Maximizing Reliability in Sealless Pump Operation

Understanding the common requirements and differences among these pumps is critical to achieving a highly reliable installation.

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The chemical processing industry is focused on managing the total life cycle cost of plant capital equipment, including sealless pumps. Equipment downtime must be regarded as a lost profit opportunity. When added to repair parts and maintenance personnel costs, the cost of downtime can easily dwarf the initial purchase price of a pump.

Although sealless pumps are used more and more in a broad range of applications, how to select the right one remains widely misunderstood, as do their operational requirements. There are three major categories of centrifugal sealless pumps: canned motor, metallic magnetic drive and non-metallic, lined magnetic drive. Where is each type best utilized? What are the major advantages and disadvantages of each? Understanding the differences and common requirements among these pumps is critical to achieving a highly reliable installation.

Canned Motor Pumps

Photo 1. A typical canned motor pump installed in a plastics facility
The single biggest advantage of canned motor pump technology is double containment.

If the primary fluid containment boundary ruptures, the external motor stator shell is a true pressure vessel. It is often rated to the pump’s full working pressure, tested to assure integrity and resistant to mechanical contact or "rub-through." This feature makes canned motor pumps the choice for lethal or extremely hazardous applications. They are also well suited for high pressure operations.

Canned motor pumps are usually available in a range of configurations that are designed to for the process lubricated bearings. The various arrangements can increase the pressure in the are being pumped, prevent process solids from entering the bearing area, provide a co temperature services and so forth. These measures mean more control over the critical b higher reliability potential. Canned motor pumps also benefit from a wide range of n preventive maintenance.

The principal disadvantage of canned motor pumps is the relatively special nature of the motor. The same metallic liner, or "can," that provides the primary fluid boundary under normal operation adds to the difficulty of decontaminating and repairing a breached motor. While it is technically feasible to repair these motors, it is often not economical to do so.

**Metallic Magnetic Drive Pumps**

Metallic mag drive pumps are well suited for a wide range of pumped materials, including:

- mild acids
- solvents
- liquids that are sensitive to heat input
- fluids containing moderate solids
- fluids that present difficult sealing challenges, such as liquids with dissolved solids that tend to precipitate out of solution
- high melting point liquids
- high temperature services including heat transfer oils

Synchronous mag drive pumps add less waste heat (from eddy current losses) to volatile fluids than canned motor pumps.

Metallic mag drive pumps are available in sizes as large as 520 hp (400Kw) and utilize standard NEMA and IEC motors.

The primary disadvantage of these pumps is that they have no secondary containment capability, making them less than ideal for lethal or extremely hazardous applications. Various secondary control devices are available from suppliers to prevent massive spills if the primary fluid containment shell ruptures.

Figure 2. Cutaway of a typical magnetic drive pump

Figure 3. Example of hydraulic performance of magnetic drive pump at 60hz
Non-metallic, Lined Magnetic Drive Pumps

The best of these designs feature a metallic outer pump case housing lined with thick, bonded fluoroplastic that combines excellent corrosion resistance with the strength of a metallic casing. Such pumps are ideal for acetic acid, hydrofluoric acid, hydrochloric and sulfuric acids as well as ferric chloride, hydrogen peroxide, sodium hypochlorite and other dangerous liquids. These pumps tend to have bearings made exclusively from silicon carbide (SiC), due to its high resistance to chemicals.

The disadvantages of lined pumps stem from the physical limits inherent in today’s fluoropolymers. Temperatures must be limited to about 250_F (120_C), and the pumps are generally limited to smaller power levels and lower developed head due to limits in bonding strength of the liners on large diameter, high tip speed impellers.

Major Causes of Failures in Sealless Pumps

While the specific applications for sealless pumps vary, the primary causes of their failures are similar. In all cases, they result from the failure to control the operating environment of the process fluid lubricated bearings.

Dry Running

The leading cause of failure in sealless pumps is probably dry running. Operating a pump for even a few seconds without liquid at the bearings will shorten pump life. Much has been written and presented at various chemical industry technical meetings on the subject of dry running bearings for sealless pumps. New materials, including hybrid carbon/SiC designs, "diamond like" coatings on SiC and a wide range of carbon graphite blends, have been tried and tested. But, no material offers a panacea for long term tolerance of dry running under loaded conditions.

