Understanding dynamic milking machine tests

The milking machine can transmit infection onto teats and disturb normal teat health. Milking-time tests allow advisors to quantify the degree to which the milking machine might be contributing to the risk of new intra-mammary infection.

Cows' teat size and position have changed as have milk flow rates. Milk yields have been rising faster than unit attachment times. Milk flow rate has been shown to be positively associated with risk of new intra-mammary infection.

Vacuum traces collected during milking can illustrate problems with biphasic milk flow or over milking and pressure records can help assess liner function. Lightweight data logging equipment is now available with excellent software to assist with interpretation.

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Key words: milking | health | machine | dynamic | tesing

The role of the modern dairy practitioner is frequently one of business advisor with the shared objective of enhancing dairy farm performance with their clients. A central aspect of dairy herd performance is to ensure that the constituent quality of milk produced matches the needs of the processor and that yields are optimised at all times. For this reason farmers frequently seek milk quality advice from veterinary surgeons in an attempt to manage both clinical mastitis and cell counts on farm.

Many farmers consider that a milking machine that has had an annual test and that still moves milk from cow to bulk tank is a working machine. However the specific characteristics of milking machine performance can have a very significant impact on udder health. This article is intended to describe how a better understanding of the milking machine can prove a useful component of the dairy veterinary surgeon's comprehensive herd performance consultancy.

Milking machine tests — a job for an engineer or for the veterinary surgeon?

If a veterinary surgeon is to suggest the most cost-effective solutions to help manage milk quality then a full overview of all the aspects which might contribute to udder health is essential. Advisors need to satisfy themselves that the milking machine is performing effectively and efficiently.

One option is to work closely with trusted local milking machine engineers but even then the veterinary surgeon should

Figure 1. Vacuum measured at several points in the cluster.

have some understanding of the principles of machine milking and how the machine can contribute to milk quality problems. It is not essential to carry out a full ISO machine test to assess the machine's impact on the cow. Gathering some basic test data using modern automated equipment can now be done fairly easily. It is then the engineer's task to ensure that machine characteristics are changed to accommodate any concerns that a veterinary surgeon has regarding impact on cows. Working together to reach a better outcome can be very rewarding.

Milking machine testing

Veterinary practitioners are generally aware that milking machine performance is usually evaluated through a rigorous testing protocol carried out by trained milking machine fitters. Many are also aware that some tests are only possible while the machine is in use. Milking machine manufacturers have engineering specifications for setting up their machinery in order to achieve the best outcome on the majority of farms. However, inevitable biological variation in cows' teats and milking characteristics mean that, in some cases, the standard settings for milking equipment are not sufficiently flexible (Zwertvaegher, 2012).

An example of this would be the farmer who is converting from a high input Holstein herd to a herd of Jersey cross grazing animals or vice versa. The former conversion is likely to mean that the majority of animals will be heifers with smaller than average teats. For the herd that is converting to fast milking high flow rate animals, the previously efficient milking equipment can become problematic.

Milk flow rates have changed significantly due to genetic progress. While milk yields have been rising at a rate of 3.5% per year, unit attachment times have not increased at the same rate (Mein, 1998). If flow rates had not increased and unit attachment times had risen in line with yields, then a milking lasting 2 hours in 1980 would now last for over 6 hours! The increase in milk flow rate is probably the principal reason why milking facilities sometimes appear to fail when they have worked adequately with the same settings in previous years.

In 1991 Grindal and Hillerton showed that quarters with a milk flow rate greater than 1.6 l/minute were 12 times more likely to acquire a new infection than were quarters whose flow rates were less than 0.8 l/minute. No information was provided regarding the flow capacity of the milking facilities involved in the study. Data acquired in 2011 from automatic milking facilities with individual quarter flow data show that half of quarters have peak flow rates of over 1.5 l/minute (author's data). It is generally considered that conventional plants milk cows more quickly than automated ('robot') milking systems (Rasmussen et al, 2001).

