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STABILIZATION OF SUCTION PRESSURE IN THE CONCEPTUAL MILKING UNIT

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ABSTRACT

The objective of the paper was to verify the structure of the system for regulation and stabilization of absolute pressure, which supplies the autonomous milking unit. The described milking unit constitutes a modern technical solution which enables separation of suction pressure from the transporting one; moreover it enables measurement of the volumetric intensity of milk outflow from the cow udder quarter. The scope of the paper included: construction of the pneumatic supply system of the milking machine, development of the concept of control system, programming a PLC controller for the accepted control algorithm (basing on the previous scientific research of authors) and verification of the system operation on the laboratory stand. The main element of the control system is a microprocessor controller, where an algorithm of suction pressure control was implemented with the use of fuzzy logic; all calculations used for controlling this size are executed there. Results of the experimental research allowed a positive assessment of the described technical solution. The structure needs to be verified in milking conditions, however, research works emphasised positive effects with regard to stabilization of pressure supplied under a teat.

Introduction

Fluctuations of pressure in a teat chamber are among main problems which occur in the mechanized cow milking (Ambord and Bruckaier, 2010). Its uncontrolled changes result in health problems of cow udders and as a consequence in reduction of the milking capacity (Wiercioch et al., 2011). The research works, which were carried out show necessity of controlling suction pressure in the function of mass intensity of milk outflow for particular quarters independently (Ipema and Hogewerf, 2008; Juszka et al., 2011b; Zaninelli and Tangorra, 2006). Correlation of those two dynamically changing parameters and additionally decrease of suction pressure at a high intensity of milk outflow from the quarter of cow udder will affect better blood supply to a teat of a cow udder (Rasmussen, 1993).

Scientific works include solutions which consist in stabilization of suction pressure directed to a teat chamber. A solution patented by Gedymin (2006) which is characterised by

a gum division operating as a membrane which suppresses pressure fluctuations in a cluster is an example of such a mechanical system of pressure stabilization in a milking unit cluster. A method for partial solution to the problem consists in separation of suction pressure from the pressure which transports milk in a pipeline (Ordolff, 2001). Solutions of this type were suggested, inter alia, in the form of a cluster with a separate transport of milk and air in Kupczyk's paper (1990) and an autonomous milking unit in the paper by Juszka et al, (2011a). When considering air flows in a cluster and changes in volume, one may notice that the change of the teat chamber capacity, which results from the teat gum work, causes that air is pressed to a milk chamber of a cluster. This phenomenon results from activity of combined vessels, which constitute those two chambers. During milking, capacity of those chambers and pressure inside may change (Ipema and Hogewerf, 2008). The manner of control and stabilization of under pressure, presented in this article, constitutes an extension of such a system of combined vessels with an accumulator with a microprocessor control and stabilization of suction pressure.

The objective of the paper was to develop a system for control and stabilization of absolute suction pressure, which supplies a column of an autonomous milking machine cluster.

The scope of work included:

- construction of the measuring and control system,
- programming PLC controller acc. to an algorithm which includes fussy logic, which describes the relation of absolute pressure with a momentary volumetric intensity of milk outflow from the quarter of a cow udder,
- verification tests performed at a laboratory milking stand.

The system of control of an innovative milking machine

The object of the research was a conceptual autonomous milking machine, presented in figure 1, where separated suction and transporting pressure was applied. The structure of this device is protected by a patent. One section which operates a quarter of a cow udder is visible, it has two containers filled in in turns. In the presented milking machine two control systems performed by one PLC controller can be distinguished. One is related to controlling milk and air inflow through electric clamp valves mounted on milking and air conduits. The second one controls suction pressure, which is provided to the teat chamber of a milking cup. It is recommended to correlate the value of this pressure with milk outflow to a given milking teat, moreover, suction pressure which delivers milk to a pipeline installation (with a higher value) may not cause changes of teat pressure.

The described system of automatic control of absolute pressure in a teat chamber of a milking cup was created as a result of modelling works carried out in Matlab-Simulink software (Juszka et al., 2011a; Lis et al., 2010). A method of fast prototyping control system was used in the process of modelling. Positive results of computer simulation allowed adjustment of particular elements of this system structure. A block scheme presented in figure 2 shows an algorithm of activity of the control and stabilization system of this pressure.

