Modernized elements of the experimental milking robot

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Abstract. The article describes the results of laboratory tests of the upgraded elements of the milking robot (liner, milking machine manifold). Comparative tests of the serial ADU-1 and the modernized experimental element of the milking robot were carried out on an artificial udder stand, developed at the Department of Mechanization and Electrification of Livestock Breeding, Tver State Agricultural Academy. The obtained values of the operating modes and the recorded oscillograms make it possible to judge the higher effective throughput of the upgraded elements of the milking robot, a decrease in the return outflow of milk and a safer mode of milking cows.

1. Introduction
The technical modernization of the agro-industrial complex provides for the renewal of its base with domestic agricultural machinery that could compete on the Russian market with leading foreign manufacturers.

The development of scientific potential and the introduction of innovative solutions are important for ensuring the competitiveness and further development of the agro-industrial complex of Russia, since the volume of agricultural products is increasingly dependent on the development and implementation of technologies and designs of machines and devices in the process of milking and primary processing of milk, while the number of various types of losses in its production.

Robotic milking of dairy cattle is likely to gain momentum in the coming years. However, at present the market is represented mainly by imported developments.

At the departments of "Mechanization and electrification of animal husbandry" and "Repair of machines and operation of the machine and tractor fleet" of the Tver State Agricultural Academy in the period 2014 - 2016 - 2018 - 2020, laboratory research and repeated modernization of elements of milking robots - experimental liner and a collector at the stand artificial udder (figure 1).

Distinctive features of the modernized experimental parts of the robot are:

• Three-chamber collector (no serial milking machine has a three-chamber collector);
• The volume of the milk chamber of the collector is increased (about 500 cm³);
• None of the serial manifolds have a working seal diaphragm;
• Various types of liners inside the teat cups.
It should be noted that the modernized experimental element of the milking robot works on the principle of a fuel pump, the next portion of milk pushes the previous portion, thereby no foam is formed and the group accounting of milk (milk meters) will be more accurate.

Figure 1. General view of the milking robot element connected to the milk pipeline: 1 - teat cups; 2 - collector; 3 - milk collection chamber; 4 - chambers of variable vacuum; 5 - way seal 6, 7 - upper and lower chambers; 8 - branch pipe; 9, 10 - inlet and outlet branch pipes 11 - connecting hoses; 12 - outlet milk hose; 13 - stop valve; 14 - base of the upper chamber; 15 - point of intersection of the bases; 16 - connecting hoses; 17 - inter-wall chamber; 18 - main vacuum hose; 19 - pulsator; 20 - suction chambers; 21, 22 - fittings; 23 - inlet pipe; 24 - vacuum hose; 25 - liner rubber; 26 - nipple of a cow.

2. Materials and methods
Laboratory tests (on an artificial udder stand, developed at the Department of Mechanization and Electrification of Livestock Breeding, Tver State Agricultural Academy) were carried out and tested for 2 years / 2014 - 2016 / and production comparative studies were carried out and tested for 2 years at the educational farm Sakharovo on a livestock farm from 2017 to 2019.

For comparative tests, the most widespread and frequently used (90% of all farms) milking machine in the Russian Federation ADU-1 (version 3) and an element of an experimental milking robot were selected.

The values of the vacuum modes were taken on a fragment of the milking installation UDV - 25 / type ADM - 25 / s with a water ring vacuum pump. Oscillograms were recorded with a Pulso Test Syncro / GEA Farm Technologies / (Germany). Thanks to the interpretation of the oscillograms, vacuum loads on the nipple of animals were obtained (Maximum specific pressure \(P_{\text{max}}\) of the teat.
liner on the teat tissue; Minute vacuum load \((F_{m})\) on the udder tissue; Vacuum load \((F_{r.d.}\)) during the period of full milking; Maximum tensile force \((F_{r.max})\) acting on the nipple.

All experiments on the values of interest to us were carried out at intervals of 5 minutes (the values were taken from all devices and sensors every minute) (table 1).

