ISSN 2347 - 3983
Volume 8. No. 6, June 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter80862020.pdf
https://doi.org/10.30534/ijeter/2020/80862020

Pairwise Milking Machines with Various Actuators: Technologies and New Opportunities

P.I. Migulev, S.I. Schukin, D.A. Abylkasymov
Tver State Agricultural Academy, Tver, Russia

ABSTRACT

This article describes comparison of serial Russian and foreign pairwise milking machines with various actuators tested on udder simulator; the acquired results and oscillograms demonstrate higher efficiency of experimental pairwise milking machine, decrease in milk drainage and safer mode of cow milking.

Key words: pairwise milking machine, teat cup liner, collector, pulsator, milk flow, milking efficiency.

1. INTRODUCTION

1.1 Design and Objectives Of The Experiments

The proposed experimental pairwise milking machine is different from serial milking machines by modernized collector fabricated by ORION (Japan) and a set of teat cup liners (teat cup actuators):

1). Teat cup liner with tensile cords.
2). Teat cup liner with cord fabric
3). Teat cup liner with modified suction cup chamber and variable stiffness of teat cup tubing [1, 2].

Laboratory studies were aimed at verification of operability of experimental and serial machines and at determination of the following properties:

- efficiency of milking machines under various vacuum regimes and various milking hardness of udder simulator;
- recording oscillograms of machine milking and detection of vacuum properties displayed by milking machines on udder tissue;
- comparative estimation of milking machines;
- detection of optimum parameters of milking machines and actuators;
- measuring of stiffness of teat cup liners of serial and experimental pairwise milking machines;
- development of procedure of experimental studies;
- selection of instruments for experimental studies and fabrication of required equipment;
- comparative experiments of operation of pairwise milking machine, as well as substantiation of design and operation parameters;
- processing of acquired experimental data.

2. METHODS

2.1 Determination of suction capacity of serial milking machines

Production efficiency was determined for the following models of pairwise milking machines:

- PAD-00.000 Nurlat (Russia);
- Kuban (Russia);
- Duovac-300C (Sweden–England);
- InterPuls (Italy).

The studies were performed at the Chair of technology and mechanization of livestock business, Goryachkin State Agricultural and Engineering University (Moscow) and the Chair of mechanization and electrification of livestock business, State Agricultural Academy (Tver). The experiments were carried out in three vacuum modes (30 kPa, 40 kPa, 50 kPa) and repeated thrice [1, 2].

Test duration of milking machines in each regime was 5 min. The time was measured using KADIO KD-1069 electronic timer. Milk ejection was determined every other minute. The amount of ejected fluid in each operation mode of pairwise milking machine was measured by milk bucket and industrial scales.

The intensity of milk ejection of milking machines as a function of nozzle diameter in vacuum mode of stiffness of udder simulator were plotted on the basis of the performed experiments (Fig. 1: 1.1-1.3) and (Fig. 2: 2.1–2.3).

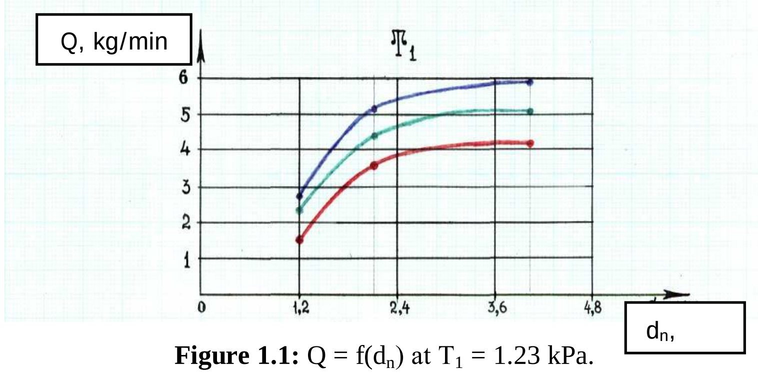


Figure 1.1: Q = f(d_n) at T_1 = 1.23 kPa.

