

A System for Automatic Teat-cup Attachment

D. ORDOLFF*

Investigations are reported on the physical problems concerning the automatic attachment of teat-cups. Results indicate that it is possible to use the front of the udder as a reference point to create a stable base for teat location. It was possible to locate teats by infrared radiation. Commercial, hydraulically operated handling equipment was used to attach teat-cups.

1. Introduction

Attachment of teat-cups to cows' teats requires about 10 s/cow. It represents about 16% of the total labour required in conventional parlour routines and approximately 100%, when it is the only remaining manual task. The development of equipment capable of automating this final step in the milking routine has been inhibited both by economic considerations and technical difficulties caused by udder shape and other factors.

Nevertheless, there exist some patents¹⁻³ which indicate that the problem has been worked on for more than 10 years. Devices for automatic teat-cup attachment, reported in the literature, are very different from the one described in the present work. Gabler² invented a unit which was to be remotely-controlled. It consisted of a shell, which was meant to cover the whole udder and was equipped with integral "teat-cups". The patent contains no precise information about the control system for this unit and there appear to be no reports about practical experience with this design.

A more realistic device is the invention of Notsuki and Ueno³ which is reported to have worked. The unit is moved from one cow to the next, and the discrete teat-cups are attached according to individual positions of teats, recorded in a memory. This system requires cows to be in identical positions for each milking, so cows have to be positioned appropriately. Udder preparation and stripping are executed by mechanical means.

Akerman¹ invented a unit which was equipped with electronic sensors to identify teats by approaching and touching or by electronic cameras. Also described is a procedure for introducing the teat into the liner. There is no information about the positioning of cows, neither is it known whether the device has been built.

In 1974, at the Federal Dairy Research Centre at Kiel, Germany, an attempt was made to develop an appropriate device for attachment of teat-cups, and in 1980 some fundamental aspects of this work were reported.⁴ This paper reports the present status of this work.

When the work at Kiel started, it was decided to design a device, based on parlour conditions, i.e. one which would not require more space than was normally available in the milking stall. It was necessary for the equipment to be able to follow motions of the cows without losing its position relative to the udder. It was planned to "lock" the unit to a defined point on the cow first, and then to start searching for teats as a second step. To avoid the necessity of storing the positions of the teats in a memory, it was decided to attach each teat-cup immediately after the detection of the corresponding teat. The mechanical components were to be activated hydraulically, because this created fewest problems for continuous positioning.

*Federal Dairy Research Centre, D2300 Kiel, West Germany

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2. Research on sensors

2.1. Searching for the udder

To find an appropriate point to use for orientation of the searching device relative to the udder, the silhouettes of several animals were analysed photographically. It was found, that the front of the udder was a significant point, even for cows in first lactation. The angle, α , between the bottom contour of the cow and the front of the udder averaged 98° , ranging from 82° to 114°

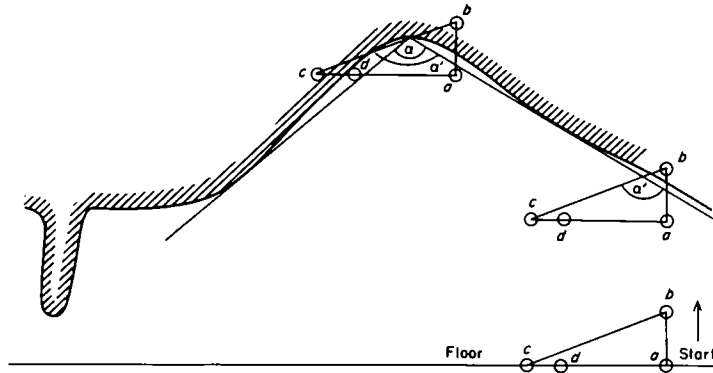


Fig. 1. Geometric arrangement of light beams for detecting the udder. a, b, c, d , Light beams; α , angle between the front of the cow's udder and abdomen; α' , angle between the light beams a and b and the cow's abdomen

(Fig. 1). Based on this result, an attempt was made to build a system of optical light beams to detect the front of the udder. For this purpose the connecting line between the points b and c in the optical system, each representing one light beam, was to be designed to create an angle α' , wider than the angle α , with the bottom contour of the cow. So, when moving the light beam system along the bottom contour of the cow towards the udder, while light beam b is covered, light beam c would be open until the unit reaches the front of the udder. This condition can be used to indicate the position of the udder.

