CONTINUOUS MONITORING OF SEALLESS PUMPS—THE NEXT STEP

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ABSTRACT

All centrifugal sealless pumps, both canned motor and magnetic drive, should be monitored to determine mechanical condition. In sealless pumps, the pumped fluid is used as the cooling and lubricating medium for the pump bearings. If intermittent monitoring is used, then the chance of detecting pump damage caused by process changes is very small.

Vibration monitoring techniques as applied to sealed pumps has been unreliable for detecting problems with sealless pumps. The effectiveness of conventional monitoring techniques is limited by the time interval between measurements, the relative isolation of the inner pump rotor from the outer measuring location, and by the pumped fluid. Other factors such as fluid effects and process noises can make interpretation difficult.

This paper presents the synergistic combination of two relatively new methods of sealless pump monitoring. These methods considerably enhance the range and magnitude of mechanical problems that can be identified on this type of pump.

One of the goals of predictive maintenance is the reduction of maintenance costs by use of condition monitoring. Identification of off-design operation conditions or mechanical damage at an early stage enables the equipment owner to correct the conditions before damage occurs, or to optimally schedule repairs. Continuous monitoring of sealless pumps, can reduce equipment maintenance costs and facilitate root cause analysis of mechanical failures and operational problems. This cost reduction is accomplished by the use of the monitoring system to immediately identify conditions that can lead to failure.

INTRODUCTION

The purpose of this paper is to present the results of experiments that were an attempt at determining reliable predictive condition measurement tools for sealless pumps. These experiments measured several mechanical and operating parameters as pump operating points were varied. The data from individual measurements were examined for correlation with other measurements, and also to mechanical condition and damage. Monitoring of mechanical condition can be used to schedule maintenance intervals, but the best use of monitoring is to allow the detection of the conditions that will lead to equipment damage. The monitoring system should provide information early enough to allow the potentially damage causing conditions to be changed. Thus, the possible cause for the response and potential for failure are eliminated.

The parameters recorded during lab tests were: power (watts), overall high frequency tracking (OHFT), rotor position, suction pressure, and capacity (gpm). The testing was done on a canned motor pump with a commercially available rotor position monitor supplied by a major pump manufacturer. A "truth" table was generated for various conditions and the table was tested using a closed pumping loop.

Sealless centrifugal process pumps fall into two major categories. One is the magnetically driven design in Figure 1, and the other is the canned motor design (Figure 2). The two types have certain similarities. For example, they both use the process fluid for cooling of the drive mechanism and lubrication of the internal bearings. The designs differ in how rotation is induced in the impeller and rotor.

The synchronous magnetic drive utilizes two sets of magnets, one on either side of a containment shell made of nonmagnetic

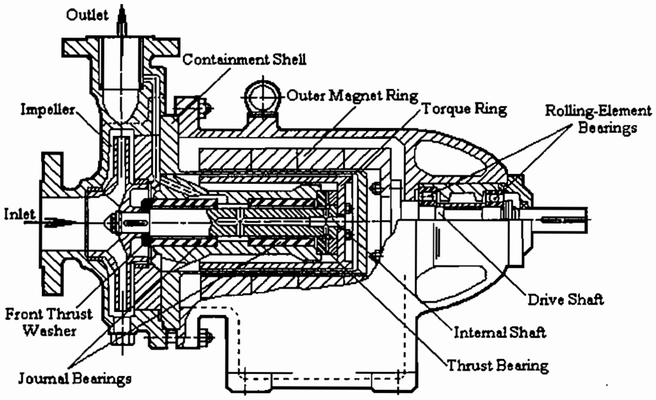

Figure 1. Magnetically Driven Pump.

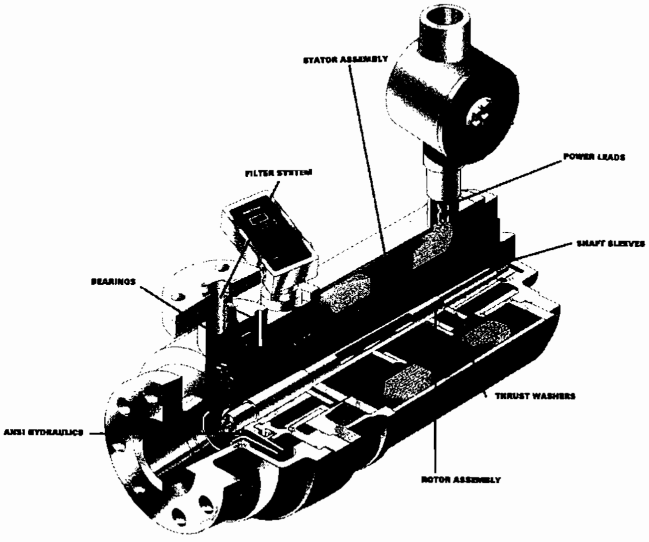

Figure 2. Can Motor Pump.

material (usually stainless steel or Hastaloy). One set of magnets (outer magnets) are moved by an electric motor and supported by oil lubricated bearings. The inner magnets follow the outer magnets because of the attraction through the containment shell. The internal magnets are protected from the process fluid by a second nonmagnetic covering. The internal magnets are attached to a shaft that drives the pump impeller. The shaft is supported on bearings that are lubricated by the process fluid.

