Maximize the Performance of Progressive Cavity Pumps

If you choose the right geometry, protect your parts, consider the application carefully, control temperature and pressure, your PC pump could last a long, long time.

By Michael L. Dillon, seepex, Inc.

As positive displacement pumps, progressive cavity (PC) pumps have the same benefits as other PD pumps. They can handle high viscosity fluids; they can produce accurate repeatable flow; the output capacity is relatively independent of head; and they can operate with fairly high efficiency at high heads.

One of the major progressive cavity pump benefits is that they have no valves. A PC pump works like a piston pump, but with the piston operating in a cylinder of infinite length. Without valves, the pump will not air lock, clog, foul or leak, and flow is predictable and repeatable.

The absence of any valves on the suction side of the PC pump contributes to its low NPSHR. The PC pump is also excellent for abrasive slurries, since in its most common form, it is rubber lined. It can be repaired on-site with only a few tolerance fits. It can handle solids up to several inches in diameter, is good for low shear pumping, is self-priming, has a reversible flow direction, and has only a single shaft that requires sealing (Figure 1 on next page).

Progressive Cavity Pump Theory

René Moineau, an aircraft designer who was trying to invent

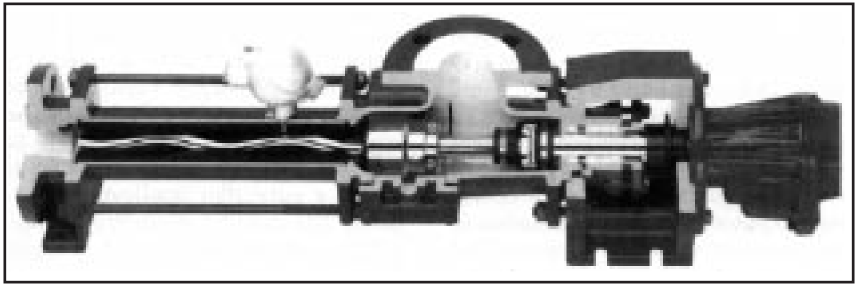

Figure 1. A progressing cavity (PC) pump fitted for industrial and municipal service

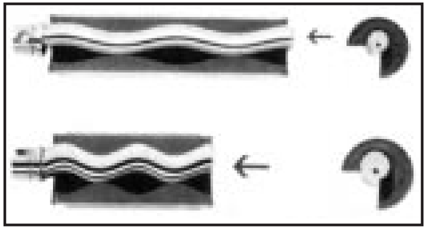

Figure 2. Conventional (top) and long (bottom) geomtery single helix rotor and double helix stator designs

an engine supercharger, designed the PC pump in 1936. The range of Dr. Moineau's patents is truly amazing. Many of his designs have only just recently become commercially available due to their manufacturing complexity.

The most familiar of the PC pump designs uses a single metal rotor, machined as an external helix, that revolves eccentrically within a rubber injection molded double internal helix that is twice the pitch length. The rotor is usually metal, the stator elastomeric with a compression fit. However, where a tolerance fit is used, rigid materials such as metals and plastics can be used for these components. With rigid materials, PC pumps behave similarly to other rotary PD pumps such as gear, screw or lobe pumps. These designs are a special consideration and will not be covered in this discussion.

Discrete cavities are created when the rotor and stator are combined. The cavities spiral or progress through the pumping elements as the rotor turns. As one cavity diminishes, the following increases. The fluid cross section is unchanged regardless of rotor position, so it functions like a piston in a cylinder of infinite length. One of the unique and defining properties of the PC pump is that more than 90% of the loading is axial instead of radial because the liquid is moving along the same axis as the rotating parts (Figure 2).

Lengthened Pitch Geometry

Lengthened pitch geometry was developed in early 1970s as a result of the availability of whirling head lathes–cutting

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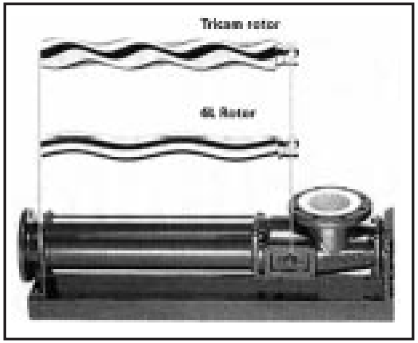

Figure 3. Double helix rotor and triple helix stator design delivers 50% more flow but with 100% increase in internal velocities

machines in which the bar stock is held stationary and several cutting tools are placed in a head that rotates or “whirls” around the bar stock. Because the cutting forces were balanced it became possible to manufacture very thin and long rotors. The previous method of cam operated single point machines required that rotors be fairly short and thick to minimize deflection caused by the cutting tool.

In the new lengthened pitch geometry, cavity volume could remain unchanged while pitch length increased and cavity and rotor diameter decreased. Reduced rotor diameter and circumference resulted in reduced surface velocity at the same rpm as the conventional geometry.

