITS PERFORMANCE (p. 29–36)

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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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DEVELOPMENT OF ALTERNATIVE STEERING MODELS FOR EV BUS: A PRELIMINARY STUDY ON THE CONVERSION OF HYDRAULIC TO ELECTRIC POWER STEERING (p. 37–46)

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This study aims to develop alternative steering models for the EV bus. The EV bus uses its energy source from the main 384 VDC 300 Ah battery and the secondary battery with a capacity of 25.8 VDC 100 Ah. The use of energy in this electric bus is divided into the main components, namely the BLDC motor as the main drive of 200 kW, 15 kW of air conditioning, 7.5 kW of hydraulic power steering, a compressor for the air braking system of 4 kW, and accessory components. The other is 2.4 kW. It is expected that this 7.5 kW electric power can be reduced by an electric system by up to 20 %. This research will study the steering system with an electric power system (EPS) to convert the hydraulic steering system (HPS). With this EPS system, it is hoped that controlling the vehicle's motion towards the steer by wire will be easier. Initially, data were collected from the types of large vehicles from various well-known brands about the steering system used. A large commercial vehicle that purely uses EPS is not yet found. The model developed for EPS on this electric bus is through the reverse engineering method by redrawing all the components involved in the previous steering system. Because this type of EV bus is included in the upper mid-size class, this paper proposes two new EPS models, namely the addition of an assist motor on the drag link and on the steering rack. The links involved in this system are wheel drive, steering column, lower steering column, rack and pinion gear, assist motor, drop link, drag link, drop link extension, drag link extension, tie rod, knuckle, kingpin, tire, axle beam and several others. The values of stiffness, inertia, and damping of each link will affect the driver's torque and the assist motor as a wheel speed function on this electric bus. The steering structure of the EV bus consists of a truss structure and a frame structure with a kinematic structure consisting of two four-bar linkages joined together.

Keywords: assist motor, wheel drive, steering column, pinion, rack, vehicle speed, torsion motor, truss structure, frame structure, four-bar linkage.

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DEVELOPMENT OF PRODUCT COMPLEXITY INDEX IN 3D MODELS USING A HYBRID FEATURE RECOGNITION METHOD WITH RULE-BASED AND GRAPH-BASED METHODS (p. 47–61)

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A machining process is very dependent on the model created. The more complicated the model, the greater the design difficulty and the greater the machining process. Reduced production costs can help a company increase profits. A focus on production cost can be achieved in a number of ways, the first of which is by replacing materials or changing the design. It is better to reduce product costs during the design stage than during the manufacturing stage. The main objective of this research is to develop an application that can recognize features in a CAD program and calculate the complexity index of shapes in real time. In this study, the prismatic features and slab features classified by Jong-Yun Jung were used. The feature recognition method applied in this study is a hybrid of the rule-based and graph-based methods, which uses the STL file developed by Sunil and Pande to obtain all the information needed. Then, the results are extracted from feature recognition data and are used to calculate the product complexity index of the model being studied. This study applied the product complexity index, following the model developed earlier by El Maraghy. Validation is performed by comparing the software count with the complexity index calculated with the STEP method by Hendri and Sholeh et al. This research develops a program that recognizes features in CAD software and calculates the index complexity of shapes in real time. This will allow designers to calculate the expected complexity value during the design process. As a result, the estimated production cost can be seen early on. Finally, this software is tested for calculating the index values for the complexity of a combined features model. The use of eight slots and eight pockets as a benchmark scoring for shape produces a more accurate product complexity index.

Keywords: features, feature recognition, complexity index, STL file, CAD, manufacturing process.

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DESIGN OF AN AUGER THERMO-RADIATION DRYER FOR DRYING PLANT-DERIVED POMACE (p. 62–69)

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This paper reports the improved model design of an auger thermo-radiation dryer for drying plant-derived pomace under a low-temperature mode (35...80 °C) to the resulting moisture content at the level of 8...13 % of solids. The dryer has an adjustable speed of auger rotation (3...4 min^{-1}), of airflow (0.05...0.09 m/s), and is characterized by the uniform distribution of heat flux. It is equipped with an energy-saving two-circuit complex that utilizes secondary energy to heat primary air from 21.1 °C to 28.9 °C. The use of Peltier elements, installed at the heating technical surface of the dryer's auger, makes it possible to convert thermal energy into a low-voltage supply voltage for the autonomous supercharger and exhaust fans.

The duration of pomace drying in the model structure of the auger thermo-radiation dryer has been determined, in particular tomato pomace, with an initial content of 75 % of solids, which is 107 min. For apple pomace whose starting content of solids is 65 %, it is 98 min. For comparison, the duration of the convective drying of tomato pomace (75 % of solids) is 120 minutes. The drying was carried out at a temperature of 60 °C to the resulting moisture content of 10...12 % of solids. Organoleptic evaluation on the example of tomato pomace confirms the effectiveness of structural solutions in the auger dryer compared to the convective technique.