The canned motor pump uses a single rotating element that is essentially an electric motor rotor with an impeller mounted on the shaft. The motor and pump casings are sealed such that there are no shaft penetrations as with conventional pumps with mechanical seals. The stator and motor rotor are protected from the process using a nonmagnetic containment shell. The rotor is supported generally using fluid lubricated film bearings. A portion of the pumped fluid is circulated to the motor to provide cooling and bearing lubrication. Canned motor mechanical construction is less complex than magnetic drive designs, but catastrophic failures of the stator assemblies are expensive to repair and difficult to decontaminate.

A method of getting reliable and timely information about the condition of sealless pumps was sought. The ideal condition monitoring method should:

- Be nonintrusive; monitoring devices should not penetrate the liquid containing parts of the pump.
- Be able to indicate process changes that influence pump operation and measure mechanical wear.
- Be reliable and proven technology.
- Be readily available.
- The results should be easy to interpret.
- Contain enough parameters to indicate a problem so "false trips" are not an occurrence and detecting failures are assured.
- Be easily retrofitted to existing sealless pumps.
- Not require the monitoring sensors to be sacrificial or consumed during normal wear of the equipment.
- Be upgradable so that new pumps do not need to be purchased to have the improved monitoring technology.
- Be able to withstand a chemical plant environment.

In Le Bleu and Xu (1995), several patterns were recognized as indicating problems with sealless pumps. These were clear and simple indications of the condition of the pump. The problem has been that many indications are given because of the sensitivity of the detection system, but not all indications could be resolved nor indicate an immediate problem. It was felt that with experimentation and the use of multiple parameters, improved diagnostics would be able to determine a healthy or unhealthy pump and pumping environment. This lead to the collaboration between a pump manufacturer and an end user to instrument a pump and induce many normally occurring operating parameters to get a known response. This collaboration resulted in the generation of a truth table. This truth table will help pump users determine the cause of conditions leading to the response measured by the monitoring systems.

Rotor position was a measurement that had been requested by sealless pump users for a long time. Measuring the rotor position allows pump operators to know where the rotor is in relation to the stationary pump components. As long as the bearings are not badly worn, serious damage caused by rotor to stator contact cannot occur to the pump. Direct measurement of rotor axial and radial position is now available in canned motor pumps in a reliable form. Historically, rotor position monitoring, when available, was applied to silicon carbide bearings, which do not wear. The benefits of rotor position measurement as a *predictive* tool were minimal. When rotor position monitoring is applied to bearings made of softer materials that wear, such as carbon/graphite, this technique becomes predictive because it allows the user to track wear on the bearings and schedule maintenance before serious damage is done. The wear monitor can give feedback on the wear rate of change in the rotor bearing system, if the position output data is viewed continuously. It allows safe operation of the pump for a time after a problem has been detected. Rotor position monitoring as a "go/no go" gauge is a maintenance scheduling device, only because it gives no rate of change or process information. Axial rotor position, if monitored continuously, gives more process information than radial position.

One manufacturer has developed a patented combination carbon/silicon carbide bearing to support the rotor. If process conditions cause the silicon carbide to fail, a "catcher" bearing made of carbon supports the rotor and allows continued operation for a time, but with no metal-to-metal contact. The silicon carbide bearing is behind the carbon bearing, so the pieces of the failed bearing are captured and maintained in the area of the shaft. They are not allowed to move freely with the liquid being pumped. Minimum damage to the rotating and stationary parts of the pump result. The combination of rotor position and dual bearing is a reasonable way to allow the use of silicon carbide bearings in a sealless pump until bearing materials can be found to allow slow and predictable failure modes for sealless pumps.

An explanation of OHFT can be found in Shea and Taylor (1990) and should be reviewed. It explains OHFT and some of its uses, but not as it applies to sealless pumps. The previous work that led to the experiments presented in this paper are documented in Le Bleu (1994), and Le Bleu and Xu (1995).

Experience has demonstrated that a narrow trace produced by OHFT at a low value is desirable. It indicates a very acceptable operating range for the pump. The only exception is loss of liquid to pump. This observation should be validated during the course of testing. Rotor position was previously monitored as a "go/no go" indication of bearing condition. Provisions are made to monitor radial and axial position continuously, if desired, and were used during these tests.