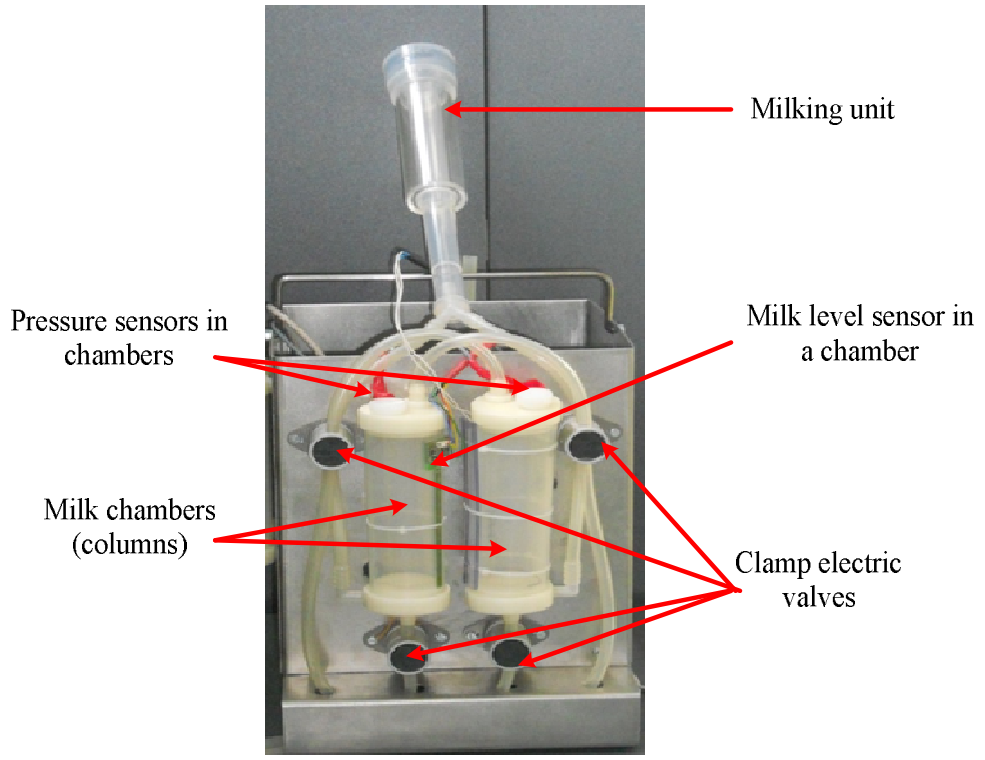

Figure 1. Autonomous milking unit

The system of automatic control of absolute pressure in the teat chamber of the milking cup is equipped with two measuring systems. The first of them measures the value of suction pressure p_s of air which is present in the milking machine, from where it directly gets to a teat chamber. The second one measures the level of milk in the columns of a milking unit and then calculation of the value of the volumetric stream of the milk outflow from a teat of a cow udder is carried out Q_V in a programmable logic controller PLC. It constitutes an input size for the control system.

Based on the signal, *Fuzzy Logic Controller* computes the set value of suction pressure for the milking machine p_{sz} (Tomasik et al., 2011). This value is comparable to the signal from the pressure sensor p_s, a computed error of control gets to the PID controller, which through control of a proportional valve (Fig.3) brings the value of pressure p_s closer to the set value p_{sz}.

The main element of the control and stabilization of air pressure is a container which suppresses fluctuations of absolute pressure (Fig. 3). It is equipped with connection pipes for connection of conduits which deliver: absolute pressure from a vacuum pump and atmospheric pressure through a proportional valve.