2.2. Locating the teats

Before starting research on sensor systems to locate the positions of single teats, a photographic analysis of the positions of teats on udders of approximately 40 cows showed that there was no regular distribution of teats on the areas of the four quarters (Fig. 2). Following the earlier decision not to store teat positions in a memory, it was necessary to locate all teats for each milking. The possibility of using a similar technique to that chosen for searching the front of the udder was considered, also using light beams for locating the teats. However, since such a system would require several small mechanical parts, it would have had to have been built to withstand corrosion and mechanical loads. Therefore a solution was sought which avoided mechanical contact with the udder and contained only a few mechanical components.

Several possibilities were considered and a promising method seemed to be to detect teats by scanning the surface temperature of the udder. Since the ratio of surface area to mass of the teats is different from that of other parts of the udder, there were likely to be differences in temperature. Recordings by surface thermometers indicated an average temperature of 37.8°C for the udder and 28.5°C for teats. Corresponding results, obtained by infrared thermometers, were similar for teats, but temperatures were at a lower level for the udder. The average difference of temperatures was only 3.6 K (Fig. 3).

Hair and the temperature of the environment influenced the general level of temperature. The difference could be increased by wetting the udder and by stimulation (Fig. 4). Exceptions to

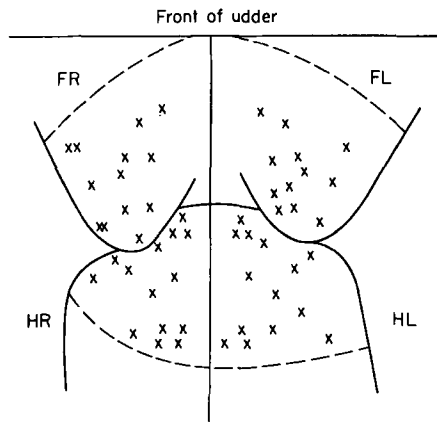


Fig. 2. Distribution of teats on udder surface

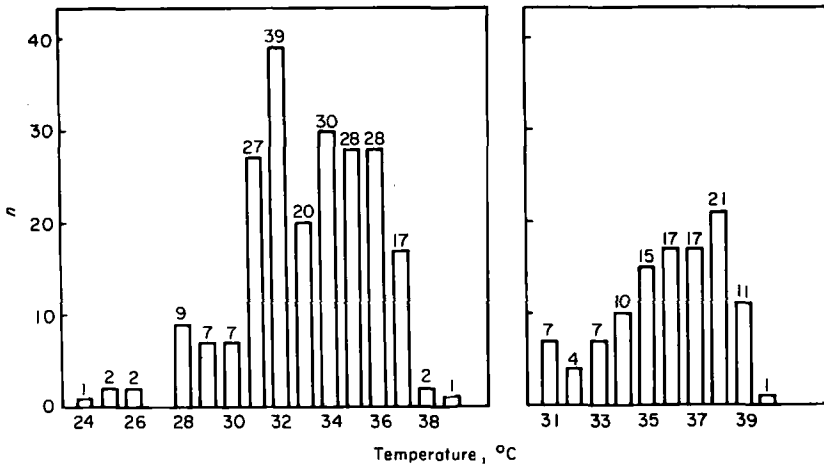


Fig. 3. Distribution of measured temperatures of (left) teats and (right) udder

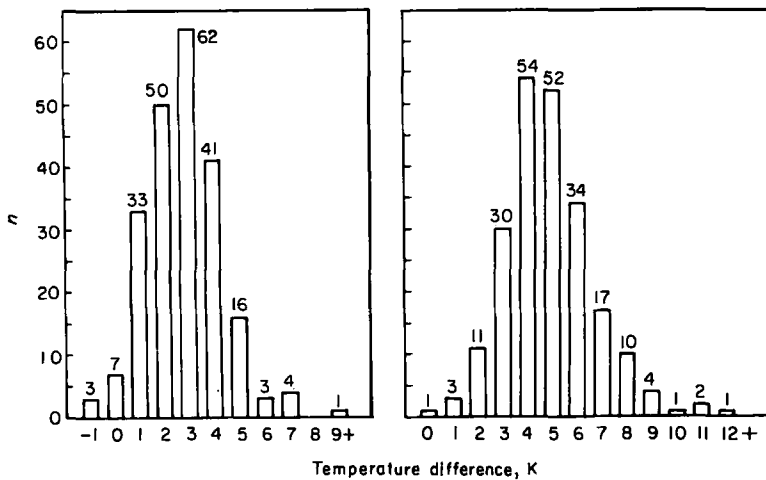


Fig. 4. Distribution of temperature differences between udder and teats for (left) dry and (right) wet conditions

the thermal conditions described so far could be found only for single quarters which due to previous mastitis or other similar events did not produce milk. In such cases there was either no temperature difference at all or the temperature of the teat was higher than that of the surrounding surface of the udder.

3. Design of mechanical components

3.1. *Optical light beam system*

The light beam array for detection of the udder-front was made up of two pairs of light beams connected to a logic unit to control hydraulic rams for vertical and horizontal movements of this device. Signals from the vertical pair of light beams (*a* and *b* in *Fig. 1*), controlling the vertical movement of the system, have a higher priority than signals from the horizontal pair (*c* and *d*), controlling horizontal movements. "Both vertical light beams open" causes rising of the device, "both vertical light beams covered" causes lowering. "Upper vertical light beam only covered" results in no signal from the vertical array and consequently the horizontal light beams (*c* and *d*) becomes activated. In a similar way to the vertical system they cause forward movement, when both are open, backward movement when both are covered and no movement when only the front light beam (*c*) is covered.