The reduced diameter and rotor cross section resulted in thrust loads that were similarly lowered. This is because thrust load (lb.f.) is a function of the cross sectional area of the rotor (in^2) times the differential pressure (psi). The longer geometry also increased the sealing line cross section while maintaining the same compression. This yields less slippage and higher volumetric efficiencies than the conventional geometry.

Longer pitch geometry is useful for abrasive applications because of its lowered velocity between the rotating and stationary components. It can also accomplish low pressure (< 60 psi) metering because it has a flatter performance curve. It should not be used on high viscosity liquids, large solids or very low NPSHA applications, however, because the entrance into the cavity is considerably smaller than on the conventional design.

Multiple Helix Geometry

Dr. Moineau also designed the newest development in progressive cavity pumps. Multiple helix rotors and stators became popular and have been used for drilling mud motors since about 1980. They became affordable for pump designs in 1993 when new whirling machines that could form double helix rotors became available (Figure 3).

Multiple helix designs can include an unlimited number of helices on the rotor and stator, as long as there is one more helix on one member than its mate. The most affordable and practical of these designs is a double helix rotor and a triple helix stator. In this design, the fluid cross-section decreases by 25% but the internal velocities double. Flows increase by 50% in the same physical space. Additionally, in the 2/3 multiple helix geometry, starting torque decreases with equivalent running torque. This design is good for thin liquids and abrasives, and it is excellent for variable frequency drive (VFD) applications. It should not, however, be used on high viscosity liquids, to pump large solids or on very low NPSHA applications. This is due to the reduced size of the opening into the cavity in relation to the linear velocity of the liquid.

Comparisons to determine which pump is best should be between similar pump styles and models from different manufacturers. Internal linear velocities and the velocity of the surface of the rotating parts must be compared, as well as the NPSHR, to determine which pump is best-suited for a particular application. Certainly the new 2/3 geometry pumps will provide the lowest cost per unit pumped, but they are severely restricted on other parameters.

Mechanical Difficulties

Unfortunately, PC pumps are prone to a variety of mechanical difficulties. These can be classified into five major areas: pumping elements, universal joints, shaft seals, bearings and drives.

Rotor Problems

Erosion is the most common problem for rotors. Operators should try to use the hardest material that is chemically compatible with the pumped liquid. Rotor coatings, such as chrome plating, ceramic and other special hard coatings (which are harder then the rotor base material) will all increase the longevity of the rotor. Unfortunately, some care must be taken with the coatings. If the coating cracks, peels or flakes, the rotor will destroy the stator. Remember that the rotor is loaded with thrust by the discharge pressure, and the drive train of the pump is trying to keep the pressure from expelling all of these components out of the rear of the pump. The rotor bends as it rotates, sometimes more than slightly, and brittle materials can easily crack. Sometimes it is better to use hardened base materials with no coating than to use very hard but easily fractured coating.

MAXIMIZE PERFORMANCE...

Another common way to increase rotor life is to derate the pressure capability of the pump as the differential pressure increases. While this increases the initial cost of the pump, and decreases its mechanical and over-all efficiency, lowering the "pressure-per-stage" can dramatically increase rotor and stator life. Since the discharge end of the stator is pushed away from the rotor by the pressure of the liquid, the stator becomes conical on the discharge side of the pump. This results in a reduced contact area on the suction side of the rotor and stator. Using more stages (or rotor and stator helix lengths) in the pump creates more contact area between the rotor and the stator. It's like adding tread depth on a tire; there is simply more material to wear away and part life is extended, sometimes dramatically. While using pumps for higher pressures can increase the purchase price by 20% or more and increase power consumption by 50% or more, this selection technique can extend the mean time between maintenance requirement by a factor of four to six or even more.

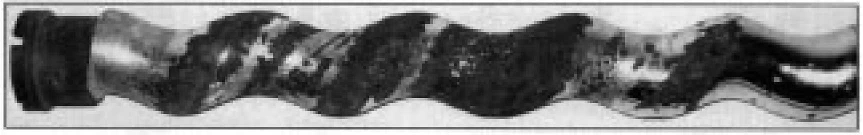

Figure 4. Failure of chrome plating due to corrosion of rotor base material (carbon steel)

Corrosion is also a problem with rotors, and selection of the correct base metal is extremely important. Luckily, there are a variety of material compatibility guides available. If there is any question as to compatibility, the pump supplier should be willing to provide test coupons of any material used in the pump, whether it is metallic, elastomeric, plastic or ceramic. Coating failures, as previously mentioned, are common. Hard chrome is subject to porosity problems, and the cracking of ceramics is also common. If the base metal starts to corrode, the coatings can easily "lift". It is critical that these is no possibility of base metal corrosion. In many cases, where some corrosion of the base metal is inevitable, rotors without any coating are the best choice. In fact, very few Hastelloy® or titanium rotors are sold with coatings because the fluids being pump will have some corrosive effect on the base material over time (Figure 4).