The results reported in this study could create conditions for the further design and implementation of the proposed structure of thermo-radiation dryer for drying plant-derived pomace involving an altered heat supply technique and the utilization of secondary energy. The designed structure of the device makes it possible to process and preserve the quality properties of plant-derived pomace, allowing the use of this product for a wide range of foodstuffs.

Keywords: auger thermo-radiation dryer, plant-derived pomace, drying kinetics, temperature field.

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DEVELOPMENT OF A MATHEMATICAL MODEL OF VIBRATORY NON-LIFT MOVEMENT OF LIGHT SEEDS TAKING INTO ACCOUNT THE AERODYNAMIC FORCES AND MOMENTS (p. 70–78)

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The modern practice of using vibratory machines when working with fine-size light-weight seeds is faced with such an undesirable phenomenon as the impact of aerodynamic forces and moments on the kinematics of vibrational movement of particles of the seed mixture fractions.

According to the results of scientific studies devoted to the solution of this problem, only mathematical models of vibrational movement are used, where the aerodynamic factor is taken into account as taking the seeds by airflow. This is typical only for cleaning modes with the rebound of seeds from the vibrating surface. Aerodynamic forces and moments are present in them only as a force of aerodynamic resistance. The action of lateral aerodynamic forces and their moments are not taken into account. Their consideration allows to extend the range of action of the aerodynamic factor on the modes of vibration cleaning (vibroseparation) without rebound (but with sliding and rolling) which are of greater interest in terms of improving the efficiency of processing fine-size seeds.

A mathematical model of seed vibration movement taking into account the action of a complete set of aerodynamic forces (dynamic resistance forces and lateral aerodynamic forces) and moments was proposed. This makes it possible to simulate non-lifting modes of vibrational movement of seeds. A system of algebraic equations that are linear with respect to the kinematic parameters of seed movement which was obtained by translating differential equations of movement into a finite-difference form was presented. The possibility of numerical solution of equations of movement by the Euler method was shown. The results of the evaluation of the model adequacy for the processes of vibration separation of tobacco seeds and false flax were presented. As shown by the results of calculations and experiments, the developed model provides an increase in the adequacy of the simulation results by 30 % in comparison with the model where the aerodynamic factor is not taken into account.

Keywords: vibratory machines, system of differential equations, aerodynamic factor, aerodynamic screen, vibrational movement, light-weight seeds.

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IMPROVING THE MECHANICAL-MATHEMATICAL MODEL OF GRAIN MASS SEPARATION IN A FLUIDIZED BED (p. 79–86)

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This paper has substantiated the prospect of modeling the processes of separating grain mass into fractions as one of the tasks in the production of high-quality seed material. It has been determined that this could optimize the parameters of separation processes and design new working surfaces for its implementation. It is noted that modeling should take into consideration the influence of the structural and kinematic parameters of grain cleaning machines, the physical and mechanical properties of raw materials, the intralayer processes and forces.

The reported theoretical study has improved the mechanical-mathematical model of grain mass separation in a pseudo-fluidized bed according to its density. The model establishes a relationship between the effective coefficient of dynamic viscosity and the density of particles in the discrete and continuous phases and the volumetric concentration of discrete phase particles. At the same time, the porosity of a fluidized bed has been accounted for, as well as the longitudinal and transverse angles of inclination of the base surface to the horizontal plane, the amplitude and frequency of oscillations of the particles of the continuous phase; the direction angle of oscillations relative to the perpendicular to the base surface.

The adequacy of the improved mechanical-mathematical model has been confirmed by comparing the experimental and theoretical results of grain mass fractionation modeling. It was found that the differences in the density values of the separated fractions of GM did not exceed 7...8 %, that is, they were within the margin of error.

It has been established that the improved model of grain mass separation in a fluidized bed could be used to determine the rational values for the parameters of a pneumatic sorting table that is used for the fractionation of the corresponding seed material. The initial data, in this case, are the density of the continuous and solid phases of grain mass, the friction coefficient of the seeds, and the equivalent radius of the particle. The result of modeling is the rational values of the amplitude and oscillation frequency of the working surface of the pneumatic sorting table, and the angles of inclination of the working surface.

Keywords: mechanical-mathematical model of separation, grain mass, seed material, fluidized bed.

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ANALYSIS OF THE EFFECT OF STIRRER AND CONTAINER ROTATION DIRECTION ON MIXING INDEX (*Ip*) (p. 86–91)

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The paper discusses the effect of the stirrer and container rotation direction on the mixing index (*Ip*). The chaos theory is the result of an in-depth study of various problems that cannot be answered by the two previous major theories, namely quantum mechanics and the theory of relativity. Effective mixing of the flow area does not depend on rapid stirring.