Bearings for sealless pumps can be designed for greater tolerance to dry running, but only at the expense of load carrying capacity, wear resistance and run life under normal operation. In general, SiC provides the greatest load carrying capacity of any available material. It also offers excellent corrosion resistance. It can’t tolerate even brief dry runs, however. Carbon graphite, on the other hand, provides a degree of self lubrication under dry run conditions, and it is more tolerant of this abuse. Yet it cannot handle unit loads as high as SiC. Nor can it withstand abrasive particles. It will therefore have a shorter useful life under even ideal conditions.

Off-Design Operation & Undisclosed Fluid Properties

Because sealless pumps rely on the process liquid for bearing cooling and lubrication, they are application sensitive. When pump suppliers recommend a specific pump configuration and bearing material selection, they do so based on anticipated operating conditions.
Deviations from these design conditions, including variations in pumped liquid characteristics, extreme changes in flow rates, contaminants and changes in temperature or viscosity, can have detrimental effects on the reliability and bearing life of sealless pumps.

**Pump Oversizing**

Although a common practice, applying too many "safety factors" to pump rated flows is detrimental to all types of centrifugal pumps. Oversizing results in off-design operation of the pump. It increases radial bearing loads, disrupts the pump’s hydraulic thrust system, and may compromise the motor’s internal cooling capacity by decreasing fluid flow. With some fluids, such as polymers, this last factor can result in the formation of particulates that clog critical internal flow passages.

**Solids Presence**

In addition to the secondary formation of solids mentioned above, sealless pumps are no more (or less) tolerant of entrained process solids than conventionally sealed pumps. Again, the central issue is bearing lubrication. Bearings made of hard materials, such as SiC, can tolerate the passage of solids more than soft materials like carbon graphite. Additionally, some manufacturers offer pump configurations specifically designed to exclude particulates from the bearing area. This is accomplished through screening or centrifugal separation or by supplying a clean secondary flush and a flush restriction device. It is critical that the nature of the entrained solids is discussed with the manufacturer to assure proper pump selection. Specifics such as particle size, percentage by weight or volume, abrasive hardness and tendencies to agglomerate — are all important details that the manufacturer must know.

**Special Considerations for High Vapor Pressure & Volatile Liquids**

When pumping high vapor pressure liquids, especially at pressures and temperatures close to the bubble point, additional information such as fluid specific heat and, if available, the actual vapor pressure curve, will be useful. Because the process fluid is used in sealless pumps to remove heat due to electrical inefficiency, containment shell eddy current losses, bearing friction and hydraulic inefficiency, the temperature of the fluid within the motor or magnetic coupling section of the pump will increase.

A potentially damaging condition exists if the line between liquid and vapor phase has been crossed when a higher temperature fluid is returned to suction pressure. Bearings may be running "dry" (i.e., in vapor rather than liquid.) Depending on the internal flow path of the specific pump design, this vapor may be routed back into the suction of the pump impeller, resulting in cavitation. The presence of vapor in the motor or magnetic coupling area reduces heat rejection and can result in overheating. Be sure to disclose as much detail as possible about the vapor pressure/temperature curve for your specific liquid to your supplier. In the case of liquid mixtures, include information on the highest vapor pressure.
constituent. Gas dissolved in the process liquid will naturally increase the likelihood of flashing within the pump. This fact, too, should be communicated to the manufacturer.

**Venting and Start-up Procedures**

This issue, important to all centrifugal pumps, is often given inadequate attention by operators. Even brief periods of operation with improper venting will cause sealless pump bearings to run dry. In the case of carbon graphite bearings, accelerated wear almost always happens under these conditions. With SiC bearings a rapid rise in bearing temperature occurs. When full venting is finally attained, the bearings are easily shocked thermally. Extremely hard, brittle materials such as SiC can shatter under these conditions. Secondary damage to pump internals, resulting from the passage of the razor sharp fragments of the shattered bearings, is also likely.

The following simple procedure can be used to assure complete venting of even hard to vent systems. It assumes the pump is empty of liquid and that both suction and discharge valves are closed.