The search-programme starts with light beams down as close as possible to the floor half-way between the back and front legs of the cow. The device is then raised up to the bottom edge of the cow's contour and then moves towards the udder until the first horizontal light beam (*c*) is covered by the udder or by a teat. When the cow moves forward, the second horizontal beam (*d*) is also covered by the udder. This causes a correction of the position of the device, away from the udder, until the desired position is again reached.

In practice the above system gave no problems and could be used right from the start to create a stable position relative to the udder for all operations concerning location of teats and attachment of teat-cups.

3.2. *Infrared sensor system*

Investigations on infrared radiation from teats were performed using an infrared thermometer. Although this was a very useful instrument for evaluation of basic data, it was found that absolute temperature could not be used for the detection of teats since temperature levels of cows differed by more than the temperature difference between udder and teats. It also proved impossible to find a typical difference of temperatures, which would have allowed reliable detection of teats.

However, it was possible to use the temperature gradient created by moving the sensor from the udder surface to the teat. This parameter could be used to detect even very small changes of temperature, providing they occurred quickly enough. By adjusting the sensor to different temperature gradients it was possible to create various levels of sensitivity. Best results were obtained by adjusting the sensor to a temperature gradient of approximately -9°C/s , so that each teat could be detected at least once during a scanning procedure.

3.3. *Attaching the teat-cups*

Although mechanical handling of teat-cups is not an insuperable problem these days, it caused many delays in the project. Different attempts to use self-made equipment failed. However, when commercial components for handling parts of tooling-machines were used, successful handling was achieved.

The teat-cup handling unit is combined with the infrared temperature sensor unit so that the teat-cups are in a fixed position relative to the sensor. When a teat is located, the handling unit picks up a teat-cup and moves it in a circular movement from the horizontal to the vertical position. Simultaneously, the teat-cup is lifted up to the teat, replacing the sensor, which is pushed away mechanically. As soon as the teat-cup meets the teat, vacuum is turned on. The

handling unit moves back to its start-position where, meanwhile, another teat-cup has been placed. As before, the sensor returns and scanning for teats continues (Figs 5 and 6).

