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Comparative study of a milking unit pulsation system in laboratory and field conditions

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Abstract. *A comparative study of the pulsation phases in classic milking units was performed. The testing of the same is done in laboratory and field conditions (during milking). The pulsation settings at which the test was performed were pulsation rate 60 min*$^{-1}$ *and 90 min*$^{-1}$*, ratio 50/50% and vacuum mode 50 kPa. The experiments were performed in the laboratory of "Machine milking" (Department of Agricultural Engineering, Faculty of Agriculture, Trakia University) on a milking installation with a pipe line and on a farm for 60 lactating cows at the same milking installation. It was found that the transients (phases "a" and "c") are significantly reduced during milking. Respectively, the actual phases (phases "b" and "d") are significantly increased during the milking process. The conclusions are related to the settings and timely diagnostics of the milking machine.*

Keywords: milking unit, pulsation phases, pulsation rate, pulsation system

Introduction

The milking unit is a functional part of the milking machine. The element of the milking machine that comes into direct contact with the teats is the milking liner (Peychev, 2001). The efficient operation and productivity of the milking machine, as well as the health of the animals (O'Callaghan, 1996) depend on its technical and operational indicators.

Researchers in the field of machine milking are unanimous about how important the adequate parameters of the pulsation system are for the animal health and the speed of its milking (O'Callaghan, 1996; Banev, 2001; Peychev, 2001; Peychev et al., 2004). For this reason, the international standard ISO 5707 (2007) defines and specifies the individual phases of the pulsation as well as the requirements of the standard to the allowable duration of each phase.

The increased frequency regime of the pulsation system of the milking machine is associated with reducing the duration of the phases of actual milking "b" and massage "d". The formal expectation is to shorten the absolute milking time and reduce the throughput of the milking unit (Peychev, 2001). Osteras et al. (1995) categorically prove that the best from the point of view of udder health is the phase of actual massage "d" to be at least 330 ms. The duration of the same below 250 ms significantly increases the total number of somatic cells. Practical experience and research show that precise structuring of the pulsation parameters is necessary in order to maintain good udder health and reduce the speed of machine milking (Ipema et al., 2005).

To this day, there is no consensus on the ideal pressure change curve, especially with regard to the transition from milking to massage and vice versa. It is really pointed out that the "milking" and "massage" strokes in the milking cups should be as completely separate as possible in order to achieve a safe and intense massaging effect. But while some authors attach particular importance to the strict separation of strokes, others, on the contrary, emphasize the good effect of the soft transition from the stroke „milking" to the "massage" (Worstorff and Bilgery, 2002; Bechev and Banev, 2008). In this way, the blood plasma invaded by the suction stroke in the teats is pushed out slowly and carefully.

In the scientific literature there are no methodological instructions for specific conditions and way to perform the settings of the pulsation systems. In this sense, the question arises if the adjustment of the pulsation system is performed in a laboratory (purely technical), whether the parameters will remain unchanged in milking mode.

The aim of the present study is to compare the pulsograms of a milking machine obtained in laboratory conditions and in a real experiment (during milking).

Material and methods

The object of the study were milking units complete with milking liners made of nitrile rubber with a round cross-section. The subject of the study was the time components of their pulsograms obtained in laboratory and field conditions (during milking).

The experiment involves recording the standard pulsation phases "a", "b", "c" and "d" (in absolute units), in the rate range 1-1.5 Hz, at a vacuum mode of 50 kPa and a pulsation ratio of 50/50%. For the experiments, a standard Vadia pulsation analyzer from the company BioControl was used which has the possibility for its own calibration and corresponds to the International standard for diagnostics of milking machines according to ISO 5707 (2007).

The experiments were performed in the laboratory of "Machine milking" at the Department of Agricultural Engineering,

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Faculty of Agriculture, Trakia University on a milking installation with a pipe line and on a farm for breeding 60 Holstein lactating cows at the same milking installation.

The processing and interpretation of the experimental data conforms to the overall graphic profile of a pulsogram by the ISO 5707 (2007) standard shown on Figure 1.