There are some special rotor problems related to material failure. Generally, chrome plating cannot be used on hardened steels because of the hydrogen embrittlement of the base metals during the chrome plating process. The base metals can crack and, unless X-ray inspected, the rotors can actually break in operation. Special coatings can be used with hardened rotors; however, some of these are proprietary. Corrosion of hardened steels in intermittent use can also be a problem. Hardened steels are not good for applications where the pump is routinely drained, as corrosion rates are amplified with the increased exposure to oxygen. It is also important to use separate materials in the u-joint to prevent galling. This is particularly true for designs such as food grade pumps, where the rotor is an integral part of the joint.

Stator Problems

Elastomer compatibility, along with dry running, is one of the most common problems with PC pumps. While the use of an elastomer stator increases the utility of the pump for abrasive or solids laden applications, chemical compatibility can cause a whole new set of difficulties. Again, there are a variety of reference sources that can help with elastomer selection. If there is any doubt as to the acceptability of a material, conduct an immersion test that lasts at least two weeks. Make sure to conduct the test at the temperature at which the pump will operate, as compatibility is dramatically affected by this variable. In general, the pump can tolerate a 10% change in the hardness of the elastomer and a 5% change in the volume of the elastomer. Undersizing the rotor diameter can easily accommodate volume change due to temperature. However, a volume change from chemical absorption can not be similarly tolerated. If the elastomer swells due to chemical attack, it will usually continue to increase in size, and its physical strength will deteriorate, eventually causing premature failure.

Abrasive resistance varies widely with elastomers. While Buna N (NBR) is the most commonly used and least expensive base polymer for stators, a relatively new compound, hydrogenated nitrile buna rubber (HNBR), is far superior. Of course, HNBR is considerably more expensive than NBR. Just because a material is chemically compatible, there is no guarantee that the material will provide the longest life. Fluoropolymers (FPM) are notoriously poor for the physical properties needed by PC pumps. There are compounds that are both less expensive (HNBR) and more expensive (Aflas®) that might be better choices. The choice ultimately depends on the material pumped.

Certain compounds, buna among them, and especially white compounds that are filled with kaolin clay as opposed to carbon black, are hydrophilic. Pure water, deionized and distilled water applications require special elastomers. Another problem with some elastomers is the high mineral oil content (This is one reason why old truck tires burn so well.) Some hydrocarbons can break down these oils over time and cause the elastomer to shrink and harden.

A final concern of stator compatibility is the presence of gases in solution in the pumped liquid. Some gases, like CO_2, can be absorbed by the stator in their compressed or liquid state. This has no effect on the performance of the pump or the elastomer, but if pressure is relieved from the system and the material changes phase from liquid to gas, it will completely destroy the elastomer.

Bonding adhesive failures are also common problems, especially with stators that are “cut-to-size”. Some manufacturers injection mold their stators in long, multiple-stage sticks and then cut off the number of stages needed. This exposes the adhesive that holds the elastomer inside the metal tube to the material being pumped. This may not be a problem for many applications. However, it is a common problem with EPDM elastomers on applications with ketones. EPDM is resistant to a wide range of chemicals, including many adhesives, and most adhesives are easily dissolved by ketones. Separating the adhesive from the pumped liquid by molding an integral rubber lip at the end of the stator is the best way to prevent adhesive failure. Gaskets tend to not be very effective because the rubber is usually pulled away from the metal when the stator is cut. This can also be a problem if carbon steel stator tubes are used for applications where all of the wetted parts are made of stainless steel or other corrosion-resistant metals.

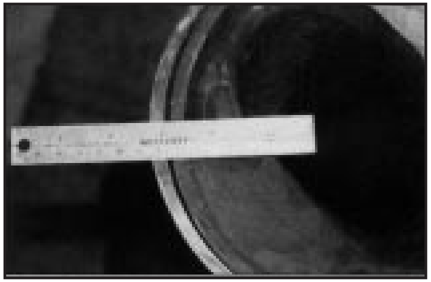

Figure 5. Rubber to metal bond failure on a “cut-to-size” rotor

Bonding adhesive failures are also common on jacketed pumps, as heat reduces the strength of the adhesives holding the rubber inside the metal tube (Figure 5). Controlling the temperature at a point below the manufacturer's recommendation for the elastomer is important. Thermostats for hot oil, water or resistance heaters, as well as pressure regulating valves for steam jacketed pumps, are an absolute requirement when heating the pump, as heat destroys the bonding chemicals.

Another stator failure problem is named after the hysteresis viscosity curve used to measure the cure rate of the elastomer during vulcanization. Excessive flexing of the rubber due to high temperatures and/or pressures, which activate the vulcanizing enhancing additives in the elastomer and can cause additional hardening, causes hysteresis failures.