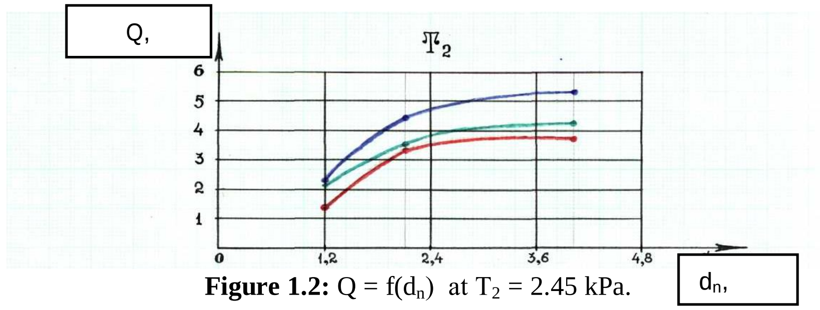


Figure 1.2: Q = f(d_n) at T_2 = 2.45 kPa.

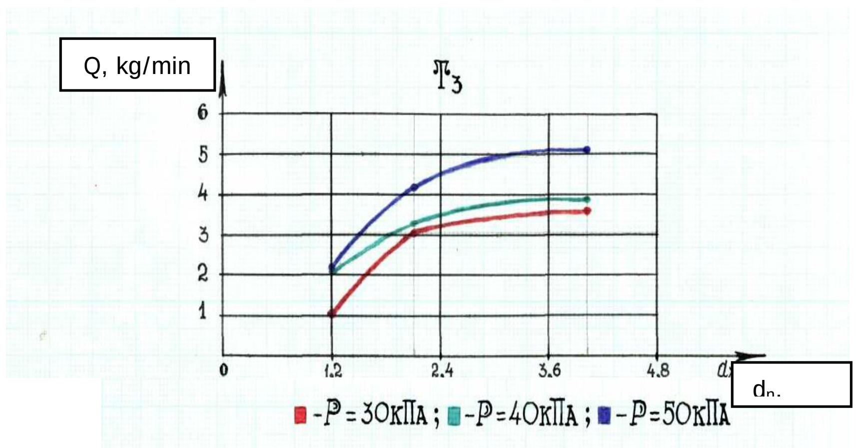


Figure 1.3: Q = f(d_n) at T_3 = 3.68 kPa.

Figure 1:.Predicted Q = f(d_n) of PAD-00.000 Nurlat milking machine [3, 4].

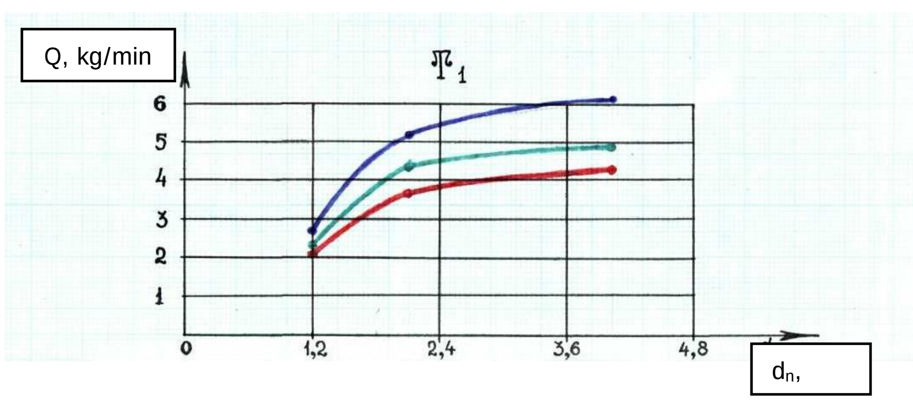


Figure 2.1: Q = f(d_n) at T_1 = 1.23 kPa.

