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Design of a vacuum control system with frequent teat-end vacuum adaption for milking machines

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Abstract

A problem of the currently available milking technology is that the teat-end milking vacuum always falls as the milk flow increases. A recently developed unit for the quarter individual control of the teat-end vacuum therefore constitutes the focus of this paper, which compares the vacuum behaviour at the teat end of the cow in the Multilactor® milking system with and without a control unit. As a result, the following differences with and without a control unit were observed: In low-flow milking stages, the milking vacuum is set to 8 kPa (release) and 17.5 kPa (suction) with a control unit in both pulse-cycle phases. By contrast, the milking vacuum reaches values of 29 kPa (release) and 33.5 kPa (suction) without a control unit. In high-flow milking phases, the milking vacuum remains relatively high at approximately 31 kPa, in both settings, with and without using the control unit. That allows a speedy and udder-tissue-friendly milking process.

Keywords: vacuum control valve, vacuum control unit, teat-end, milk flow

1 Introduction

The development and improvement of milking systems is an important technology division in the field of engineering for livestock management (Ströbel et al., 2013a). What does the vacuum application in milking systems is concerned, it can be stated that stable vacuum conditions in milking systems are seen as important precondition for a successful milking processes by several authors (Hoefelmayr and Maier, 1979; Nordegren, 1980; Schlaiß, 1994). Meanwhile, the vast majority of milking systems produce stable vacuum conditions at the teat-ends of cows, yet they are still commonly affecting the tissue observed, after milking the animals. The optimal fine adjustment of the milking vacuum at the teat end is still intensively debated (Ströbel et al., 2013a). Hamann (1987) and other authors state that the teat tissue at the teat end must be hold healthy and clean. An important finding of Reinemann et al. (2001) was that low milking-vacuum reduced pressure at the teat end, has a positive effect on the teat condition but prolongs the duration of milking, which tends to be an increasing stress factor for the tissue around the teat ends.

A careful treatment of the teats and optimization of vacuum application in modern milking systems is consistent to the literature situation and therefore necessary, even if the research focus of the milking technology in recent years has not more strongly focused on this topic (Ströbel et al., 2013a).

2 Materials and methods

In the experiments carried out, in each test the influence of valve adjustment and milk flow on the teat-end milking vacuum was measured. Technically, a vacuum control valve (VCV), as an actuator in one of the quarter-individual milk tubes within the milking system MultiLactor® was incorporated (Fig.1 (4)). The VCV can change of the cross-section opening area in the valve and was installed in one of the individual milk tubes next to the milk meter of the milking system (Ströbel et al., 2013a). The milking system was produced in 2009, the system vacuum worked with 35 kPa as machine vacuum and the pulsation was 65:35 and the inner diameter of the four individual quarter milk tubes was 10 mm.

There were wet-test measurements ISO-method (ISO 6690, 2007) carried out on the laboratory-milking parlour at the Leibniz Institute for Agricultural Engineering Potsdam Bornim. The wet tests were carried out with artificial teats, which were made according to ISO 6690 (DIN ISO 6690, 2007). Water was used to simulate the flow of milk in the udder and the set flow rates were 0.0 to 1.1 l/min/quarter, as up to this maximum flow rate, a vacuum reduction was considered as necessary (Ströbel et al., 2013a). To simulate the milk flow, four flow meters (Parker Hannifin Corporation, Cleveland, USA), which are installed on a base plate were used. For each flow, the flow rate is adjustable from 0.0 to 2.0 l/min/quarter. The measurement accuracy is ± 2%. In detail, experiments were conducted with the following listed flow rates: 0.0; 0.3; 0.4; 0.5; 0.6; 0.8; 0.9; 1.0 and 1.1 l/ min/quarter. During the wet tests, the milk flow was always set the same level for each udder quarter (Ströbel et al., 2013a).

The vacuum was measured with the vacuum gauge MilkoTest MT52 (System Happel GmbH, Friesenried, Germany). The measurement accuracy is ± 0.1 kPa. The requirements according to DIN ISO 6690 (2007) to be at least ± 0.6 kPa. The recording rate used for the experiment for measurements was 500 Hz. The vacuum at the top of the DIN-ISO teat (DIN ISO 6690, 2007) was measured in the pulsation chamber and in the main vacuum line and for seven pulse cycles per each single experiment. Thus, it was measured for 45 pulse cycles per single test. The sensors were connected directly, to the DIN ISO-teat (DIN ISO 6690, 2007) or they were connected to the main vacuum line, or via a T-piece with the pulse tube (Ströbel et al., 2013a).

