Comparison of Liner Action with Pulsation Performance

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Abstract
The method of milking an animal with a machine relies on the pressure difference between the udder and the vacuum applied to the teat. The application of a vacuum to the teat can create undesired problems if the teat is not periodically rested in a proper manner. It is the intent of the liner opening and closing through the action of the pulsator that the resting is provided. This research has determined that the design of the pulsator plays a significant role in how the liner opens and closes to provide the desired proper resting of the teat.

Introduction

Modern conventional milking machine pulsation design has remained relatively unchanged since the 1960s. The typical pulsator has a movable plunger or diaphragm that moves up and down to open and close ports connected to either vacuum or fresh air. Providing vacuum to the teat cup pulsation chamber (shell) opens the liner exposing the teat to the milking vacuum resulting in the flow of milk. A connection to fresh air closes the liner reducing the vacuum applied to the teat end. If the liner were to remain continuously open the teat would swell significantly as a result of the constant vacuum applied to the teat. The result would be increased pain and greatly diminished milk yield.

Prior research has proven that conventional milking machines cause teat swelling and teat canal damage even with the pulsating liner action. Research[1] at Teagasc documented that teats are typically swollen by up to a few millimeters after the machine is removed when compared to their size prior to machine attachment. Additional research[2] at Teagasc also documented physical damage to teat canals referred to as teat sinus injury. Others have determined that conventional machine-milking removes more keratin from the teat canal than hand milking or calf suckling, yet calf sucking causes a much higher differential pressure across the teat canal than does machine milking.

This research compared the liner action achieved by a conventional milking machine to that provided by the CoPulsation™ Milking System (CMS). The CoPulsation™ Milking System pulsator design is unique in that it has two synchronized solenoids with one controlling the admission of vacuum into the shell and the other controlling the fresh air. This design prevents the mixing of air and vacuum sources during the transition between milk and rest phases and also eliminates any internal pulsator restriction to fresh air flow enabling a much higher flow rate into the shell. The result is a change in liner dynamics that improves the environment of the teat during the true massaging rest phase.

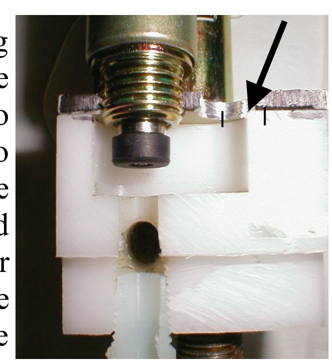


Figure 1: CoPulsation™ pulsator fresh air section

Material and Methods

This study evaluated the physical condition and dimensions of various liners from different conventional pulsation systems at the end of their useful life and compared them to a liner used with the CoPulsation^{tm} Milking System. Each of the liners selected for this study was one specifically designed to be used by the conventional milking system it was used with. This ensured that all parts of the conventional milking machine satisfied the individual manufacturer's specifications. The liners were removed from use after the manufacturer's recommended service life.

Results

The shape and diameter of the each of the conventional pulsation liners was evaluated following removal of the liner from service. It was noted that the shape and dimensions of the conventional liners in the area of the mouthpiece exhibited signs of wear. The mouthpiece area was no longer perfectly round and was distorted/stretched from the many times that a teat was engaged with the teat. This condition was a typical result of liner wear and to be expected as the mouthpiece must form an air-tight seal around the teat during milking. The section of the liner that envelopes the teat during the milking process was also evaluated. That section had the same basic dimensions and shape at the end of service as a new liner. The interior of the conventional liners showed no specific evidence of liner action from the opening and closing events of the milking process.

The liner used with the CoPulsation^{tm} Milking System was evaluated in the same manner. The mouthpiece area was no longer perfectly round and was distorted/stretched. An inspection of the length of the liner which envelopes the teat during milking was significantly changed at the end of service condition. The specific section of the liner in the area of the teat was measurably larger in diameter from the enhanced liner action consisting of a fuller opening combined with a compressive full teat massage. The section below where the teat is inserted was unchanged in diameter and shape. An inspection of the interior of the liner revealed two distinct small sharp lines running the length of the liner located directly opposite one another.

