Milk Pump: Types, Construction, Maintenance and Use

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Abstract
A simple portable piece of equipment applied for transferring raw milk, process milk or any other fluids to process plant. Pumps are used in a wide range of industrial and residential applications. In our Dairy Industry, pumps have various applications. Dairies utilise milk pumps for the transport of milk or cream. Also in the production of yoghurt or ice cream, milk pumps are integrated into the production process. Centrifugal, liquid-ring and positive displacement pumps are significantly used in dairy industry. Now a day's pump having unique impeller design that gives high performance efficient pumping with the range of speed and having number of advantages related to reduced cost level as well as noise and give gentle conveying of milk.

1. Introduction

A pump is a device used to move fluids, such as liquids, gases or slurries. Pumping is the process of addition of kinetic and potential energy to a liquid for the purpose of moving it from one point to another.In process operations, liquids and their movement and transfer from place to place, plays a large part in the process. The flow of liquid is also affected by friction, pipe size, liquid viscosity and the bends and fittings in the piping.

To overcome flow problems, and to move liquids from place to place, against a higher pressure or to a higher elevation, energy must be added to the liquid. To add the required energy to liquids, we use ' PUMPS '. A pump therefore is defined as ' A machine used to add energy to a liquid. Pumps are used in a wide range of industrial and residential applications. Pumping equipment is extremely diverse, varying in type, size, and materials of construction. Many components in high-speed machinery require constant lubrication by special pumps to keep them working.

There are many types of pumps that can be used. The different types of pumps can be classified in two broad categories — positive displacement pumps and dynamic pumps or non-positive displacement pump. Positive displacement pumps will normally produce a low, consistent flow rate at sometimes very high pressures. The volume of the fluid delivered is independent of the discharge pressure.

The volume of the fluid delivered is independent of the discharge pressure. Dynamic pumps usually give high flow rates at relatively low pressures, and the discharge pressure directly affects the volume of delivered fluid.

2. Classification of Pump

Types of Pumps

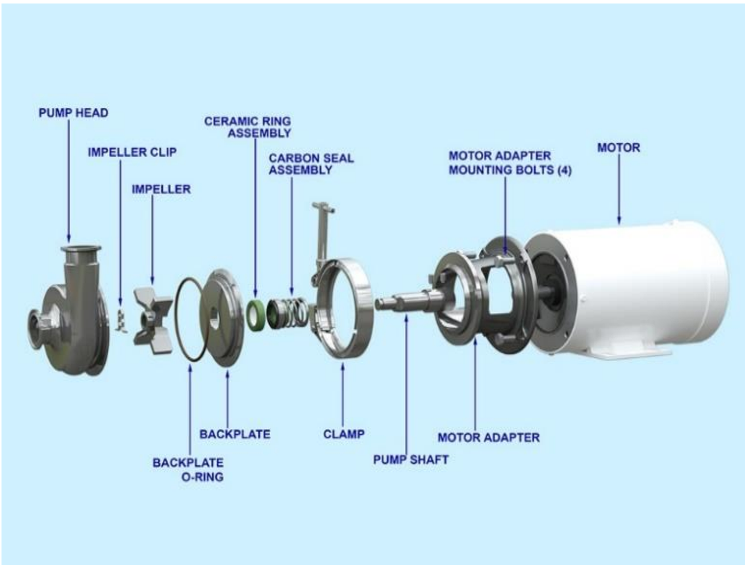
2.1. Positive displacement
 2.1.1 Reciprocating type
  2.1.1.1 Plunger
  2.1.1.2 Diaphragm
  2.1.1.3 Piston
 2.1.2 Rotary
  2.1.2.1 Gear
  2.1.2.2 Screw
  2.1.2.3 Lobe
  2.1.2.4 Vane

2.2. Non-positive displacement
 2.2.1 Centrifugal
  2.2.1.1 Impeller
   2.1.1.1 Open
   2.1.1.2 Semi-open
   2.1.1.3 Closed
  2.2.1.2 suction
   2.1.2.1 Single
   2.1.2.2 Double
  2.2.1.3 Stage
   2. 2.1.3.1 Single
   2. 2.1.3.2 Multi
  2.2.1.4 Head
   2.2.1.4.1 Low
   2.2.1.4.2 Medium

