MILKING MACHINE WITH ELECTROPULSATOR

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Abstract. The authors proposed a technology of machine milking of cows. The milking mode is controlled by the new pulsator. The pulsator has a linear-moving actuator. This allows to specify the transient time from sucking to compression in the milking cup. Previously, researchers have found that the transient time of 120 milliseconds has positive effect on the animal during milking and corresponds to the physiological characteristics of the cow milking process. Construction of the pulsator is protected by several patents. At this stage of research, laboratory and manufacture testing of the milking machine with the new pulsator were conducted. The article describes the control system operating the pulsator modes. The control system allows milking in adaptive mode, which allows to get the maximum amount of milk per milking. The pulsator equipment consisting of four linear motors allows to milk every quarter of the udder in an adjustable independent mode. The same principle is used in modern milking robots, and it allows to fully automate the process of milking. The feature of the control system is the presence of two independent channels, with the current feedback. The most universal and flexible way to create full controllers is the use of a specialized microcontroller module with digital signal processing. This solution is economically advantageous due to a smaller number of electronic components than it is needed when using analog devices. The proposed control system increases the reliability of the device and can change the functionality at the software level without changing the circuit design. The article also describes how to obtain the oscillogram of pressure changes and determine the transient time in the interval chambers of the milking cups.

Keywords: mechanical milking, milking machine, teat cup, pulsator, liner, pulsation chamber, vacuum fluctuations, pulsation cycle, prevention of mastitis, physiology of machine milking.

Introduction

The basic technological process in dairy animal industries is machine milking, which thanks to labour input reduction, improvement of the quality of milk and the work organisation has forced out the manual. For today, machine milking is widespread not only on large cattle-breeding complexes with milking machines and robots, but it is used also in small farms. Despite all advantages, machine milking in comparison with manual, has a number of lacks. All milking machines injure an udder, therefore cows have inflammations, and the probability of disease by a mastitis raises, and it leads to culling of cows, every third from the herd. Besides, the milking machine has "a rigid" mode of milking and does not consider physiological features of the milking process at animals owing to what at them arises, the so-called "stress at milking" that decreases the efficiency. As a result it is not to the full carried out "milking" and the genetic potential of cows is not used that finally leads manufacturers of milk to the missed benefit and reduces profitability of the branch as a whole.

Most milking in the developed world is done using milking machines. The teat cups are attached to the cow's teats, then the cups alternate between vacuum and normal air pressure to extract milk. When the teat cup is applied to the teat, the end of the inside chamber is filled by the teat. During the milk phase the vacuum applied inside the liner is constant and keeps a constant negative pressure at the end of the teat. The vacuum applied to the chamber, between the shell and the thinner walled part of the liner, keeps the liner from collapsing under the vacuum. During the rest phase, the vacuum inside the chamber is monetarily off. Air enters the chamber instantly, reaches atmospheric pressure, collapsing the rubber liner around the teat end, massaging the teat and maintaining the blood flow. The lower part of the chamber maintains its vacuum, while the upper part around the teat momentarily loses vacuum. This alternating vacuum-atmospheric pressure in the chamber is controlled by a pulsator.

Experiment program

The program provides experimental verification of quantification of dependence between the pressure in the interspace chambers of the teat cups and the movement of the linear motor armature, and determination of the duration of the phase transition milking, and also carrying out check of operability of the advanced milking machine under production conditions. In this connection, the following problems of experimental studies are discussed:

- to receive oscillograms of the change of pressure in the interwall chambers of the teat cups of the advanced milking machine;
- determine the duration of transients in the interspace chambers of the teat cups;
- build electromechanical characteristics of the linear motor, the proper milking phases;
- test the functionality of the advanced milking machine with pulsator on the basis of the linear motor in industrial conditions.

Experimental studies were carried out by known methods using modern equipment and devices in accordance with the current regulatory documentation.

For this purpose we used: mobile milking unit AID-1 oscilloscope TPX 2024 pneumatic tester PDD-1, vacuum TM 100, linear displacement sensor LIR-2, light of linear displacement LIR-510, electronic scales, a potentiometer, a modified teat cup.