This study uses a container with a double stirrer, camera, programmable logic controller, tachometer, 6 A adapter, and a computer. DC electric motor (25 V) for turning stirrers and housings. The diameter of the primary and secondary stirrers is $Dp=38$ mm and $Ds=17$ mm. The diameter of the container made of transparent plastic is $Dw=160$ mm and height is 170 mm. Primary stirrer rotation $(np)=10$ rpm, secondary stirrer rotation $(ns)=22.3$ rpm, and container rotation $(nw)=13$ rpm, the angular velocity of the container is $\Omega w=360^\circ$ while the angular speed of the primary stirrer is $\Omega p=180^\circ$. The liquid consists of a mixture of water and paint (white). For dye, a mixture of water and paint (red) is used. For testing the Brookfield viscometer, the viscosity of the liquid and dye is used. The results showed that turning the stirrer in the opposite direction to the container, there will be stretching, bending, and folding around the stirrer, and the smallest mixing index was P2V-b (0.94). In addition, based on the mixing index value above, the highest mixing effectiveness level is obtained, namely: P2V-b, P2S-b, P2B-b, P2V-a, P2B-a, and finally P2S-a. The mixing index is inversely related to the effectiveness level. So the highest effectiveness level is given by the following treatment: 1) variation rotation (between opposite rotating mixers); 2) opposite rotation (stirrer rotation opposite direction to the container); 3) unidirectional rotation (stirrer rotation in the direction of the container).

Keywords: mixing index, chaos, stirrer, container, mixing effectiveness, rotation direction.

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DEVISING A METHOD TO PARAMETRIZE THE JACKET STYLE VARIETIES THROUGH THE MODIFICATION OF TIPOLOGICAL SERIES STRUCTURES (p. 92–105)

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The study reported here has revealed the issue related to the inefficient scaling of the uniformity of jacket model designs in the processes involving a typical representative as a result of modification parameters uncertainty.

A variant has been proposed to synchronize the critical points of silhouetted allowances by grouping the numeric series in the vector of choosing the value for an increase in the allowance according to the characteristics of style varieties. The influence of shape-forming segmentation on the formation of a classifier of the structural and technological solutions for a jacket has been determined. The built model to support modification vectors has made it possible to describe the sequence of procedures execution by the method of typical representation. The presence of one design category, the same structural parts, the uniformity of style simplifies the processes of choosing and selecting the most characteristic models of the jacket.

It was found that the morphological combination of attributes of the physical appearance affects the adjustment of style preferences in a manufacturer's products. The parameters for typical segmentation relative to the junction points of the structural zones of the optimized five-seam prototype design have been defined as the most influential vectors of jacket modification.

A method for scaling the allowance for free fitting has been devised on the basis of data from empirical research. An adequate regression model has been derived for normalizing the silhouette allowance parameters. The constructed model makes it possible to scale silhouette structures by changing the increments at the corner points of the contour according to the prototype of gradation under an automated mode.

Practical recommendations have been compiled on the parameters of zonal-modular modification of silhouette designs of jacket varieties: a linear character of the state silhouetted transformation relative to ASi1 = 5 cm. The normalized parameters for constructing functional and decorative parts have been proposed.

Keywords: typological series, parameterization, calibration, silhouette allowance, normalization method, jacket variety.

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АНОТАЦІЇ

ENGINEERING TECHNOLOGICAL SYSTEMS

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РОЗРОБКА ТЕХНОЛОГІЧНИХ ПРИЙОМІВ УПРАВЛІННЯ ПРОЦЕСОМ УТВОРЕННЯ ЗОНАЛЬНОЇ ЛІКВАЦІЇ У ВЕЛИКИХ СТАЛЕВИХ ЗЛИВКАХ (с. 6–13)

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Методом фізичного моделювання вивчено вплив зовнішніх дій на процеси кристалізації і формування структури зливків. Проведено короткий аналіз існуючих гіпотез про розвиток фізичної, структурної та хімічної неоднорідностей у великих сталевих зливках. Визначено параметри структури і двофазної зони, а також характер розподілу ліквативів по перетину зливків в залежності від умов їх затвердіння. Доведено вирішальне значення конвективного і капілярного масопереносу в міждендритних каналах зливків, що тверднуть, на формування зональної неоднорідності по їх перетину.

Експериментально при кристалізації модельного середовища (камфена) наочно підтверджено, що потік ліквативів в междендритних каналах виникає при накопиченні в них певної кількості домішок. Встановлена чітка залежність швидкості цього потоку від швидкості кристалізації розплаву. Зі збільшенням затверділої частини розплаву швидкість переміщення ліквативів ($V_л$) збільшується, при цьому швидкість кристалізації (R) зменшується через погіршення умов тепловідведення. На певній відстані від поверхні зливка ці швидкості стають рівними один одному і домішки виносяться на кордон затвердіння, що є головною причиною утворення зональної ліквації.

Отримані результати показують, що розвитком зональної ліквації в зливках можна управляти, використовуючи різні прийоми зовнішнього впливу на розплав, що твердіє. Як показали проведені дослідження, в якості таких інструментів можуть бути використані: регульована інтенсивність тепловідведення від зливка, а також додаток зовнішнього надлишкового тиску на розплав, що твердіє. У даних дослідженнях для отримання зливків з мінімальним рівнем хімічної неоднорідності досить забезпечити такі умови затвердіння сплаву: значення швидкостей кристалізації сплаву на рівні $R_{кр} \geq 9 \cdot 10^{-2}$ мм/с або зовнішній тиск на вільну поверхню зливків $P_{зовн.} \geq 135$ кПа.