Figure 1 shows schematically the test set-up and the installation point of the vacuum control valve (VCV). The milking system MultiLactor® was developed by Siliconform GmbH & Co.KG, Türkheim and is produced in Germany. The main technical innovations at the milking system MultiLactor® are: Quarter individual tube guidance, cluster - between cleaning and disinfection is cleaned through an automatic flushing unit, sequential pulsation and an automatically vacuum-stop function separately for each udder quarter, when one of the teat cups will fall to the ground. With a drop or reduction of one or more teat cups to the vacuum stop valves switches off automatically. To start the milking process a magazine automatically swings under the udder, which includes the milking cluster. The teat cups are then, manually removed and attached in pairs. The removal of the teat cups is automatic, but not quarter individually (Rose and Brunsch, 2007) now. The vacuum control valve (VCV), which has fundamental importance for the conducted experiments, is shown in Figure 1.

For the VCV several prototypes have been developed and produced to improve the development and function of the valve. Purpose of VCVs was over the entire development period, the possible fast and accurate setting to be able to provide different opening cross sections areas in the four milk tubes (Ströbel et al., 2013a). The twelve different adjustable opening areas in the VCV laid between 0.0 to 78.5 mm². A milk tube with an inner diameter of 10 mm has a cross-section opening area of 78.5 mm² (Ströbel et al., 2013a).

The calculation of the average vacuum for the individual milking phases was carried out according to the specifications of DIN ISO 6690 (2007). With this method of calculation, accurate correlations for teat-end milking vacuum were found depending on the flow of milk. For each combination of the measured milk flow, and the opening cross section at the VCV eight repetitions were performed. Then, the setting combinations were from the total pool of all possible variants selected. For the software development the fitting variants were chosen manually, which corresponded to the aim of producing a rise in the milking vacuum at an increasing milk flow (Ströbel et al., 2013a).