An easier understood explanation is the "exploding truck tire" phenomenon. No one ever sees big chucks of truck tires inside town. They are always on the highway. If a truck is overloaded, with too much compression on the elastomer tire, it can run at low speeds without a big problem. If this same truck runs at higher speeds on the highway, the elastomer is compressed and relieved at a higher frequency. Heat builds up that can cause the elastomer to further cure and become hard, like plastic. Without resiliency the elastomer starts to break apart and big chunks of rubber come off the tires, just like they will come out of the end of the pump.

To avoid this problem, the rotor must always be sized for the correct temperature and the pump should never be exposed to higher than rated pressures. Hysteresis failure can be caused by repeated "dead head" operations that take place for short periods of time but at high frequencies, which is why it is always important to cycle valves when the pump is not operating.

Run Dry Damage

The most common problem with stators is probably run dry operation. The compression fit used with elastomer stators needs lubrication to carry away heat. Heat will build up if there is no fluid, or if there is fluid but it is not moving through the pump. In this situation, it is heating up to above the temperature limit of the elastomer. There are various devices available to prevent the problem, but all of them have limitations.

Thermistors can be imbedded in the stator to measure the operating temperature, and a set point controller can be used to shut off the pump at a specific temperature. These devices are inherently very reliable, but are only available as part of a new stator; they cannot be used with adjustable stators; they are not allowed in dairy (3A) applications, and they cannot be used on very small PC metering pumps (Figure 6 on next page).

Paddle-type flow switches can be used, and they are very inexpensive. However, they are not recommended on viscous or solids-laden materials, which are a common application area for progressive cavity pumps. Heat transfer flow switches are reliable on a great number of applications, but they are generally more expensive than the thermistor devices and are not suitable for most explosion proof applications.

There are a number of fluid detectors that can be used to protect the pump. Keep in mind

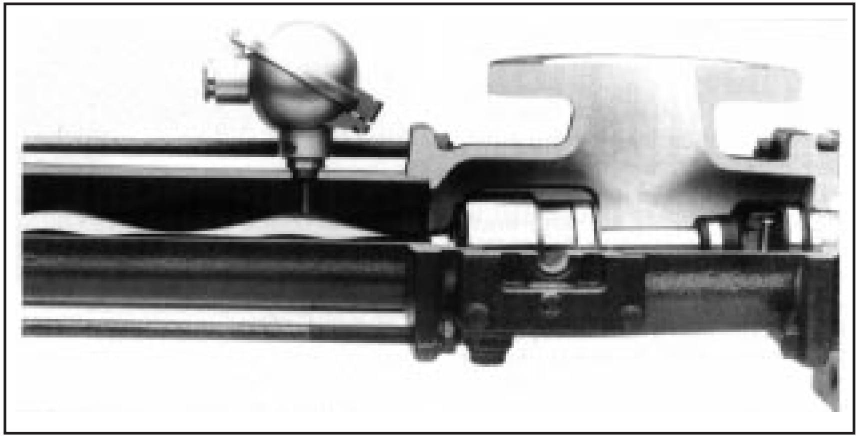

Figure 6. Thermistor imbedded in stator to protect against run-dry damage

that these devices generally only measure the presence or absence of a fluid and not heat, which is the real cause of stator failure. These devices should always be installed with a pressure switch to prevent either dead head or closed suction conditions. They also have to be installed in a vertical or self-draining line to be effective. Capacitance-type detectors are about the same price as a thermistor ($650), and are available in a food grade design at a somewhat higher price. Some customers have used tuning fork fluid sensors, but they need to be inspected periodically because they can foul and become unreliable. They are, however, less expensive than the capacitance type fluid detector.

It is also possible to integrate flowmeters into process instrumentation to prevent run dry operation. This is the least expensive way to protect the pump, provided you can get the equipment installed, programmed and operating before start-up.

Pressure switches can also be used, with some precautions, to protect the pump from run dry damage. A switch, used on the suction side with a minimum pressure set point, can prevent damage to both starved suction and emptied suction tanks (if the static fluid level is high enough to detect these conditions). Many customers also like to draw down tanks to empty, but there is not enough sensitivity in a standard pressure switch to draw a tank down to zero static head without running the pump dry.

A pressure switch, rupture disc or pressure relief valve should always be used on the discharge side of the pump to protect from pumping against a dead head. These pumps are positive displacement pumps, and if they are operated against a dead head, they will try to build pressure until one of the components or the piping fails. Pressure switches can protect against running the pump dry by using a dual set point switch that protects against both over and under pressure conditions. Discharge pressure is a combination of both static head and friction loss. If a suction line is closed or the feed source empties, the friction component of the total head will disappear and the recorded pressure will drop. This system is not very reliable when the friction loss component of the total head is very low.