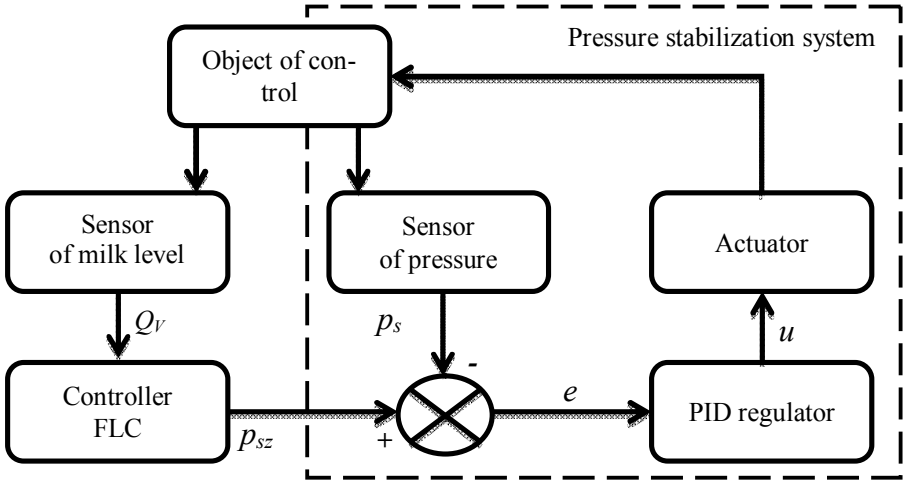

Figure 2. Schematic representation of the autonomous control system

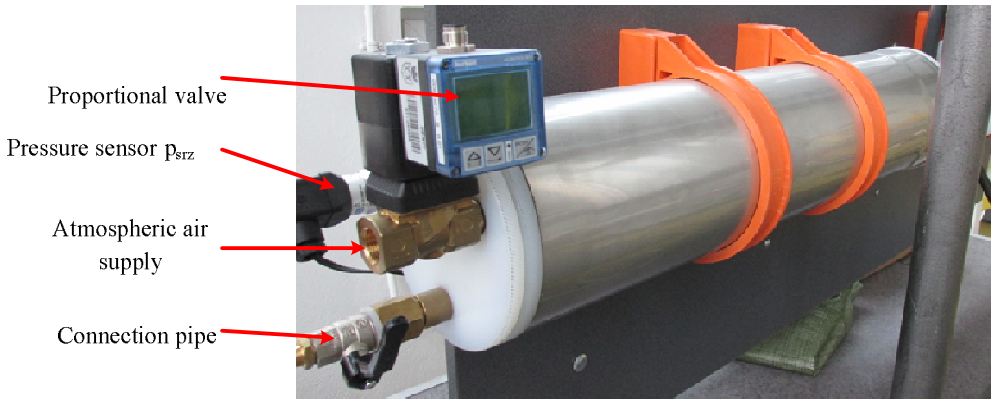

Figure 3. Container of suction pressure which supplies milking machine

Realization of the controlling algorithm with the size of suction pressure is programmed in the function of volumetric intensity of milk outflow from a teat of a cow udder. This size is computed by a functional block in the PLC controller. The input information for this block is the level l (mm) of milk in a chamber, measured by a sensor for each chamber independently. A cross-section of a chamber is fixed for the entire measurement scope (1):

$$Q_V = \frac{dV}{dt} \; (m^3 \cdot s^{-1}) \tag{1}$$

where:

Q_V – volumetric flow intensity, ($m^3 \cdot s^{-1}$)

V – present capacity (m^3) computed as a product of cross section area of a chamber s and levels of milk l

t – time, (s)

Moreover, in the PLC controller a functional block of fuzzy logic controller FLC and a functional block of the PID controller were programmed. Furthermore, a presented system of pressure stabilization was reflected in the form of visualization on the PLC controller, which enabled observation of its operation and registration of data for analysis (fig. 4).

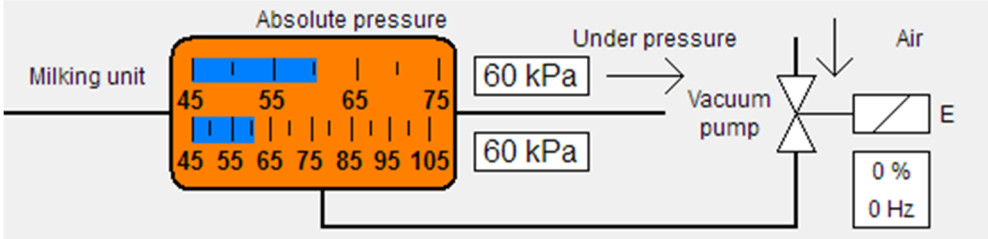

Figure 4. Visualization of operation of pressure system from the control programme

Analysis of operation of the pressure stabilization system in the conceptual milking machine

Graphs, which picture operation of the control and stabilization system of absolute pressure supplied to a cluster, were presented in Figures 5-8. The value of pressure was registered with the measurement card Advantech PCI-1711 with resolution of a converter of 12 bits. For measurement of suction pressure in the teat chamber the sensor of absolute pressure with precision of 0.25% was used. The system was tested in laboratory conditions. Distilled water was used instead of milk. The results of measurement of pressure, registered by a measurement card, were transferred to DAsyLab software, where they were registered. This program enabled scaling pressure sensors only in bar units, suction pressure is scaled as under pressure. In a milk pipeline, there was a transport pressure of 0.55 bar size (under pressure 55 kPa).

