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Note on a portable simulator for analysis of milking machine performance

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A portable flow simulator was developed for recording vacuum variations in commercial milking machine clusters. The cluster in the milking unit under evaluation was mounted on the frame of the simulator and the flow of water through each liner was regulated by separate flow meters. By placing an artificial teat into the liners the flow characteristics during actual milking were simulated. Measurement vacuum sensors were mounted in the claw, in one artificial teat, in the pulsation chamber and in the milk pipeline. Analog and digital outputs were recorded. The system was validated by comparing the outputs with those obtained with a laboratory flow simulator and with recordings taken during cow milking. The recordings with the portable simulator and the laboratory simulator were identical; the profiles of the analogue signals obtained with the portable simulator and from cow milking were similar. The portable flow simulator will allow recording of vacuum variations in commercial milking machines during simulated or actual milking.

Keywords: Milking machines; vacuum; simulation

Introduction

For milking systems, the losses in vacuum in relation to flow are usually measured under laboratory conditions, where water is used instead of milk and artificial teats are inserted into the liners to stimulate the flow conditions during milking. Nordegren (1980) used a laboratory flow simulator to study the effect of different mechanical factors on cyclic vacuum fluctuations at the teat end and in the claw during the four phases of liner movement. Stewart (1997) developed a portable flow simulator for field-testing of milking equipment but it is not clear whether this system mimics the degree of vacuum fluctuation that occurs in practice. Also the four artificial teats had a common supply tube and the water flow to the teats may not be evenly distributed. Both Woyke and Czarnocinski (1993) and Wiercioch and Szlachta (1994) used a microprocessor measurement system for recording vacuum conditions in a laboratory flow simulator. With the exception of Nordegren (1980) the

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flow of liquid during milk-flow simulation tests has been controlled with a single valve on the inlet to a manifold connected to individual liners. O'Callaghan (2002) developed a new design of artificial teat that gave vacuum recordings similar to those obtained during actual milking. The objective of the present work was to develop a portable milk flow simulation system for recording vacuum conditions in commercial milking units.

Materials and Methods

The mobile simulator consisted of a water reservoir connected to a water supply. The level of water in the reservoir was maintained by allowing the mains water to overflow via a 38-mm diameter overflow pipe. Four flow meters were connected to the base of the water reservoir and each meter outlet was connected to an artificial teat inserted in the cluster. The artificial teats were identical to those described by O'Callaghan (2002) except that a second outlet was drilled at the apex to allow for increased flow capacity. The cluster was mounted on a frame with the water reservoir and the flow meters. By measuring time to empty the reservoir the flow of water through each liner was established. Vacuum transducers were mounted in the claw, in one artificial teat, in the pulsation chamber and in the milk pipeline. Vacuum levels in the pulsation chamber, teat end, claw and system vacuum levels were measured using gauge pressure transducers with a full scale of ±100 kPa (Seniortechnics, Puchheim, Germany. Model No. BTE6N01G4). The response time (10% to 90% of full-scale output) for the pressure transducers was 1 ms, which equates to a maximum rate of change of vacuum of 160 MPa/s. Each of these pressure transducers provided a 4 to 20 mA current output. The 4- to 20-mA signals were converted to voltage levels, in the 0 to 10-volt range. This voltage signal was input to a personal computer via an analogue data acquisition card (Computerboards Inc., Middleboro, Massachusetts, USA, Model No. DAS08). The first-order low-pass filter used in the circuit had a cut-off frequency of 159 Hz. This frequency resulted from the components in the circuit and was adequate for the present application. Data from each of the four input channels was recorded at 1000 times per second for one period of 5 s. On completion of each 5-s scanning period, the pulsation rate, pulsation ratio and phases of pulsation were computed according to ISO 3918 (ISO, 1996). The maximum, minimum and mean value of vacuum level in a full pulsation cycle and during the four phases of a pulsation cycle were also computed for each measurement sensor. The analogue output displayed simultaneous traces of vacuum variations for the four sensors and the differential vacuum between the claw and the teat end. The mean teat-end vacuum was computed during a full pulsation cycle (TV) and in the "b-phase" of the pulsation waveform (TVB). Claw vacuum was also computed during full pulsation cycles (CV) and during the "b-phase" of pulsation (CVB). Vacuum fluctuation at the teat end (TVF) and vacuum fluctuation in the claw (CVF) were defined as the difference between the maximum and minimum vacuum level recorded over a complete pulsation cycle. Vacuum fluctuation at the teat-end during the "b-phase" of pulsation (TVFB) and corresponding value in the claw (CVFB) were computed as the difference between maximum and minimum levels recorded in the "b-phase" of pulsation. Measurements of vacuum were made in a laboratory with both the portable flow simulator and with a laboratory simulator developed by O'Callaghan and Gleeson (1997) using a mid-level milking unit shown in Figure 1. Vacuum measurements were then made with the portable simulator in one unit of a commercial high-level milking parlor with artificial teats and during an AM milking of one cow. The milking unit in the parlor had similar configuration to that used for the laboratory tests. The measurement cluster was fitted with a wide-bore tapered liner and a 150-ml claw. A milk diversion valve and a Dairymaster electronic milk meter (Dairymaster Weigh-all Milk Meter, Dairymaster, Causeway, Co. Kerry) were located near the milk pipeline. Simultaneous pulsation, a 16-mm bore long milk tube, a pulsation rate of 60 Hz and a pulsation ratio of 68% were used. During cow milking the electronic milk meter gave outputs of the overall flow from the four quarters and this output was used to trigger vacuum measurements with the portable simulator. Recordings of claw vacuum and pulsation chamber vacuum taken during flow simulation in the parlor and from cow milking were compared (Figure 2).