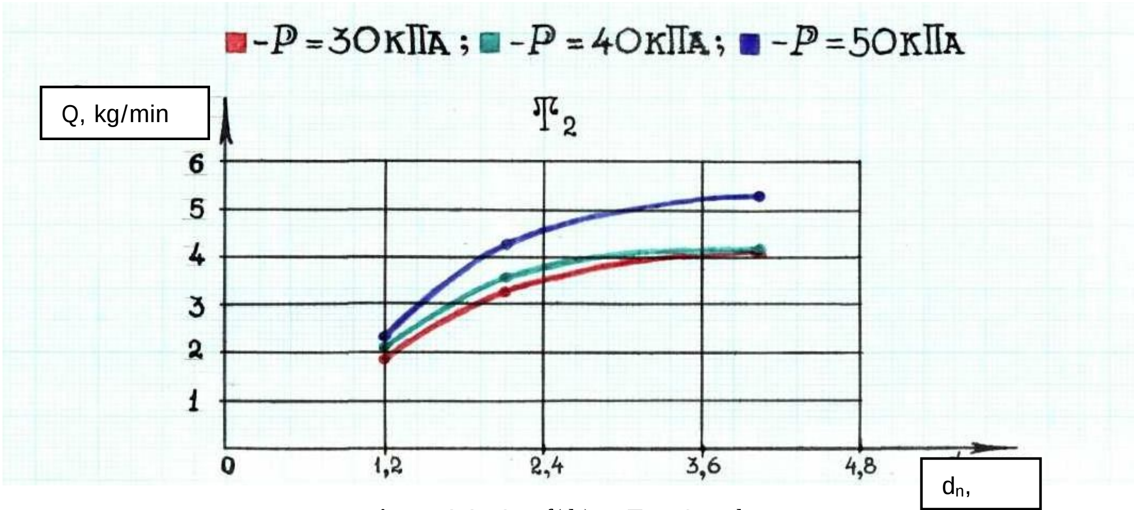


Figure 2.2: Q = f(d_n) at T_2 = 2.45 kPa.

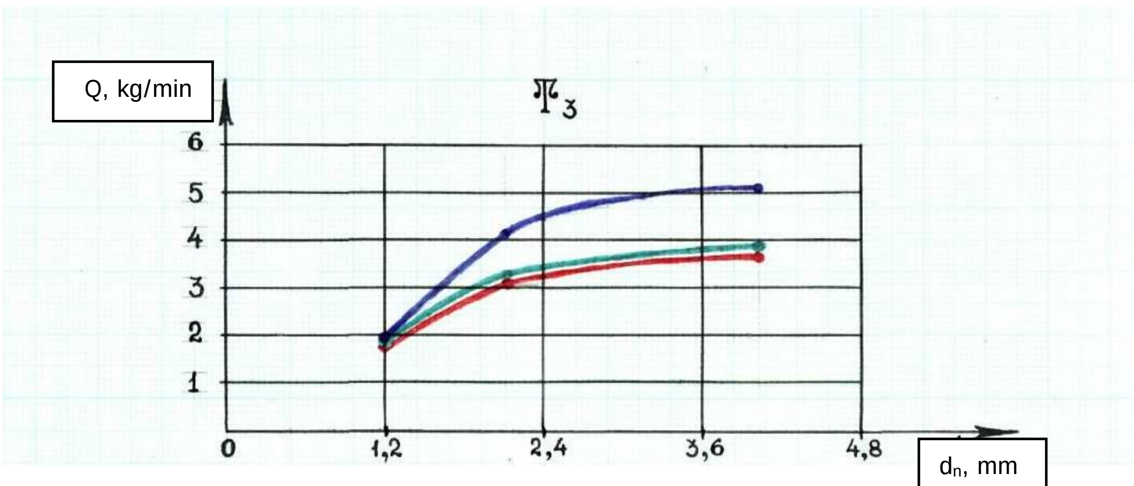


Figure 2.3: Q = f(d_n) at T_2 = 3.68 kPa.

Figure 2: Predicted Q = f(d_n) of Kuban milking machine [1, 2].

Analysis of intensity of milk ejection by serial pairwise milking machines demonstrates that with the increase in vacuum level and nozzle diameter (simulation of cow sphincter using udder simulator), the intensity of milk ejection increases, and increase in load weight (simulation of hard milking on udder simulator) results in its decrease.