Figure 5 presents a dynamic characteristic of suction pressure changes before starting the liquid flow through a milking cup and a cluster column. It is a pressure, which directly affects teats of a cow udder during milking at the use of an autonomous milking unit. A recommended value of this absolute pressure should be within 0.35 bar to 0.47 bar. Analysing the amplitude of changes, one may notice, that the system is in a determined state.

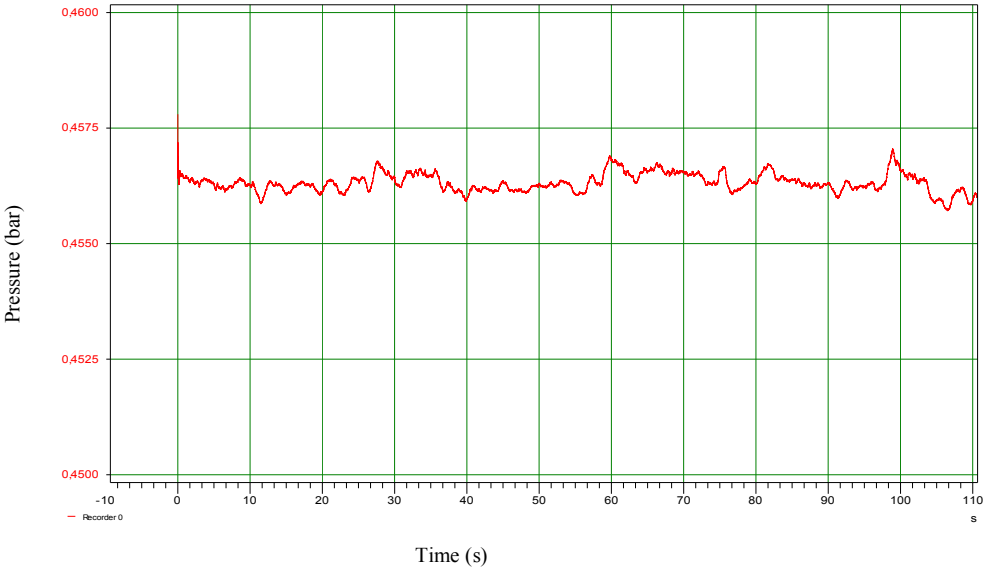

Figure 5. Changes of under pressure in teat chamber of milking cup before the liquid flow is initiated

The next stage in the research was introducing milk replacing liquid to circulation. Three basic values of liquid flow were assumed: 0.236 $dm^3 \cdot min^{-1}$, 0.850 $dm^3 \cdot min^{-1}$ and 1.625 $dm^3 \cdot min^{-1}$. The last value corresponds to the maximum flow, possible only for high productive diary cows. The values were selected, taking into consideration suggestion presented in scientific works (Ipema and Hogewerf, 2008). It should be noticed that they refer to one quarter of an udder, since one column of a milking unit includes only one quarter. Total volumetric intensity of outflow for a cow may be within 4 to 9 $dm^3 \cdot min^{-1}$.

Figure 6 reflects a characteristic of suction pressure for flow of 0.236 $dm^3 \cdot min^{-1}$. Impulse changes of pressure during switching between chambers can be reported. A clamp valve closes inflow of milk replacing liquid to one chamber, the other one opens inflow of liquid to the second chamber. The first chamber is emptied in this time with a higher suction pressure in order to speed up this process. As a result of filling in chambers, suction pressure decreased from 0.45 bar to 0.42 bar.

Characteristic of suction pressure for the liquid flow of the value of 0.850 $dm^3 \cdot min^{-1}$ is presented in figure 7. Varied pressures for each chamber were reported, values differed at the average by 0.02 bar. Cluster chambers were supplied as in all measurements with pressure of 0.45 bar.