The liner used with the CoPulsation^{tm} Milking System was also used for the full rated life life with a conventional milking machine to confirm the fact that it is the unique pulsation performance that is making the difference and not the liner. An inspection of CoPulsation^{tm} Milking System liners after use on a conventional milking machine reveals that the liner exhibits signs of wear in the area of the mouthpiece but not along the length of the liner. The resulting liner condition was effectively the same as that of all other liners used with conventional milking machines.

The photos below show examples of the various liners evaluated. The liners in Figure 2 are as follows: new/unused CoPulsation^{tm} (CMS) liner, CoPulsation^{tm} liner at end of life, sectioned CoPulsation^{tm} liner at end of life, three liners from different conventional milking machines at end of life. This photo clearly shows that the CoPulsation^{tm} Milking System provides a unique liner action that results in a distinct evidence of having interacted with the teat in a manner different than that provided by conventional milking machines. Figure 3 shows three CoPulsation^{tm} liners, the first is one at the end of life, the second is a section of one at the end of life and the third is one that was used in a conventional milking machine and is also at the end of life. The one used with the conventional pulsation does not show evidence of teat massage or full opening. The liner must open and close sufficiently to permit both milking and compressive massage. A liner that opens and closes in such a manner will experience a physical plastic deformation with repeated cycles.

Figure 2: CMS new, CMS end of life, CMS end of life section, three conventional at end of life

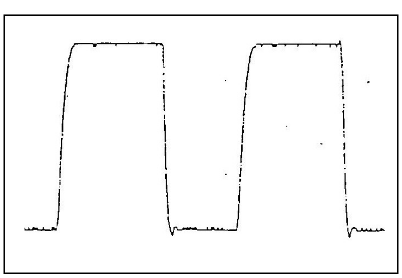
Figure 3: CMS end of life, CMS end of life sectioned, CMS end of life used with conventional pulsation

Evaluation of results

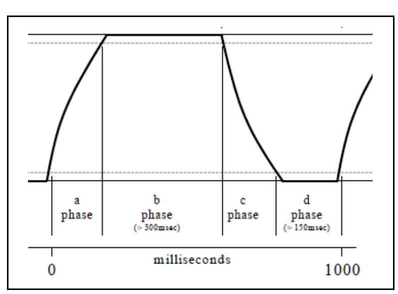
The comparison of conditions of liners used with conventional milking machines to those used with the CoPulsation™ Milking System provides visual evidence of a difference in liner action provided by pulsation. The evaluation has also proven that it is the functional performance of the CoPulsation™ Milking System pulsator that is responsible for this difference. This discovery led to a further evaluation of pulsator design and performance characteristics to understand the reason for the difference in liner wear.

The CoPulsation™ Milking System pulsator is a simultaneous pulsator but still has two solenoids that act in a synchronized manner. One solenoid controls the admission of vacuum to enable the liner to open for the milk phase. The other solenoid is dedicated to admission of the fresh air to permit the closure of the liner for the rest phase. This design provides for a significant reduction in air flow restrictions within the pulsator. The two solenoids are never open at the same time.

This design permits the use of a very large diameter fresh air inlet hole in the pulsator that is .5 inches in diameter as compared to conventional pulsators that are typically less than .15 inches in diameter. The design also eliminates the need for the fresh air to be forced between the solenoid plunger and coil wall. The fresh air solenoid plunger is offset from the fresh air inlet hole permitting fresh air to pass through the pulsator two to three times faster than through a conventional pulsator. Figure 3 provides a comparison of pulsator graphs measured at the shell. The typical CoPulsation™ C phase is 60 milliseconds in duration with conventional being 120 milliseconds to 160 milliseconds or more. The CoPulsation™ pulsation rate is 43 ppm compared to 60 ppm for typical conventional.



