

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 3, March 2018

Alternate Vacuum Generation Technology for Bucket Milking Machine

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ABSTRACT: The control of vacuum pressure within a milking unit is of utmost importance for the proper functioning of milking pulsators employed by the system. The vacuum regulation device is the primary emphasis in this paper but the regulation of the inlet parameters of the device is also studied to obtain the optimal vacuum. The entire setup is engineered around the 2 major factors namely, Cost effective (So that it can be employed on even small farms) Health of the cows (As we aim to provide the same milking quality as the current high end commercial milkers) For the latter factors we employed De-Laval's pulsator available with their BMS (2011 onwards) model and for cost effectiveness we tried to incorporate more common and recyclable components instead of highly specialised components which are used in high end products.

KEYWORDS: vacuum pressure, vacuum regulation, pulsator, cow health

I. INTRODUCTION

The milking machine is a nearly automatic machine installation for milking cows. It is not a single unit, but rather an assembly of components designed to handle as many as 200 cows an hour. The system consists of the cluster (the assembly that is manually attached to the cow), a milk tube, a pulse tube and pulsator, a vacuum pump or blower, and perhaps a recorder jar or milk meter that measures yield. The cluster consists of teatcups, a shell and liner device that actually performs the milking action, and a claw or manifold that spaces the teatcups and connects them to the milk and pulse tubes. The milk tube carries the milk and air mixture away from the cow's udder to receiving tanks. The pulse tube, or airline, carries the varying air pressure from the pulsator device to the tanks, drawing the milk and fluids out of the cows as well. In operation, milk is drawn from the cow's teats because a vacuum is created within the cup device, forcing the milk through the teat canal. The pulsator alternates the pressure, first creating a vacuum (milk phase), and then applying air, which causes the flexible liner in the cup to collapse and massage the teat (rest phase). The alternating process of milk-and-rest is continued in a rhythmic pattern for the cows' health and good milk productivity. The major aim of the project is to develop a flexible vacuum generation system for the milking machine. That purpose is to alter the vacuum between 100 to 500 mm hg vacuum so that the milking can be done on a healthy standard depending on the cow and therefore obtain flexibility for the milking.

II. LITERATURE REVIEW

This brief history of vacuum regulation is taken from the well researched and entertaining works by Hall (1959 and 1977) and Dodd and Hall (1992). Milking machines were first introduced in the late 1800's. It is presumed that the vacuum was set by trial and error to arrive at a vacuum level that worked reasonably well.

The first successful commercial milking machine the, Murchland machine, illustrated here, came on to the English the market in 1889. This machine used vacuum rather than pressure developed by mechanically squeezing teats and won

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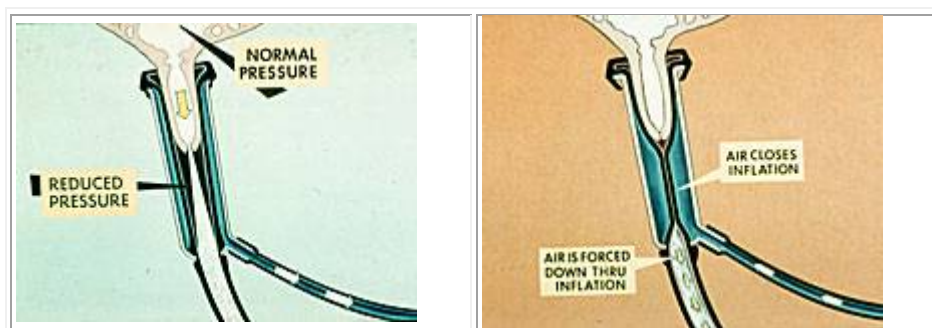
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the Royal Agricultural Society of England (RASE) prize that year. The vacuum applied to the teat was continuous and the teat cups were specifically designed to keep the teat surrounded with milk. This machine, developed by a plumber, used a hand operated vacuum pump to maintain a vacuum of 37 kPa (11"Hg) using a water column as the regulation device. This vacuum control strategy has a great deal of merit in that there are no moving parts. Dodd and Hall (1992) introduced an interesting sociological note in that the advertising for this machine states that the machine could be "powered" by one boy while the skilled task of operating two or three units each should be entrusted to up to three girls. The teat end vacuum in this machine was probably comparable to machines of today. A water column is an accurate and effective way to control vacuum and the bucket arrangement would have eliminated the major source of vacuum changes, those introduced by a long milk tube. The next machine to win the RASE prize was the Nicholson and Gray machine in 1891. This machine used a nominal vacuum level of 45 kPa (15 "Hg). Thus began the pendulum swing of recommended milking vacuum over this same range that has continued until today. The method of vacuum regulation in the milking machines used in the early 1900's is not well documented but weighted or spring devices were probably the main control technologies.