1. Open suction valve. (Pump fills part way.)
2. Close suction valve.
3. Open discharge valve. (Once the pressure equalizes, air will rise into the discharge piping.)
4. Open suction valve.
5. Start pump.

(Additional information on this topic can be obtained from an article by Michael D. Smith in the November 1993 issue of *Pumps* and Systems magazine.)

**Misapplication of Design and Materials**

When selecting a sealless pump, note that the process of application engineering for this type of pump is in many ways similar to selecting a proper mechanical seal and seal support system. As mentioned, the more detail manufacturers know about the service, fluid properties and intended operation of the pump, the better they will be able to select a configuration and proper materials of construction. This helps ensure long, reliable service. Be prepared to supply information on not only design point conditions but the full range of intended flows and pressures. Be as exact and comprehensive as possible in identifying fluid properties.

Also, don’t forget to describe piping and control system details. Try to detail any upset conditions that the pump may experience. Remember that corrosion rates are accelerated by increases in temperature. A solid understanding of all these factors will help the manufacturer select a pump with the highest potential reliability for your service.

**Inadequate Monitoring**
While the primary advantage of sealless pumps is the complete, hermetic sealing of the process liquid, this can also lead to one of the biggest frustrations with pumps of this design: You can’t see what’s going on inside. Whereas normal seal wear in an ANSI pump can be detected visually, normal bearing wear occurs with no outward indication. If preventive maintenance is not conducted in a timely manner, more serious and expensive peripheral damage is likely.

**Core Issues for Reliable Operation**

- The top causes of unreliable sealless pump operation are:
  - bearing loads, design and material options
  - process fluid lubrication
  - cooling and "the other NPSH" value

Proper control of bearing loads is basically within the control of the pump designer. Look for thrust balancing designs that can reduce the hydraulic loads imposed on the bearings. The more conservative the load placed on the bearing, the better. No single bearing material is right for all liquids and pump operating scenarios. As stated, softer materials are more tolerant of the abuses of liquid flashing or intermittent dry running, but they provide a shorter useful life under normal operation. Harder materials such as SiC provide increased wear resistance to abrasive particles, and will yield longer life under ideal conditions. However, these materials are intolerant of dry running and may result in more extensive peripheral damage if they are run to failure.

Process fluid lubrication of the bearings is, by definition, dependent on the properties of the fluid pumped. Bearings require two things for reliable operation: liquid (not vapor) between the bearing surfaces, and that this liquid be relatively clean and non-abrasive. Even with this obvious constraint, much can be done to create an improved bearing environment. For fluids containing abrasive solids, a secondary clean fluid flush can be injected into the bearing area. With volatile liquids, pre-cooling or internal flow schemes that boost and maintain the liquid pressure above the bubble point are available.

Cooling is a relative term as applied to sealless pumps. Modern rare earth magnetic drive pumps function well without external cooling to approximately 250°F. Torque ring design mag drive pumps can tolerate temperatures to 750°F without external cooling. Canned motor pumps featuring ceramic motor insulation systems can operate up to 850°F without supplemental cooling.

Bear in mind, however, that these temperatures are based solely upon the technical capability of the individual pump design. The requirement of limiting the fluid temperature within the pump may be based on maintaining the characteristics of the process fluid required for reliable bearing life: liquid (not vapor) and no abrasive solids. Therefore, in the case of certain fluids such as polymers, cooling may be required to prevent localized hot spot polymerization within the bearings. When pumping volatile liquids such as chlorine, cooling may be required to ensure that the liquid does not flash off to a gas within the
bearings.

With high temperature applications such as heat transfer oils, can-ned motor pumps with conventional organic resin insulation systems may require cooling to protect the motor stator core from overheating.

The "other NPSH value" is a widely misunderstood phenomenon. In sealless pumps the process fluid is circulated within the motor (or mag coupling) and through the bearings to remove heat. The amount of heat generated varies widely from design to design and is generally less in non-metallic lined mag drives due to the absence of eddy current generation across the non-metallic containment shroud. Metallic mag drives rank second in heat generation. The heat from electrical inefficiency of the drive motor is removed through air cooling rather than by the process liquid. Canned motor pumps generally add the most heat to the pumpage.