TEST SETUP

The pump was installed in a test loop consisting of instrumentation, a supply tank, and associated piping. A schematic of the test loop is shown in Figure 3. The electronic data acquisition and logging block diagram is illustrated in Figure 4. The pump was subjected to conditions that attempted to simulate what can be encountered during plant operation. The pressure on the supply tank could be varied giving the ability to induce or eliminate cavitation in the pump to measure its response with the sensors.

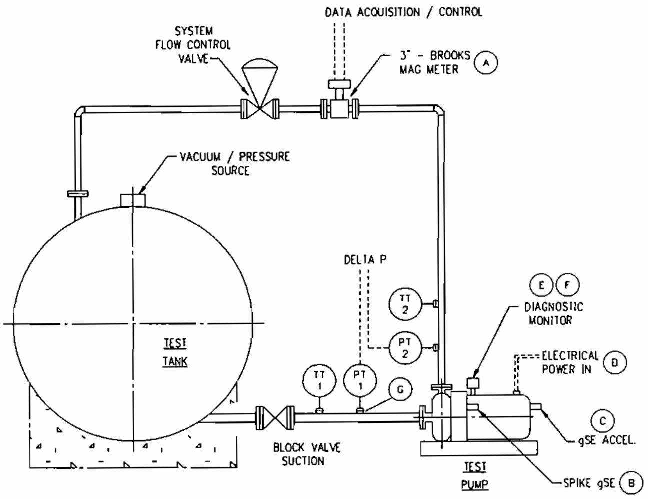

Figure 3. Pump Test Loop.

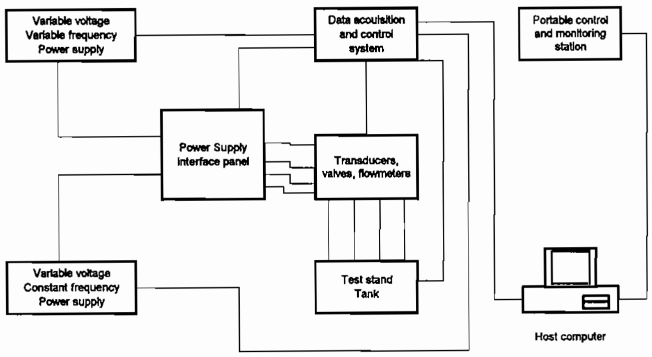

Figure 4. Data Acquisition Block Diagram.

Testing was done at the manufacturer's facility in Warrington, Pennsylvania. The canned motor pump supplied for the test was a Model NC-AB-6, 3450 rpm, 3 × 1½ × 6. Figure 5 is the operating curve for this pump. The pump was equipped with the manufacturer's rotor position monitoring device. This device monitors both axial and radial rotor position. OHFT was measured using two accelerometers that were connected to a dual channel monitor. It was reasoned that measurements of rotor position, OHFT, and power would provide sufficient information to determine pump mechanical condition. It was hoped this combination would also provide advance warning of process conditions that would adversely affect the pump's health. With two or more indications of a problem, the possibility of false trips should be minimized or eliminated.

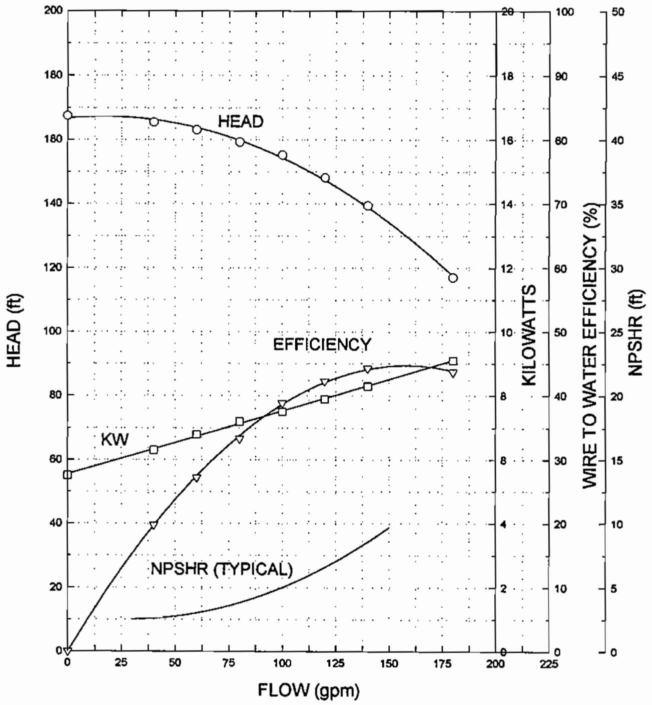

Figure 5. Test Pump Operating Curve.