III. OPERATION OF MILKING MACHINE

The milking system is divided into the milking side and the pulsator side. When the system is turned on, vacuum is created everywhere by a vacuum pump that removes air from the system. When the cows are not attached to the milking system, the vacuum created will be the same on both the milking side and the pulsator side of the system. When the cows are attached to the milking system by the milking claws, milk and vacuum are present on the milking side. This will cause the vacuum on the milking side of the system to be somewhat lower than the vacuum on the pulsator side. The pulsator side will never have milk, only vacuum or air.

The easiest way to understand the milking system is to look at the action taking place at the teat cup level. There are 4 teat cups with liners attached to the milking claw. The area between the liner and the claw is part of the pulsator side of the system. The area between the teat and the liner is on the milking side of the system. The pulsators are devices that sit on top of the pulsator lines on the pulsator side of the system. They alternately expose the area between the liner and the shell to air and vacuum. When exposed to vacuum, the liner is pulled open around the teat and milk flows. Milk flows because the teat is exposed to vacuum. When exposed to air, the liner collapses around the teat, and the teat is not exposed to the vacuum on the milking side of the system, so milk ceases to flow and the teat rests. This is how the cow is milked. This pulsator action generally takes place around 60 times a minute.



VACUUM GENERATION METHOD IN CONVENTIONAL MACHINE:

The compressor removes air and creates the vacuum. The vacuum is measured by the amount of cubic feet per minute of air the compressor can be remove at 15" Hg. Most compressors are rotary oil sealed compressors. Air is drawn in through the inlet port by the rotation of the rotor, compressed and ejected to atmosphere. The vacuum regulator admits atmospheric air in and out of the system to keep the vacuum at a predetermined set level. If the vacuum gets too high,

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the vacuum regulator will open and let air into the system to lower the vacuum. A preset force holds the valve closed until vacuum lifts it and allows air to enter. Valve should maintain vacuum to within the limits of $\pm kPa$ of the designed working vacuum.

IV. VACUUM GENERATION METHOD UTILIZED

A converging diverging venture passage was utilized to generate vacuum in the canister ,which was then transmitted through out the milk line. This principle is known as ejector principle. The advantage of using an ejector is that varying the inlet pressure will change the vacuum generated at the nozzle constriction. The vacuum generator which has been used in the project is fabricated by the FESTO COMPANY (GERMAN MAKE), and the product description is given by the name VAD (1/4). All Festo vacuum generators have a single-stage design and operate according to the venturi principle.



Fig: VAD (1/4)

The VAD model had an inlet port ,a vacuum port at the nozzle constriction and a exit or silencer port. The compressed air from the compressor ,stored in a reservoir was allowed to pass through the inlet port of the vacuum generator. The vacuum port of the VAD was connected to the canister. The generated vacuum gets stored in the canister. A non return valve (NRV) was used after the vacuum generator to ensure one directional flow and was usefull in ontrolling the vacuum. The vacuum gauge attached to the canister would give the level of vacuum generated in the milk line and vacuum tube. When the desired value of pressure is reached the compressor line is cutoff manually and milking is continued for the required period.

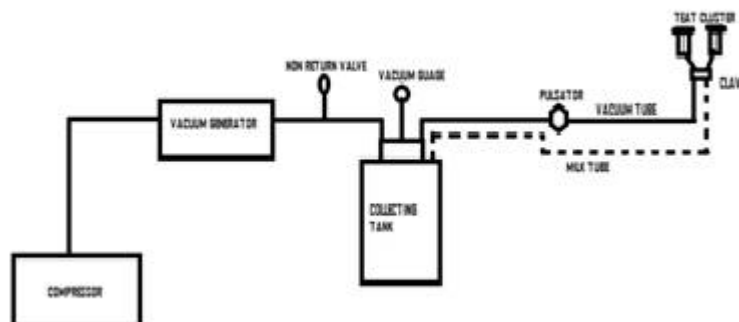


Fig: Schematics of the setup

The above line diagram describes how the flow takes place and how vacuum is generated.

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V. EXPERIMENTATION

The main objective of the experiment is to demonstrate the vacuum pressure obtained at the steady state and the variation of the mass flow rate of the fluid (i.e. milk) with the inlet pressure of the venturimeter.

The apparatus consists of the following components:

1. A vacuum generator (VAD ¼ TYPE)
2. A compressor
3. Collecting tank i.e. canister
4. Teat cups
5. Non return valve (NRV)
6. Vacuum gauge
7. Hoses, for both suction and the milk line

DEMONSTRATION SETUP

The compressor is turned ON and allowed to run until the steady state of 7 bar is obtained. The pressure regulating valve is subsequently adjusted to obtain a constant inlet pressure for the vacuum generator. This setup is allowed to run until the steady state vacuum is obtained at the canister as shown by the vacuum gauge. Once the steady state vacuum is obtained, the teat cluster is lowered into a bucket full of water and the volume of water transferred in a time of 20 sec is measured using a measuring jar. From this we obtained the steady state vacuum pressure generated and the mass flow rate obtained at the inlet pressure for the vacuum generator. The observations are made for different values of inlet pressure.