To transport fluid, it is essential that enough energy be added to overcome frictional losses. Many factors are considered when the size and type of pump are selected:

1. The pressure required (pressure head)
2. Volumetric flow rate (velocity head)
3. Properties of the fluid handled
   a. Density
   b. Viscosity
   c. Oxidation sensitivity
   d. Abrasiveness
   e. Flow properties (Newtonian or non-Newtonian)
   f. Foaming
   g. Shear damage
4. Temperature of the fluid and the vapor pressure
5. Operational considerations, such as intermittent or continued use

Typical dairy pumps are the centrifugal, liquid-ring and positive displacement pumps. The three types have different applications. The



centrifugal pump is the type most widely used in dairies.

Fig. 1: Essential parts of Centrifugal pump

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3. Centrifugal Pumps

The word, 'Centrifugal' is derived from the Latin language and is formed from two words 'Centri' meaning 'Centre' and 'Fugal' meaning 'To Fly Away from'. Centrifugal - 'To Fly Away from the centre'. This is the force developed due to the rotation of a body - solid, liquid or gas. The force of rotation causes a body, or a fluid, to move away from the center of rotation. A centrifugal pump is known to be a "pressure generator" vs. a "flow generator".

3.1 Parts of Centrifugal Pump

A centrifugal pump is built up of two main parts:
1. The Rotor (or Rotating Element).
2. The Casing (or Housing or Body).

3.1 The Rotor

One of the greatest advantages of a centrifugal pump is that it has very few moving parts which minimizes mechanical problems and energy losses due to friction. Other than the bearings, (and of course the driver), the only moving part in a centrifugal pump is the Rotor.
The Rotor (Rotating Element), is made up of the following main components:
1. The Impeller(S) -Often called the 'Wheel(s)'. (In the centre of an impeller, is the 'eye' which receives the inlet flow of liquid into the 'Vanes' of the impeller).
2. The Shaft -The impeller(s) is/are mounted on the shaft and enclosed by a casing.

3.1.2. The Impellers

These consist of wheel shaped elements containing 'Curved Vanes' at the centre of which is the liquid inlet called the 'EYE' of the impeller. The wheel(s) is/are mounted on the shaft, (together called 'the Rotating Element' which is rotated at high speed. There are various types of impeller depending on the duty to be performed by the pump.
1. The Open Impeller: This type consists of vanes attached to a central hub with no side wall or 'shroud'. It is used for pumping highly contaminated slurry type liquids.
2. Semi-Open Impeller: This type has the vanes attached to a wall or shroud on one side. It is used mainly for lightly contaminated and abrasive liquids and slurries.
3. Closed Impeller: This impeller has the vanes enclosed on both sides by a shroud and is the most efficient impeller, used for clean or very slightly contaminated liquids.

3.1.3. The Shaft

The Impeller(s) are mounted on this part of the pump which is then referred to as the 'Rotor' or rotating element which is coupled (connected) to the pump driver. The driver imparts the rotation to the rotor that is housed in the casing, supported by the bearings.
This is the stationary part of the pump and includes the:
1. Suction Nozzle(s) (or Port(s)).
2. Discharge Nozzle (or Port).
3. Bearings.
4. Seals.
Briefly, the purpose of bearings is to support the weight of the rotor and to minimize radial and axial movement and therefore, vibration. Seals are used to prevent leakage of fluid to atmosphere and/or between the stages of a multi-stage machine.

3.1.4 Prime Movers

The prime movers for pumps are the devices used to drive them - whether they are rotating machines or otherwise. The types of prime mover used for modern pumps are: Electric Motor. Diesel (or petrol) engine. Gas Turbine.

3.2 Characteristics of Centrifugal Pump

Centrifugal pumps are specified by four characteristics.

3.2.1. Capacity

This is defined as the quantity of liquid which is discharged from the pump in a given time. Capacity is expressed in 'm^3/hr.', 'gal/min', etc. The capacity of a pump is governed by the 'Head', the 'Speed' and the 'Size' of the pump.

3.2.2. Total Head

The total head of a pump is the difference between the pump suction and discharge pressures expressed in terms of meters or feet head:

3.2.2.1 Suction Head

This is the vertical distance, in feet or meters, from the centerline of the pump to the level of liquid in the vessel from which the liquid is being pumped. If the liquid level is above the pump centerline, the suction head is positive. If below the centerline, the suction head is negative.