As noted earlier, there are special considerations for volatile liquids. It is not solely the added heat that is of concern, but the combined effect of heat vs. pressure and the operating point on the fluid vapor pressure curve. The internal flow paths within the pump must also be considered.

The most common internal flow scheme used in sealless pumps takes a side stream of liquid from the pump discharge (or at least a point within the pump volute where partial discharge pressure has been generated) and circulates it across the rotor, between the bearings and back to suction. It is the pressure differential between discharge and suction that causes the stream to flow. With this setup, liquid at an elevated temperature is being introduced directly into the pump suction. If the liquid is prone to flashing at this lower pressure and higher temperature, it will do so in the pump suction eye. Thus, even though the NPSH of the pump is determined to be a lower value, cavitation can still occur. Be sure to consider this phenomenon when selecting a pump. Alternate internal flow schemes are available to avoid this problem. You can maintain higher internal pressures or return the side stream directly to the suction vessel rather than the impeller eye.

**Improving Reliability in Sealless Pumps**

Look for various configurations to control the bearing environment. Variations in internal flow paths, centrifugal separation, screens or filters, auxiliary heat exchangers, flush injection points, flush restriction devices and auxiliary impellers are available to assure that the bearings operate in as ideal an environment as possible. This will result in long, reliable life.

Bearing materials should be determined based on fluid properties and the anticipated "real world" operating range. The hottest place in a sealless pump moving corrosive liquid is the bearings. A wide variety of carbon graphite binders are available to suit the corrosive nature of most process fluids.
Avoid building in unnecessary "safety factors" in establishing the design flow rate of the pump. Look for suppliers with a wide range of hydraulic designs to match your required conditions. Some vendors have hydraulic designs for low specific speed (low flow, high head) services that help you avoid selecting too large a pump and operating well back on the curve. These designs help minimize radial loads imposed by off-design operation.

Use monitoring devices appropriately. Fortunately, many good products for sealless pumps are available. One of the simplest and most economical ways to protect a sealless pump from operational abuse is by using a power control monitor. This measures input Kw and enables the user to detect potentially damaging operation of the pump, such as low or high flow (beyond recommended operating range) and dry running (resulting from improper venting and/or loss of flow). Upsets in fluid viscosities are also easily detected by an increase in Kw. Power control monitors are readily available for use on mag drive pumps, where it may be impractical to use other types of direct sensing bearing wear monitors.

Several manufacturers of canned motor pumps offer a variety of bearing monitors, including direct-acting mechanical units that sense axial and radial rotor position (Photo 2), mechanical monitors with electrical switches to provide a remote alarm/shutdown feature, and electronic units that can provide a progressive indication of the rotor’s position within the motor. The most advanced of these monitors (Photo 3) can determine precise rotor positioning independently at both radial bearings, as well as axial rotor positioning, and they can identify thrust direction, direct detection of two phase (gas/liquid) flow at the bearings, and direction of rotation. Several user interfaces are available, including intuitive local displays using LEDs to indicate rotor position (Figure 4). Automatic, remote monitoring is available through relays and a 4-20 mA signal. Two manufacturers offer RS485 serial port communication links to the user’s DCS system. This enables the operator to access a wide range of data from the monitor’s host software and use it for advanced rotor dynamics analysis including shaft orbital plotting, time waveform analysis and spectrum frequency analysis. All the monitors are non-invasive and maintain the integrity of both the primary and secondary liquid containment boundaries.
Given the enclosed "black box" nature of sealless pumps, it is vital that one of these technologies is included in all sealless installations.

All sealless pumps should have some sort of monitoring device, if only a power control monitor. These devices are inexpensive and will pay for themselves quickly by reducing maintenance costs. For critical applications, extremely hazardous liquids, special pump designs or larger, relatively expensive pumps, consider including an electronic diagnostic monitor.

Choose from the available technologies of canned motor pumps, non-metallic lined mag drives and metallic mag drives based on application. And avoid "one technology fits all" decision making. You wouldn’t put the same seal on all applications, would you?

Summary

As with all mechanical equipment, the results depend on a thorough understanding of the capabilities and requirements of the technology. A firm knowledge of your process, along with an open relationship with a manufacturer who thoroughly understands sealless pump technology, can yield similar results for your company.

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