Universal Joint Problems

While some manufacturers try to make universal joint design a major difference between progressive cavity and other pumps, they generally do it to give themselves an advantage in written specifications. The truth is that for most applications, it is only important to ensure that the universal joints are positively sealed from the pumpage and are properly lubricated. Sealed u-joints are imperative, as any auto mechanic working on front wheel drive cars can tell you. There is also no real use in having a universal joint that will not need rebuilding before the rotor needs replacing, since you have to disassemble the joint to replace the rotor.

Generally, it is also advisable to have sacrificial or low cost wearing parts in the joint. This will minimize the cost of repair and makes it fairly easy to work on. Gear type u-joints are notorious for their high replacement cost and repair difficulty, but they are very good for high thrust load

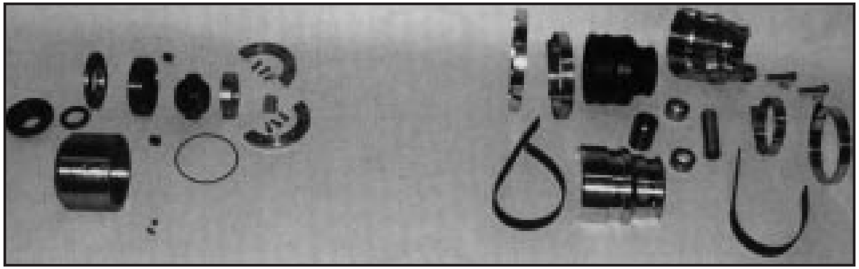

Figure 7. Gear type and sealed pin-type universal joints in comparable sizes

applications. Remembering that thrust load is a function of pressure and rotor diameter, high thrust loads are only seen in very high pressure situations (> 1000 psi) or in very large pumps (rotor Ø > 6"). Cardan joints can also be used in these applications, but they have to be oil filled, the same is true for some gear type universal joints. For 95% of PC pump applications, simple sealed and grease lubricated pin joints, which are made by almost all of the major PC pump manufacturers, are acceptable (Figure 7).

Excessive thrust loads caused by high differential pressures (ΔP), as mentioned above, can cause problems with the universal joints. On abrasive applications the stator and rotor will normally fail before the universal joint. The opposite is true for non-abrasive, ambient or lower temperature applications–the joint will fail first. The weakest component in these cases is usually the joint lubricant. The high thrust load combined with friction between the joint components can produce enough heat to vaporize the lubricant, which is why some manufacturers in their larger or higher pressure pumps use oil-filled joints. It is always wise to use only the manufacturer's recommended lubricant in the joint and check the operating pressures, especially on the second and third shift operations where plant personnel are always more willing to use throttling valves than variable speed drives to control flow.

Suction pressure can cause joint problems as well. If the seal that protects the joint from the pumpage is damaged or displaced, the joint will fail. Many gear joints are limited to 25 psi in the suction casing. There are some double seal designs that can handle up to 50 psi. Hydraulically balanced sealed pin joints are available that can operate up to 175 psi. This is something that you really need to consider if you are operating the pump in reverse, such as with a suction lift application or when pulling against a vacuum, i.e., a crystallizer or concentration unit. The discharge pressures will affect the universal joints.

Universal joints angularity, again, is a point pushed by some manufacturers to try to exclude competition. The truth is that the correct angularity varies with the type of universal joint. The angularity must match the u-joint design. For gear joints it should be < 2° , because they generate a lot of heat due to the thrust plates, which enables them to absorb the higher thrust loads. Pin joints should have an angularity of around 3° . Cardan joints need to have an angularity of > 5° to ensure that the needle bearings inside of each bearing cup rotate to promote even wear.

Shattered joint parts are a sign of cavitation, and this happens in any type of universal joint in a PC pump. The implosion of vapor bubbles on the discharge of the pump causes high momentary thrust loads on the drive train. Most manufacturers use some hardened steel or cast iron components in their joint, and the shock loads caused by cavitation can fracture these parts. In gear joints with soft alloy thrust plates, galling and deformation leading to failure of the joint seal is common with cavitation. Pumps with flexible shafts, instead of u-joints, will break these shafts. Cavitation should be avoided in any pump, and while Dr. Moineau originally designed PC pumps as compressors, cavitation will have a damaging effect over time. PC pumps can withstand some cavitation because they operate at slow speeds. There is a pressure gradient as the fluid travels the entire length of the pumping elements, and the drive train is mounted in a resilient mounting (the elastomer stator). Cavitation, however, will have a negative effect on your pump.

Sealing Problems

PC pumps are famous for not having sealing problems. Compared to many other rotary PD pumps, they have an advantage because they only have one shaft to be sealed. This seal is usually only exposed to the suction pressure condition and 95%+ of the total load is axial rather than radial.

In cases with low NPSHA or suction lift applications, as mentioned previously, it is advisable to run the pump in reverse. This prevents air from being sucked in through the packing or the mechanical seal. A flush or a quench can help alleviate this problem. Failure to prevent this loss of prime through the sealing area can lead to run dry damage of the stator.