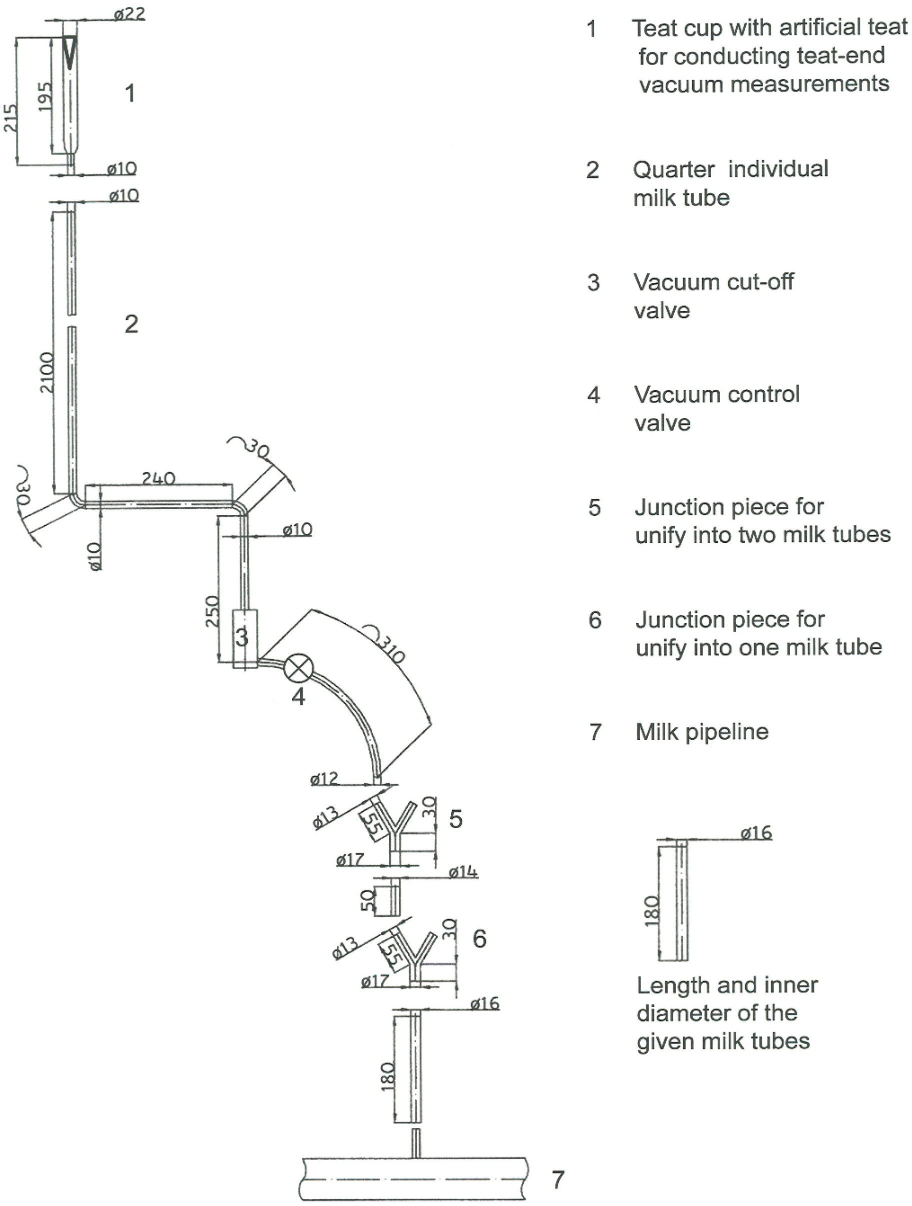


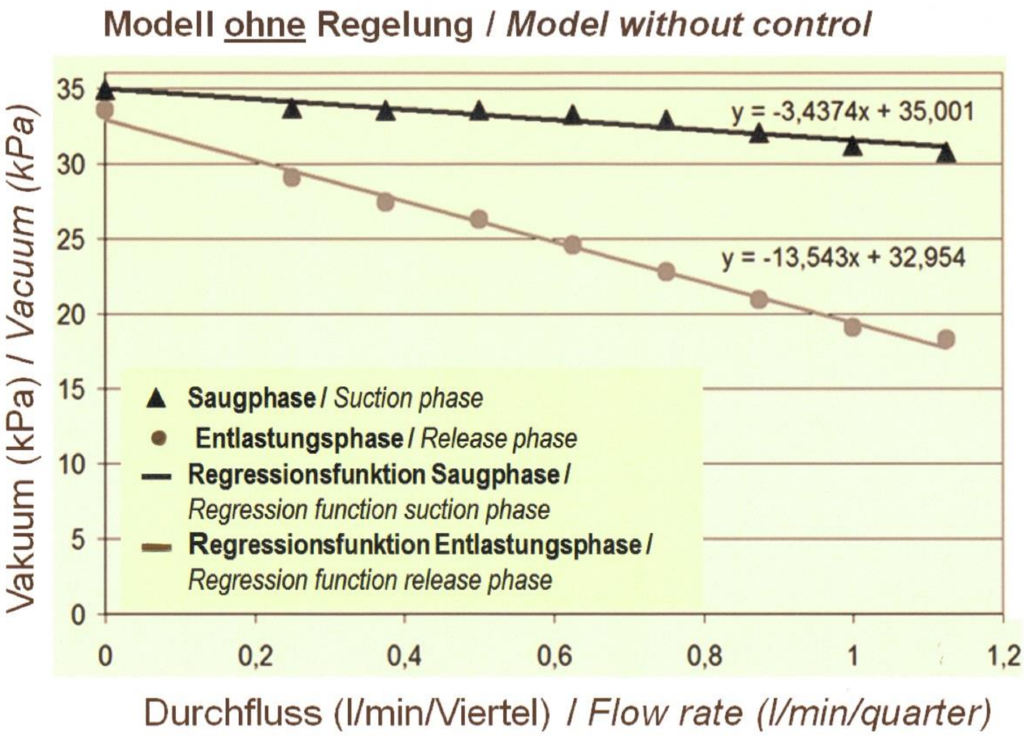
Figure 1: Schematic drawing of the test set-up: The duct system of the Multilactor® milking system with inserted vacuum control valve (VCV) (Ströbel et al., 2011).

3 Results and Discussion

Figure 2 can explain the effect of the series of experiments with the vacuum control system. In Figure 2, it can be seen that the vacuum control unit can reduce the teat-end vacuum to approximately 16.0 kPa in the suction phase and to about 7.0 kPa in the release phase. In the case without control unit at the same flow rate of 0.2 l/min/per udder quarter, however, the measured data were 34.0 kPa and 29.0 kPa at the teat end for the suction and release phase (Ströbel et al., 2013b). This yields, in particular at low flow rates, a much lower vacuum load for the cow's teats by the use of the developed vacuum control system (Ströbel et al., 2012b).

