EVALUATION OF A DATA AQUISION SYSTEM FOR MEASURING THE MILKING MACHINE PROCESS PARAMETERS

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Abstract

The purpose of the paper is the development and evaluation of a computer driven system for the assessment of the mechanical milking machines. The system consists of two parts: an electromagnetic pulsator, controlled by a computer driven impulses generator and a pressure recording system, equipped with an artificial teat with force sensor and absolute pressure sensors. Tests were performed using two types of teat-cups (the WestfaliaSurge Classic Proliner and the WestfaliaSurge Classic liner), in different operating conditions (50, 55 and 60 cycles/min pulsation rates and 60/40 and 50/50 pulsation ratios), at a vacuum level of 47 kPa (54.3 kPa absolute pressure). The recorded data was used to evaluate the durations of the pulsation phases, the teat-liner contact pressure and the pressure difference at which the liners starts to close. The experimental results confirmed the functionality of the system. As far as the pulsation ratio was concerned, the relative differences between the values prescribed by the computer software and the recorded ones were lower than 3% for 10 of the 12 variants. The results concerning the other pulsation characteristics were in accordance with the results reported by other authors; the ClassicPro liner recorded the lowest contact pressures and the highest critical collapsing pressure differences.

Key words: mechanical milking, teat-cup, pressure sensor, force sensor, liner

INTRODUCTION

The principle of mechanic milking relies on the pressure difference between the udder and the vacuum applied to the teat. In order to limit the development of congestion and edema and provide relief to the teat from the milking vacuum, the pulsation principle is used. The ISO 5707: 2007 standard defines the pulsation phases based on the evolution of the pressure in the pulsation chamber of the teat-cup: a is the increasing vacuum phase, b is the maximum vacuum phase, c is the decreasing vacuum phase and d is the minimum vacuum phase. The pulsation ratio is defined as the ratio between the duration of the a + b phases and the duration of the entire cycle.

All the researchers agree that the pulsation characteristics affect the milk yield and the health of the animals. According to Bade et al. [2], the pulsation rate and ratio, the vacuum level and the compressive load applied to the teat when the liner collapses are the factors affecting the peak milk flow rate; Adley and Butler [1] stated that inadequate liner collapse could lead to high infection levels, while Mein and Reinemann [5] showed that liner compression during d phase affected the milk flow rate and that increased liner compression led to the development of teat-end hyperkeratosis.

Several methods for measuring the liner compression pressure are described in the scientific literature. Reinemann et al. [7] used an extruded clay ribbon, a flat tube and an excised teat and also an artificial teat equipped with a pressure sensor in order to measure the compressive load applied by the collapsed liner. Davis et al. [3] used an excised teat tip and a load cell in order to measure the compressive load over a sensor with different coverings. It is obvious that it is difficult to apply these methods outside an adequate research laboratory; moreover, in the everyday life the use of an excised teat cannot be regarded as a common practice. Adley and Butler [1] also developed and

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artificial teat, equipped with a load cell, loaded by a free piston; the teat was covered with a thin latex tube.

Although some authors [7] concluded that the use of a flexible pressure-sensitive layer is not an accurate measuring method, others, like Van der Toll et al. [10], used it in order to measure the pressure at the teat-liner interface and concluded that the horizontal shear forces did not degrade the sensor's pressure readings.

The aim of the study is to present and evaluate a relatively cheap computer driven test system, which can be used outside a specialized test laboratory in order to measure the working parameters of the mechanical milking system (pulsation rate and ratio, duration of the pulsation phases, contact pressure between the liner and an artificial teat). The system may also be used in real life conditions in order to study the effect of the pulsation characteristics (rate and ratio) over the cows' health and milk yield.

MATERIAL AND METHODS

The developed system consists of two parts:

- a computer controlled impulses generator, completed with an electromagnetic pulsator, which can be used to test the teat-cup liner in different working conditions (pulsation rates and ratios);
- a pressure recording system, used for monitoring the claw vacuum, the short pulse tube vacuum and the liner-teat contact pressure. An artificial teat, according to the specifications of the ASAE EP445.1 standard [11], equipped with a force transducer, was used for recording the contact pressure between the collapsed teat-cup liner and the artificial teat.