The milking machine and causes of mastitis

The milking machine can contribute to the establishment of new intramammary infections in several ways:

- It can transfer some pathogens onto the teat skin as a fomite
- It can be involved in disturbing the normal skin structure such that pathogens can more readily become established on the teat surface and then multiply on teat skin

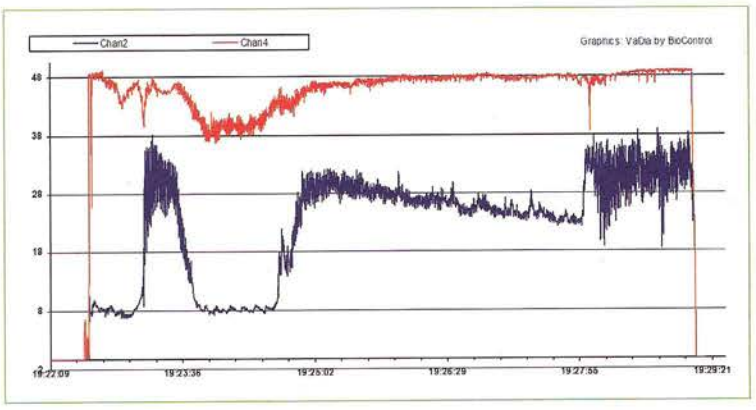

Figure 2. Vacuum traces taken at mouthpiece and short milk tube illustrate biphasic milk flow. The blue line shows the vacuum measured at the liner mouthpiece chamber. The red line is that measured in the short milk tube.

- It can be involved in moving pathogens from the external environment to within the teat and udder
- It can disturb teat tissue health such that the normal defences within the udder are disrupted and their effects reduced. This may lead to a greater proportion of invading bacteria becoming established within the udder.

One of the most critical components of the factors identified above is the propensity for the machine to allow pathogens to move into the teat. Machine evaluation during milking can be especially helpful in determining how the milking machine behaves in this regard.

Dynamic milking machine tests

Testing of milking machines during the milking process is often referred to as 'dynamic testing' of the milking plant. Some authors refer to 'wet testing' or 'dry testing' to differentiate

Figure 3. A typical 'claw' with a 250 ml capacity bowl.

Figure 7. Hyperkeratosis is often more severe on pointed teats like the ones illustrated here.

Figure 8. A manual vacuum pump that can be used to assess over-pressure and the risk of hyperkeratosis.

Flow away from the claw

With many modern milking facilities the flow rate away from the cow can be sufficient to cope with air ingress and will maintain net movement of milk away from the teat end. The capacity to move fluid away from the cluster can be assessed using air as a proxy for a milk/air mixture in some 'static' or 'dry' machine tests. In these tests, an airflow meter, which has been specially calibrated to work at typical milking machine vacuums and volumes, is fixed to the long milk tube at the point where the claw is normally attached (*Figure 4*).

Air is admitted gradually until the vacuum measured close to the airflow meter has fallen from system vacuum level to either 2 kPa or 5 kPa below the system vacuum figure. The volume of air admitted per minute to achieve this lower figure is a useful indicator of the ability of the milking machine to move fluid through the milk side of the pipework. It is then possible to repeat this procedure at any point where the pipework can be broken to assess the resistance to effective flow offered by various components. The specific impact of changes in pipe diameter or turbulence within valves and meters can be measured. For instance it would not be uncommon for in-line milk filters to create some turbulence and, hence resistance to effective flow away from the claw (*Figure 5*).

Because air is admitted via the airbleed at the claw, flow within the cluster cannot easily be assessed using an airflow meter. Instead, some features of the milking time vacuum trace indicate the capacity of the cluster to allow rapid flow of milk away from the teat. One way to observe the effect of cluster design is to fit a modern high flow cluster to any milking point and to compare the traces seen with traces obtained with the existing cluster. Typically the regular 'cyclix' seen as the liner opens and closes is of much smaller amplitude when milk is able to move rapidly away from the teat and into the milk/air mix of the modern high volume claw. Features relating to the capacity of the short milk tube, the claw nipple design and internal diameter of the liner can all influence this (*Figure 6*).

Hyperkeratosis, 'over-pressure' and the milking machine

When the liner closes on the teat tissue it must do so with sufficient force to drive exhausted circulation fluids out of the teat. The liner must also remain closed for sufficient time for this to occur. To ensure that there is a pressure gradient from teat end to teat base the liner is fitted within the shell of the teat cup with a little longitudinal tension. It is this tension along with the rigidity of the liner mouthpiece that ensures that the teat end is compressed with more pressure than the teat barrel and base. During liner collapse fluids will then move away from the tip of the teat and towards the udder where they can re-join the normal circulation.