2.2 Determination of stiffness of teat cup liner

In order to develop mathematical model of operation of pairwise milking machine, it is required to determine stiffness of teat cup liners applied in serial and experimental machines.

We used two instruments to measure these properties of teat cup liner aiming at their comparison: (Fig. 3) and (Fig. 4).

Instrument for metering stiffness of teat cup liners developed by MIISP (Russia).

The milking apparatus (Fig. 3) is comprised of a control panel with the vacuum meter 2, the valve 1, the manifold 4, the tap handle 3 and connections to vacuum machine (on reverse side).

The instrument operates as follows. The tubing is connected to vacuum machine. Then the teat cup is installed onto the valve 1 and the milk hose of teat cup liner is connected to the manifold 4. The tap handle 3 is switched into on-position, and the stiffness of teat cup liner is recorded using the vacuum meter 2. Then the tap handle 3 is turned into off-position and the teat cup is removed.

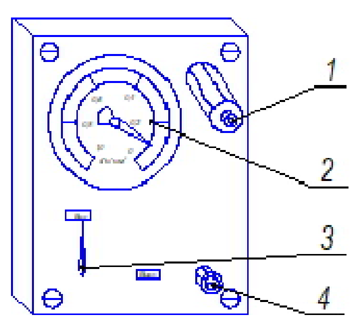


Figure 3: Instrument for metering of tit cup liner stiffness: 1 - sensor; 2 - vacuum meter; 3 - tap; 4 - manifold for connection of tit cup tubing.

UZT-1 instrument (Fig. 4) for metering elasticity and stiffness of cow mammary gland [3].

The instrument is comprised of the sensor 1, the generator and transformer of loads, the reverse counters, the presetting generator with controlled frequency divider, comparators, digital indicators, and power supply.

We measured the stiffness of teat cup liner by the UZT-1 instrument (Fig. 4).

We used teat cup liner of Russian and foreign pairwise milking machines.

Three holes with the diameter of 14 mm were drilled at various sites along the vertical of teat cup.

The UZT-1 recorded the values of digital indicators 3 (Fig. 4).

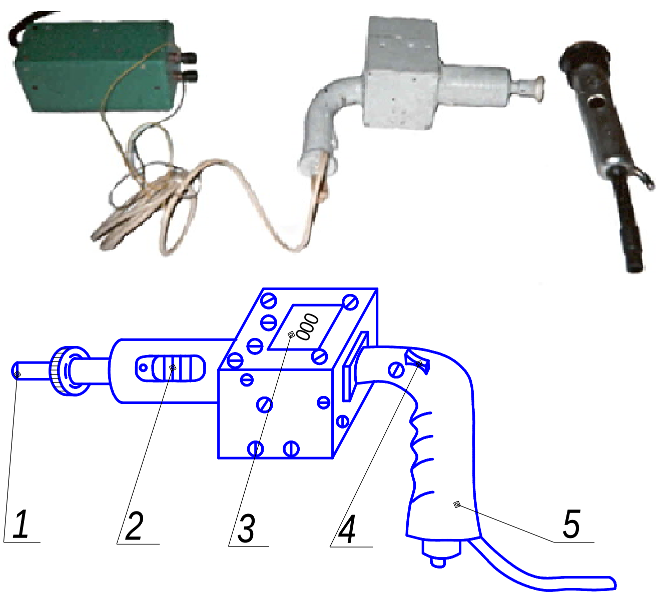


Figure 4: Schematic view of UZT-1 instrument for metering of tit cup liner stiffness:
1 - sensor; 2 - metering unit; 3 - indicators; 4 - switch; 5 - handle.

2.3 Determination of vacuum properties of serial and experimental pairwise milking machines

Zootechny detects virus and technical reasons of mastitis of lactating animals.

The technical reason is mechanical impact on udder teats of milked cow. In its turn, the technical reason can be subdivided into three main reasons as follows:

- compression of teat channel opening during milking;
- impact of teat cup tubing on teat upon compression stroke in the form of beat. Per one machine milking, the machine generates in average 400-600 of such beats;
- occurrence of aerosol effect upon compression, when milk drains reversely from teat cistern to udder cistern together with pathogenic microbes [1].