PROCEDURES

Measurements were taken for the following pump operating conditions:

- Pump capacity range from shutoff to 30 percent greater than BEP, with data taken at 20 gpm intervals in the range
- A sudden large increase in pump flow
- Air leakage into the suction of pump (injected)
- Dry pump operation (part of the "air leakage" test)
- Best efficiency point. (Part of first item above; this was considered a baseline.)
- Reduced $NPSH_A$

The following information was recorded for the operating conditions listed above:

- Motor input power (watts) "D" (1 volt = 0 kW, 5 volts = 15.5 kW)
- OHFT
  0 to 16 gSE on the casing "B" (1 volt = 0 gSE, 5 volts = 16 gSE)
  0 to 5 gSE on the rear bearing housing "C" (1 volt = 0 gSE, 5 volts = 5 gSE)
- Rotor position (axial and radial)
  Axial "E" (1 volt = .000 in, 5 volts = .100 in)
  Radial "F" (1 volt = .000 in, 5 volts = .013 in)
- Flow "A" (1 volt = 0 gpm, 5 volts = 300 gpm) 3 in mag-flowmeter
- Suction pressure "G" (1 volt = 0 psia, 5 volts = 30 psia); absolute pressure transducer

The data in parentheses are the plot scale factors for the data presented in the paper. An increase in voltage for the rotor axial position data represents a movement of the rotor toward the suction flange of the pump. The letters in apostrophes represent the letters on the graphs for that data set.

TEST RESULTS

The data indicate a direct correlation between a change in the axial rotor position and a change in the magnitude of the OHFT readings. When hydraulic operating conditions such as cavitation or pump flowrates were changed, similar indications were evident in the axial rotor position and the OHFT. For example: if cavitation moved the rotor toward the suction flange of the pump, it also increased the noise in the pump casing, which was subsequently detected and indicated by the OHFT sensor. Rotor axial position and OHFT levels appeared to track each other closely.

The rotor on this pump normally operates in a position slightly closer to the back plate of the pump and away from the suction. This is a function of the hydraulic balance and the normal running clearances around the pump impeller. The indicated radial position of the rotor did not change unless there was bearing wear, catastrophic failure of the bearing, or dry running. A general correlation between OHFT levels and repair costs are: operation at high OHFT levels will result in higher repair costs.

There were two OHFT monitors and sensors (accelerometers) installed on the test pump. Both of the sensors indicated identical patterns, but at different magnitudes. One OHFT sensor was mounted on the head of a bolt that attached the pump casing to the main housing of the pump. The plots are marked with a "B" for this sensors' readings. It was oriented in the axial direction. This mounting method was chosen so that the sensor could be easily mounted on more than one pump if desired. A second sensor was mounted on the outboard bearing housing in the axial direction. The plots are marked with a "C" for the output from this sensor.

Changes in Flow

The changes in data as a result of variation in flow over the range of 50 gallons per minute (gpm) to 190 gpm are represented in Figure 6. Note that at capacities greater than the best efficiency point, the rotor begins to move toward the suction flange of the pump and OHFT begins to move up scale and increase in width. The trace becomes wider in both rotor position and OHFT as the fluid flow and rotor position respond to the changes in pumping conditions. Wider traces of both OHFT and axial position are indicative of operating conditions to avoid in pumps and especially sealless pumps. Radial position was constant because there was no bearing wear.

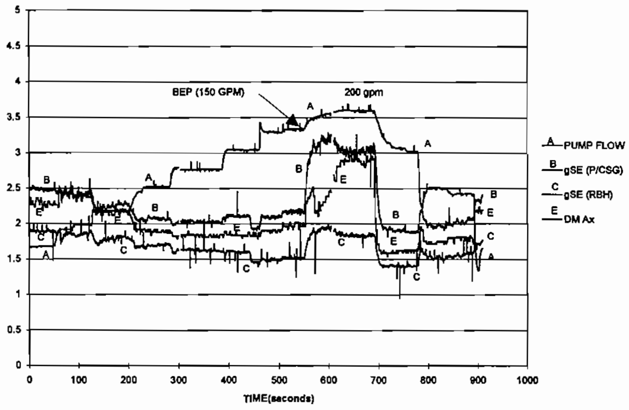

Figure 6. Flow Changes (20 GPM Increments).