Впровадження отриманих результатів у виробництво дозволить удосконалити технологію отримання великих ковальських зливків, забезпечить економію матеріалів та енергоресурсів, підвищити вихід придатного металу і поліпшити його якість.

Ключові слова: фізичне моделювання, великий зливок, зональна ліквація, конвективний і капілярний масоперенос.

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ВИЗНАЧЕННЯ ТОВЩИНИ ЗРІЗУВАНОГО ШАРУ ПИЛКАМИ З РІЗНОНАПРАВЛЕНИМИ ЗУБЦЯМИ (с. 14–20)

О. А. Охріменко, В. В. Вовк, С. В. Майданюк, Ю. В. Лашина

Для прогнозування працездатності конструкції інструмента на стадії його проектування необхідно провести розрахунок параметрів зрізуваного шару таким інструментом, оскільки величина зрізуваного шару визначає силові та динамічні характеристики процесу різання.

Відомо, що на величину та форму зрізуваного шару впливає схема зрізання припуску, закладена в конструкцію інструмента. Тому параметри зрізуваного шару інструментом необхідно досліджувати з урахуванням реальних форм та розташування різальних кромок зубців інструмента та схеми різання окремими зубцями.

Існуючі аналітичні залежності по визначенню товщини зрізуваного шару не враховують групового розташування зубців, які мають різну форму та розташування їх різальних кромок. Тому запропоновано методику аналітичного визначення товщини зрізуваного шару, на прикладі дискових пил з різнонаправленими зубцями, з урахуванням особливостей розташування різальних кромок окремих зубців та реальних рухів інструмента в процесі його роботи.

Запропонована методика дозволяє визначати параметри зрізуваного шару інструментом як з постійною, так і з прогресивною схемами зрізання припуску. Крім того, можна визначити параметри зрізуваного шару в довільний момент роботи інструмента та аналізувати зміну форми зрізу у часі.

На основі аналізу параметрів зрізуваного шару встановлено, що пилки з різнонаправленими зубцями працюють не всією шириною різальної кромки, а лише її частиною, частка якої не перевищує 55 % ширини інструмента.

Наведена методика може використовуватися для визначення завантаження різальної частини інструментів з більш складною схемою різання, до якої також відносяться інструменти, що працюють методом обкатки.

Ключові слова: товщина зрізуваного шару, дискова пила, схема зрізання припуску, різальна кромка, форма різальної кромки, різнонаправлені зубці.

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ВИЯВЛЕННЯ ЗМІН ТЕХНІЧНИХ ПАРАМЕТРІВ ДІЙКОВОЇ ГУМИ В ВИРОБНИЧИХ УМОВАХ З ВСТАНОВЛЕННЯМ ВПЛИВУ НА ПРОЦЕС ДОЇННЯ (с. 21–28)

А. П. Палій, Е. Б. Алієв, О. В. Нанка, О. В. Богомолов, В. В. Бредихін, А. П. Палій, О. І. Шкромада, Ю. В. Мусієнко, О. Г. Стоцький, Н. П. Гребеник

Багаторічний досвід експлуатації доїльних апаратів засвідчує, що дійкова гума була й залишається недовговічною й ненадійною ланкою в технологічному процесі машинного доїння. У процесі експлуатації гума швидко втрачає міцність і пружні властивості, стає жорсткою й менш еластичною, деформується, змінюючи форму.

Метою дослідження є виявлення змін технічних параметрів дійкової гуми в виробничих умовах з встановленням впливу на процес доїння. Отримані результати дозволять здійснити раціональний вибір дійкової гуми доїльних стаканів, що забезпечить ефективний процес доїння.

Під час проведення досліджень на первинному етапі експериментально встановлювали фізико-механічний стан дійкової гуми за парової дезінфекції та в наслідок насичення виробу молочними жирами. На наступному етапі виявляли вплив натягу дійкової гуми у доїльному стакані на швидкість доїння.

Встановлено, що дійкова гума в процесі експлуатації активно піддається впливу молочного жиру, що призводить до втрати її ваги відносно початкового значення. На 1000 день роботи втрата ваги, по відношенню до початкового значення (100 г), за температурних режимів промивання у 85 °С, 50 °С, 35 °С та 20 °С становила 1 г, 3,3 г, 5 г та 4,2 г відповідно. Встановлені залежності маси набухання дійкової гуми M від температури миючих розчинів T і тривалості експлуатації t в наслідок насичення молочними жирами.

