Vacuum fluctuation in short milk tube during peak milk flow

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Summary

This paper reports results of field tests on milking units of 16 milking machines installed in low-level milking systems of herring bone, auto-tandem and parallel parlours of which 3 were equipped simultaneous and 13 with alternate pulsation. Vacuum was measured with MILKOTEST 2004 (Gebrüder Bilgery, Switzerland) connected to the short milk tube at the time of peak milk flow. The results were processed by correlation analysis taking nominal vacuum, air vent admission, claw volume, and short milk tube bore as independent variables and maximum vacuum in the short milk tube and vacuum fluctuation range as dependent variables. The frequency of excessive vacuum (vacuum maximums exceeding nominal vacuum) and signs of teat injury (teat tip cyanosis, local ischaemia, teat canal eversion, and hyperkeratosis,) were assessed by nonparametric correlation. Significance of differences was tested for all variables in milking units with simultaneous and alternate pulsation. Significant difference ($P < 0.05$) was found only for the occurrence of excessive vacuum which was higher in units with simultaneous pulsation. Therefore, only variables found in systems with alternate pulsation were subjected to correlation analysis. Highly significant positive correlation was demonstrated between nominal vacuum and maximum short milk tube vacuum ($r = 0.983$; $P < 0.01$). Significant negative correlation was found between air vent admission and the range of vacuum fluctuation in the short milk tube ($r = -0.648$; $P < 0.05$). Significant positive correlation coefficient (0.500) of nonparametric analysis was obtained only for the frequency of excessive vacuum occurance and hyperkeratosis of teat orifice.

***Key words**: Milking machine, natural milking, vacuum fluctuation, short milk tube, teat injury, dairy cows.*

Introduction

Short milk tube vacuum, its mean value, and dynamics are factors decisive for rapid, considerate and complete milking. Many years ago, Thiel and Mein (1977) summarised their own results of experimental studies focused on functional mechanics of milking machines and formulated principles of vacuum dynamics during a pulsation cycle. Our first experimental approach to this problem dates back to 1973 (Ryšánek *et al*., 1973). Since that time, the construction of milking machines has underwent considerable changes the principles of which have been codified (ISO 1996). This process was imbued with an effort to explain effects of structural and functional characteristics of milking machines on the occurrence of teat injury due to milking (Hamann, 1994). Our earlier papers, too, dealt with the relationship between functional characteristics of milking machines and development of clinically apparent teat injuries (Ryšánek *et al*. 1968; Ryšánek, 1974; Ryšánek and Babák, 1996).

The objective of this study was to assess differences and relationships among selected structural and functional characteristics of clusters of contemporary milking machines, as well as the relationship between functional characteristics and frequency of teat injuries.

Materials and methods

Our measurement were carried out on 16 milking machines (3 with simultaneous and 13 with alternate pulsation) manufactured by Agrostroj Pelhrimov, Alfa Laval, Bou-Matic, Fullwood, Gascoigne-Mélotte, Melk Systeme, Miele, Manus, No-pulse, Strangko, and Westfalia and installed in herringbone, auto-tandem, or parallel parlours. The measurements were carried out in 1996 through 2000.

Structural characteristics, i.e. pulsation system, claw volume, and short milk tube bore were adopted from manufacturers' documentation and tested by own measurements. Functional characteristics, including air vent admission, maximum short milk tube vacuum, range of short milk tube vacuum fluctuations, nominal vacuum, and frequency of excessive vacuum were established by own measurements and are expressed as arithmetic means of measurements on six milking units of each machine. The term excessive vacuum is used to describe short milk tube vacuum exceeding the nominal value; its frequency was expressed in terms of percentage. Air vent admission was established by measurements on 10 milking units of each machine using the standard ISO 6690 procedure (1996).

Vacuum dynamics were measured using the MILKOTEST 2004 apparatus (Gebrüder Bilgery, Switzerland) connected to the short milk tube. The measurements were done at the peak milk flow. The obtained values were expressed as arithmetic means of measurements on 6 milking units of each machine.

Teat injuries were assessed visually in each parlour in 25 randomly selected cows immediately after cluster removal. Findings of the following signs of injury were recorded: teat tip cyanosis, local ischaemia (sponge cake-shaped ischaemic patches corresponding to the teat surface area exposed to permanent vacuum as a result of incomplete closure of liner walls during the rest phase), teat canal eversion, and teat orifice hyperkeratosis. The findings are expressed in percentages.

Statistical processing included determination of significance of differences in arithmetic means of structural and functional characteristics was done by the Students' t-test. Further, calculation of correlation coefficients incl. significance assessment, and Spearman's test of nonparametric correlation incl. calculation of Spearman's correlation coefficients and significance assessment were done. Data were processed using the software STAT Plus (Veterinary Research Institute, 1993).

Results

Characteristics of the individual milking machines are defined by arithmetic means ±S.D. given in table 1 which also shows the significance of differences between milking machines differing in pulsation systems. Since significant difference was demonstrated only for excessive vacuum, further analyses were done only on data obtained in milking machines with alternate pulsation.

Table 1. Significance of differences between characteristics of milking installations with alternate and simultaneous pulsation.