3.2.2.2 Discharge Head

Is the discharge pressure of the pump, expressed in feet or meters of liquid?

3.2.2.3Total Head

Discharge head -Suction head

3.2.3. Power

This is the energy used by the pump in a given time. Its unit is 'Horsepower' (HP). 1 HP is equivalent to 0.746 kilowatt. (kW).

3.2.4. Efficiency

This is a percentage measure of the pump's effectiveness in transferring the power used into energy added to the pumped liquid.
The formula for calculation of efficiency is:
Efficiency = (Output power)/ (Input power) X 100%
Pumps in industry, usually operate at 70% to 80% efficiency.

3.2.5 Net Positive Suction Head Required

The pump manufacturer's specified margin of suction pressure above the boiling point of the liquid being pumped, is required to prevent cavitation. This pressure is called the 'Net Positive Suction Head' pressure (NPSH).

3.3 The Valve of Centrifugal Pump

1. Suction Valve: Allows liquid to enter the pump.
2. Discharge Valve: Allows liquid to flow from the pump to other parts of the system.
3. Check or Non-Return Valve: In the discharge line -Prevents back-flow from discharge to suction through the pump.
4. Vent (priming) Valve: This is used to vent off air/gases from the pump before start-up.
5. Gauge Isolation Valves: Allows the replacement of pressure gauges on suction and discharge lines, the most important being the discharge pressure.
6. Gland Seal Valve: (where fitted). Controls the flow of cooling media to the pump gland cooling fluid.
7. Recycle Valve: This is a flow line valve which is used to recycle pumped liquid back to the suction side or to the suction vessel, in order to maintain a flow through the pump when the discharge valve, (and/or FCV), is closed. (Prevents heat build-up).
8. Drain Valve: Fitted on the bottom of the pump casing and used to drain the pump prior to maintenance work being done.

3.4 Centrifugal Pump Operation

3.4.1 Pump Start-up Procedure

1. Line up the pump valves.
2. Ensure that the drain valve is closed.
3. Open the suction valve.
4. Open the vent valve to bleed off gases - when liquid comes from the vent valve - close it again. (This is called 'Priming the pump').
5. Open the gland-seal valve (if fitted).
6. Commission the bearing and oil cooling systems (if fitted).
7. if an oil bottle or 'slinger-ring' reservoir is used for the bearings, ensure it is full and functioning properly.
8. Check by hand that the pump shaft is freely rotating - (power is OFF at this point).
9. Energies or, if the rule applies, have the electrician energies, the power supply.
10. The discharge valve, at this point, should still be closed.
11. Start the pump motor. Check that the pump is rotating in the correct direction.
12. Check that the discharge pressure is steady - if not check at the vent and release any further trapped gas.
13. Check for vibration, overheating and/or any undue noise from the pump, bearings or coupling.

14. Re-check the lube and cooling systems and check for leaks at the pump glands. (With the 'packed' type gland seal, a slight leakage is desirable for lubrication and cooling of the gland).
15. Open the discharge valve.
16. Report to control room that the pump is in operation and all is O.K. (If not O.K. -shut down the pump and have the control room operator call a maintenance mechanic).

3.4.2 Pump Shut-down Procedure

1. Close the discharge valve.
2. Press the stop button.
3. Leave the suction open unless the shut-down is for maintenance. This will prevent pressure build up due to temperature increase on hot days.

3.5 Centrifugal Pump Applications

The centrifugal pump is the most commonly used pump in the dairy industry it's because of a centrifugal pump is usually cheaper to purchase, operate and maintain, High efficiency, Low power consumption, Low noise level, Low NPSH requirement is also the most adaptable pump for different operating conditions. The centrifugal pump can be used for pumping of all liquids of relatively low viscosity which do not require particularly gentle treatment. It can also be used for liquids containing relatively large particles, provided of course that the particle size does not exceed the dimensions of the impeller channel.

A disadvantage of the centrifugal pump is that it cannot pump aerated liquids; it "loses prime" and stops pumping. It must then be stopped and primed – filled with liquid – and started again before it can continue pumping. Consequently, the centrifugal pump is not self-priming and the suction line and pump casing must be filled with liquid before it can operate. The installation should therefore be carefully planned.