Description of the circuit of the control unit of operation of the milking machine

When carrying out pilot studies, the operating modes of the advanced milking machine were set by the control unit. The circuit control unit arranged two independent channels with current feedback. The most versatile and flexible way to create full-fledged controllers is the use of specialized microcontrollers with integrated DSP. This solution in addition to efficiency due to the use of fewer electronic components (compared to completely analog devices) also increases the reliability of the entire device and the ability to quickly change the functionality at the software level without changing the circuit design [1].

Fig. 1 shows a functional diagram of a coil control channel. The scheme is provided for the possibility to control the channel mode of operation, it can be enabled or disabled. The module of formation of a task can operate in one of the modes of the fixed or cyclical task. In the first case it acts as a reference to the particular value of current supplied to the linear motor coil, variable by the user request. Which mode is used in experiments is determined by the mechanical characteristics of the linear motor. Mode changes cyclically require a table describing the changes in the output current in the range of 1s. Each 4 ms on the module of comparison the next task on which the amount of the current supplied to coils of the linear motor coil. This approach allows to set the desired algorithm for controlling movement of the linear motor armature, which affects the duration of transients in the interspace chambers of the teat cups. This mode corresponds to the operational mode of operation if the improved milking machine.

In order to achieve smooth and predictable movement of the armature of the linear motor under the influence of the magnetic force generated by the coils, in the control circuit unit two contours of negative feedback have been organized.

An indirect parameter of the current position of the armature is the RMS current flowing in the coils of the linear motor. The feedback signal from the current sensor is scaled, converted ADC module and fed to the comparator unit.

The received value of a mismatch arrives on processing of the PID-regulator, which represents expression calculation:

$$B = k_P \cdot O_P + k_I \cdot O_I + k_D \cdot O_D,$$

(1)

where B – output value of the controlled variable;
   k_P, k_I, k_D – regulator coefficients, respectively, proportional, integral, differential
   O_P, O_I, O_D – error values, respectively, proportional, integral, differential.

At the output of the PID-regulator the value B is defining the duty cycle of pulse width modulation.

The duty cycle – the ratio of the repetition period to the duration applied to the coils of signal [2].

Generator module PWM control generates a sequence of pulses with a frequency of 50 kHz and a predetermined duty cycle. The received pulses are supplied to the power switch through a driver, which is connected in series in the power supply circuit and coil.

The control path is executed by the second coil similarly.

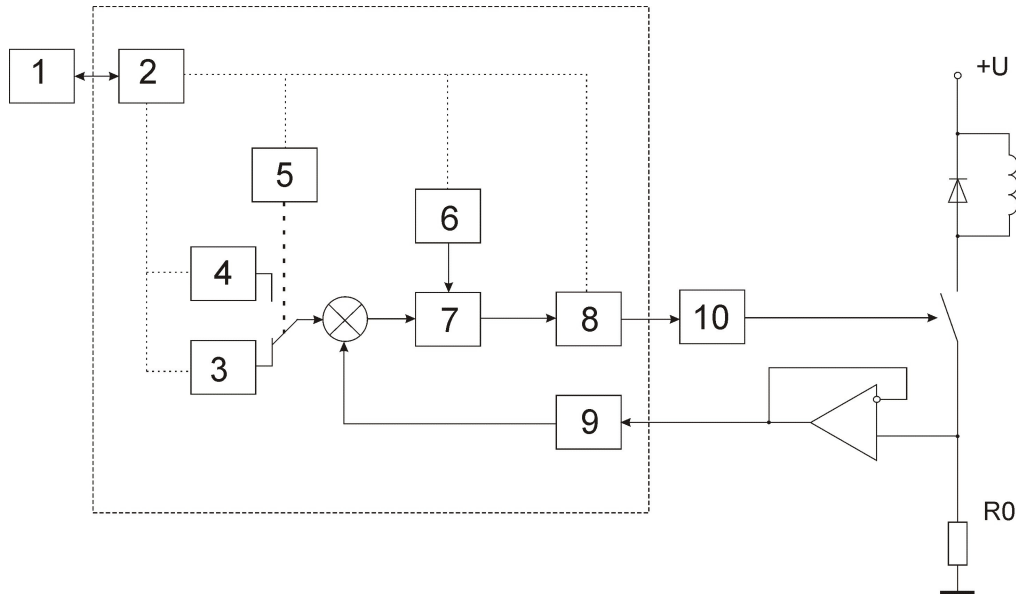PC interface allows to configure and edit modes of the control circuit.