The authors aimed at development of milking machine actuator allowing to minimize impact of active part of teat cup tubing on cow udder during operation in conformity with zootechnical requirements and eliminating the technical reasons of udder mastitis.

In order to solve this problem, a new design of teat cup liner was developed. Tensile cords with the diameter of 0.9…1.1 mm and the length of 0.3…0.7 l [1, 4] were embedded along the periphery. Total number of cords was 3-6 with cord fabrics. The cord length was 0.3 l …0.7 l of total length of active part of teat cup tubing, 60…80 mm. The mentioned cord length provided the required stiffness of upper part of teat cup tubing, thus decreasing the beat impact of teat cup tubing against teat walls upon suction and compression strokes (Fig. 5).

The number of beats occurring upon operation of milking machine with the serial liner and the proposed new design of teat cup liner was determined using universal VShV-003-M2 instrument (meter of noise and vibration) with DN-3-M1 sensors. This equipment makes it possible to detect sharp beat impact of teat cup liner on udder teat. The obtained experimental data in 300 s of operation of teat cup tubing are summarized in Table 1.

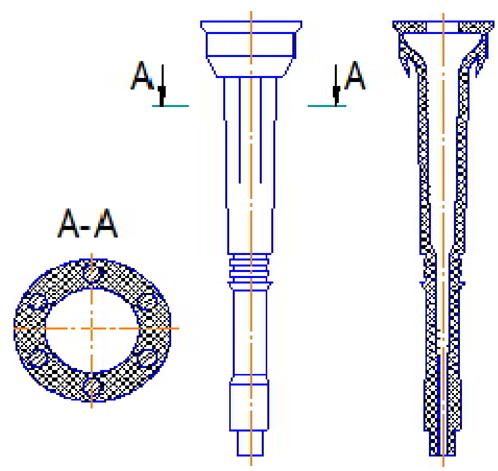


Figure 5: New design of tit cup liner:
1 - suction cup chamber; 2 - working part of suction cup tubing; 3 - milk tubing; 4 - tensile cord.

The experimental results of teat cup liners (tubing) are summarized in Table 1.

Table 1: Tests of suction cup tubing [1, 2]

Performances	Average number of beats
Number of cords	
0	280-350
3	190-240
6	42-50
9	3-8
Cord length (as a function of number of cords -9)	
0.3 ℓ	35-40
0.6 ℓ	5-8
0.8 ℓ	28-34

It is obvious that the optimum operation conditions are provided by the cord length equaling to $0.5\ell \ldots 0.7\ell$ with six–nine cords. With the number of cords less than six, the number of beats increases, with more than nine cords (cord fabric), no positive effect is achieved.

Therefore, the proposed new design of teat cup liner allows to decrease the beat impact of teat cup tubing on udder teat.

However, the new design of teat cup tubing does not completely decrease vacuum load on udder tissues, finally it can result in udder disease.

In addition, fabrication of the new design of teat cup liner with reinforced tensile cords and cord fabric is sufficiently labor consuming, resulting in higher production costs.

A further task was to develop teat cup liner allowing to decrease vacuum load on udder tissue and to simplify the design.