The computer controlled impulses generator is driving the electromagnetic pulsator by the means of the computer software and electronic hardware.

The electronic hardware consists of a control board with 14 ports, produced by PC Control Ltd[2] connected to the USB port of the computer; fig. 1 presents the diagram of the pulsator command circuit.

[2] http://www.pc-control.co.uk/minibee_info.htm

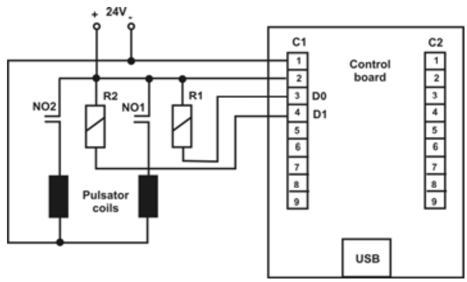

Fig.1 Schematics of the pulsator command circuit

The computer software was written in Visual Basic 6 and allows the adjustment of the pulsation rate and ratio; the graphical user interface (GUI) of the program (fig. 2) is used to set the cycle rate f [cycles/min] and the pulsation ratio, P [%]. The milk extraction time t_1 [s] and the duration of the rest phase t_2 [s] are computed using the following relations:

$$T = \frac{60}{f} \quad [s], \qquad (1)$$

$$t_1 = \frac{T \cdot P}{100} \quad [s], \qquad (2)$$

$$t_2 = T - t_1 \quad [s], \qquad (3)$$

where T is the cycle period, in seconds.

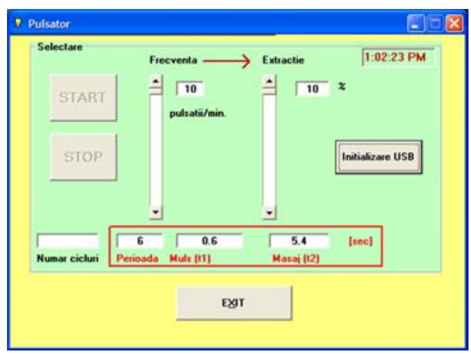

Fig. 2 The graphical user interface of the pulsator command program

The pulsation ratio may be adjusted between 10 and 90% and the pulsation rate may be adjusted in the range 10 – 120 cycles/min.

The computer controlled pressure recording system consists of:

- absolute pressure transducers type SPD015AAsil (SMARTEC), with analogical output and the absolute pressure range between

15 and 102 kPa, which are used for sensing the claw vacuum and the intermittent vacuum into the short pulse tube of the teat-cup. The sensors have a response time of 1 ms.

- data acquisition board type USB6009 (National Instruments), with a sample rate of 48 samples/s and 4 differential analogue input channels.

- an artificial teat, manufactured according to the specifications of the ASAE EP445.1 standard (fig. 3), equipped with an A201 FlexiForce (Tekscan) type force transducer, with a diameter of the sensing area of 9.53 mm.

- a virtual instrument, designed with the LabView 7.1 software package, allowing both the visualization and the recording of the pressure signals.

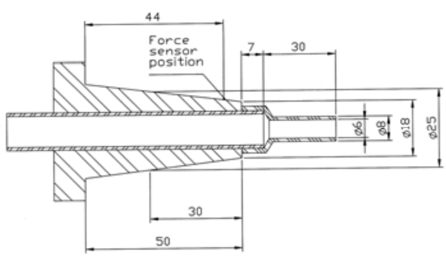

Fig. 3 The artificial teat

Because force sensing is based on the modification of the electrical resistance of the transducer, a signal conditioning circuit is used in order to convert the variation of the electrical resistance into a voltage signal. Both the pressure and the force sensors were calibrated before the beginning of the tests, in order to establish the pressure-output voltage relationship.

In order to evaluate the system two types of teat-cups were tested:

1. WestfaliaSurge Classic Pro silicone liner, part. no 7029-2725-010, for cow teats with the diameter between 21 and 28 mm, a mouthpiece diameter of 23 mm and the wall thickness of 2.5 mm; when mounted into the shell, the teat-cup liner is elongated by 6.8%.