Characteristics	Simultaneous pulsation			Alternate pulsation			t_{calc} / t_{tab}	Signi-ficant
	n	Mean	±S.D.	n	Mean	±S.D.		
Nominal vacuum [kPa]	3	43.0	2.3	13	43.6	3.1	0.294 2.145	no
Air vent admission [l/min]	3	5.2	2.3	13	6.4	2.2	0.886 2.145	no
Claw volume [ml]	3	326.0	172.0	13	352.0	50.8	0.252 2.145	no
Short milk tube bore [mm]	3	9.3	1.1	13	9.9	1.5	0.850 2.145	no
Short milk tube vacuum maximum [kPa]	3	44.9	2.4	13	43.3	3.3	0.795 2.145	no
Short milk tube vacuum fluctuation-range[kPa]	3	11.9	4.5	13	6.2	1.4	2.158 4.254	no
Excessive vacuum occurrence [%]	3	89.2	18.6	13	29.6	35.1	2.800 2.160	P<0.05

Correlations among selected structural and functional characteristics are shown in table 2. Highly significant positive correlation ($P < 0.01$) was found between nominal vacuum and maximum short milk tube vacuum and significant negative correlation ($P < 0.05$) between air vent admission and range of fluctuation of short milk tube vacuum.

Table 2. Correlation among selected structural and functional characteristics of milking installations with alternate pulsation.

Design and functional characteristics Variables				
Independent	Dependent	r	t_{calc} t_{tab}	Significant
Nominal vacuum	Short milk tube vacuum maximum	0.983	12.781 3.106	P<0.01
	Short milk tube vacuum range	0.180	0.599 2.201	no
Air vent admission	Short milk tube vacuum maximum	0.291	0.969 2.201	no
	Short milk tube vacuum range	-0.648	2.370 2.201	P<0.05
Claw volume	Short milk tube vacuum maximum	0.162	0.537 2.201	no
	Short milk tube vacuum range	0.057	0188 2.201	no
Short milk tube bore	Short milk tube vacuum maximum	0.029	0.097 2.201	no
	Short milk tube vacuum range	-0.284	0.946 2.201	no

Table 3. Correlation between selected structural characteristics of milking installations with alternate pulsation and occurrence of excessive vacuum.

Design and functional characteristics Variables				
Independent	Dependent	Spearman´s correlation coefficient	S_{calc} S_{tab}	Significant
Nominal vacuum	Extensive vacuum occurrence	-0.065	387 188	no
Air vent admission	Extensive vacuum occurrence	-0.308	328 188	no
Claw volume	Extensive vacuum occurrence	0.218	398 188	no
Short milk tube bore	Extensive vacuum occurrence	0.030	342 188	no

Particular attention was paid to the frequency of excessive vacuum. As can be seen in table 3, no significant correlation was demonstrated between this parameter and any of the selected structural characteristics. Negative correlation approaching the significance level was observed only between air vent admission and the frequency of excessive vacuum.

Data on correlations between selected functional characteristics and occurrence of teat injuries, given in table 4, indicate that significant relationship described by a positive correlation coefficient can be expected only between the frequency of excessive vacuum and the occurrence of hyperkeratosis.

Discussion

Functional characteristics of the up-to-date milking machines were rather uniform. This finding reflects the unification of designs resulting from the codification of the individual construction elements. It is rather surprising that the difference between milking machines with simultaneous and

Table 4. Correlation among selected functional characteristic of milking installations with alternate pulsation and signs of teat injury.

Functional characteristics Independent variables	Signs of teat injury Dependent variables	Spearman´s correlation coeffitient	S_{calc} S_{tab}	Significant
Short milk tube vacuum maximum [kPa]	Cyanosis	-0.162	423.0 188.0	no
	Local ischaemia	-0144	416.0 188.0	no
	Teat canal eversion	-0.396	508.0 188.0	no
	Hyperkeratosis	0.015	358.0 188.0	no
Short milk tube vacuum range [kPa]	Cyanosis	-0.180	429.0 188.0	no
	Local ischaemia	-0.091	397.0 188.0	no
	Teat canal eversion	0.170	302.0 188.0	no
	Hyperkeratosis	0.368	230.0 188.0	no
Extensive vacuum [kPa]	Cyanosis	0.081	334.0 188.0	no
	Local ischaemia	0.210	287.0 188.0	no
	Teat canal eversion	0.221	283.0 188.0	no
	Hyperkeratosis	0.500	182.0 188.0	P<0,05

alternating pulsation were only inconsiderable. Significant difference was found only for the occurrence of excessive vacuum that was higher in machines with synchronous pulsation. The difference in vacuum fluctuation range approached statistic significance. Both the findings are consistent with the data published by Thiel and Mein (1977), although their measurements were done in machines that have already become obsolete.

The highly significant positive correlation between nominal vacuum and vacuum maximums in the short milk tube was not surprising. On the other hand, rather unexpected in the up-to-date machines was the significant negative correlation between the air vent admission and the range of vacuum fluctuation in the short milk tube. This finding was particularly surprising when the fact is considered that only milking machines with alternating pulsation were tested. We see the explanation in the low air vent admission. Minimum values of this parameter were lower than the codified limit of 4 l per min.

Particular attention was paid to the occurrence of excessive vacuum. Surprisingly, no significant correlation was found between selected structural and functional characteristics of milking machines and the occurrence of excessive vacuum. Only negative correlation between air vent admission and the occurrence of excessive vacuum approached the significance level. Of principal importance is the demonstration of excessive vacuum in up-to-date milking machines and the fact that the occurrence of excessive vacuum was the only functional characteristic showing significant positive correlation with the occurrence of teat orifice hyperkeratosis.

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