Встановлена залежність швидкості молоковіддачі V від сили натягу дійкової гуми F доїльних стаканів. Так встановлено, що при зміні сили натягу дійкової гуми від 25 до 60 Н різниця середньої інтенсивності молоковіддачі становить 0,13 кг/хв. (10,8 %). Стосовно величини удою за зазначеного натягу, то різниця має значення у 0,15 кг (2,5 %). За натягу гуми від 60 до 25 Н середній час доїння збільшується на 0,46 хв. (8,3 %). Отже встановлено, що доїльний апарат з дійковою гумою з різним натягом при загальному часу доїння буде нерівномірно видоювати різні частки вимені тварини. Середнєквадратичне відхилення швидкості молоковіддачі при цьому може складати 0,07 кг/хв.

Проведені дослідження розширюють уявлення про техніко-технологічні характеристики гумових виробів, а саме її зміни за парової дезінфекції та в наслідок насичення молочними жирами.

Ключові слова: дійкова гума, експлуатація гуми, параметри гуми, молочний жир, швидкість доїння.

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КОМПЛЕКСНА ОЦІНКА ВПЛИВУ КОНСТРУКЦІЙНОГО ТЕРТЯ В ПІДВІСЦІ ТРАНСПОРТНОГО ЗАСОБУ НА ЕКСПЛУАТАЦІЙНІ ЯКОСТІ (с. 29–36)

В. П. Пісарєв

Прийняття рішення на етапі проектування щодо застосування будь якої нової конструкції викликає на практиці необхідність проведення її порівняння з існуючою за багатьма показниками. Особливістю нової конструкції гідропневматичної підвіски є наявність рухомих з'єднань (гвинтового і шліцьового) у складі гідропневматичного елементу. Наявність конструкційного тертя за рухомими з'єднаннями потребує мати, зокрема, оцінку із впливу цього тертя на процес коливань при русі по перетнутій місцевості за порівняльним аналізом. У якості комплексної оцінки з порівняння вибрані експлуатаційної якості за ергономікою (плавність ходу) і зчепленням з опорною поверхнею (зусилля у контакті коліс з опорною поверхнею).

Результати теоретичного дослідження на машині з параметрами (маса, розміри) близькими до бронетранспортерів БТР70, БТР80, але з гідропневматичними підвісками, показали, що при русі по перетнутій місцевості із швидкостями до 65 км/год має місце суттєвий запас за ергономікою. Незалежно від наявності (відсутності) конструкційного тертя, при коефіцієнтах тертя до 0,085. При русі по поверхні з великими нерівностями запас по максимально допустимим (3 g) прискоренням на місці водія у 4,708 рази (конструкційне тертя відсутнє) і 3,768 рази (конструкційне тертя присутнє). При русі по поверхні з малими нерівностями запас по максимально допустимим (0,5 g) прискоренням на місці водія у 2,093 рази (конструкційне тертя відсутнє) і у 2,616 рази (конструкційне тертя присутнє).

В найбільш небезпечних режимах руху (з найбільшими швидкостями) при русі по малим нерівностям наявність конструкційного тертя позитивно впливає як за ергономікою, так і стійкістю. Так, при русі із швидкістю 65,679 км/год мінімальний запас по зчепленню більший в 1,4 рази, а прискорення в 1,249 рази менші.

Ключові слова: транспортний засіб, експлуатаційні якості, плавність ходу, зчеплення з опорною поверхнею, коливання, підвіска, конструкційне тертя.

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РОЗРОБКА АЛЬТЕРНАТИВНИХ МОДЕЛЕЙ РУЛЬОВОГО УПРАВЛІННЯ ЕЛЕКТРОБУСА: ПОПЕРЕДНЄ ДОСЛІДЖЕННЯ ПО ЗАМІНІ ГІДРОПІДСИЛЮВАЧА КЕРМА НА ЕЛЕКТРОПІДСИЛЮВАЧ (с. 37–46)

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Метою даного дослідження є розробка альтернативних моделей рульового управління електробуса. Електробус використовує енергію від основного акумулятора з напругою 384 В постійного струму і ємністю 300 Ач і вторинного акумулятора з напругою 25,8 В постійного струму і ємністю 100 Ач. Споживання енергії в даному електробусі розділене на такі основні компоненти, як вентильний двигун в якості головного двигуна потужністю 200 кВт, 15 кВт система кондиціонування повітря, 7,5 кВт гідропідсилювач керма, компресор для повітряної гальмівної системи потужністю 4 кВт і допоміжні компоненти. Решта становить 2,4 кВт. Очікується, що електрична потужність в 7,5 кВт може бути знижена до 20 % за допомогою електричної системи. В даному дослідженні була досліджена система рульового управління з електропідсилювачем керма (ЕПК) для заміни гідропідсилювача керма (ГПК). За допомогою ЕПК очікується спрощення управління автомобілем за допомогою електроніки. Спочатку були зібрані дані за типами великих транспортних засобів різних відомих марок про використовувану систему рульового управління. Великого комерційного автомобіля, що використовує виключно ЕПК, поки не знайдено. Модель ЕПК електробуса розроблена методом зворотного проектування шляхом перемальовування всіх компонентів, задіяних в попередній системі рульового управління. Оскільки даний тип електробуса відноситься до верхнього середнього класу, в статті пропонуються дві нові моделі ЕПК, а саме додавання допоміжного двигуна на поздовжній рульовій тязі і на рульовій рейці. Тягами в цій системі є привід колеса, рульова колонка, нижня рульова колонка, рейкова передача,