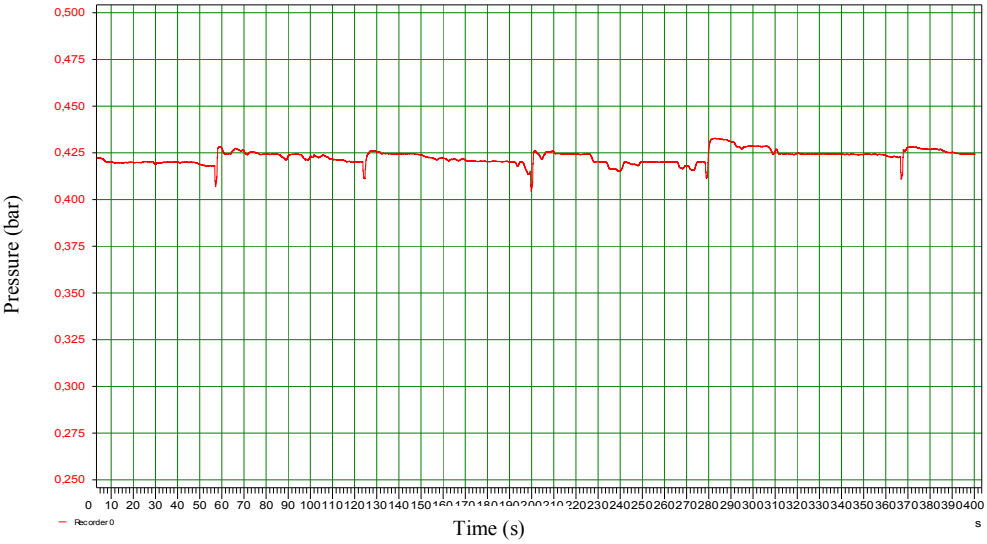

Figure 6. Changes of pressure in teat chamber of milking cup at the liquid flow of 0.236 $dm^3 \cdot min^{-1}$

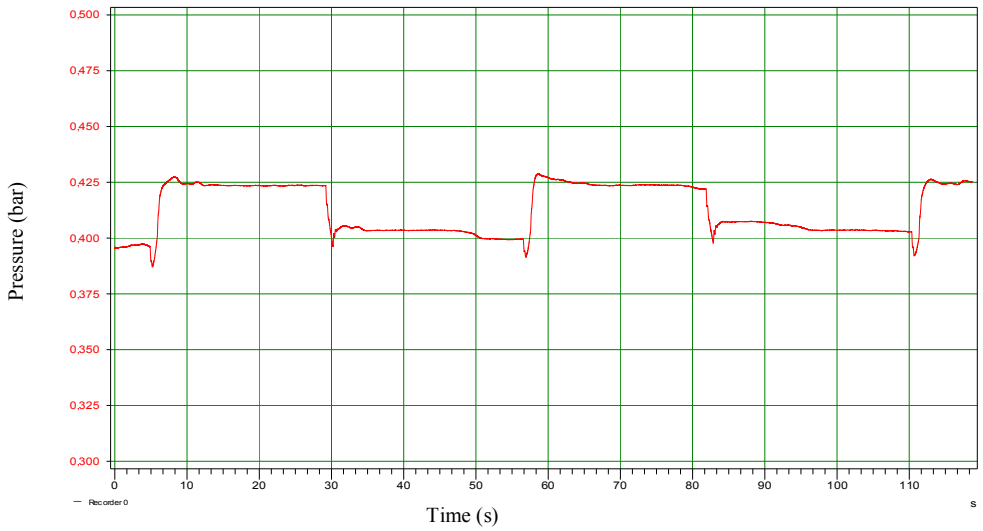

Figure 7. Changes of pressure in teat chamber of milking cup at the liquid flow of 0.850 $dm^3 \cdot min^{-1}$

In the last series of tests presented in figure 8, measurement of suction pressure was carried out for the flow of 1.625 $dm^3 \cdot min^{-1}$. As it was mentioned before it is a border flow reported in case of highly productive dairy cows. As in the above presented measurement a difference in pressures for particular chambers was reported, it was at the average of 0.03 bar. At such a high intensity of liquid flow a further decrease of suction pressure was reported to 0.37 bar.