Results and Discussion

Measurements of teat-end vacuum and claw vacuum taken in the laboratory with the portable flow simulator were almost identical to those obtained with the static laboratory simulator. Successive pulsation cycles were treated as replicates and the vacuum values were the mean for five consecutive cycles. The average difference between the two systems for 'a', 'b', 'c' and 'd' values of the pulsation chamber waveform or for TV, TVB, CV and CVB was less than 0.2 kPA. For TVF, TVFB, CVF and CVFB the average difference was less than 0.3 kPa. Measurements of claw vacuum, pulsation chamber vacuum and system vacuum were made at an estimated flow rate of 4 l/min during cow milking with the same cluster as used in the tests with the portable and laboratory simulator. The vacuum profile in the claw during these measurements was similar to that obtained with the laboratory and portable flow simulators. This shows that vacuum measurements with the portable simulator correspond to those during real milking. O'Callaghan (2002) reported a similar result with a laboratory simulator. With the portable simulator exact measurements of vacuum losses can easily be established in the field and the feasibility of altering or re-designing milking units can be established.

Commercial companies require a simulator to check vacuum losses in field situations or in laboratories with various combinations of

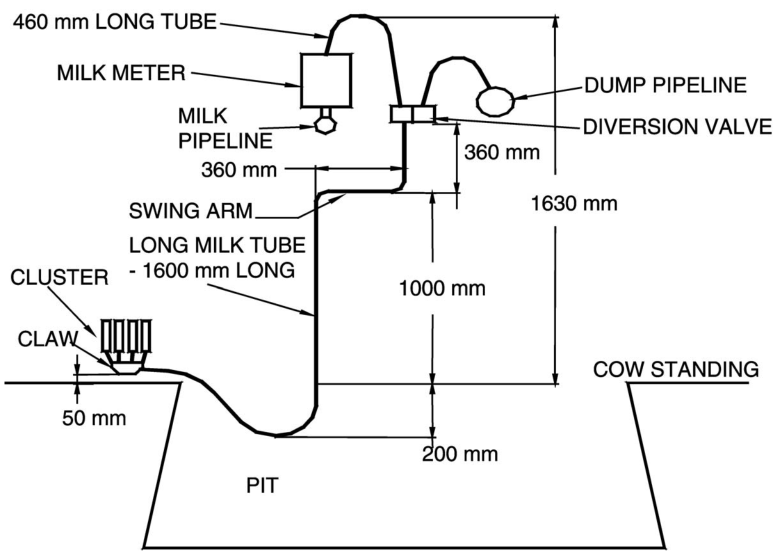

Figure 1: Cross-section of milking unit.

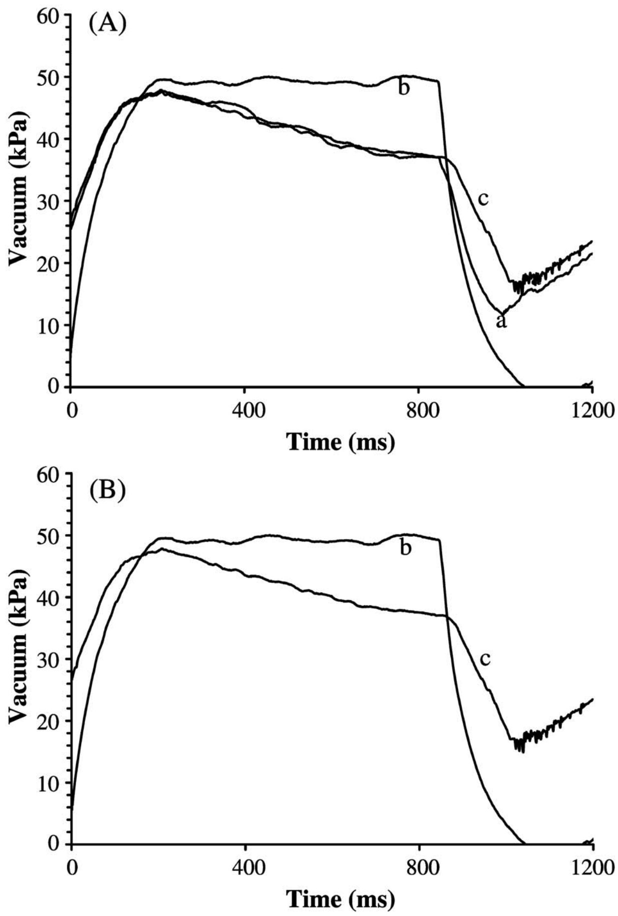

Figure 2: Vacuum traces recorded with portable simulator in milking parlor with artificial teats (A) showing (a) teat-end vacuum (b) pulsation chamber vacuum and (c) claw vacuum for a water flow of 4 l/min and vacuum recordings with portable simulator during milking with an estimated milk flowrate of 4 l/min (B) showing (b) pulsation chamber vacuum and (c) claw vacuum.

components in milking units. In field situations routine tests for vacuum losses can be implemented either between milkings or during milking with the portable simulator. Recordings with artificial teats between milkings are probably more interesting as the teat-end vacuum variations are available and the flow through each artificial teat is controlled. One of the main advantages of the simulator is probably that the analogue phase relationship of vacuum at the teat-end and in the pulsation chamber is displayed with corresponding digital values during the ‘b-phase’ of pulsation.

While from an energy standpoint reducing vacuum losses during milk flow in milking units should be a priority, the main benefit should be a reduction in milking time.

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