допоміжний двигун, тяга стабілізатора, поздовжня рульова тяга, подовжувач тяги стабілізатора, подовжувач поздовжньої рульової тяги, сполучна тяга, кулак, шкворень, шина, балка осі і ряд інших. Значення жорсткості, інерції і демпфірування кожної тяги будуть впливати на крутний момент водія і допоміжний двигун у вигляді функції швидкості колеса на даному електробусі. Структура рульового управління електробуса складається з фермової конструкції і каркасної конструкції з кінематичною структурою, що складається з двох з'єднаних разом суставних чотириланковиків.

Ключові слова: допоміжний двигун, привід колеса, рульова колонка, зубчасте колесо, рейка, швидкість автомобіля, торсіонний двигун, фермова конструкція, каркасна конструкція, суставний чотириланковик.

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РОЗРОБКА ІНДЕКСУ СКЛАДНОСТІ ВИРОБУ В 3D-МОДЕЛЯХ З ВИКОРИСТАННЯМ ГІБРИДНОГО МЕТОДУ РОЗПІЗНАВАННЯ ОЗНАК ЗА ДОПОМОГОЮ МЕТОДІВ НА ОСНОВІ ПРАВИЛ І ГРАФІВ (с. 47–61)

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Процес обробки сильно залежить від створеної моделі. Чим складніше модель, тим вище складність проектування і тим складніше процес обробки. Зниження собівартості виробництва може допомогти компанії збільшити прибуток. Зосередити увагу на собівартості виробництва можливо декількома способами, перший з яких полягає в заміні матеріалів або зміні конструкції. Собівартість продукції краще знизити на стадії проектування, ніж на стадії виробництва. Основною метою дослідження є розробка програми, яка може розпізнавати ознаки в програмі САПР і обчислювати індекс складності форм в режимі реального часу. У даному дослідженні були використані призматичні ознаки та ознаки плит, класифіковані Чен Юн Чжуном. Метод розпізнавання ознак, що застосовується в цьому дослідженні, являє собою гібрид методів на основі правил і графів, в якому використовується STL-файл, розроблений Суніл і Панде, для отримання всієї необхідної інформації. Потім результати витягують з даних розпізнавання ознак і використовують для обчислення індексу складності виробу досліджуваної моделі. У даному дослідженні застосовувався індекс складності виробу за моделлю, розробленою раніше Ель-Марагі. Перевірка виконується шляхом порівняння програмно-реалізованого лічильника з індексом складності, розрахованим за допомогою STEP методу Хендрі і Шоле і ін. В рамках даного дослідження розробляється програма, яка розпізнає ознаки в програмному забезпеченні САПР і обчислює індекс складності форм в режимі реального часу. Це дозволить проектувальникам розрахувати очікуване значення складності в процесі проектування. В результаті орієнтовна собівартість виробництва можна побачити на ранній стадії. Нарешті, проведено випробування даного програмного забезпечення для обчислення значень індексу складності моделі комбінованих ознак. Використання восьми слотів і восьми кишень в якості еталонного показника форми дозволяє отримати більш точний індекс складності виробу.

Ключові слова: ознаки, розпізнавання ознак, індекс складності, STL-файл, САПР, виробничий процес.

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РОЗРОБКА ШНЕКОВОЇ ТЕРМОРАДІАЦІЙНОЇ СУШАРКИ ДЛЯ СУШІННЯ ВИЧАВОК РОСЛИННОГО ПОХОДЖЕННЯ (с. 62–69)

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Вдосконалено модельну конструкцію шнекової терморадіаційної сушарки для сушіння вичавок рослинного походження в низькотемпературному режимі (35...80 °С) до кінцевого вологовмісту на рівні 8...13 % сухих речовин. Сушарка має регульовану швидкість обертання шнеку (3...4 хв$^{-1}$), повітряного потоку (0,05...0,09 м/с) та характеризується рівномірністю розподілу теплового потоку. Оснащена енергоощадним двохкільцевим комплексом з використання вторинної енергії для підігрівання первинного повітря з 21,1 °С до 28,9 °С. Використання елементів Пельтьє, розмішених на нагрівальній технічній поверхні шнеку сушарки, дозволяє перетворити теплову енергію в низьковольтну напругу живлення автономних нагнітального та витяжного вентиляторів.