If the forces applied across the end of the teat are too great then a cow's teat can develop more keratin (Mein et al, 2003) as a response in a similar way in which skin on hands or feet becomes thickened and hardened at points where repetitive pressure is applied. For this reason it becomes important that the pressure

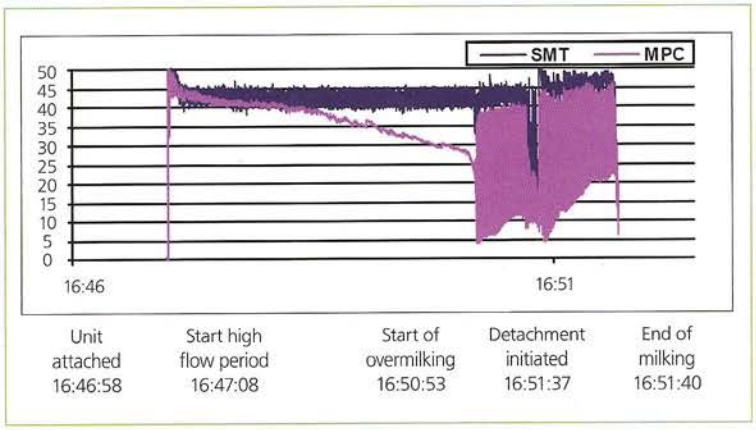

Figure 9. Vacuum traces recorded with the VaDia at the mouthpiece (MPC) and at the short milk tube (SMT) illustrating when milk flow ceases and over-milking begins.

Figure 10. The VaDia recorder simplifies collection of milking-time machine test data.

Figure 11. Progressive dairy vets advising large herds are acquiring a better understanding of milking machine function and its ability to impact on udder health.

Using milking-time tests

- Average vacuum levels within the liner at peak flow can be identified
- Can determine how well the milking plant can handle modern high flow cows
- Vacuum levels at short milk tube and mouthpiece can be monitored at the same time
- Allows identification of biphasic milk flow and the duration of over-milking
- Non-cyclic fluctuations can be identified
- Can determine the frequency of reverse flow and teat end impacts
- Can determine the amplitude of cyclic vacuum fluctuations
- Helps determine the flow capacity of the cluster
- Can measure liner over-pressure
- Assess if the machine is a risk factor for hyperkeratosis

applied over the teat by a collapsing liner is sufficient but not excessive.

The forces involved are a mechanical function of vacuum difference across the liner wall and the tension and stretch characteristics of the liner itself. However, they are also a function of the cow in that different teat size and shape will influence the forces involved. Pointed teats are often more severely affected than blunt ended teats (*Figure 7*) (Ohnstad et al, 2007). As discussed earlier milk flow rate will also influence the vacuum level within the liner. The pressure difference across the liner wall when the liner is closing and closed is the difference between the prevailing atmospheric pressure and the vacuum within the liner.

At the fifth IDF Mastitis Conference in New Zealand in 2010, Jimenez and Mein described a milking time machine test that can be used to assess the 'over-pressure' applied to a teat during milking. The concept of over-pressure describes the pressure measurement over and above that pressure required to just close the liner over the teat during milking. In this test the short pulsation tube is detached such that atmospheric air is allowed into the pulsation chamber and the liner becomes closed. Observation of the claw usually allows the operator to observe if milk is flowing into the claw from the test quarter. A manual vacuum pump (*Figure 8*) is then used to gradually apply vacuum to the pulse tubing such that a point is reached when milk is observed to begin to flow into the claw. The negative pressure required to reach this precise point is considered to be a proxy measurement for the over-pressure involved in closing the liner on this specific teat with the milk flow characteristics of that specific cow. Ideally this test should be carried out during the peak flow phase of milking.

Over-milking

In systems where milk is lifted away from the udder a large difference between 'system' vacuum and vacuum at the teat end during milking is to be expected. Indeed, the aim is to expose the teat only to vacuum levels of between 35 kPa and 40 kPa for the majority of the unit attachment period (see recommendations made by Reinemann et al (2007). When milking plants have system vacuum set near to 50 kPa which is typical for highline plants, then teat vacuum exposure can rise to undesirably high levels when milk flow ceases.

