Pump ED 101

Positive Displacement Pumps

Part II – Rotary Pumps

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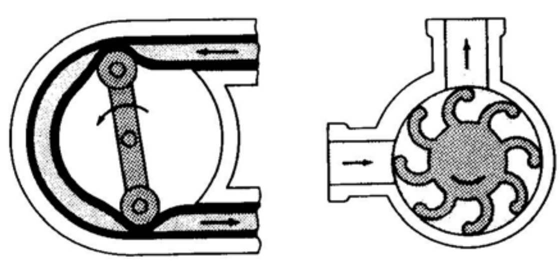
Rotary pumps are positive displacement pumps that utilize rotary, rather than reciprocating, motion in their pumping action. They can be designed to pump liquids, gases, or mixtures of the two. As is the case with reciprocating pumps, their capacity per rotation is independent of driven speed. Unlike reciprocals, however, they develop a dynamic liquid seal and do not require inlet and discharge check valves. Since the rotating element of the pump is directly connected to its driver via a shaft, some sort of drive shaft sealing arrangement is required. This is usually accomplished via a stuffing box, lip seal, or a mechanical seal.

The pumping cycle, which can appear complicated, is actually no more complex than that of piston or plunger pumps. All rotary pumps, regardless of their design, undergo three rotational conditions. In this age of acronyms they have been designated as OTI/CTO, CTIO, and OTO/CTI. These conditions are the equivalent of the suction and discharge strokes of a reciprocating pump. The acronyms stand for open to inlet / closed to outlet, closed to inlet and outlet, and open to outlet / closed to inlet.

PERISTALTIC PUMPS



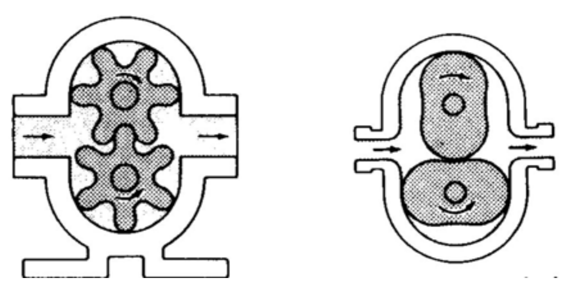
The peristaltic pump, seen on the left side of the figure, belongs to a rotary family known as flexible member pumps. It is one of the simplest of the rotaries, and offers the clearest portrayal of the three pumping cycles. The peristaltic pump gets its name from the muscular action of the human esophagus which, during the swallowing process, contracts progressively and moves solids and liquids through the alimentary canal. Its rotor is a bar with a roller at either end while its pumping chamber, or stator, is a continuous length of flexible tubing or hose set in a U-shaped housing. The rolling motion of the rotor "pinches" the inner walls of the tubing together and forces liquid through the pump. Peristaltic pumps are popular in chemical applications because corrosive fluids are completely contained within the tubing and do not come into contact with other parts of the pump.

In the drawing the rotor is turning counter clockwise. The portion of the tubing to the right of the upper roller is open to the inlet and closed to the outlet of the pump (OTI/CTO) and is at suction pressure. The section between the rollers is closed to both the inlet and the outlet (CTIO) and is at a similar pressure. Finally, the portion of the tube to the right of the lower roller is open to the outlet but closed to the inlet (OTO/CTI) and is at discharge pressure. In the example shown, the pressure "stroke" is a little less than one half revolution and all of the torque necessary to produce application pressure is placed upon the CTI roller.

Another sibling of the flexible member family is the flexible vane or rubber impeller pump. The right side of the figure on the previous page is a cross section of such a pump. The rotor is made of rubber or some other elastic material. The vanes of the rotor are flexible and are in direct contact with the inner periphery of the pump case. The OTI, CTIO, and OTO volumes exist between any two of the vanes. In this example, four volumes are CTIO while two each are OTI and OTO. A major application for these pumps is raw water cooling in the marine industry.

GEAR PUMPS

One of the most common rotary pumps is the gear pump. A typical cross section is shown in the left hand side of the figure to the right. It consists of two gears (rotors), one of which is driven by a shaft. The other acts as an idler and rotates through meshing action with the driven gear. Unlike the peristaltic pump, the gear pump has extremely close tolerances between its rotors and the walls of the pump case. It is these clearances and the meshing of the gear teeth that allow the liquid sealing process to occur.