Визначено тривалість сушіння вичавок у модельній конструкції шнекової терморадіаційної сушарці, зокрема томатних вичавок з початковим вмістом 75 % сухих речовин – 107 хв. Для яблучних вичавок з початковим вмістом 65 % сухих речовин складає 98 хв. Для порівняння тривалість конвективного сушіння томатних вичавок (75 % сухих речовин) становить 120 хв. Сушіння здійснювалося за температури 60 °С до кінцевого вологовмісту 10..12 % сухих речовин. Органолептичне оцінювання на прикладі томатних вичавків підтверджує ефективність конструктивних рішень у шнековій сушарці в порівнянні з конвективним способом.

Отримані результати дослідження забезпечать умови для подальшого проектування та впровадження запропонованої конструкції терморадіаційної сушарки для сушіння вичавок рослинного походження зі зміненим способом теплопідведення та використанням вторинної енергії. Розроблена конструкція апарату дає змогу переробляти та зберігати якісні властивості рослинних вичавків, що дозволяє використовувати даний продукт в широкому спектрі харчової галузі.

Ключові слова: шнекова терморадіаційна сушарка, рослинні вичавки, кінетика сушіння, температурне поле.

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РОЗРОБКА МАТЕМАТИЧНОЇ МОДЕЛІ ВІБРАЦІЙНОГО БЕЗВІДРИВНОГО РУХУ ЛЕГКОГО НАСІННЯ З УРАХУВАННЯМ АЕРОДИНАМІЧНИХ СИЛ І МОМЕНТІВ (с. 70–78)

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Сучасна практика застосування вібраційних машин при роботі з дрібним насінням малої ваги зіштовхується з таким небажаним явищем, як вплив на кінематику вібраційного руху частинок фракцій насіннєвої суміші аеродинамічних сил та моментів.

За результатами наукових досліджень, присвячених розв'язанню цієї проблеми, використовуються лише математичні моделі вібраційного руху, де аеродинамічний фактор враховується як віднiс насіння повітряним потоком. Це характерно тільки для для режимів очищення з відскоком насіння від вібруючої поверхні. В них аеродинамічні сили та моменти присутні тільки у вигляді сили аеродинамічного опору. Не враховано дію бокових аеродинамічних сил і їх моментів. Їх врахування дозволяє поширити діапазон дії аеродинамічного фактору на режими віброочищення (вібросепарування) без відскоку (з ковзанням та перекочуванням), які мають більш великий інтерес з точки зору підвищення ефективності обробки саме мілконасіннєвих культур.

Запропоновано математичну модель вібраційного руху насіння з урахуванням дії повного набору аеродинамічних сил (сили аеродинамічного опору та бокових аеродинамічних сил) і моментів. Це дає можливість моделювати безвідривні режими вібраційного руху насіння. Наведено систему алгебраічних рівнянь, які лінійні відносно кінематичних параметрів руху насіння, що отримано при переведенні дференційних рівнянь руху у кінцево-різницеву форму. Показано можливість чисельного розв'язання рівнянь руху методом Ейлеру. Наведено результати з оцінки адекватності моделі для процесів вібраційної сепарації насіння тютюну та рижію. Як показали результати розрахунків та експериментів, розроблена модель забезпечує, у порівнянні з моделлю, де аеродинамічний фактор не враховано, підвищення ступеня адекватності результатів моделювання на 30 %.

Ключові слова: вібромашина, система диференціальних рівнянь, аеродинамічний фактор, аеродинамічний екран, вібраційних рух, легке насіння.

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УДОСКОНАЛЕННЯ МЕХАНІКО-МАТЕМАТИЧНОЇ МОДЕЛІ СЕПАРУВАННЯ ЗЕРНОВОЇ МАСИ У ПСЕВДОРОЗРІДЖЕНОМУ ШАРІ (с. 79–86)

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Обґрунтована перспективність моделювання процесів розділення зернової маси на фракції, як однієї із задачі виробництва високоякісного насіннєвого матеріалу. Відзначено, що це дозволить оптимізувати параметри процесів сепарування та розробити нові робочі поверхні для його реалізації. Відмічено, під час моделювання необхідно враховувати вплив конструктивно-кінематичних параметрів зерноочисних машин, фізико-механічні властивості сировини, внутрішньошарові процеси і сили.

Теоретичними дослідженнями удосконалена механіко-математична модель сепарування зернової маси у псевдозрідженому шарі за її густиною. Модель встановлює зв'язок між ефективним коефіцієнтом динамічної в'язкості й густиною частинок дискретної і неперервної фаз та об'ємною концентрацією частинок дискретної фази. При цьому враховані порозність псевдорозрідженого шару, повздовжній і поперечний кути нахилу опорної поверхні до горизонтальної площини, амплітуда і частота коливань частинок неперервної фази; кут напряму коливань відносно перпендикуляру до опорної поверхні.

Доведено адекватність удосконаленої механіко-математичної моделі шляхом порівняння експериментальних та теоретичних результатів моделювання фракціонування зернової маси. Встановлено, що відмінності у значеннях густини розділених фракцій ЗМ не перевищують 7...8 %, тобто знаходяться у межах похибки.