When operating with packing, it is important to flush abrasives with a lantern ring spacer in the packing and an API plan 32 or 52 flush. These flushing systems create a pressure barrier in the packing that prevents abrasives from entering. They also keep the packing cool and lubricated, and this prevents damage to the pump shaft. There is a myriad of packings available, and they can be fitted to any PC pump. Your PC pump manufacturer or local distributor can install your favorite packing for you. Like pump vendors, if you have a packing supplier that you trust and provides good service, use his or her recommendation. Your trusted pump supplier will respond in kind. For packing, though, it is always recommended that you use a hard coated shaft or shaft sleeve. Packing rubs against the shaft and where there's rubbing, there's wear. The harder the shaft, the longer it will last on packing.

Single seals are gaining in popularity. For seepex, more than half of all the pumps we sell have single seals. The prices of hard faced, silicon carbide or tungsten carbide seals, especially rubber bellows seals, have gone down dramatically over the last several years. Generally, the price for a single seal is equal to the cost of a good packing with a hard coated drive shaft and a lantern ring seal flush. In some PC pump designs, it is actually easier to replace a seal than it is to replace packing.

There are a few caveats with single seals. You should use a quench if there is more than five foot suction lift when running the pump in standard rotation. A quench is just an area behind the seal faces, sealed by a rubber lip seal, where a clean liquid (water or machine oil, generally) is present at atmospheric pressure. This forms a viscous barrier that prevents air from entering through the seal when the suction pressure in the pump is at less than atmospheric pressure. The quench can also be used to prevent crystallization of the product on the seal faces. Single seals with quench have proven to be effective on paper coatings, paint, sugar solutions, honey, salt solutions and a variety of other crystallizing materials that are known for destroying packing and single seals without a quench.

On certain applications it is important to use slurry seal housings for abrasives. It is advisable to keep these hard faced seals cool by placing the seal inside the suction casing of the pump. Ceramic or carbide seal faces can fracture or chip if they are allowed to get too hot. The pumpage keeps the seal cool and prevents the build up of solids around the seal. This cannot be achieved by placing the seal inside a stuffing box designed for packing. Some PC pumps can easily accommodate this seal mounting arrangement. Others, which have the stuffing box cast as part of the suction casing, require expensive modifications to accept this seal.

Double seals, of course, are still widely used. However, most double seals in use now come in the form of a cartridge seal. Double seals are still widely used on fine abrasives (like pigments) and crystallizing materials (like latex), which can foul single seals with a quench. Double seals must have a flush systems with the seal flush liquid at a pressure that is usually 5 psi higher than the pressure in the suction housing. Again, an API plan 52 flush system, which can cost as much as a small PC pump, needs to be installed with a double seal. If a double seal is not flushed, it can be destroyed within minutes.

One last word regarding double seals: Split cartridge seals may not fit into some PC pumps. Please be careful when using these seals, which have very large diameter glands. Some manufacturers are making units that will fit. Others may fit but may require modification to the suction casing or the bearing housing of the pump. The added cost may not be worth the added convenience of the split seal.

Bearing Problems

Bearing problems, because so much of the load is axial rather than radial, are not a severe or common problem in PC pumps. First, new bearings always run hot (up to 160° F), and they will take several days to run in. Because of the high axial loads, avoid ball bearings except on very small pumps. Tapered roller bearings can handle higher thrust loads and are a better investment. Proper fitting of the bearing cover plate is important, and while bolted plates are easier to use than snap ring fitted plates with adjustment shims, the tolerances are the same. Once properly set and lubricated, you can expect tapered roller bearings to last a long time.

Close coupled PC pumps are becoming more popular. In Europe, the majority of PC pumps sold are close coupled or block configuration. These arrangements have made it possible for PC pump suppliers to reduce the costs to users by as

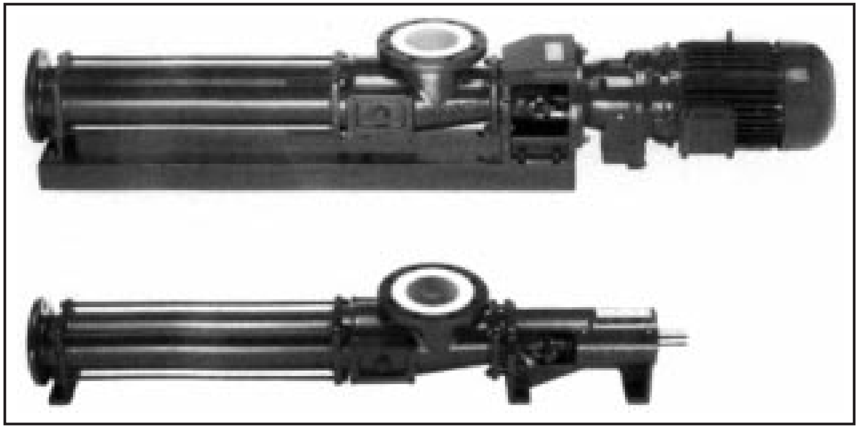

Figure 8. Integral or "block" pump construction (top) where gear reducer bearings absorb pump thrust and radial loads