CoPulsation™ graph



Conventional pulsation

The CoPulsation^{tm} Milking System design features simply follow basic air flow dynamic design best practices to reduce the restriction to air flow. The importance of having a pulsator design that can deliver air flow into the shell two to three times faster is based on the minimal energy density that exists to provide movement of the liner. One must first consider the fact that a milking system operates at around 13inHg to 15inHg (~ 45KPa) which is equivalent to only about 7 psi. This low pressure differential provides for very little available force or energy to move a liner, especially in the area where the teat resides when milking a cow.

When the fresh air flow into the shell is at a low rate as is the case for conventional systems, the liner will close at the point of greatest available energy which is below the teat. As the liner begins to close the pressure inside the liner where the teat is located begins to rise. This is simple physics of the relationship between volume and pressure (P =K/V). The rising pressure decreases the available energy to close the liner and the liner simply stops closing around the teat resulting in the crushing or pinching of the teat as can be felt with ones finger in a working liner of a conventional machine.

The CoPulsation^{tm} Milking System changes the dynamics of the liner action by providing a fresh air flow into the shell that is sufficient to enable the liner to utilize the small available energy around the teat to allow the liner to actually close fully along the length of the teat. The liner also closes off fully below the teat and does not apply a crushing or pinching action. This unique liner action has several important facets. The first is that the liner provides a true compressive massage on the length of the teat, a fact physically felt with ones fingers. This compressive massage relieves the vacuum during the rest phase eliminating teat congestion by permitting proper blood flow. This action is similar to the benefits afforded by compression socks worn by individuals with poor circulation in their legs. This massage action results in teats that are smaller in diameter after milking as documented in a prior study[3].

Another facet is the ability to close off the liner below the teat. This allows the canal to be properly rested. A conventional system fails to relieve the canal of the milking vacuum resulting teat canal stress during the rest phase. The failure rest the teat canal contributes to canal damage and scar tissue formation that blocks the flow of milk causing slow milking quarters and mastitis. It also damages and destroys the primary defense mechanism of the teat to prevent bacterial invasions. The proper closure action achieved by CoPulsation^{tm} can be observed by placing a clear flat plate over the end of a working liner and shining a light into the cluster to observe the liner action. One can also watch a cow milking and see the full and complete cessation of milk flow during the rest phase, something that does not occur with a conventional system as it effectively over-milks the teat the full duration of milking.

The final facet is that the unique liner action combined with the simultaneous pulsation prevents the wetting of the teats during milking. This is a fact readily visually observed when the CoPulsation^{tm} Milking System machine is removed from the teats.

Conclusion

The design of a milking machine has a direct affect on the health of a teat and the resulting quality of milk produced by the animal. Conventional milking machines create an unfavorable environment in which the teat end is pinched/crushed during the rest phase causing pain, physical damage to the teat canal. This pinching forces the protective keratin from the canal and often leads to physical tearing of the canal lining creating scar tissue that blocks the flow of milk. There exist numerous independent studies that have documented the fact that conventional milking machines create an unhealthy environment for the teat. Individuals milking animals can easily observe the results of this damage and pain through the wetting of teats, creation of slow and uneven quarters, teat swelling and general kicking[4] of cows while milking.

There have been many advances in the past few decades introducing automation and methods of gathering data but there has been no effort put forth to improve the heart of the milking system that is directly responsible for milking the animal. The unique design of the CoPulsation[tm] Milking System provides the first evolution in basic pulsation design in decades and provides an environment for the teat that most closely matches that of the natural suckling of a calf.

Author

William Gehm is an engineer with a BS in Applied Physics and an MS is Electrical Engineering with 20 years or experience researching the effects of milking machines on milking performance. Mr. Gehm is the co-owner of numerous dairy equipment patents with Lanny Gehm, both of whom are partners in LR Gehm LLC.

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