2. WestfaliaSurge Classic Pro liner, part no. 7021-2725-350 for cow teats with the diameter between 20 and 27 mm, a mouthpiece diameter of 23 mm and the wall thickness of 2 mm; when mounted into the shell, the teat-cup liner is elongated by 5.4%.

A high milk line type milking machine was used, operated at a vacuum level of 47 kPa (54.32 kPa absolute pressures).

The artificial teat was mounted into the teat-cup taking into account the shape of the collapsed liner, so that maximum contact pressure was applied over the area where the force sensor was placed.

Two pulsation ratios (60% and 50%) and three pulsation rates (50, 55 and 60 cycles/min) were used during the tests.

For each test the following parameters were evaluated:

- the pulsation ratio and rate;
- the duration of the cycle phases;
- the maximum contact pressure between the liner and the artificial teat;
- the critical collapsing pressure difference.

The phases of the pulsation cycle were defined according to the requirements of the ISO 5707: 2007 standard, using the pressure signal from the short pulse tube.

The maximum contact pressure between the teat-cup liner and the artificial teat was measured during the d phase of the pulsation cycle.

The critical collapsing pressure difference Δp was defined as the point at which the liner begins to buckle because of the pressure difference across the walls, applying pressure over the teat (during the c phase of the pulsation cycle) and was evaluated with reference to the absolute pressure inside the teat-cup, as shown in fig. 4.

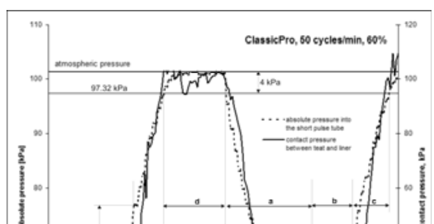

Fig. 4 Intermittent vacuum and contact pressure chart

For each working condition (pulsation rate, pulsation ratio and type of teat-cup) at least three tests were performed and then the average values were calculated.

RESULTS AND DISCUSSIONS

The results concerning the ***pulsation rate and ratio*** are presented in Table 1; the values were obtained using the averaged values for the duration of the pulsation phases.

According to the recorded data, differences were recorded between the theoretical (set) pulsation rates and the achieved (real) ones (which are lower), but, for most of the regimes (nine of the twelve tested), the relative differences did not exceed 5%. As far as the pulsation ratio was concerned, the relative differences between the values prescribed by the computer software (pulsator ratios) and the recorded ones (pulsation ratios) were lower than 3% for ten of the twelve variants.

The results referring to ***the duration of the cycle phases*** are summarized in Table 2. As expected, higher pulsation ratios led to longer and b phases and shorter d phases; increasing the pulsation rate led to shorter a, b and d phases. From this point of view, there were no significant differences between the two types of teat-cup liners. The duration of the c phase was practically unaffected by the pulsation rate and ratio or by the type of teat-cup liner; the average duration of the c phase was 0.2014±0.0024 s. This result is in accordance with the results obtained by Bade et al. [2].

Table 1 Results concerning the pulsation ratio and rate (average values)

Set pulsation ratio [%]	60			50		
Set pulsation rate [cycles/min]	50	55	60	50	55	60
WestfaliaSurge Classic Pro silicone liner						
Measured ratio [%]	58.17	57.8	60.9	50.4	49.1	49.4
Measured rate [cycles/min]	46.7	52.8	57.7	48.3	51.0	57.3
WestfaliaSurge Classic rubber liner						
Measured ratio [%]	60.0	57.5	59.0	50.6	50.3	49.2
Measured rate [cycles/min]	48.1	51.8	57.2	48.9	52.3	55.7