Unlike automatic (robot) milking systems, detachment of the cluster in conventional milking plants is 'all or nothing'. Individual quarters that cease flow earlier than others will suffer higher vacuum levels until the whole cluster is detached. The period in which the teat cup is still attached but when milk has ceased flowing is known as over-milking. Over-milking is considered undesirable (Rasmussen, 2004) because the forces driving liner collapse are magnified after milk has ceased to flow due to the higher vacuum within the liner. As mentioned earlier, the pressure difference across the liner wall is one of the components that influences the magnitude of force applied to teat tissues. Negative consequences can arise if these forces are excessive.

Vacuum measured and recorded simultaneously close to the teat end and at the liner mouthpiece can be used to assess the

duration of over-milking on any one teat cup and cow. The principle involved depends on the teat becoming narrower when the teat cistern becomes empty and as result, the vacuum at the mouthpiece generally rises to match the vacuum being recorded near to the teat end (*Figure 9*).

There are circumstances where the mouthpiece vacuum tracks the vacuum near to the teat end for the early part of the milk flow period. This is typically seen where the teat is too narrow for the liner. As milking continues the teat often swells, possibly as a consequence of the high vacuum surrounding the teat base. After several minutes the mouthpiece vacuum can be observed to drop. In these situations the whole teat tissue is traumatised through the period of unit attachment.

Capturing milking time test data

Most milking machine manufacturers also make testing equipment that allows a record to be made of vacuum against time. Several can record more than one point simultaneously. Biocontrol of Norway has developed a very light (80 grams) and cost effective data capture device that can be attached to one teat cup of the milking machine cluster and left in place during milking. Biocontrol's 'VaDia' device (*Figure 10*) can monitor vacuum at four sites simultaneously and runs on a single rechargeable battery. 'VaDia Viewer' software then allows all data to be interrogated and uses industry validated algorithms to develop reports. Information can be gathered on the frequency of non-cyclic vacuum fluctuations, over-milking duration and period to the onset of peak milk flow. Reports and traces can be shared with other users of the equipment to help develop relevant and practical action plans and to sustain positive discussions with machine engineers.

Conclusion

Examination of an individual sick animal involves collecting all possible information in order to form the best judgement regarding diagnosis, therapy and prognosis. If a client reports a finding or some further history a judgement is made about the validity of the information and some further tests may be carried out.

For a milk quality problem the same principles apply and dairy practitioners may be well advised not to take a recent machine test on trust. Progressive dairy veterinary practitioners advising large herds are acquiring a better understanding of milking machine function and its ability to impact on udder health. Better technologies such as the VaDia device now exist that allow veterinary practices to collect machine performance data and to work more closely with engineers regarding any possible areas of concern (*Figure 11*). LS

Conflict of interest: James Allcock is a veterinary surgeon and an independent advisor in milk quality matters. He is not employed by any company mentioned in this text and has no affiliations with any of the authors referred to. Epi Postma is employed by Biocontrol of Norway, the makers of the VaDia vacuum recording instrument.

A video explaining more about the the VaDia device can be viewed here: http://www.youtube.com/watch?v=w9_pkn_Tv18

KEY POINTS

- Milking time tests now provide objective data on the contribution of the milking machine to milk quality problems.
- Vacuum measurements at the cluster help provide information on liner sizing and milk flow during cluster attachment.
- Over-pressure measurements can be used to help manage hyperkeratosis issues.
- Modern instrumentation makes data collection simple and flexible.
- Effective milking machine function is an important part of milk quality management

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Glossary

- Long milk tube: the tube running from the cluster to the jar or milk meter
- Short pulse tubes: the narrow tubing that connects the chamber surrounding the liner but within the rigid teat cup with the part of the claw that distributes the pulsation vacuum
- Shell: the rigid metal or plastic part of the teat cup
- Teat cup: the rigid assembly comprising the shell and liner that is attached to the cow
- Air bleed: the small hole, typically between 0.8 mm and 1.2 mm that admits air into the claw
- Claw: the centre part of the cluster that has the four teat cups attached to it and the long pulse and milk tubes attached
- Mouthpiece: the open end of the liner
- System vacuum: the operating vacuum level governed by the plant regulator.