Large Flow Decrease

A large flow decrease from 200 gpm to shutoff is represented in Figure 7. OHFT, indicated by "B" and "C" on the chart, is at a high value and a wide trace at 200 gpm indicating cavitation and pump stress. The axial rotor position also has a wide trace during this part of the test indicating the rotor was "hunting" to find its hydraulic balance. When the flow is decreased from 200 gpm to 150 gpm, the rotor moves to a normal and more balanced axial location and OHFT decreases from 10 gSE to approximately 4 gSE. When the flow is reduced to shutoff, the rotor moves toward the suction of the pump and OHFT is somewhat elevated over best efficiency operation. If left to operate at this condition for some time, OHFT would increase, because the liquid in the pump would begin to flash. Tests performed in England allowed the liquid to boil in the pump while measuring temperature and OHFT. The results were high temperatures and high OHFT levels. When the flowrate is returned to near best efficiency point, OHFT returns to a previously observed level for normal operation. Because it returned to previous levels, no permanent damage to the pump has been done. Years of plant experience has shown this to be the case. When serious damage occurs, such as metal-to-metal contact or excessive operating clearances on the wear rings, the OHFT levels do not return to baseline indications. Experimentation and field experience have shown that OHFT levels are repeatable at different capacities, as long as the pump is undamaged.

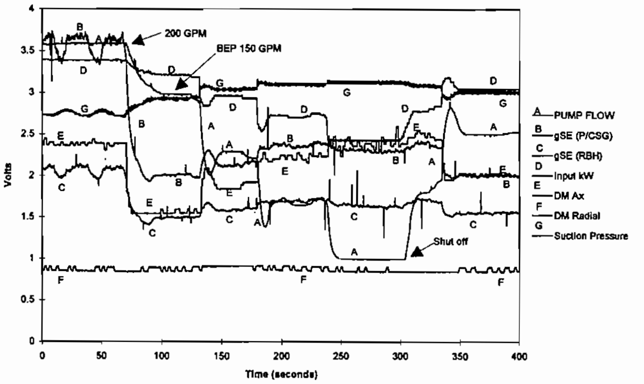

Figure 7. Large Flow Decrease.

Large Flow Increase

Large flow increases are illustrated in Figure 8. At very low flows, the OHFT value is high and the rotor axial position is near center. At BEP, 150 gpm, OHFT is at a minimum level and rotor axial position is slightly toward the motor. When flow is increased to levels significantly higher than BEP, the onset of cavitation is indicated by an increased width of signal in both the OHFT and axial rotor position data. Rotor axial position oscillates at the high flow level, and this "hunting" of the rotor is indicated by the wide data trace "E." This oscillation is caused by the rapidly changing pressure balance on the impeller during cavitation. The OHFT signal also becomes less stable and "noisier" when the pump is in cavitation.

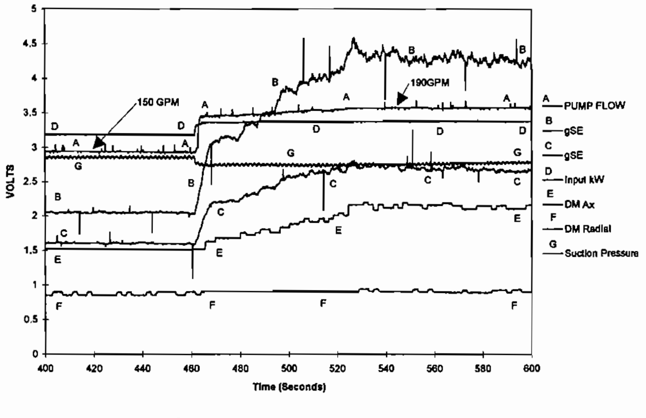

Figure 8. Large Flow Increase.

Suction Side Restriction

The suction valve was closed at a constant flow to measure the response in terms of the measured parameters. The results are illustrated in Figure 9. The width of the trace representing axial rotor position and OHFT begin to increase. Both of these indicate instability. One is in the rotor position and the other is in pumped fluid. This could represent a suction strainer plugging in the suction line, if there were one, or a valve that was not opened fully. It can also represent a fluid that has become too hot and is flashing in the suction of the pump. This means that failure of sealless pumps, due to inadequate suction conditions or other cavitation inducing operation, can be minimized through the connection of the monitors to appropriate operator alarms. As was previously discussed, the monitoring system also allows the user to quantify the severity of the operating condition and assess the pump condition after elimination of the cavitational condition. Indications of severe bearing wear or permanent damage will be indicated.

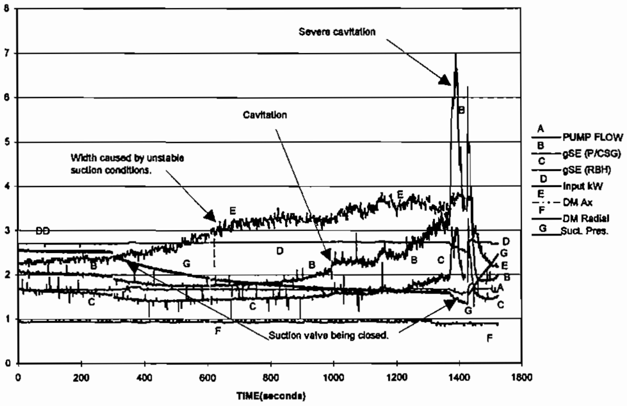

Figure 9. Suction Side Restriction.