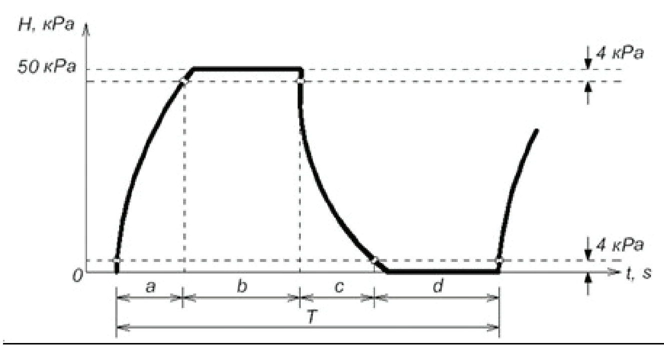

Figure 1. Overall graphic profile of a pulsogram by the ISO 5707 (2007) standard
Legend: a- the duration of the transitional process from atmospheric pressure to nominal vacuum in the volume of the milking cup pulsation chamber (front of the pulsogram); b- duration of the "true milking" phase (vacuum mode within the pulsation chamber volume); c- duration of the transitional process from nominal vacuum to atmospheric pressure in the volume of the pulsation chamber (back of the pulsogram); d- duration of the "true massage" phase (atmospheric pressure within the volume of the pulsation chamber).

The period of the pulse (T) is determined by the following expression:

$T = t_1 + t_2$, ms, (1)

Where: t_1 - duration of stroke "milking", ms;
t_2 - duration of stroke "massage", ms.

The duration of stroke "milking" (t_1) is described by the amount of:

$t_1 = a + b$, ms (2)

Within the time, the pressure in the pulsation and the milking chamber aligns and the milking liner is in equilibrium - "milking" stroke is performed.

Time massaging effect (t_2) on the teat tissue is defined by the amount:

$t_2 = c + d$, ms (3)

In the period t_2 pressure in the pulsation and milking chamber is different (ΔH=50 kPa), as a result of which the milking liner collapses and performs the stroke "massage".

The repeatability of the experiments for each pulsation characteristic is tenfold and all data obtained are averaged.

Results and discussion

The experimental results for the absolute duration of the pulsation phases measured in laboratory and field conditions are illustrated in Figures 2 and 3. Increasing the pulsation rate from 60 min^{-1} to 90 min^{-1} leads to some shortening of phase "a" (Figure 2). The specific reduction is about 18% for laboratory measurements and about 10% during milking. On the other hand, the measurement conditions have a significant impact on the duration of the transition process "a". In the measurements during milking the reduction of phase "a" is within the range of 31-37% compared to the laboratory experiment. The findings of Worstorff and Bilgery (2002) are in the same direction. The authors found that the shortening of phase "a" is significantly influenced by the measurement conditions.

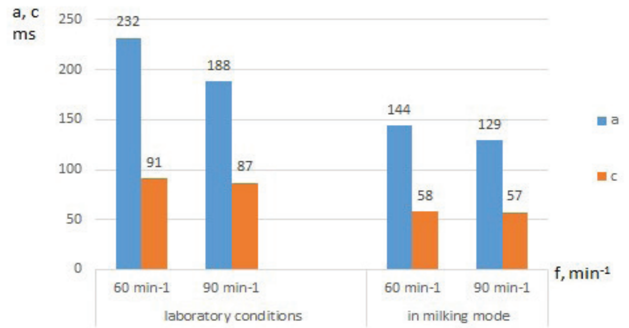

Figure 2. Experimental data on the absolute duration of the transients (phases „a" and „c") measured in laboratory conditions and in milking mode

The analysis of the values obtained so far emphasizes that the increased pulsation rate and measurement conditions reflect a shortening of the transition phase "a". From a practical point of view, the consequence of this reduction may have a negative impact on the so-called "creeping" of the milking cups and difficulty in extracting the milk after the third minute from the beginning of milking. Spencer and Rogers (1991) arrived at similar findings.

The effect of the pulsation rate and measurement conditions are similar in the transient "c" phase. The duration of the same is reduced with increasing the pulsation rate within the experimental modes. The duration of phase "c" decreases by 4% in measurements in laboratory conditions while in the experiment in field conditions its duration is a constant value. The measurement conditions have a stronger influence on the shortening of the transition phase "c". The duration of the same decreases by 34-36% during milking compared to laboratory measurements. The probable reason is that in the experiment during milking the milk chamber of the milking unit was filled with a teat. Its "free" volume is drastically reduced. This fact changes the time constant of the pulsation system (Banev, 2001).