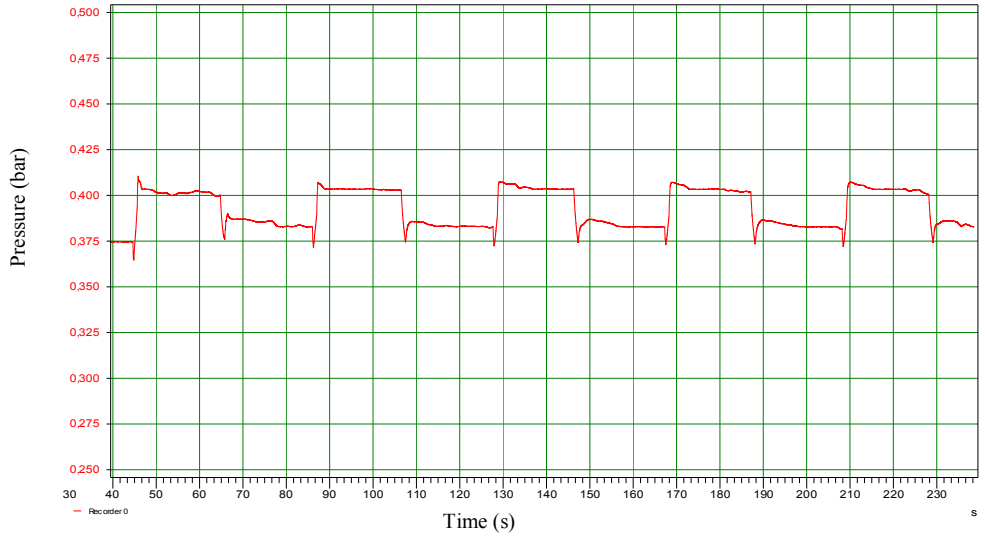

Figure 8. Changes of pressure in teat chamber of milking cup at the liquid flow of 1.625 $dm^3 \cdot min^{-1}$

Conclusions

1. The application, programmed with fuzzy logic methods, which carries out the function of the suction pressure programmer allows correlation of the milk flow intensity from a cow teat with the suction pressure, which is in a teat chamber of a milking cup. Such a controlling module does not influence the extension of the programming cycle of PLC controller XC-101.
2. Registered drops of suction pressure are so low that they will not negatively influence the cow udders.
3. The increased pressure used for transport of milk replacing liquid did not affect the suction pressure fluctuations at a lower flow intensity. Since, the chamber was emptied faster than the other was filled in, the suction pressure was stabilizing around the set value.

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STABILIZACJA CIŚNIENIA SSĄCEGO W KONCEPCYJNYM APARACIE UDOJOWYM

Streszczenie. Celem pracy była weryfikacja konstrukcji układu regulacji i stabilizacji ciśnienia bezwzględnego, zasilającego autonomiczny aparat udojowy. Opisywany aparat udojowy stanowi nowatorskie rozwiązanie techniczne, umożliwiające odseparowanie ciśnienia ssącego od transportowego, ponadto umożliwia pomiar objętościowego natężenia wypływu mleka z ćwiartki wymienia krowy. Zakres pracy obejmował: budowę pneumatycznego układu zasilającego aparat udojowy, opracowanie koncepcji systemu sterowania, zaprogramowanie sterownika PLC dla przyjętego algorytmu sterowania (bazującego na wcześniejszych badaniach naukowych autorów) oraz weryfikację pracy systemu na stanowisku laboratoryjnym. Głównym elementem układu regulacji jest sterownik mikroprocesorowy, w którym zaimplementowano algorytm regulacji ciśnienia ssącego, korzystając z logiki rozmytej; w nim realizowane są wszystkie obliczenia wykorzystane na użytek sterowania tą wielkością. Wyniki przeprowadzonych badań doświadczalnych pozwoliły na pozytywną ocenę opisywanego rozwiązania technicznego. Konstrukcja wymaga weryfikacji w warunkach doju, jednak prace badawcze uwidoczniły pozytywne efekty w zakresie stabilizacji ciśnienia dostarczanego pod strzyk.

Słowa kluczowe: aparat udojowy, ciśnienie ssące, regulacja automatyczna