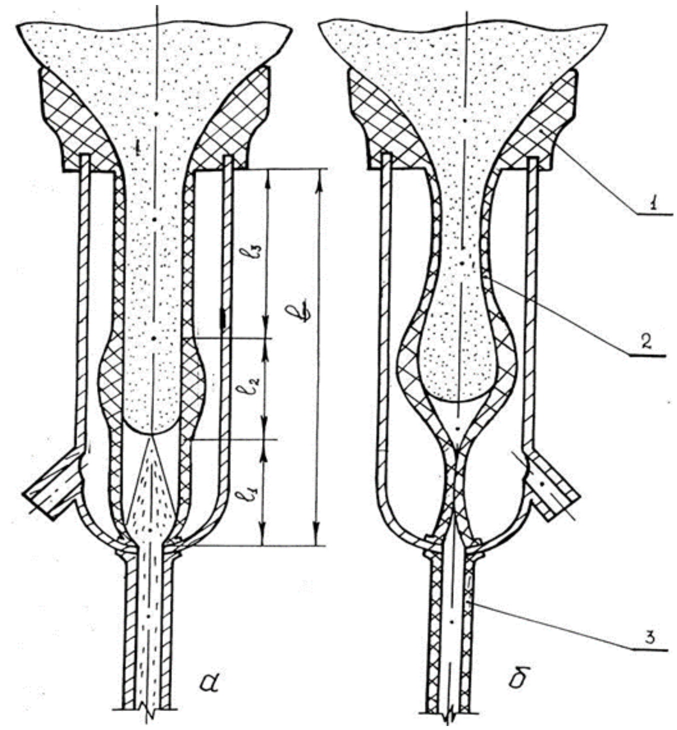
This task was solved by another more reasonable design of teat cup liner [5].

This invention is comprised of three characteristic parts:

- new design of suction cup chamber;
- variable stiffness of active part of teat cup tubing;
- lower ellipsoid shape sealing the parts of teat cup tubing.

The tubing of teat cup liner (Fig. 6) is made of elastic material (neoprene-based food rubber) and comprised of upper part and discharge part, the middle of active part (≈ 40 mm) made thickened by 3.5…4 mm. The thickness of lower active part (≈ 40 mm) of cup tubing is 2.0…2.5 mm. The thickness of teat cup tubing walls of known milking machines is 2.0…2.5 mm, the length of active part is 120 mm. The variable stiffness of active part of teat cup tubing allows to decrease vacuum load on udder tissues and to avoid impact on teat tissues, preventing aerosol effect [1, 2, 5].

Occurrence of aerosol effect promotes penetration of pathogenic microbes into the cavity of udder cistern. In addition, ellipsoid shape of tubing in its lower sealing part prevents beat impact.



a – suction stroke; b – kneading stroke.

Figure 6: Milking machine with new design of teat cup liner:
1 - suction cup chamber; 2 - working part of teat cup liner; 3 - milk discharge manifold

3. RESULTS

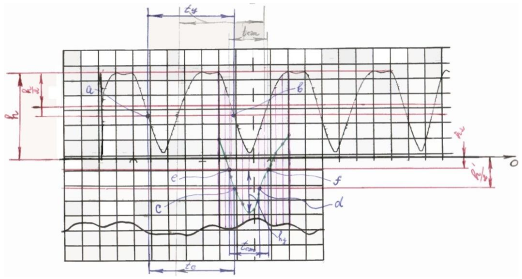
The udder simulator was used for laboratory tests developed by Chair of technology and mechanization of livestock business, Goryachkin State Agricultural and Engineering University. Operation oscillograms of vacuum modes of milking machines were obtained at 30, 40, and 50 kPa with various nozzles (diameter of 1.2 mm; 2.1 mm, and 4 mm) (Figs. 3.14, 3.15) and simulation of various milking hardness of udder teats (load weight of 50, 100, 150 g, Figs. 7, 8).

The experimental results of serial and experimental pairwise milking machines at the vacuum of 50 kPa, the load weight of 150 g, the nozzle diameter of 4.0 mm are summarized in Table 2.

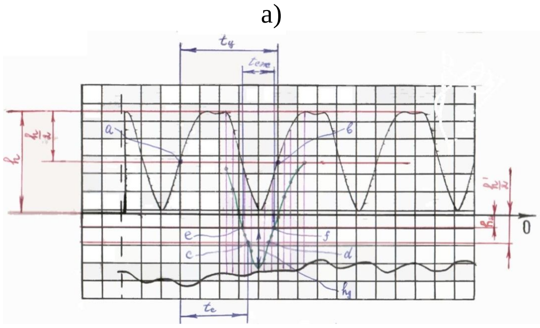
Table 2: Analysis of serial pairwise milking machine [1, 2]

