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Positive Displacement Pumps

by Ross Mackay

POSITIVE DISPLACEMENT PUMPS

In the many differences that exist between centrifugal and positive displacement pumps, one which has caused some confusion has been the manner in which they each operate within the system.

Positive displacement pumps operate with a series of working cycles where each cycle encloses a certain volume of fluid and moves it mechanically through the pump into the system. Depending on the type of pump and the liquid being handled, this happens with little influence from the back pressure on the pump.

While the maximum pressure developed is limited only by the mechanical strength of the pump and system and the driving power available, the effect of that pressure can be controlled by a pressure relief or safety valve.

A major advantage of the P.D. pump is that it can deliver consistent capacities because the output is solely dependent on the basic design of the pump and the speed of it s driving mechanism. This means that, if the liquid is not moving through the system at the required flow rate, it can always be corrected by changing one or both of these factors.

Such is not the case with the centrifugal pump because that design can only react to the pressure demand of the system and, if the back pressure on the pump changes, so will the capacity of the pump. This can be disruptive for any process dependent on a specific flow rate and can also have significant ramifications on the stability, efficiency and reliability of the centrifugal pump.

To varying degrees, positive displacement pumps are suitable for handling highly viscous liquids. They are also self-priming and therefore have the ability to handle liquids with a certain volume of entrained air.

The Piston Pump

The oldest and best known positive displacement pump is the piston pump which uses a piston or plunger to force liquid from the inlet side to the outlet side of the pump.

As the piston moves upwards, it will reduce the pressure in the pump body which causes the pressure in the suction line to open the suction valve and permit the liquid to flow into the pump. In the same way, the higher pressure in the discharge line keeps the discharge valve closed. This is called the 'suction cycle'.

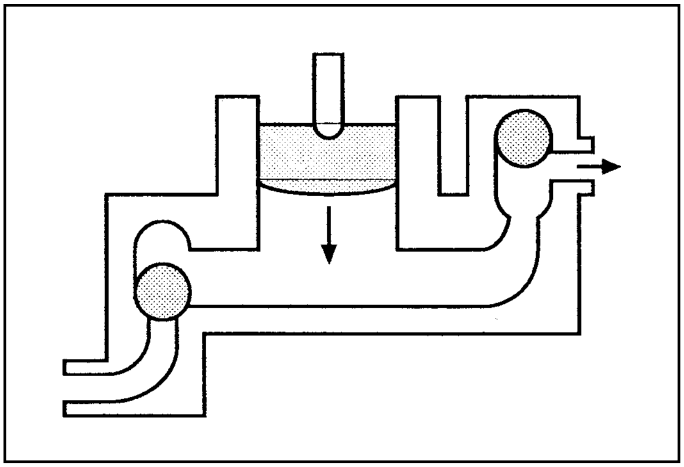

Fig. 1 - Piston Pump

When the plunger moves downwards, it increases the pressure in the body which closes the suction valve and opens the discharge valve to force the liquid out of the pump. This is called the 'discharge cycle'.

As the movement of the plunger inside the pump body creates pressure inside the pump, you must ensure that this kind of pump is never operated against a closed discharge valve. All discharge valves must be open before the pump is started, to prevent any fast build-up of pressure that could damage the pump or the system.

The Diaphragm Pump

A single diaphragm pump can be similar to the plunger pump except that the up and down motion causing movement of the liquid through the pump is created by a diaphragm instead of a plunger.

Larger models of this kind of pump are used to pump heavy sludges and debris-laden wastes from manholes and catch basins.

Smaller models of the same basic design are used as chemical metering or proportioning pumps where a very constant and specific amount of liquid is required.

The Air Operated Double Diaphragm Pump

A more common type of diaphragm pump is the air-operated double diaphragm pump which uses pressurized air to actuate the diaphragms instead of a mechanical device. This is basically two pumps in one where one is on the suction cycle while the other is on the discharge cycle. The air valves alternately pressurize the inside of one diaphragm chamber and exhaust air from the other one.

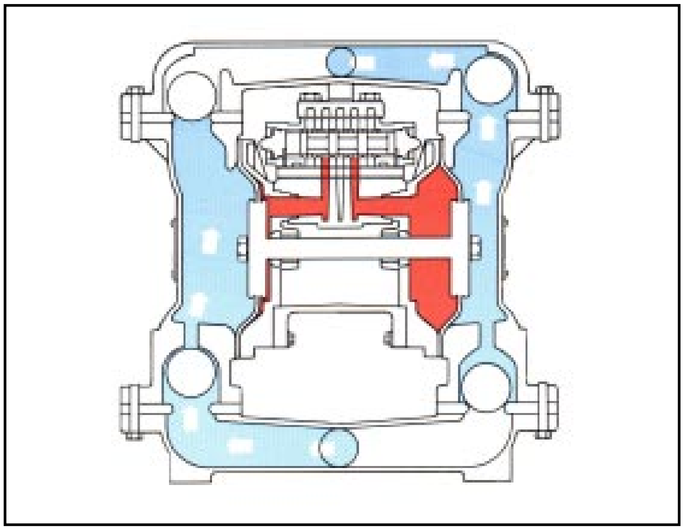

Fig. 2 Double Diaphragm Pump

The Rotary Gear Pump

The external rotary gear pump is a positive displacement pump where the unmeshing of the gears produces a partial vacuum to draw the liquid into the pump. The liquid is carried between the gear teeth and the casing to the opposite side of the pump. The meshing of the gears forces the liquid into the outlet line.