Fig. 1. **Functional diagram of the control channel:** 1 – PC; 2 – Serial interface; 3 – Sample Loop; 4 – Fixed assignment; 5 – Mode; 6 – k_P, k_I, k_D; 7 – PID; 8 – PWM generator; 9 – ADC; 10 – gate driver
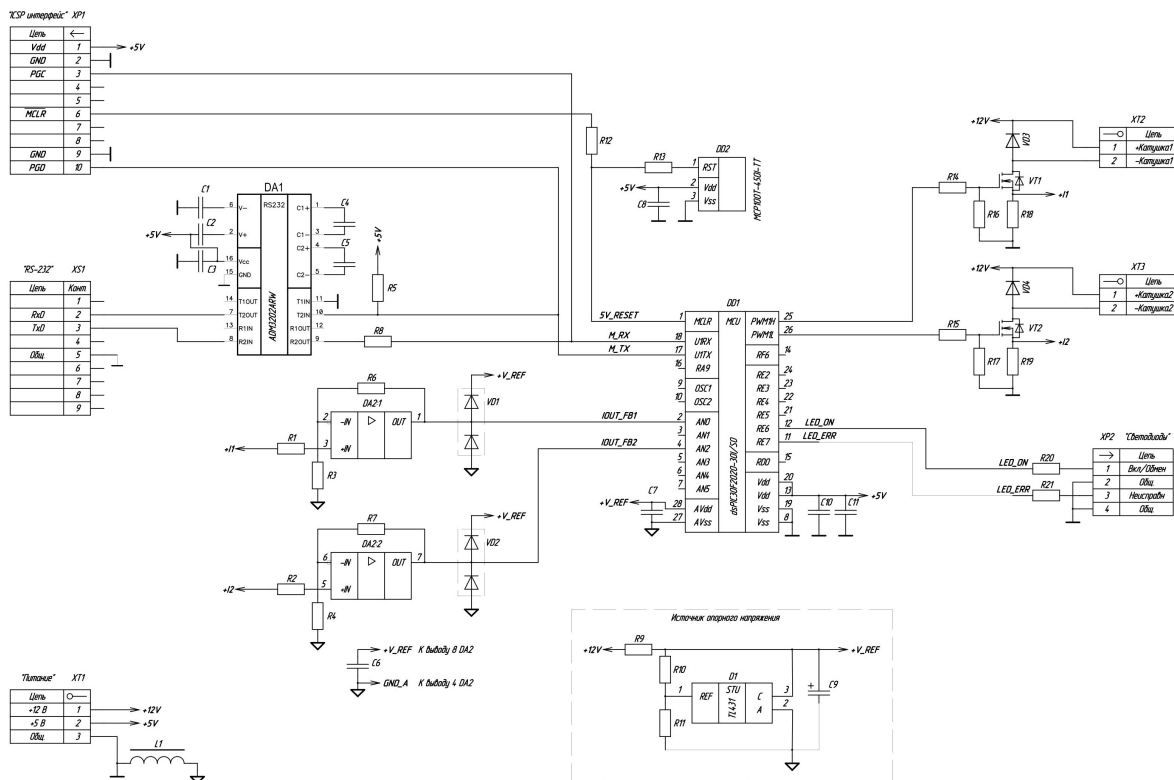

Fig. 2. **Schematic diagram of the control circuit**

This microcontroller contains 3 independent modules PWM (Pulse Width Modulation), 6 inputs of analogue-to-digital conversion, 3 ultra fast comparators, universal interface of serial connection and a core of digital signal processing. Power supply of circuit is carried out from two voltage sources. Source (12 V) is used to power supply of magnetizing coils in the linear motor. From the source of 5V nodes of control circuit are powered. Additionally, on-chip D1 precision voltage reference for the measurement of the control circuit is assembled. The chip DD2 is the voltage supervisor and is intended for resolving the inclusion of the microcontroller DD1 only after installing and stabilizing the

voltage supply above 4.5 V. This enables guaranteed to getting rid of incorrect work of the control circuit during power failures.

Control of currents, which are fed to the magnetizing coils, is carried out with outputs PWM DD1and transistors VT1 and VT2. Resistors R18 and R19 are included in the circuit of flowing of power currents and used as current shunt sensors. The voltage from the shunt and proportional to the current in a coil scale on the operational amplifiers DA2: 1 and DA2: 2 and fed to the inputs ADC DD1. Embedded software of the microcontroller DD1 realizes the two independent PID-regulators of the current control in each of the coils of the linear motor. Also, for each regulator cyclic control under the certain law is formed. On the basis of specified set points and feedback signals the control modules of PWM are set, keeping the coils in a certain value of current.