4. Positive Displacement Pump

A positive displacement pump causes a fluid to move by trapping a fixed amount of it then forcing (displacing) that trapped volume into the discharge pipe. Positive displacement pumps, unlike centrifugal or roto-dynamic pumps, will produce the same flow at a given speed (RPM) no matter what the discharge pressure. Thus, positive displacement pumps are "constant flow machines".

A positive displacement pump must not be operated against a closed valve on the discharge side of the pump, because it has no shut-off head like centrifugal pumps. A positive displacement pump operating against a closed discharge valve will continue to produce flow and the pressure in the discharge line will increase, until the line bursts or the pump is severely damaged, or both.

A relief or safety valve on the discharge side of the positive displacement pump is therefore necessary. The relief valve can be internal or external. The pump manufacturer normally has the option to supply internal relief or safety valves. The internal valve should in general only be used as a safety precaution, an external relief valve installed in the discharge line with a return line back to the suction line or supply tank is recommended.

4.1Types of Positive Displacement Pump

A. Rotary pumps
B. Reciprocating pumps

4.1.1. Rotary pumps

Rotary-type, Internal gear pump, vane or sliding vane pump, Lobe rotary pump, Screw pump and Peristaltic pump.Positive displacement rotary pumps are that move fluid using the principles of rotation. The vacuum created by the rotation of the pump captures and draws in the liquid. Rotary pumps are very efficient because they naturally remove air from the lines, eliminating the need to bleed the air from the lines manually.

4.1.2 Gear Pump

There are two basic types of gear pumps: external and internal. External gear pumps usually have two gears with an equal number of teeth on the outside of each gear. Internal gear pumps have one larger gear with the teeth turned inward, meshing with a smaller gear with external teeth. Designed for low pressure at low speed.

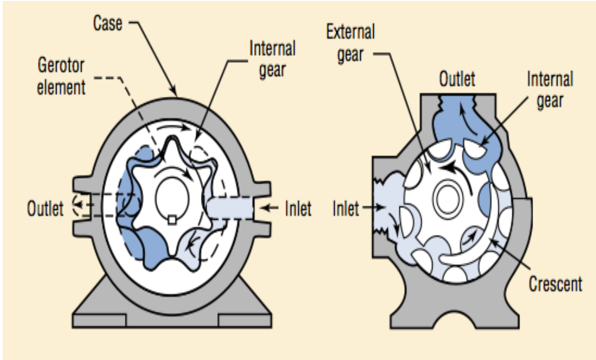

Fig. 2 Gear pump

These pumps are simple to assemble and repair, with little training, and, when applied appropriately, can do the job well and inexpensively.

4.1.3 Lobe Rotor Pump

Rotary Lobe Pumps are self-priming, valve less, positive displacement pumps. The even rotation of the rotor pair

Fig 3. Lobe Rotor Pump

creates a vacuum on the priming side of the pump, which can be defined by the direction of rotation of the drive. This vacuum draws the liquid into the pump chamber. With further rotation, the pumped medium is conveyed past the pump wall into the pressure area. Up to six chamber charges are displaced with each drive rotation–depending on the rotor type. When the rotor is at a standstill, the pump seals off almost completely.

4.1.4 Vane Pump

A rotary vane pump is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside of a cavity. In some cases, these vanes can be variable length and/or tensioned to maintain contact with the walls as the pump rotates.

4.1.5 Screw Pump

A screw pump is a type of positive displacement pump that uses two or more screws that intermesh to pressurize fluids and move them in a system. The screws take in fluid then push it out from the other side while increasing its pressure.

4.1.6 Peristaltic Pump

This is the simplest form of positive displacement pumps with wide applicability. A flexible tube is laid in the curved track of the pump. The central rotor can have two or more rollers set at the periphery. As the rotor turns, the advancing roller progressively squeezes the tube driving the fluid before it. The portion of the tube behind the roller returns to its normal shape, thus creating low pressure to draw more fluid into the tube, which will be driven forward by the following roller. These pumps are used in small-scale operations where capacities up to 10 to 12 m^3/h and relatively low pressures of up to 200 kPa are required. The durability of the tube is a problem, and special reinforced elastomers offering high chemical resistance at elevated temperatures are used. There is an industrial design that can achieve heads of 1 to 1.5 MPa and flowrates up to 75 m^3/h. The pumping action is gentle, and large pieces of solids can be handled in the pumps

4.1.7 Advantages of Rotary Pump

1) They can deliver liquid to high pressures.