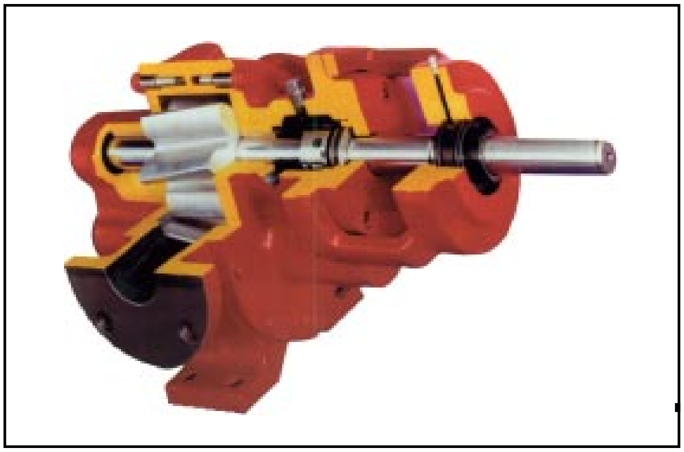

Fig. 3 Rotary Gear Pump

The direction of pump rotation determines which of the nozzles will be the inlet and the outlet. By reversing rotation, the function of the nozzles will be reversed and the pump will be able to pump 'backwards'.

Where one gear is driven by the other, the driven gear usually runs in sleeve type bearings. The bearings and shaft journal are located in the pump casing and surrounded by the pumped fluid. Consequently, these bearings and gears are dependent on the lubricating qualities of the pumped fluid.

The type shown in Fig. 3, is referred to as an 'External Gear Pump' and have all the gear rotors cut externally. On the 'Internal Gear Pump', one rotor with externally cut gears runs in the bore, and meshes with a second internally cut gear.

Other types are available where the gears have no metallic contact with each other. In such cases, both rotors are driven by synchronised gears separated from the pump chamber. As both shafts pass through the pump casing, two sets of seals are required. The absence of metallic contact between the surfaces of the rotors and the casing, means that wear on these parts is insignificant. The only wear that occurs is due to friction with the pumped fluid.

The Lobe Rotor Pump operates on exactly the same principles, except there are usually only two or three 'teeth' in each lobe. This arrangement permits the handling of larger solid particles and reduces the shear effect on the liquid.

Screw Pumps

Screw pumps are a special type of rotary positive displacement pump in which the flow through the pumping elements is truly axial. The liquid is carried between screw threads on two or more rotors and is displaced axially as the screws rotate and mesh.

Fig. 4 Screw Pump

The meshing of the threads on the rotors and the close fit of the surrounding housing create one or more sets of moving seals in series between pump inlet and outlet. These sets of seals act as a labyrinth and provide the screw pump with its positive pressure capability.

The successive sets of seals for fully enclosed cavities move continuously from inlet to outlet. These cavities trap liquid at the inlet and carry it along to the outlet, providing a smooth flow with minimal pulsations.

The Progressive Cavity Pump

This pump has been referred to as a single-end, single-rotor type of screw pump where the pumping elements comprise a single rotor and a stator.

The stator usually has a double helical internal thread with a pitch twice that of the single helical stator. This results in two leads on the stator, and one on the rotor.

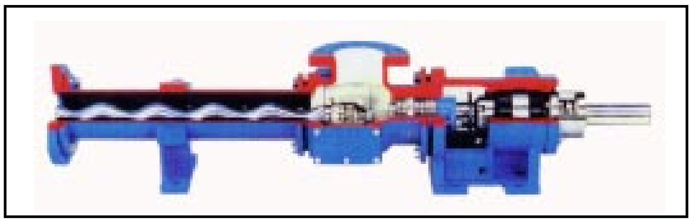

Fig.5 Progressive Cavity Pump

As the rotor rotates inside the stator, two cavities form at the suction end of the stator, with one cavity closing as the other opens. The cavitites progress from one end of the stator to the other.

The result is a flow with relatively little pulsation. Since the longest path through the elements is a spiral, and not far from a straight line, the shear rates will also be low in comparison to those in other types of pumps.

The compressive fit between the rotor and stator creates seal lines where the two components contact. The seal lines keep the cavitities separated as the cavitities progress through the pump with each rotation of the rotor.

The elastomeric stator and stainless steel rotor allow the pump to handle large solid particles in suspension and a certain percentage of abrasives.

The manner in which the rotor turns within the stator complicates the mechanical design of PC pumps. As the rotor turns in the stator, the centreline of the rotor orbits about the centreline of the stator. This eccentric motion means the pump must be fitted with universal joints to transmit power from the concentric rotation of the drive shaft to the eccentrically rotating rotor. These joints must transmit torsional and thrust loads.

Depending on the size of the pump, designs of this drive mechanism range from simple ball-and-pin mechanisms to heavy-duty sealed gear couplings.

Application

The most common applications of positive displacement pumps range from services where a very specific amount of liquid is required to be moved into a system, to the heavier duty services where the liquid is simply to viscous to be handled by a centrifugal pump.

Ross Mackay specializes in helping companies reduce pump operating and maintenance costs through his unique Mackay Pump School.

He is also the author of
"The Practical Pumping Handbook"
the most comprehensive book on pumping applications written for the 21st. century.

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