Uncontrolled reduction of the time component "c" (phase of devacuation of the pulsation chamber) sharply increases the differential pressure between the milking and pulsation chambers of the respective milking cup (Banev, 2001). The walls of the milking liner contract impulse with their maximum deformation immediately around and below the tip of the teat. This could provoke parakeratotic changes at the tip of the teat. This hypothesis is supported by Kochman et al. (2008). They prove that the unjustified shortening of phase "c" leads to an increase in pressure on the teat and is accompanied by discomfort for the animals during machine milking. The same authors warn that the uncontrolled increase of phase "c" over 120 ms has a negative impact as it violates the ratio between the times "c" and "d" (within one cycle) and prolongs the total time of machine milking.

The change in pulsation rate within the experimental levels has a very strong effect on the duration of the actual milking phase "b" within one period (Figure 3). The duration of phase "b" is reduced by an average of 45% with increasing frequency mode. Increasing the pulsation rate shortens the absolute time for sucking milk (within one pulse) and this will inevitably reflect on the prolongation of the time for machine milking and calls into question the complete milking of the animals. On the other hand, the time component "b" increases by an average of 27% during milking compared to laboratory measurements. An unjustified increase in the duration of the actual milking phase above certain values carries certain risks from the point of view of udder health. Reinemann (2019) arrives at the same conclusions. The author proves that it is necessary to look for a balance between the duration of phase "b" and the level of the vacuum regime in order to reduce the occurrence of the teats edema.

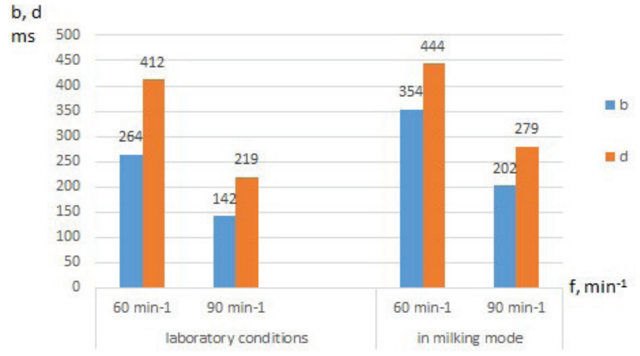

Figure 3. Experimental data on the absolute duration of the actual milking phases (phases „b" and „d") measured in laboratory conditions and during milking

The trend in terms of the influence of the pulsation rate is absolutely similar in the phase of actual massage (phase "d"). The increase in the pulsation regime reduces the absolute time for massaging the milking papilla by an average of 38%. This could create a risk of haemo- and lymphostasis causing painful edema of the teats. This hypothesis is in line with the research results of Upton et al. (2016).

A comparison of the experimental data obtained during milking shows that phase "d" is prolonged by an average of 15% compared to laboratory measurements. The increase in the duration of the massage phase has a positive effect on the restoration of blood circulation in the mammary glands.

The results of the experiments emphasize the need for a single methodological standard for selecting a specific pulsation rate and method of recording pulsograms. Currently, such an instruction is missing in both the theory and practice of machine milking. In a similar direction are the conclusions made by Reinemann (2019). The author recommends establishing a balance between the factors of the duration of the actual phase "b" and the vacuum mode of the milking machine. However, the question arises: "can this balance be suitable for all dairy breeds, for all herds and under what conditions to adjust the pulsation system of a milking unit?".

Conclusion

Increasing the pulsation rate leads to some shortening in the absolute duration of the pulsation phases. The measurement conditions have a significant influence on the time components of the pulsogram. The duration of the transients (phase "a" and phase "c") is reduced by an average of 35% during milking compared to laboratory measurements. The duration of the established phases "b" and "d" increases by 27% and 15%, respectively, in milking mode compared to the laboratory measurements. It is necessary to prepare a uniform standard for selection of pulsation parameters and ways of measuring pulsograms of a milking unit.

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