VI. TABULATION AND CALCULATION

SL NO.	INTLET PRESSURE (bar)	SUCTION PRESSURE (VACUUM) (mm of Hg)	VOLUME OF FLUID SUCKED (m ³)	TIME TAKEN TO SUCK (sec)	VOLUME FLOW RATE (m ³ /sec)	MASS FLOW RATE (kg/sec)
1.	6	445.5 (-0.58 bar)	2.70×10^{-3}	20.36	1.3×10^{-4}	0.13
2.	4	350 (-0.46 bar)	2.37×10^{-3}	20.20	1.17×10^{-4}	0.117
3.	2	165 (-0.21 bar)	1.71×10^{-3}	20.19	0.84×10^{-4}	0.084

READING NO. 1:

$$\begin{aligned} \text{VOLUME FLOW RATE} &= \text{VOLUME SUCKED} / \text{TIME TAKEN} \\ &= 2.70 \times 10^{-3} / 20.36 = \mathbf{1.3 \times 10^{-4} \text{ m}^3/\text{sec}.} \end{aligned}$$

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$$\begin{aligned}\text{MASS FLOW RATE} &= \text{VOLUME FLOW RATE} * \text{DENSITY OF WATER} \\ &= 1.3 * 10^{-4} * 1000 = \mathbf{0.13 \text{ kg/sec.}}\end{aligned}$$

RESULT

The result of the experiment has been derived from the tabulation and the calculation of various parameters and the following points can be derived:

1. The value of the vacuum pressure (-ve pressure) is increasing with the increasing inlet pressure value to the venturimeter.
2. The mass flow rate of the fluid is decreasing with the decreasing suction pressure (vacuum pressure).

The following graphs based on the various parameters have been plotted:

1. Suction pressure vs Inlet pressure of ejector

2. Mass flow rate vs Suction pressure

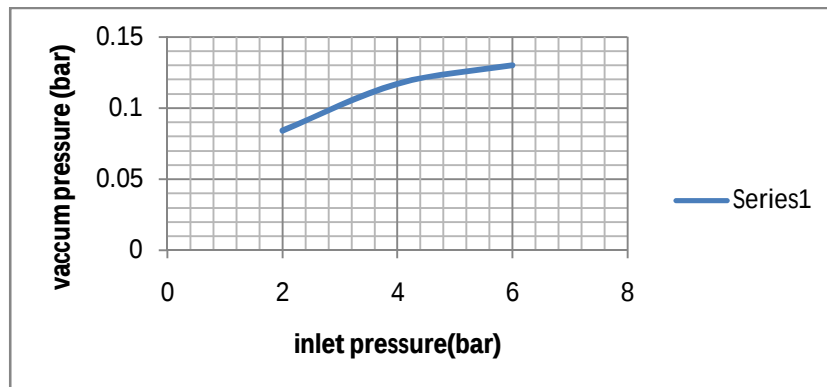


Fig: vacuum pressure vs inlet pressure

The above figure shows how the inlet generated vacuum varies with inlet pressure. Increasing the inlet pressure increases the vacuum generated and this is exactly depicting the flexibility with which one can use the milking machine. The optimum vacuum for each cow can be identified by the farmer and applied accordingly rather than high end vacuum which destroys the health of the cow.

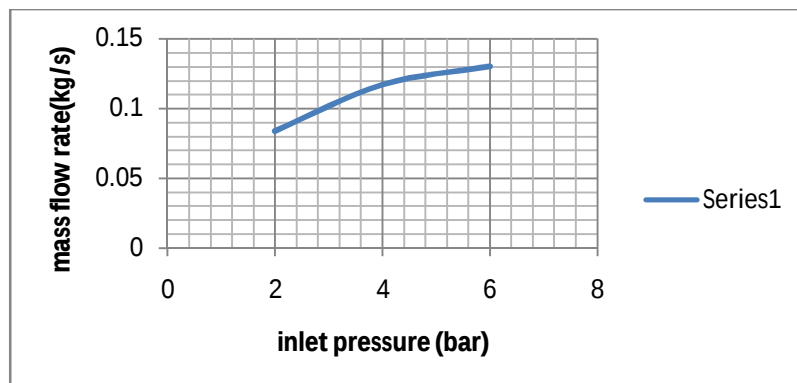


Fig: mass flow rate vs inlet pressure

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A storage tank mimicking the cow's milk chamber was made and the water flow rate was measured. The water flow rate increases with the inlet compressor pressure. This is because the vacuum generated increases with the inlet pressure. This is conclusive of the fact that the mass flow rate of the milk would increase with increasing inlet pressure.

VII. CONCLUSION

The applied method of vacuum generation and milking was found effective and provide with high flexibility for farmers. The cow's health being a major criterion was ensured. This method is also cost effective in a lot of ways. The cost of the ejector is only in the range of Rs.1000 and the entire milking set is available for less than Rs 5000. But the market value of these machines are Rs 40,000. So it is important to study and develop on the existing machines to make it as safe and cost effective as possible for the farmers.

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