These same clearances also determine the amount of leakage (slip) that occurs during operation.

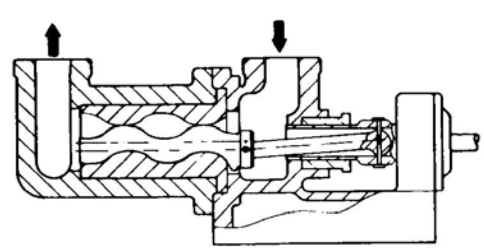
Although it is a bit more difficult to envision, the gear pump exhibits the same three pumping conditions. You will notice that more than one tooth to tooth chamber is involved in all three parts of the cycle at any given time. Because fluid is discharged by both driven and idler gears, each shares the torque produced.

LOBE PUMPS

The right side of the figure on the previous page is a cross section of a typical multiple lobe pump. These pumps are often seen in sewage aeration applications where high volume and low pressure is the norm. A major difference between lobe and gear pumps is that the rotors are designed to remain in close contact throughout rotation. By close contact, I mean that the lobes rotate about one another at extremely close tolerances. Also, unlike the gear pump, the rotors of the lobe pump do not mesh. Therefore exterior timing gears are required to maintain proper rotation. As before, the pumping cycles are readily apparent. In the figure the CTIO volume is seen below the lower rotor while the inlet and outlet volumes are bounded by both rotors. Pumping torque is shared equally by both rotors; however, their individual loading at any given point in time depends upon their axial position to one another.

SCREW PUMPS

The screw pump differentiates itself from other rotary pumps in the way fluid moves through it pumping chamber. Fluid flows axially within the screw pump, but circumferentially in all others. They are available in single and multiple rotor designs and offer flows to 5000 gpm and pressures to 5000 PSI. To the right is a cross section of a single rotor, single end screw pump.



It consists of auger like rotor with lobe shaped surfaces that mesh with a mating stator made of rubber or some other synthetic elastomer. Its pumping action creates a number of moving seals as CTIO volumes move axially through the stator. Since each CTIO volume appears to move intact through the entire length of the pumping chamber, this particular design is often referred to as a progressing cavity pump. These pumps will accommodate a wide range of liquids and viscosities. They are most often seen pumping sewage sludge and other process solutions with suspended solids.

OPERATING CHARACTERISTICS

Pressure

As with reciprocating pumps the maximum pressure (P) generated by a rotary pump is determined by the application and the pump and driver components. Maximum working pressure is specified by the manufacturer while maximum differential pressure depends upon the pump's fluid sealing capability. For this reason, these pumps are also often called "semi" positive displacement pumps.

Capacity

The capacity (Q) of a rotary pump is proportional to its displacement (D) times it driven speed (rpm) less slip (S).

$$Q = (D \times rpm) - S$$

The displacement of a rotary pump is defined as the net volume of fluid transferred from OTI to OTO during one revolution. And, believe me when I say that this is all you will ever want to know! Because of the complex geometry that exists between the rotor and pump case, calculus is required to compute actual displacement. In fact it can be so complex that displacement is often approximated.

Slip is similar to that in a reciprocating pump and is defined as the quantity of fluid that leaks from OTO to OTI per unit time. It depends upon the clearances between the rotors and case and the operating pressure. Generally, slip increases in direct proportion to pressure and is most marked in designs like the flexible member pump. Flexible vane pumps (page 1) are especially subject to slip at higher pressures and, in fact, tend to be inherently protected against over pressure.

Power

The power required for rotary pumps is calculated in the same manner as it is for reciprocals.

bhp = (Q x P) / (1714 x ME)

where 1714 is the bhp conversion factor and ME is mechanical efficiency. Again, mechanical efficiency is the ratio of pump power output to pump power input.

Obviously, we do not have room here to cover all of the rotary pump designs. The five we discussed, however, are common ones and illustrate both differences in design and the pumping cycle shared by all. Neither have we the time to discuss some of the more important operational considerations. Such things as pulsation, accumulation, and pressure relief will have to wait for another tutorial.