Air Injection and Dry Run

The air injection and resulting dry run test in Figure 10 is a graphic representation of the effects on axial rotor position when air leaks into the suction. OHFT immediately begins to decrease in amplitude. The axial position does not change immediately, because the loss of fluid is not immediate. The radial position of the rotor changes because the loss of fluid in the radial bearings and around the rotor reduces the radial support stiffness. OHFT levels are very low because of the loss of coupling fluid and transmissibility between the pump casing and the rotor. If dry running operation is continued to the point of actual bearing damage and possible metal-to-metal contact, the OHFT level will increase. When the liquid is reintroduced to the pump, cavitation exists for a short time, and OHFT levels increase. The wattmeter shows no load on the pump and the flow has fallen to zero. If dry operation is continued much longer, the pump will be destroyed. This test does show that a "dry run," as with a tank pump out, does not result in an instantaneous catastrophic failure. The effects of dry running and severe cavitation are cumulative.

Low Suction Pressure Induced Cavitation

While factory NPSH testing defines the onset of cavitation as a three percent loss of head, cavitation effects are sometimes seen well before a measurable head loss occurs. Continuous monitoring of OHFT and rotor axial position represents a practical method to measure the actual onset of cavitation through the direct measurement of pump response to hydraulic conditions. A test was conducted where the suction pressure was reduced with the pump capacity held at a constant 150 gpm to observe the effects on the monitored parameters. Figure 11 is the graphic representation of the results of that test. The axial rotor position moved dramatically toward the suction flange as the suction pressure was reduced. OHFT levels increased with a widening trace width. Power decreased and flow was held somewhat constant by adjustment of the discharge valve. The discharge pressure was not recorded but was observed to decrease as suction pressure was reduced, as expected. When suction pressure was reestablished at atmospheric normal, the rotor moved back to its normal run position and the other parameters returned to normal operating levels as well.

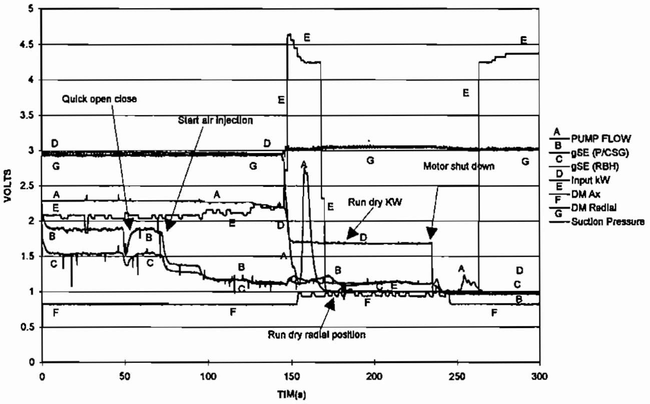

Figure 10. Air Injection.

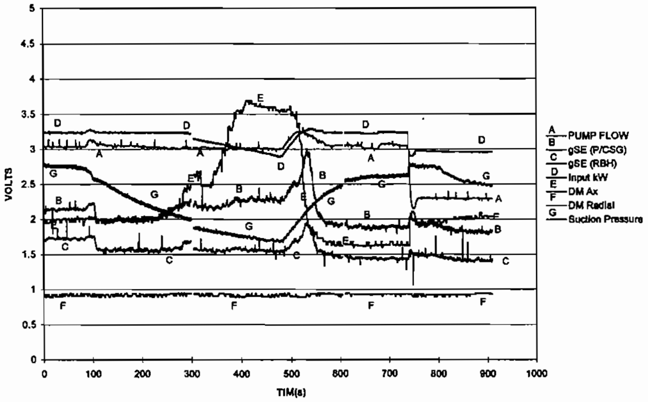

Figure 11. Reduced Suction Pressure (at Constant 150 GPM).

Table 1 represents all the data that were recorded during the testing of the pump for each measured parameter and test condition. The table can be used with whatever combination of sensors exist in the user's plant and will be helpful in the interpretation of indications. For example, if OHFT is added to a system that already has a power monitor, useful information can be obtained that should minimize maintenance costs and catastrophic failures. The table should be most beneficial in differentiating between normal and abnormal operating conditions and providing verification of possible problems. Monitoring must be on a continuous basis to gain these advantages on sealless pumps.

OHFT (Overall High Frequency Tracking)

During pump testing, several new items were noted regarding OHFT. These items were:

- The mounting of the sensor was found not to be as critical as originally suspected. That is, if the sensor is mounted solidly to the pump casing, the orientation as to axial or radial did not significantly change the magnitude of the overall readings. This premise was confirmed by taking readings with the sensor mounted in the original position, radial at 11 o'clock when viewed from the suction end, and then in the axial direction. The overall readings were fundamentally the same for both transducer locations. It is very important to have the sensor firmly attached to the pump, ideally using a stud mount, directly to the mounting surface.