**Table 1.** Comparative laboratory tests of the ADU-1 serial milking machine and the upgraded element of the milking robot.

| Indicators | 40 kPa | 45 kPa | 54 kPa |
|------------|--------|--------|--------|
| **Milking machine "ADU-1" (average value)** | | | |
| Maximum specific pressure \((P_{max})\) of teat rubber on the nipple tissue, kPa | 4.02 | 3.79 | 4.80 |
| | 4.26 | 4.26 | 4.85 |
| | 4.07 | 3.63 | 4.86 |
| Minute vacuum load \((F_{m})\) on udder tissue, N s | 316.41 | 402.96 | 477.48 |
| | 339.04 | 410.89 | 483.36 |
| | 322.24 | 548.10 | 484.27 |
| Vacuum load \((F_{r.d.})\) for the period of full milking, N s | 1588.49 | 2017.49 | 2367.97 |
| | 1695.33 | 2054.57 | 2416.72 |
| | 1702.58 | 2034.01 | 2421.32 |
| Maximum tensile force \((F_{r.max})\) acting on the nipple, N | 1.9 | 3.47 | 3.19 |
| | 2.1 | 2.93 | 3.02 |
| | 2.2 | 2.89 | 3.14 |
| **Milking robot element (average value)** | | | |
| Maximum specific pressure \((P_{max})\) of teat rubber on the nipple tissue, kPa | 3.85 | 3.42 | 4.41 |
| | 3.7 | 3.37 | 4.32 |
| | 3.6 | 3.43 | 4.33 |
| Minute vacuum load \((F_{m})\) on udder tissue, N s | 285.37 | 364.4 | 434.5 |
| | 294.82 | 371.3 | 443.2 |
| | 304.21 | 369.5 | 437.8 |
| Vacuum load \((F_{r.d.})\) for the period of full milking, N s | 1427.3 | 1774.3 | 2163.1 |
| | 1474.2 | 1796.6 | 2110.5 |
| | 1493.1 | 1784.3 | 2135.0 |
| Maximum tensile force \((F_{r.max})\) acting on the nipple, N | 1.73 | 2.48 | 2.81 |
| | 1.86 | 2.70 | 2.76 |
| | 1.93 | 2.62 | 2.81 |

Time was recorded using an electronic stopwatch.

As milk on the stand of an artificial udder, we used ordinary water \(\rho_{1}(water = 1000kg / m^3)\) from a water supply system, since the density of water (slightly different from the density of fresh milk. The amount of "milk" milked per minute was measured using a container (milking bucket) and electronic scales, and then recorded in a special journal.
Further, the obtained values were processed and summarized in tables, and then the analysis was performed.

3. Results and Discussion

Based on the results of the experiments, the calculated - graphic dependencies of the throughput of the milking devices and the milking time were built (figure 2).

![Graph](image.png)

**Figure 2.** Computational - graphic dependences of the throughput of milking devices (serial milking machine ADU-1 (a) and a modernized element of the experimental milking robot (b).

Analyzing the calculated and graphical dependencies of the throughput of milking devices, we can say that the throughput of the upgraded element of the experimental milking robot increases by about 5% with an increase in the vacuum pressure in the suction chamber of the milking cups and is almost straight.

The results of laboratory studies of a serial milking machine and an upgraded element of the milking robot are shown in table 1.

When comparing the results of vacuum loads of milking devices, we see that all indicators of the upgraded element of the milking robot are less from 6.5% to 8% compared to the serial milking machine ADU - 1 (version 3). This reduction of the vacuum effect of the proposed milking element will lead to a decrease in the injury to the nipples of the animal. All the obtained values correspond to zootechnical requirements and the international standard ISO 5707 - 87.

Consider the oscillograms of the operating modes of the serial milking machine ADU-1 and the upgraded element of the milking robot at various vacuum modes in figures 3 and 4.

When comparing and analyzing the milking oscillograms of the ADU-1 serial milking machine and the upgraded elements of the experimental milking robot, we see more elongated oscillograms of milking the milking robot element. This suggests that the vacuum effect decreases, the blow to the nipple practically stops, and this, in turn, removes the "aerosol" effect and "technical" mastitis in animals.
Figure 3. Oscillogram of the ADU-1 milking machine at various vacuum modes.

Figure 4. Oscillograms of a milking robot element.
4. Conclusion

Thus, according to the results of the experiment, the following conclusions can be drawn:

- The modernized element of the milking robot has shown that its productivity is higher from 5 to 8% in comparison with the serial milking machine ADU - 1 (version 3).
- Considering the obtained milking oscillograms and decoding the values (Pmax, Fm, Fpd, Fr max, h d), it can be concluded that it is more expedient compared to the serial milking machine ADU - 1 and all other brands of milking machines. The element of the milking robot "gives out" a decrease in the number of blows to the body of the nipple of the animal, and, therefore, helps to reduce the outflow of milk back to the udder tank by 10%, which leads to an increase in the intensity of milk flow in cows.
- The upgraded element of the milking robot with a new design of the collector and a modified liner has shown optimal parameters in various modes of operation of the vacuum system, which, apparently, contributes to a safer process of machine milking and less traumatic effects on the nipple of the animal.

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