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Vacuum application for individual quarters in modern milking systems

Using individual quarter milking systems can substantially improve the conditions for milkers and dairy cows. A separate conduction of the milk from the four udder quarters leads to distinctive benefits for the further technical development of these milking systems. A prototype of an individual quarter-wise working milking system with a vacuum control system allows a precise vacuum adjustment per quarter with a high response rate of the control system, based on the milk-flow of each udder quarter.

Keywords
Milking technique, vacuum control system, vacuum reduction, individual quarter milking

Abstract
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Consumer expectations mean that ensuring animal well-being and health has an increasingly important position in livestock production. In future this will lead to requirements for a stronger conformation of animal management in Germany [1]. Quarter-individual milking technology contributes towards this expectation through paying greater attention to the respective requirements of each dairy cow. Advantages of quarter-individual milking technology are:

- The possibility for recording individual data for each udder quarter so that milking procedure and milk quality can be more precisely monitored.
- The separate regulating of milking vacuum for each quarter.
- Optimal adjustment possibilities of vacuum so that teat tissue can be protected [2].

A stable and optimally adjusted vacuum is, according to Tan und Reinemann [3], enormously important to animal health and for the efficiency of the milking process. Too great a vacuum can substantially damage the teats. For example this causes more tissue and lymph fluids to be drawn into the ends of each teat compared with the situation with low vacuum. Should there then be an insufficient return flow massage process, blood congestion and disruption of the teat function can result. The current situation normally is that vacuum adjustment in milking systems applies to the entire udder i.e. all four teats. A technique for regulating vacuum per quarter does not, so far, exist in practical farming.

Vacuum regulation and quarter-individual milking in existing systems

In conventional milking parlours and automatic milking systems (AMS) the milking technology differs in important points. With conventional milking systems it has always been most practical to pipe the milk from the udder into a cluster claw positioned very near to the udder. In the development of the AMS, however, bundling of milk supply from the cluster cups to a collection claw has proved impractical [2]. Quarter-individual milking appears to offer in future a technique permitting a higher automatic identification rate for mastitis, although this approach also increases the costs and complexity of such systems. Additionally, quarter-individual milking can allow more precise monitoring of milk cell counts thus reducing loss of milk production from infected animals [4]. The product quality of milk is also assured. The development of an improved milk tube transport technique now enables quarter-individual milking in conventional milking parlours too. As a rule, such technical improvements offer higher milking efficiency because the quarter-individual technique supports a greater degree of automation so offering the possibilities of reductions in production cost factor labour.

Many important advantages of quarter-individual milking are transferrable from AMS into conventional milking parlours [2]. Thus Rose [5] confirms that milk tubes from each quarter (without cluster claw) permitted more uniform distribution of the vertical forces acting on teats compared with the cluster claw system. The tissue of teats and udder are thus in general less liable to damage during milking.

Apart from this, using quarter-individual milk tubes prevents transfer of disease-causing organisms in milk from one quarter to another. From a business efficiency point of view the conventional milking parlour offers the advantages of much lower capital investment and running costs compared with an AMS [2]. This is why most dairy farms in Germany still work

with conventional milking parlours. Just a few years ago the proportion of AMS farms represented only around 0.5% of all dairy farms in Germany [6]. However the sales figures of AMS manufacturers lead to the conclusion that a further steep rise in the number of AMS farms is to be expected. Most AMS are, as before, installed in the Netherlands and in Denmark [7].

Many modern milking systems, including AMS, are currently equipped with sensors and regulating mechanisms for optimising the milking process. This trend was conformed through a patent search for the appropriate electronic regulating systems. However, none of these milking systems enables precise quarter-individual vacuum regulation in relationship to milk flow. The systems already in existence mostly have their vacuum regulated at other points in the system or influence milking vacuum on a per udder basis and not quarter-individually.

Multilactor® as system basis for research into vacuum regulating units

The Multilactor® milking system developed and marketed by the company Siliconform GmbH & Co. KG in Türkheim, Germany is the first quarter-individual milking system available on the market for conventional milking parlours. The Multilactor® was selected as research basis for a dissertation on the theme "Development of an online analysing and control unit for quarter-individual milking systems" because the system was already in an advanced stage of development at the beginning of the planned research [10]. The research aim was creation of a control system for a quarter-individual milking capable of regulating the vacuum at each teat end individually, intelligently and with due regard to animal welfare [2]. The aim was also that the vacuum control be automatic and in relationship to milk flow. The system vacuum level in the laboratory milking parlour with Multilactor® (**Figure1**) was 35 kPa throughout the entire trial period.