Відзначено, що удосконалена модель сепарування зернової маси у псевдорозрідженому шарі може бути використана для визначення раціональних значень параметрів пневмосортувального стола, на якому проводять фракціонування відповідного насіннєвого матеріалу. Вихідними даними при цьому є густина неперервної і суцільної фаз зернової маси, коефіцієнт тертя насіння та еквівалентний радіус частинки.

Результатом моделювання є раціональні значення амплітуди і частоти коливань робочої поверхні пневмосортувального столу та кути нахилу робочої поверхні.

Ключові слова: механіко-математична модель сепарування, зернова маса, насіннєвий матеріал, псевдорозріджений шар.

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АНАЛІЗ ВПЛИВУ НАПРЯМКУ ОБЕРТАННЯ МІШАЛКИ І ЄМНОСТІ НА ІНДЕКС ЗМІШЕННЯ (*Ip*) (с. 86–91)

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У статті розглядається вплив напрямку обертання мішалки і ємності на індекс змішення (Ip). Теорія хаосу є результатом глибокого вивчення різних завдань, рішення яких не можуть дати дві попередні основні теорії, а саме квантова механіка і теорія відносності. Ефективність змішування області потоку не залежить від швидкого перемішування.

У даному дослідженні використовується ємність з подвійною мішалкою, камера, програмований логічний контролер, тахометр, 6 А адаптер і комп'ютер, а також електродвигун постійного струму (25 В) для обертання мішалок і ємностей. Діаметр первинної і вторинної мішалок становить $Dp=38$ мм і $Ds=17$ мм. Діаметр ємності, виготовленої з прозорого пластику становить $Dw=160$ мм і висота 170 мм. Швидкість обертання первинної мішалки становить $np=10$ об/хв, вторинної мішалки $ns=22{,}3$ об/хв і ємності $nw=13$ об/хв, кутова швидкість ємності $\Omega w=360°$, кутова швидкість первинної мішалки $\Omega p=180°$. Рідина складається з суміші води і фарби (білої). Для барвника використовується суміш води і фарби (червоної). Для випробування віскозиметра Брукфільда використовується в'язкість рідини і барвника. Результати показали, що при повороті мішалки в напрямку, протилежному ємності, навколо мішалки будуть відбуватися розтягнення, згинання і складання, а найменший індекс змішення склав P2V-b (0,94). Крім того, виходячи з наведеного вище значення індексу змішення, отримано найвищий рівень ефективності змішування, а саме: P2V-b, P2S-b, P2B-b, P2V-a, P2B-a і, нарешті, P2S-a. Індекс змішення обернено пропорційний рівню ефективності. Таким чином, найвищий рівень ефективності досягається при наступній обробці: варіативне обертання (між протилежно обертовими мішалками); протилежне обертання (обертання мішалки в напрямку, протилежному ємності); односпрямоване обертання (обертання мішалки в напрямку ємності).

Ключові слова: індекс змішення, хаос, мішалка, ємність, ефективність змішування, напрямок обертання.

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РОЗРОБКА МЕТОДУ ПАРАМЕТРИЗАЦІЇ СТИЛЬОВИХ РІЗНОВИДІВ ЖАКЕТА ЗАСОБАМИ МОДИФІКУВАННЯ КОНСТРУКЦІЙ ТИПОЛОГІЧНОГО РЯДУ (с. 92–105)

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Проведеними дослідженнями виявлено проблему неефективного шкалування однорідності модельних конструкцій жакета у процесах проробки типового представника через невизначеність параметрів модифікування.

Запропоновано варіант синхронізації критичних точок силуетних прибавок шляхом групування числових рядів у векторі вибору величини прибавки відповідно до характеристики стильових різновидів. Визначено вплив формотворних членувань на формування класифікатора конструктивно-технологічних рішень жакета. Сформована модель забезпечення векторів модифікування дала змогу описати послідовність реалізації процедур методом типового представництва. Наявність однієї конструктивної категорії, однакових конструктивних частин, єдність стилю спрощує процеси відбору і селекції найхарактерніших моделей жакета.

Виявлено, що морфологічна комбінація ознак зовнішнього вигляду впливає на корегування стильових вподобань в продукції виробника. Виділені, як найбільш впливові вектори модифікування жакета, параметри типових членувань відносно точок стикування конструктивних зон оптимізованої п'ятишовної конструкції прототипу.

Розроблено метод шкалування прибавок на свободу прилягання за результатами досліджень емпіричних даних. Одержано адекватну регресійну модель нормалізації параметрів прибавки на силует. Розроблена модель дозволяє здійснювати масштабування силуетних конструкцій шляхом змінювання приростів у кутових точках контуру за прототипом градації в автоматизованому режимі.

Сформульовано практичні рекомендації щодо параметрів зонально-модульного модифікування силуетних конструкцій різновидів жакета: лінійний характер силуетної трансформації стану відносно Пси1=5 см. Запропоновано нормалізовані параметри побудови функціонально-декоративних деталей.

Ключові слова: типологічний ряд, параметризація, калібрування, силуетна прибавка, метод нормалізації, різновид жакета.