much as 40%. It has also helped to reduce lead times. Additionally, it is safer than "V" belts and pulleys, and more reliable. It's a great idea. But like a lot of great ideas, it can be abused. These units are typically oil lubricated. If a manufacturer proposes a close coupled pump, make sure that the gear box is rated with, at the minimum, a 1.5 service factor based upon the motor input power. This is the minimum factor according to AGMA for class II gearing with a positive displacement pump. Secondly, ensure that the pump manufacturer provides you with the actual maximum thrust load calculation and the maximum thrust load rating of the gear box. The gear box should be rated for more load than the actual calculated load. Otherwise, use a larger gear box or a pump with dedicated bearings (Figure 8).

Protection of the bearings from contamination is always a major concern. Use IP65 double lip seal protection or labyrinth seals for the bearings on fine slurry or coating type fluids to prevent contamination. Because of the extremely slow speeds used with PC pumps on highly abrasive applications, shaft slinger rings can be useless. High quality fluid-end and bearing seals will solve most bearing problems associated with PC pumps.

Drive Problems

Until about a decade ago, variable pitch pulley belt drives were the most popular drives for PC pumps. They are still one of the least expensive ways to achieve variable flow in a rotary pump. Unfortunately, there are some sizing and reliability concerns with these drives.

It is very important to ensure

that the proper hp rating is used. Some manufacturers rate these units on their input power, and some rate them on the output power. This can be a big difference, due to the mechanical losses associated with both the variable pitch belt and the gear reduction unit. Make sure that you have enough power at the drive output to power the pump.

Since these units are invariably integral with a gear reduction unit, make sure that the service factor of the gear box at low rpm is sufficient. Because they are a mechanical drive, the torque increases as the speed is reduced. Some units may have very low service factors on the gears at slow speeds–some may be less than 1.0.

It is recommended that customers buy the hardened or hard coating pulley option on these drives. The belt has a tendency to run a groove in conical pulleys. Most manufacturers recommend that users run the drive all the way to its maximum speed and all the way down to its minimum speed once a week to prevent grooving. I've never known a user to have this step in their formal PM procedures, so the hard coating is a worthwhile safety precaution.

One of the most common problems with gear boxes and mechanical drives, which are integral with gear boxes, is venting. If the box is not vented, vapors will build up and the pressure will blow out the oil seals. Be sure gear box breathers, which are shipped separately to prevent loss of lubricant during shipping and installation, are installed. Failure to install breathers is probably the most common cause of gear box failure.

Mechanical friction drives can be used on PC pumps, but it is important to ensure that the drive is rated for maximum pump starting torque and not the maximum running torque. The shock load associated with PC pumps can shatter the phenolic friction ring in these drives if they are undersized. Again, be sure that the gear box breathers are installed.

Electronic drives have become extremely popular for all variable speed applications in the last decade, including PC pumps. While the electronics have eliminated a lot of the problems associated with mechanical components, they have given rise to other problems. Progressive cavity pumps are constant torque devices, if the differential pressure is constant. Therefore, if a variable frequency drive (VFD) is used, it must be of the constant torque type.

VFDs must be sized considering the drive's starting torque capability as well as its operating torque capability. VFDs cannot generate as much starting torque as a mechanical variable speed drive, and PC pumps, due to the compression fit between the rotor and the stator, require a lot of starting torque. Depending on the operating pressure, starting torque is usually 50% higher than the running torque and can be as high as two or three times the running torque if the pump pressure capability has been severely derated to improve rotor and stator life. Use of the following formula to calculate the proper drive size, given the pump maximum speed and starting torque in lb. ft.:

(lb. ft. x rpm)/(5250 x starting torque current boost) = VFD horsepower

VFDs are basically computers, and they can be difficult to program. Of course, each VFD is different; but there are a few guidelines to remember:

- Set the current boost for starting to the maximum setting.
- Minimize the ramp up and soft start capabilities. This increases the amount of starting torque.
- Locate the VFD as close as possible to the motor. Problems start to arise when the VFD is more than 100 feet from the motor.
- For more turn down (>6:1), set the maximum pump speed @ 90 Hz with four- or six-pole motors. This will enable you to use a higher reduction on the gear box, which provides more torque for starting. It will also have the motor running at higher speed to allow for improved cooling of the motor.

Just about any type of prime mover including, but not limited to, air motors, hydraulic motors, DC motors, gasoline and diesel engines can drive PC pumps. There have even been hand-operated PC pumps. Remember to match both the starting and running torque requirements, and size the unit over its entire operating speed range.