Table 1. "Truth" Table of Results.

WATTS	ROTOR POSITION		AXIAL WIDTH	SPIKE	SPIKE WIDTH	LIKELY CAUSE
	Radial	Axial				
GU	NC	TS4	N4	GU	N4	Large flow increase
GD	NC	AFS	N	GD	N	Large flow decrease
GU	NC	NC	N	GU	N	Small flow increase
GD	NC	NC	N	GD	N	Small flow decrease
MNL	NC	NP	W	GU	W	Shut off
HIGH	NC	TS	W	GU	W	Excessive flow (10% or more past BEP)
MNL	NC1	M2	N	GD	W	Air injestion
MNL	NC1	TS	N	GD	N	Dry running
HIGH	NC1	TS	W	HIGH	W	Cavitation caused by too much flow
GD	NC1	TS	W	GU	W	Cavitation caused by insufficient NPSH
NORMAL	NC1	NP	N	LOW	N	BEP (Best efficiency point)
NC	NC1	TS3	W	HIGH	W	Metal to metal in axial
NC	WEAR2	NC	N	HIGH	W	Metal to metal in radial
SM	NC1	SM	W	UP / DOWN	N5	Excessive, recurring control vlave movement.
GD	NC1	TS	W	GU	W	Reduced suction pressure

NOTES:
1= If there is no bearing wear or damage.
2= Indicates an alarm (radial) or trip based on amount of wear.
3= Indicates an alarm (axial) or trip based on amount of wear.
4= Unless past BEP.
5= Unless outside of pump operating capacity.

GLOSSARY
MNL = Motor no load
GU = Going up
GD = Going down
NC = No change
W = Wide (Usually an adverse condition)
TS = Toward suction
NP = Normal run position
SM = Slight movement
AFS = Away from suction
N= Narrow
M = Movement

- Lower baseline OHFT readings will result when the accelerometer is mounted on the upstream side of the cutwater. Higher baseline readings resulted when the accelerometer was mounted downstream of the cutwater. Presumably, the increased baseline noise was caused by possible turbulence or hydraulic noise associated with liquid passing by the cutwater.

- A rule of thumb when using OHFT is that less is better than more. The quieter the pump is operating, generally the better and more trouble free it will operate. The exception to this rule is dry running.

- Wider traces of both OHFT and axial rotor position are indicative of operating conditions to avoid in pumps, especially sealless pumps.

- A time interval of one second or less should be used as a sample rate for capturing OHFT data. This will capture all of the fast changing operating and mechanical data that can take place with the pump.

- Mounting the sensor closer to the source of the stimuli is better, which usually means on the pump casing.

- It was noted that conditions that raised the OHFT level caused the rotor to move significantly in the axial direction. Generally it was in the direction of the suction of the pump on our test pump.

- Recently, a pump was found that had a high baseline noise in its casing area. This high baseline level could not be brought down. Testing was tried with the high gSE level, but sensitivity was so low pump problems could not be detected. It was learned that if the baseline noise is much above 20 gSE, the sensitivity suffers so as to make monitoring questionable and measurements are so desensitized that the data are not useful. The known patterns may not be easy to find and interpret.

ROTOR POSITION MONITORING

The rotor is monitored through a series of wound coils located outside the primary containment, protected from the process fluid by the stator liner. Electrical signals received from the coils are used to continuously monitor the actual running position of the rotor. The device detects any change in rotor position, both in the axial and radial direction simultaneously. By comparing the instruments' output with the original factory test baseline of a new pump, the condition of the internal radial and axial bearings are determined. The control center of the monitor is a factory programmed microprocessor that can provide digital, analog, and relay outputs. Analog output was used for each variable during these tests.

After the initial calibration, radial bearing wear is determined by a change in output in the radial direction greater than the baseline data for new bearings. The amount of wear is proportional to the change in signal. It should be noted that normal operation of a sealless pump does not promote wear of the radial and axial bearing surfaces. The process upset conditions leading to lack of lubrication and rapid heat rise are the main causes leading to wear of these surfaces. Continuous monitoring enables users to trend these damaging events to predict and improve the mean time between maintenance intervals.

Analysis of rotor position for many of the upset conditions encountered during the testing gave very good correlation with OHFT. Note that the amount of rotor movement will likely be different for various pump models, due to the stiffness of hydraulic balance and susceptibility to cavitation or air ingestion. Once a baseline set of data is taken with the pump operating in its process, monitoring of the rotor position and noting changes in position will provide data to develop a good predictive maintenance tool incorporating process condition effects on pump wear, thereby providing an early warning of potential problems.