Property	PAD-00.000 Nurlat	Kuban	Duovac-300C	InterPuls
Maximum specific pressure (P_{max}) of teat cup liner on teat tissue, (kPa)	24.3	16.9	25.6	34.4
Minute vacuum load (Fm) on udder tissue, (N·s)	971	1,060.7	1,040.8	916
Vacuum load (F_{tm}) per total milking cycle, (N·s)	4,855	5,303	5,204	4,581.5
Maximum tensile force (F_{Pmax}) acting on teat, (N)	18.5	18.6	18.5	17.9

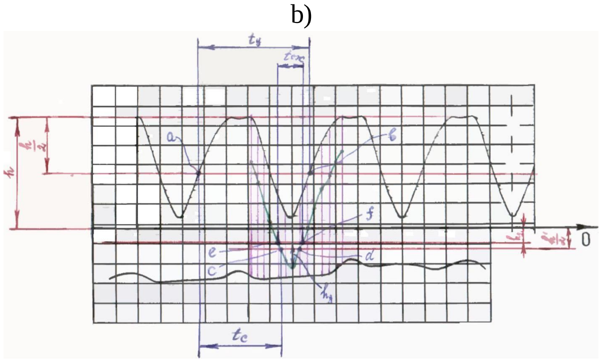
It follows from Table 3.2 that the minute load (FM) on udder tissue and the vacuum load (Ftm) per total milking cycle are in the range corresponding to ISO 5707-87 standard (FM = 700…1,200 N·s; Ftm = 3,600…6,000 N·s), and the maximum tensile force (FPmax) acting on teat does not comply with the standard (FPmax = 17 N) [2].



a)

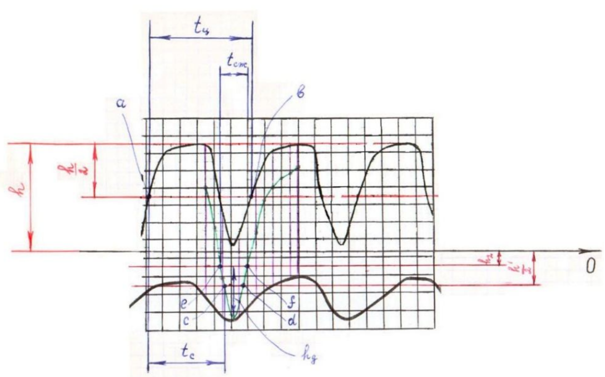


b)

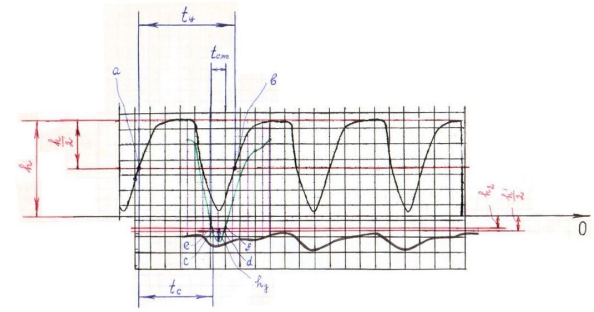


c)

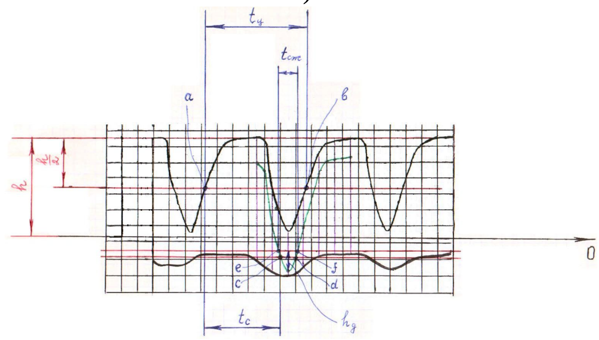
Figure 7: Oscillograms of machine milking by Nurlat machine upon vacuum milking B = 50 kPa (laboratory tests): a) ø1.2 mm; b) ø2.1 mm; c) ø4.0 mm.



a)



b)



c)

Figure 8: Oscillograms of machine milking by the experimental machine upon vacuum milking B = 50 kPa (laboratory tests): a) ø1.2 mm; b) ø2.1 mm; c) ø4.0 mm.