Application Problems

Some very specific application problems need to be mentioned to finalize this topic. High viscosity applications usually require open hopper pumps. It is important to size the hopper so that material will not "bridge" in the unit. These pumps are available in a variety of designs depending on the particular application conditions. They are available with and without extension tube "induction" zones to improve the volumetric efficiency of the pump, and they are available with

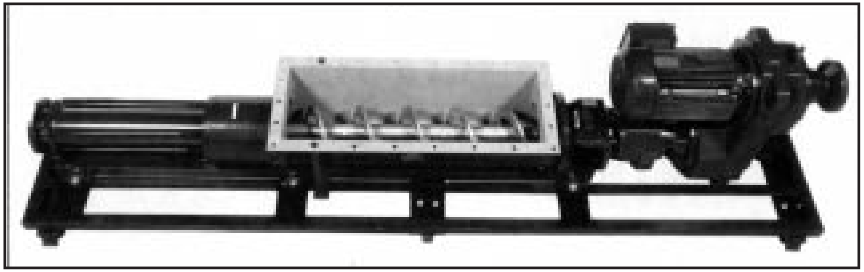

Figure 9. Open hopper type pump used for high viscosity liquids and sludges. Note auger feed device.

internal cutters for chopping up potatoes or beets or fruit. Special augers, some with mixing capabilities, can be installed as part of the drive train, and separately driven "bridge breakers" can be installed in the suction casing of the pump. These not only protect against bridging of the product above the open hopper pump's auger, but will impart additional shear to lower the apparent viscosity of thixotropic or pseudo-plastic fluids. This makes them easier to pump (Figure 9).

Excessive speed is another common cause of premature PC pump failure. Again, rpm is not a useful measure of speed. What is important is the surface velocity of the rotor against the stator. Necessarily, as higher flows are needed, the cavity in the pump increases in both length and diameter, and the rotor summarily increases in diameter and circumference. Some broad guidelines for maximum speed relative to the flow rate required are:

> 500 gpm = < 250 rpm

> 50 gpm = < 350 rpm

> 5 gpm = < 500 rpm

> 0.5 gpm = < 1000 rpm

Cavitation, as mentioned previously, can cause problems with the universal joints, and it can damage the rotor and stator. Don't *ever* install a pump without comparing NPSHA to NPSHR. Even though the suction may be "flooded," high viscosity applications commonly have enough friction loss associated with valves and piping to reduce the NPSHA to a level below the NPSHR. It is also important to know the standard being used by the pump manufacturer to measure NPSHR. There are differences between the standards used by the Hydraulic Institute, API and other organizations. The pump may not produce according to the published performance curve, even if the NPSHA is above the manufacturer's listed NPSHR, because of the standard used to measure NPSHR.

It is important to install gauges on both the suction and discharge sides of the pump. Some manufacturers do not have gauge connections on their pumps or they may only offer them at an extra charge. It is impossible to diagnose a pump problem in the field without pressure gauges. Pressure is, after all, one of only two components that defines work in a pump. If no provision is made for gauge installation, your piping will have to be changed. It's like flying in a snow storm without an altimeter.

Excessive pressure and/or temperature in an application will cause several of the earlier listed conditions: stator hysteresis, u-joint or bearing failure. It is imperative that you know the temperatures and pressures for your PC pump installations. One of the things that PC pumps are not good for are applications with wide temperature fluctuations. This is due to the expansion and contraction of the elastomer. High temperatures will cause either increased erosion rates or hysteresis failure of the elastomer. Low temperatures will cause reduction of the compression in the pumping element, excessive slip and necessitate premature replacement of the stator and/or rotor. Proper selection of the elastomer material will help to minimize this problem, but applications with temperatures fluctuations of more than 150° F are generally not recommended for PC pumps.

While PC pump manufacturers like to promote slow speeds to increase the life of the pumping element, this can backfire on some heavy and hard-solid laden slurries where there is insufficient internal velocity, and the solids settle in the pump cavities. In these instances, rotors will wear as fast or faster than stators, u-joint covers can get holes worn in them and fail, and stators will quickly erode. The best solution is to install an auger or propeller type coupling rod to add turbulence and prevent settling. Using a long or multiple helix geometry will also increase the linear velocity in the pump while still keeping the surface velocity of the rotor low.

Conclusion

Progressive cavity pumps are versatile and adaptable for a wide range of applications. Unfortunately, they are somewhat more "sensitive" than other more commonly used pumps. If care is taken with proper selection and installation, PC pumps can be a superior choice. Choosing the proper materials of construction, speed, geometry, seals and drive are only part of the job for a good pump installation. Proper installation requires the inclusion of a reliable and appropriate device to prevent dry running and offer pressure protection. In addition, process temperature controls and properly programmed electronic drives will ensure that your PC pump is dependable for a long time.

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