CONCLUSIONS

There are many benefits to monitoring sealless pumps continuously. Since the trend in process plants is to use distributed control systems, much of the plant equipment is being remotely operated. Presently, the board operator in a control room has little or no feedback on the operating condition of most of the pumps, other than possibly flow and discharge pressure. Most of these parameters are not instrumented with trip or alarm limits. It is possible for the pump to be operating in an off-design condition or have mechanical damage with no feedback supplied to the operator. The feedback presently comes in the form of failed equipment and expensive repairs. Because the feedback and the cause of the problem with the pump occur over a relatively long period of time and are usually not immediate, the cause and effect relationship may never be discovered. With continuous monitoring, it is possible to get immediate feedback on the condition of the pump and on the process conditions. Conditions such as cavitation, dry running, and extreme operating parameters that will result in pump failure can be immediately detected. Armed with this information, the operator can make decisions to improve operating conditions that will prolong equipment life and maintain product quality.

For new pump installations, use the latest technological advances being offered by sealless pump manufacturers, such as rotor position monitoring. It is best to utilize both radial and axial monitoring of rotor position. The data presented in this paper demonstrate that there are many conditions that will not be detected by radial monitoring alone. This is especially true with silicon carbide bearings. OHFT appears to be applicable for older installed pumps that have had catastrophic failures that were not detectable early enough to prevent serious damage to the pump.

For retrofit of OHFT monitoring systems to sealless pumps, the following suggestions are made to minimize maintenance costs on pumps and eliminate liquid leaks from damaged containment cans or shells. When metal-to-metal contact is taking place, the pump should be stopped and scheduled for maintenance. Successful monitoring practices used with OHFT, or OHFT in combination with a power meter are:

- When OHFT is added to a pump, the condition of the pump should be known and a baseline representing that condition recorded. OHFT values should be fairly low in the 10 to 40 percent of full scale range. The full scale reading should be in the zero to five, zero to 10, or zero to 15-18 gSE range. If the baseline level is higher than these levels after installation of the monitoring system, there may already be a problem with the pump, or OHFT may not work on this application. The baseline must be fairly low or the system becomes so insensitive that the desired information will be missed. On occasion there have been pumps that are so "noisy," hydraulically, that OHFT could not be used.

- A baseline set of readings should be taken with the pump operating at its normal capacity. This should be done even if the discharge valve has to be throttled to achieve this with the size of the impeller that is being used.

- When an increase in OHFT is detected, the process should be varied, if possible, to eliminate the "noisy" condition. This will help to determine if the increase is due to mechanical or process conditions. This is especially true if a change in operation that affects this pump was recently made. If a recognized pattern of mechanical failure is seen, such as is illustrated in Le Bleu and Xu (1995), the pump should be shut down for repair.

- If the OHFT levels are reduced to a relatively low value by adjusting process conditions to normal pump design values, the pump most likely does not have a mechanical problem, but is probably not being operated on its curve. To test this, allow the process to settle for a short while. Start the standby pump, if one exists, and look at its OHFT readings. If it is substantially lower than the recently running pump, leave the spare pump in service and put the other in standby mode. Schedule the recently stopped pump for maintenance.

- If the OHFT noise cannot be reduced by switching pumps, this may be an indication that the pump may be incorrectly sized for the process and will be a maintenance problem. Past experience has shown that two pumps seldom exhibit the same problem at the same time unless the cause is process related. The pump application should be investigated for proper sizing and adequate suction conditions. This has been a successful method of determining if the process or damage to the pump is the source of increased OHFT.

If a new pump is required as an upgrade or for a new application, then rotor position monitoring should be considered. Rotor position monitoring is an excellent way of tracking bearing condition. It should prevent breeches of the primary containment, if continuously monitored. Bearing wear is easily detectable with rotor position monitoring. If the pump rotor is past the limits of the bearings original position by more than 50 percent, maintenance should be scheduled while the rotor position is continuously monitored. If the wear is more than 70 percent of the original clearance, the pump should be stopped because catastrophic failure will ultimately result. With abradeable bearing material, the radial position monitor output should be trended over time to schedule maintenance. Depending on process conditions, the wear rate may not be linear and care should be exercised as limits are reached. Our testing indicated that there are some process conditions that will be detected using continuous rotor position monitoring, if both radial and axial positions are monitored.

The greatest savings will come from detecting the conditions that will cause a problem in a pump early enough to eliminate them and thus prevent a failure. If early detection of off-process operation is not possible, the next best maintenance practice is to detect a problem at its inception and schedule the pump for maintenance while the problem will result in minimal maintenance costs, business interruption, and no leakage.

NOMENCLATURE

gSE = Dimensionless unit of spike energy. It stands for acceleration in "g's" of spike energy
OHFT = Overall high frequency tracking

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