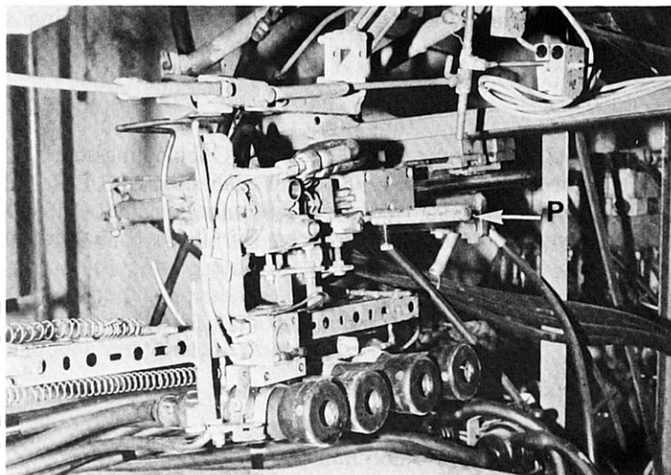


Fig. 5. Teat-cups ready to be attached. P denotes a pointer which replaces the infrared sensor for simulations with the artificial udder

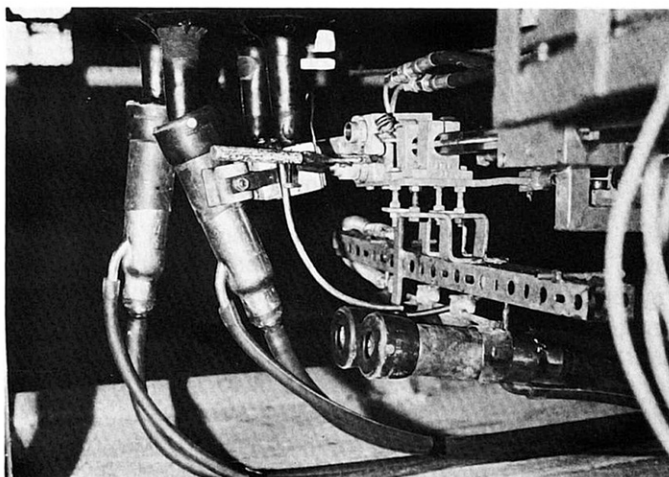


Fig. 6. Simulation of attaching teat-cups to teats on artificial udder

4. Conclusions

Although the device described offers only limited facilities for movements of the sensor and handling unit, it has been helpful in acquiring experience. The sensors and the handling unit of the system described have been shown to work with an artificial udder, and have been used to attach teat-cups mechanically to three different cows, which had been trained for the purpose. There was no problem with the cows' behaviour but it was found that the handling equipment

required more vertical movement to cope with variations in udder height. Some current problems of lack of mobility of the system may be solved by using advanced commercial handling equipment. Attachment of teat-cups individually has been shown to be possible and the next step will be to control the whole system automatically. Apart from the mechanical problems, work needs to be done on hygienic problems, connected with fully-automatic milking, and also on economic aspects which may allow the farmer the opportunity of using such equipment to increase overall efficiency.

REFERENCES

- ¹ Akerman, D. E. *Verfahren und Vorrichtung zum Melken*. Dt. Offenlegungsschr., 1979 **28** (49) 227
- ² Gabler, E. *Melkeinrichtung, vorzugsweise für große Milchviehbestände*. G.D.R. Patent 82 592, 1971
- ³ Notsuki, I.; Ueno, K. *System for managing milking cows in stanchion stool*. U.S.-Patent 4 010 714, 1977
- ⁴ Ordloff, D. *Melkzeuge automatisch ansetzen—demnächst Wirklichkeit?* Landtechnik, 1980 **35** 222–224