The teat cup liner according to RF patent №2230452 [4] with six tensile cords and cord fabrics is given in Table 3 as prototype.

Table 3: Tests of experimental pairwise milking machines [1, 2]

Property	Prototype (6 tensile cords)	Prototype (cord fabric)	Claimed specimen
Maximum specific pressure (P_{max}) of teat cup liner on teat tissue, (kPa)	25.6	24.9	25.1
Minute vacuum load (Fm) on udder tissue, (N·s)	1,068	933.8	458.2
Vacuum load (F_{tm}) per total milking cycle, (N·s)	5,340	4,669	2,291
Maximum tensile force (F_{Pmax}) acting on teat, (N)	18.2	15.3	12.0

It follows from Table 3 that the minute vacuum load F_M on the experimental milking machine with new teat cup liner decreased by two times in comparison with serial specimens. The same occurred with vacuum loads during total cycle of machine milking.

Lower maximum tensile force (F_{Pmax}) acting on teat was obtained in comparison with serial milking machine. Therefore, the proposed design of new teat cup liner makes it possible to decrease significantly vacuum load on udder tissues and tensile force on teat, which will be favorable for cow health, udder in particular (Tables 4, 5).

Table 4: Predicted stiffness of suction cup tubing of serial and experimental milking machine (MIISP instrument)

Milking machines	Stiffness, kPa (sealing vacuum)			
	1	2	3	Average
PAD-00.000 Nurlat	13.8	16.5	17.6	16
Experimental pairwise milking machine	15.3	14.8	15.2	15.1

Table 5: Predicted stiffness of teat cup liners (UZT-1 instrument)

Stiffness, Pa							
Serial milking machine				Experimental milking machine			
First groove on teat tubing		Third groove on teat tubing		First groove on teat tubing		Third groove on teat tubing	
Lower hole	Upper hole	Lower hole	Upper hole	Lower hole	Upper hole	Lower hole	Upper hole
h =10 mm		h =40 mm		h =10 mm		h =40 mm	
305	408	317	439	311	400	309	399
295	411	319	442	314	402	311	408
310	405	325	428	324	332	304	408
303	408	320	426	315	378	308	401

It follows from Tables 3.4 and 3.5 that the stiffness of teat cup liner in different parts varies from 0.3 to 16 kPa.

4. CONCLUSION

1. The obtained results of comparative tests of serial and experimental pairwise milking machines revealed unsteady operation of Duovac-300C (Sweden) and InterPuls» (Italy) serial machines at vacuum pressure of 33.3 kPa.
2. The analysis of oscillograms demonstrated that the experimental pairwise milking machines decreased the number of beats against teat, hence, promoted decrease in milk drainage back to udder cistern and improved milking efficiency.
3. The experimental milking machine with new design of suction cup and variable stiffness of suction cup tubing demonstrated optimum parameters and vacuum, which, probably, promoted safer mode of machine milking.

REFERENCES

1. S.I. Shchukin. Sovershenstvovanie rezhimov raboty ispolnitel'nogo mekhanizma doil'nogo apparata [Improvement of operation modes of milking machine actuator]. Podolsk: Proceedings, 7th International Conference GNU VNIIMZh, vol. 13, Part 2, 2004.
2. S.I. Shchukin. Rezul'taty laboratornykh ispytanii seriinykh i eksperimental'nykh doil'nykh apparatov poparnogo deistviya [Laboratory tests of serial and experimental pairwise milking machines]. Tver: Proceedings, International Conference, 2004.
3. Ustroistvo dlya izmereniya tonusnosti [Tonus metering device]. Informatsionnyi listok VIZh, Dubrovitsy, 1992.
4. S.I. Shchukin, N.P. Pronichev. Teat cup tubing. RF Patent 2230452. Bulletin no. 6, February 27, 2004.
5. S.I. Shchukin, N.P. Pronichev. Teat cup tubing. RF utility patent 58291. Bulletin no. 33, November 27, 2006..