To influence milking vacuum a mechanical throttle valve was built into the milk tubeclose to the casing of the Multilactor®. The valve was equipped with a function for altering the tube cross sectional area [8]. **Figure 2** shows an optimised prototype of the mechanical throttle valve. The effect of altering the cross section of the milk tube on the milking vacuum at the teat end was investigated in order to establish suitable mean vacuum values in relationship to the influence factors cross sectional area and milk flow. As a way of assessing both these influence factors the so called wet-test (ISO DIN 6690 [9]) was carried out. This method simulates – with unchanging throughflow amounts over longer periods - the milking process in each udder quarter with the help of a water tank and four throughflow regulators. In the investigation all possible combinations of throughflow volume (0.0 to 1.13 l/min/quarter) and cross sectional areas of openings (0.0 to 78.0 mm²) were varied over short intervals one after another. Thereby the milking vacuum at the teat ends was measured and recorded for the suction and release phases. To achieve an increasing average milking vacuum in line with increasing throughflow in the suction and release phases the optimal cross sectional area was calculated for every throughflow value with the help of the experiment data. This regulating model helped develop the software for the further developed vacuum control unit [10].

Gentler milking through vacuum regulating

The effect of the vacuum control unit is explained in **Figure 3**: The comparison of both diagrams shows that the developed control unit results in a marked reduction in teat-end vacuum at low milk flows. This is practical in that no great amount of vacuum is required for the transport of the milk. The low vacuum during such phases prevents high pressures on the teat tissue and enables a "gentle" milk withdrawal [2]. In milking phases with a high milk flow the vacuum within the milking system with control system is also high in the milk tubes during the suction phase. In this milking phase high teat-end vacuum values are desired. In the suction phase the vacuum should reach a level that is near to the value of the machine vacuum. With the high vacuum a rapid milking-out effect is possible. In the release phase, on the other hand, a reduction of vacuum on

Fig. 1

Milking system Multilactor® in the laboratory milking parlour (Photo: Ströbel)

Fig. 2

Prototype of the vacuum control valve in the vacuum control system [8] (Photo: Ströbel)

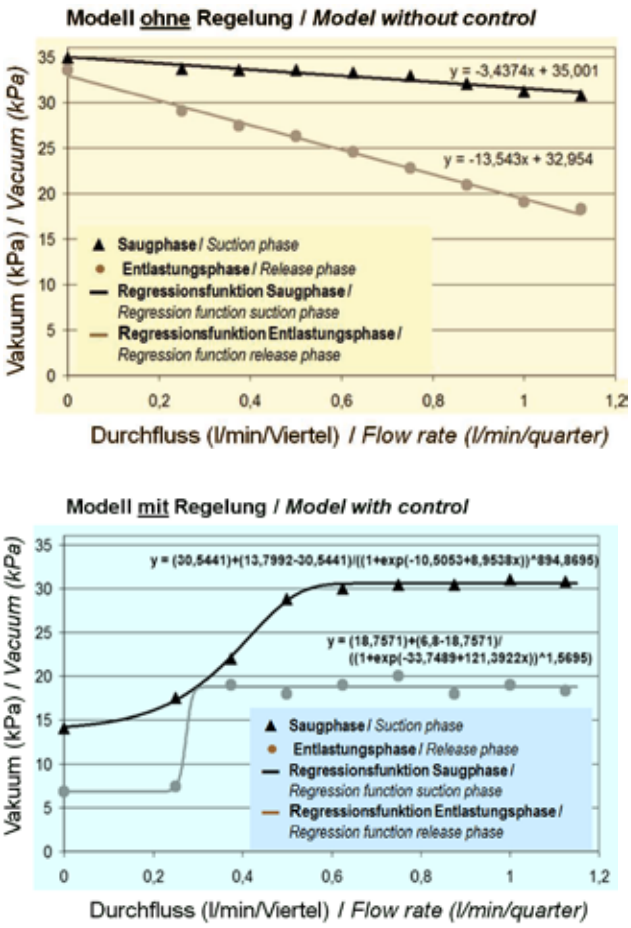
the teat is desired because a low vacuum related to the milk flow helps protect the sensitive udder tissue of the cows [2]. In **Figure 3** it can be seen that the vacuum can be lowered where the control unit has approx. 16 kPa in the suction and approx. 7 kPa in the release phase. On the other hand, without a control unit the kPa value at the teat ends is 34 and 29 respectively during the vacuum and release phases with the same milk flow of 0.2 l/min/quarter. Thus vacuum stress on cow teats can be reduced through application of the control unit, especially with low throughflow.

With the new control unit the vacuum can be precisely adjusted with the expectation of positive effects on animal health. It can therefore be assumed that there's a possibility of reducing udder diseases in this way. The application of the gentler quarter-individual milking technique can therefore probably lengthen dairy cow production lifetime and increase performance potential. Thereby positive effects on total energy balance in milk production can be expected: increased dairy cow longevity means rearing energy inputs are spread over a longer production period [2].

Conclusions

The vacuum control unit described here achieved the desired effect, through which the teat-near milking vacuum during the release phase, and in phases with low milk flow, could be markedly reduced. Many further innovations on the milk technology equipment market show that further development of a quarter-individual milking system represents considerable animal welfare oriented potential in milking. The required electronic module groups for improving the milking process are, in principle, available right now. It is now the role of agricultural engineering to take the available electronic components and adjust them to suit the operational conditions in livestock farming and develop a suitably robust technology [2]. In future the comprehensively tested vacuum control unit should be further tested under practical conditions to see if it can deliver the required positive effect in protection of udder tissue and udder health.

Fig. 3



Effect of the vacuum control system on the teat-end vacuum depending on the milk flow [8]

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