Condition of the control scheme is reflected by LED (light-emitting diode) VD1 indicators – "on" and VD2 – "fault". In communication facilities with the personal computer we can change the settings of regulators and laws of modes of control in work of the milking machine.

Methods of determining the duration of the transient processes and obtaining oscillograms of the changes in pressure in the interspace chambers of teat cups

To identify the quantitative dependence between the displacement of armature in the linear motor and the pressure in the interspace chambers of teat cups, as well as determining the duration of the transitional phases of milking oscillograms of changes in pressure must be received. A stand (Fig. 3) was designed for this purpose.
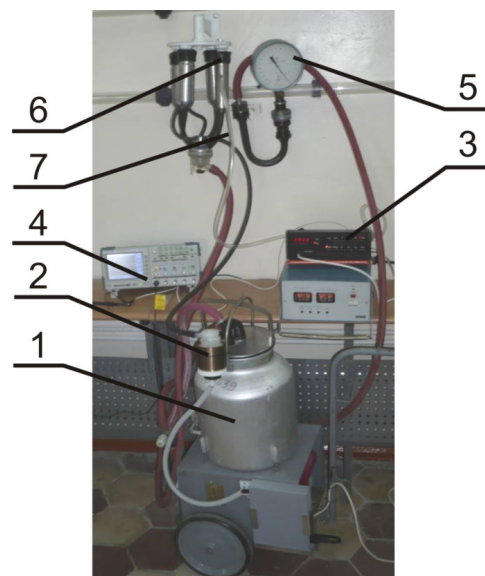

Fig. 3. **Stand for obtaining oscillograms of the changes in pressure in the interspace chambers of teat cups:** 1 – milking machine, 2 – pulser based on the linear motor; 3 – pneumotester PTD-1; 4 – Oscilloscope TPX 2024; 5 – vacuum regulator; 6 – modified teat cup; 7 – hose of variable vacuum

The stand includes a milking machine; one of the cups has an extra valve seat for connecting to pneumotester PTD-1, oscilloscope TPX 2024, vacuum regulator. The modified teat cup has a valve seat in the sleeve, to which by means of the hose of variable vacuum we can join the pneumotester PTD-1. Vacuum regulator is set and controlled by the pressure in the milking machine system. The stand is made on the basis of the pneumotester PTD-1. This device has a relatively low cost and it is widespread in the laboratories for testing of the milking equipment. Therefore, it was chosen for the experiment, but this device does not monitor the dynamics of the pressure changes in the process and does not allow to fix this information for further processing and analysis.

Functional diagram of the pneumotester PTD-1 is shown in Figure 4. A primary pressure converter is a strain gauge transducer, which reacts to pressure changes in the milking machine system. By using the variable vacuum hose we connect the sensor to the milking cup interspace chamber. Signal from the sensor is amplified by the instrument amplifier and input to the analog-to-

digital converter, which is a ten-digit K1113PV1A integrated circuit, which is a foreign counterpart AD571K [3]. Working of the pneumotester PTD-1 is controlled by a microcontroller, which is performed on the basis of single-chip KR1816VE35, in which the measured information is processed. On a command from the microcontroller, the analog-to-digital converter changes the analog signal from the sensor into a digital code. By means of the controller keyboard and display we selected and set control commands, which are used to output information on the display of the pneumotester PTD-1 [4].
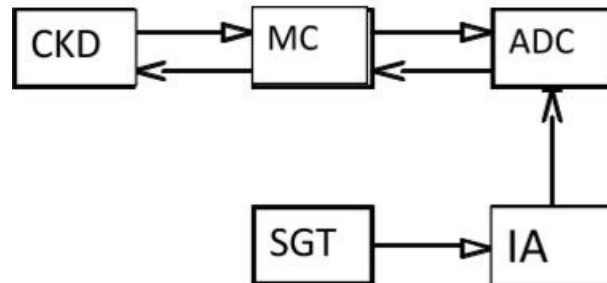