Table 2 Results concerning the duration of the pulsation phases

Pulsation ratio [%]	60			50		
Pulsation rate [cycles/min]	50	55	60	50	55	60
WestfaliaSurge Classic Pro silicone liner						
Phase a [s]	0.500	0.470	0.437	0.433	0.39	0.360
Phase b [s]	0.247	0.207	0.197	0.193	0.190	0.157
Phase c [s]	0.217	0.207	0.190	0.200	0.197	0.193
Phase d [s]	0.320	0.273	0.217	0.417	0.403	0.337
WestfaliaSurge Classic rubber liner						
Phase a [s]	0.493	0.46	0.443	0.427	0.397	0.357
Phase b [s]	0.256	0.206	0.177	0.193	0.180	0.173
Phase c [s]	0.206	0.210	0.207	0.193	0.200	0.197
Phase d [s]	0.293	0.283	0.223	0.413	0.370	0.350

The results concerning ***the maximum liner-teat contact pressure*** are displayed in fig. 5. The Classic Pro teat-cup liner achieved lower contact pressures compared to the Classic liner. According to van der Toll [10], the lower liner tension of the Classic Pro liner (5.4 % stretch, compared to the 6.8 % stretch of the Classic liner) was the cause of the lower maximum contact pressure; Davis [3] also noticed that the compressive load over the teat increased with liner tension. The thicker wall of the silicone liner was another factor leading to the reduction of the compressive load over the teat [6].

For the both types of teat-cup liners, higher contact pressures were recorded for the 60% pulsation ratio than for the 50% pulsation ratio. In the case of the Classic Pro silicone liner, the pulsation rate had little effect over the maximum contact pressure; for the Classic rubber liner, lower contact pressures were recorded at higher pulsation rates.

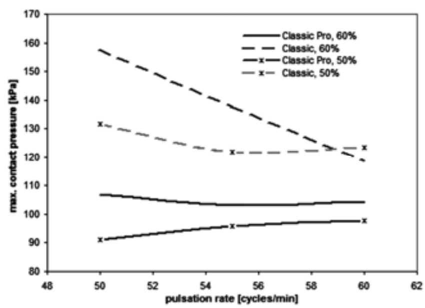

Fig. 5 The maximum teat-liner contact pressure

The results presented in fig. 6, referring to the pressure difference across the walls at which the liner begins to buckle, showed that a higher pressure difference was needed in order to close the Classic Pro liner. This was a rather unexpected result because the lower mounting tension of this liner (5.4 % elongation, compared to 6.8 % for the Classic liner) would normally result in lower pressure differences [4]; the different elastic properties and the thicker wall of the silicone liner were the probable cause of this behaviour.

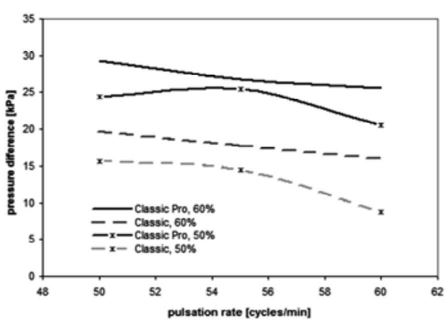

Fig. 6 The critical collapsing pressure difference

The higher critical collapsing pressure difference (of the Classic Pro liner) implies a higher touch point TP - the pressure difference required to collapse the liner to the point where the opposing walls touch each other [5] - and a higher touch point leads to a lower compressive load over the teat [9], which is in agreement with the results regarding the maximum teat-liner contact pressure (fig. 5). The recorded values of the critical collapsing pressure difference were within the range of values reported by other authors - 11.9 kPa pressure difference according to Spencer and Jones [8].

CONCLUSIONS

A computer controlled system for the evaluation of the mechanical milking machines; the system contains a computer driven pulses generator and a computer controlled pressure recording system. The system is a relatively low cost one and can be used for real life testing of milking machines.

Two types of teat-cups were tested in order to evaluate the performances of the system, at different pulsation rates and ratios. The experimental results showed that for a prescribed pulsation ratio, the achieved pulsation ratio could be considered constant, as only minor variations were recorded. The recorded pulsation rate was also constant, although the achieved values were lower than the set ones. These results confirm the functionality of the computer driven pulses generator.

The results concerning the maximum liner-teat contact pressure showed that lower contact pressures were achieved by the silicone liner compared to the rubber one; the results concerning the critical collapsing pressure difference were consistent with the findings of other researchers, thus confirming the functionality of the pressure recording system.

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