2) Self - priming.
3) Give a relatively smooth output, (especially at high speed).
4) Positive Acting.
5) Can pump viscous liquids.

4.1.8 Disadvantages of Rotary Pump

1) More expensive than centrifugal pumps.
2) Should not be used for fluids containing suspended solids. Excessive wear if not pumping viscous material.
3) Must never be used with the discharge closed.

4.2. Reciprocating Pumps

To 'Reciprocate' means 'To Move Backwards and Forwards'. Mainly two types of reciprocating pumps are used in dairy industry:

1) Piston pump
2) Diaphragm pump

4.2.1 Piston Pump

A piston pump consists of a piston which reciprocates in a cylinder, figure 6.7.15. Inlet and outlet valves control the flow so that it flows in the right direction. Piston pumps in dairies are mainly used as metering pumps. A homogenizer is also a type of piston pump.

4.2.2 Diaphragm Pump

Air Operated Double Diaphragm (AODD) pumps are suitable for a host of applications in the dairy industry, including raw materials transfer, drum emptying, recirculation, filling machines, mixing and dosing, processing and sampling. They will readily handle viscous liquids as well as fluids containing soft and hard solids such as fruit puree containing seeds and pips. This versatility makes them well suited to pumping many different fluids such as:

- Yogurts, including various flavorings
- Creamed cottage cheese
- Cream
- Ice cream mix, syrups and toppings, chocolate coatings
- Margarine and fats

4.2.3 Advantages of Reciprocating pump

1) Gives high pressure at outlet.
2) Gives high suction lift.
3) Priming is not required in this pump.
4) They are used for air also.

4.2.4 Disadvantages of the reciprocating pump

1) High wear and tear, so requires a lot maintenance.
2) The flow is not uniform, so we have to fit a bottle at both ends.
3) The flow is very less and cannot be used for high flow operations.
4) More heavy and bulky in shape.
5) Initial cost is much more in this pump.

5. Liquid-ring pump

A liquid-ring pump is a rotating positive-displacement pump. They are typically used as a vacuum pump, but can also be used as a gas compressor. The function of a liquid-ring pump is similar to a rotary vane pump, with the difference being that the vanes are an integral part of the rotor and churn a rotating ring of liquid to form the compression-chamber seal. They are an inherently low-friction design, with the rotor being the only moving part. Sliding friction is limited to the shaft seals. Liquid-ring pumps are typically powered by an induction motor.

5.1 Description of Operation

The liquid-ring pump compresses gas by rotating a vaned impeller located eccentrically within a cylindrical casing. Liquid (usually water) is fed into the pump and, by centrifugal acceleration, forms a moving cylindrical ring against the inside of the casing. This liquid ring creates a series of seals in the space between the impeller vanes, which form compression chambers. The eccentricity between the impeller's axis of rotation and the casing geometric axis results in a cyclic variation of the volume enclosed by the vanes and the ring.

Gas, often air, is drawn into the pump through an inlet port in the end of the casing. The gas is trapped in the compression chambers formed by the impeller vanes and the liquid ring. The reduction in volume caused by the impeller rotation compresses the gas, which reports to the discharge port in the end of the casing.

5.2 Application

Liquid-ring pumps for the dairy industry are used where the product contains large quantities of air or gas, and where centrifugal pumps therefore cannot be used. The clearances between impeller and casing are small, and this type of pump is therefore not suitable for handling abrasive products. A common application is as a CIP return pump for cleaning solution after a tank, as the CIP solution contains normally large amounts of air.

6 Conclusions

Maintenance of Dairy Pump should done as per schedule. Routine maintenance (Can be made during pump operation). Perform the following tasks whenever you perform routine maintenance:

- Clean bearing bracket from any oil if found.
- Check oil drain plug.
- Lubricate the bearings.
- Inspect suction and discharge flanges for any leak.
- Inspect pump casing for any unusual damage signs.
- Inspect the seal.
- If the pump is offline check the coupling and its shims for any damage.
- Make sure that the coupling guard s well tightened to pump base plate.
- Check that motor alignment bolts are all in place.

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