The comparison of the two graphs shows that the developed control system causes a significant reduction of the teat–end vacuum at low milk flows. This makes sense, since there is no high vacuum required for the removal of the milk, when the flow rate is low. The low vacuum in this time-section of a milking process of a cow, prevents a lot of strain on the teat tissue, thus ensuring a "smooth" milk withdrawal (Ströbel et al., 2012a). In other time-sections of the milking process with a high milk flow, it is needed in the suction phase that the milking process takes place with a high vacuum at the teat end. In most cases, the height of the teat-end vacuum is adjusted automatically. In the suction phase at high flow rates, a brisk milking should be made possible through a vacuum that is almost at the level of the machine vacuum. That also is realized with the help of the vacuum control system (Figure 2). The measured vacuum in that case is around 31.0 kPa. In the release phase, however, a reduction of the vacuum at the teat is desirable, because a low, the milk flow exactly matched vacuum, protects the sensitive tissue of the udder of cows (Ströbel et al., 2012a).

The new control unit can produce such a vacuum, that fit optimal to the teat tissue and that has positive effects on animal health and teat-tissue condition. Therefore, it can be assumed that udder diseases will decrease. The use of gentle individual quarter milking equipment is expected to extend the service life and performance of dairy cows (Ströbel et al., 2012a). This also has positive effects on the overall energy balance of the milk production. Thus, theoretically the energy absorbed by the animal in the rearing phase "without milk production", are spread over to an extended period of production when the service life cows will be extended (Ströbel et al., 2012a).



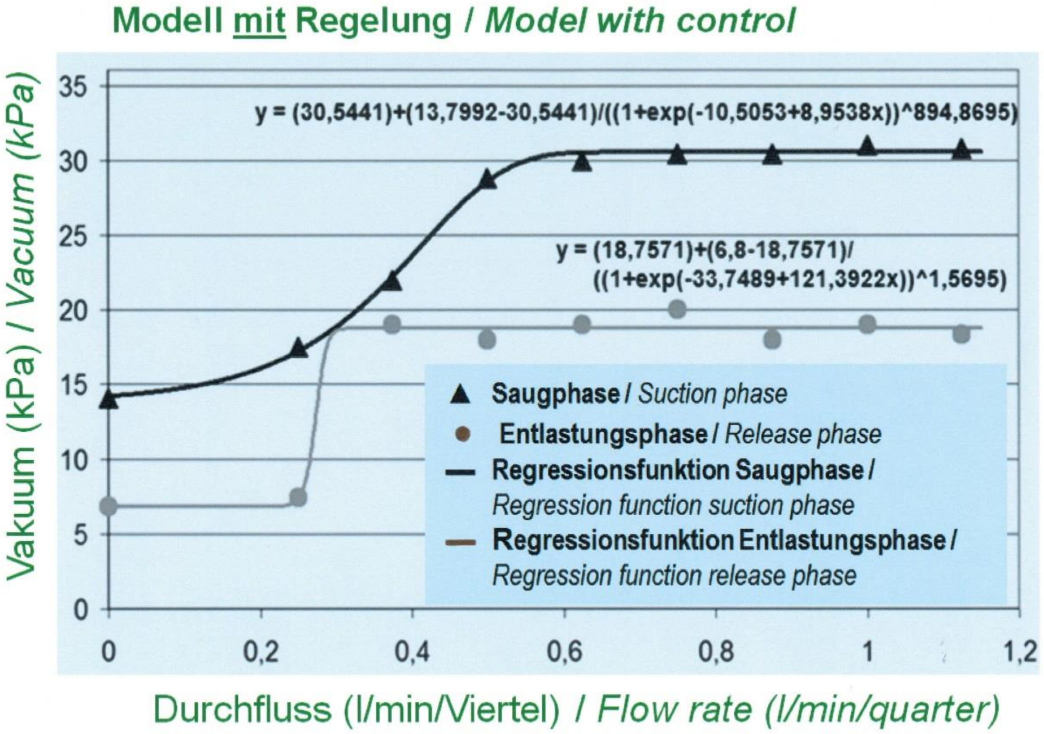


Figure 2: Effect of the vacuum control unit on the teat-end vacuum depending on the milk flow rate (Ströbel et al., 2011).

4 Conclusions

The vacuum control unit described investigations to reach the desired vacuum application in which the teat end milking vacuum in the release phase and in the milking phases with low milk flow is reduced significantly in comparison to milking phases with high milk flow (Ströbel et al., 2012b). Many other innovations in the market of milking systems show that the development of individual quarter milking systems has great potential for a much more animal-friendly and milker-friendly technology (Ströbel et al., 2012a). Since the necessary electronic components to improve the milking and working conditions for animals and milkers are already in principle available, it is the task of industry and research to adapt the available electronic components to the terms of use in animal husbandry. With this work, the production of robust technique is possible, for usage by the farmers in practice, to the advantage of cows, farmers and industry (Ströbel et al., 2012a).

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