Fig. 4. **Functional diagram of pneumotester PTD-1:** CKD – controller of the keyboard and display; MC – microcontroller; ADC – analog-to-digital converter; IA – instrument amplifier; SGT – strain gauge transducer

For creation of oscillograms of the change in pressure in the interspace chambers of teat cups as a recording device the storage oscilloscope TPS 2024 probe is used, which is connected to the analog input and analog "earth" K1113PV1A circuit (Fig. 5).
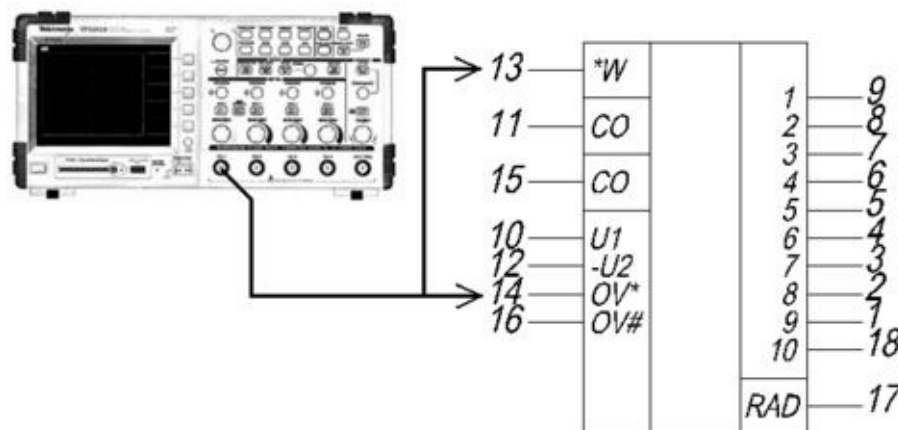

Fig. 5. **Connection of the oscilloscope to the microcircuit K1113PV1A (AD571K) and pin assignment:** 1 – ninth digit; 2 – eighth digit; 3 – seventh digit;4 – sixth digit; 5 – fifth digit; 6 – fourth digit; 7 – third digit; 8 – second digit; 9 – first digit; 10 – supply voltage U1; 11 – damping and transformation;12 – U2 supply voltage; 13 – analog input; 14 – analogue "earth"; 15 – zero shift control; 16 – digital "earth"; 17 – data set ready; 18 – tenth digit (under)

Conclusions

Thus, there was the functionality of the pneumotester PTD-1 expanded and oscillograms of the changes in pressure in the interspace chambers obtained, which can estimate the value of the pressure at a particular point in time and duration of the transient processes. According to the obtained oscillograms is it possible to determine the duration of the strokes of milking and the corresponding vacuum value. For this purpose on the oscillogram the vacuum scale is set, which is determined by calibration of the readings from the exemplary vacuum gauge of the milking machine, and time-scale established by the knob of oscilloscope. In the same way the number of pulses per minute and a correlation of strokes, which are defined as the ratio duration of the sucking stroke to the stroke of compression, are defined.

References

1. Vostrukhin A., Vakhtina E. Analog-to-digital Converter based on the transient process in RC-circuit, 14th International Scientific Conference Engineering for Rural Development 20-22.05.2015 Jelgava, Latvia. pp. 452-457. [online][25.05.2015]. Available at: http://www.tf.llu.lv/conference/proceedings2015/Papers/074_Vostrukhin.pdf.

2. Vostrukhin A.V., Vakhtina E.A. Equilibration of the Wheatstone Bridge by the Pulse-Width Modulation method, ARPN Journal of Engineering and Applied Sciences. – vol. 9(4), 2014. pp. 568-573. [online][06.05.2014]. Available at: http://www.arpnjournals.com/jeas/research_papers/rp_2014/jeas_0414_1072.pdf .

3. Patent RF № 126563, MPK8 A 01 J 5/14. Электропульсатор доильного аппарата двойного действия (Electropulsator of doble-action milking machine), Nikitenko G.V., Kapustin I.V., Grinchenko V. A., owner – Stavrop. university – № 2012123542/13; date. 06.06.12; accepted. 10.04.13.

4. Nikitenko, G.V., Grinchenko V.A., Avdeeva V.N., Antonov S.N., Dorozhko S.V., Konoplyev E.V., Lysakovand A.A., Molchanov A.G. The milking machine with an electropulsator of a new design. 2015, Wschodnioeuropejskie Czasopismo Naukowe, 4.