Centrifugal pump vibration

It is necessary to be interested in vibration because it has a major affect on the performance of your pump. At least six components are seriously affected by vibration:

- The life of the mechanical seal is directly related to shaft movement. Vibration can cause carbon face chipping and seal face opening. Drive lugs will wear, and metal bellows seals will fatigue. In some instances the shaft movement can cause the rotating seal components to contact the inside of the stuffing box, or some other stationary object, causing the seal faces to open and allowing solids to penetrate between the lapped faces. Vibration is also a major cause of set screws becoming loose and slipping on the shaft, causing the lapped seal faces to open.

- Packing is sensitive to radial movement of the shaft. You will not only experience excessive leakage, but excessive sleeve or shaft wear also. Additional flushing will be required to compensate for the heat that will be generated by the high friction packing.

- Bearings are designed to handle both a radial and axial load. They were not designed for the vibration that can cause a brinneling (denting) of the bearing races.

- Critical dimensions and tolerances such as wear ring clearance and impeller setting will be affected by vibration. Bearing internal clearances are measured in tenths of thousands of an inch. (thousands of a millimeter)

- Pump components can be damaged by vibration. Wear rings, bushings and impellers are three examples.

- Bearing seals are very sensitive to shaft radial movement. Shaft damage will increase and the seals will fail prematurely. Labyrinth seals operate with a very close tolerance. Excessive movement can damage these tolerances also.

- Pump and motor hold down bolts can become loose.

The vibration comes from a number of sources that include :

Mechanical causes of vibration

- Unbalanced rotating components. Damaged impellers and non concentric shaft sleeves are common.
- A bent or warped shaft.
- Pump and driver misalignment.
- Pipe strain. Either by design or as a result of thermal growth.
- The mass of the pump base is too small.
- Thermal growth of various components, especially shafts.
- Rubbing parts.
- Worn or loose bearings.
- Loose hold down bolts.
- Loose parts.
- Product attaching to a rotating component.
- Damaged parts.

Hydraulic causes of vibration

- Operating off of the best efficiency point (BEP) of the pump.
- Vaporization of the product
- Impeller vane running too close to the pump cutwater.

- Internal recirculation
- Air getting into the system through vortexing etc.
- Turbulence in the system (non laminar flow).
- Water hammer.

Other causes of vibration.

- Harmonic vibration from nearby equipment.
- Operating the pump at a critical speed. Watch out for this problem in variable speed and pulley driven pumps.
- Seal "slip stick" at the seal faces. This can occur if you are pumping a non lubricating fluid, a gas or a dry solid.
- A pump discharge recirculation line aimed at the seal faces.

You can read the vibration a variety of ways:

- Frequency
- Amplitude
- Velocity
- Acceleration
- Spike Energy
- Acoustic emissions
- Deflection

Many systems read vibration by recording acceleration. The problem with this method is that if you do not know the frequency the readings are not very meaningful. Because of this most systems read an average of all of the frequencies involved and recommend taking action when this average reading doubles in a particular location. If bearings are your primary concern high and low electronic filters can be used in some equipment to filter out frequencies below 55 Hz. and above 2500 Hz. These filters will help the operator zero in on those frequencies normally associated with bearing problems.

Unfortunately, most vibration data references bearing operation. There is little to no information available about mechanical seal vibration modes. The problem is further compounded by:

- The large variety of seal materials in use.
- Major differences, in design between popular brands of single and multiple seals.
- Availability of vibration damping in these seal designs.
- The wide spread use of environmental controls.
- The variety of fluids surrounding the seal

The vibration readings almost always means that the equipment has started to destroy its self. Most companies are trying to collect enough data to predict the remaining life before total destruction takes place.

The obvious solution to all of this is to adopt good maintenance practices that will eliminate most of the vibration and then try to install hardware that can live with the vibration you have left. Recording vibration makes sense only after good maintenance practices are in force.

Mechanical Problem Solutions

- Balance all of your rotating equipment. If you do not have dynamic balancing equipment in your plant there are contractors and vendors anxious to work with you. Balance is always a problem when you are pumping abrasives, or a slurry, because the rapid wear always destroys balance. In the higher speed pumps this wear can be very severe.

- Bent shafts are a problem. If you can straighten them go ahead and do it, but most attempts are unsuccessful. In the majority of cases you are better off replacing the shaft.

- Do a proper pump/ driver alignment using either a Laser or the reverse indicator method. Upgrading the pump power end to a "C" or "D" frame motor adapter is a more sensible and economical decision. Once the conversion is made misalignment ceases to be a concern. These adapters are available for most motors and will maintain the proper alignment as the equipment goes through its normal temperature transients.

- Always pipe from the pump suction to the pipe rack, never the other way. There are some more piping practices that you should follow:

  - If you are experiencing pipe strain because of thermal growth at the suction, you might convert to a "centerline" design wet end and solve the problem. Center line designs make sense any time you are pumping a fluid in excess of 200 degrees Fahrenheit (100 Centigrade)
  - Try to use at least ten diameters of pipe between the pump suction and the first elbow.
  - Valve stems, T branches and elbows should be perpendicular to the pump shaft not at a right angle to it. This is especially important with double suction pumps because uneven inlet flow will cause the impeller to thrust in one direction causing bearing problems on one end of the pump.
  - Pipe supports and hangers should be installed at unequal distances.
  - Use lots of hangers to support the piping.
  - Use lots of loops and expansion joints in the piping system.
  - After fabrication and testing remove all supports and lock pins from the spring hangers, loosen pipe flanges and adjust the system to free the pump from pipe strain.
  - Reference the "Hydraulic Institute Manual", or a similar publication to learn the proper methods of piping several pumps from the same suction source to prevent vortexing etc.

- The mass of the pump concrete foundation should be five times the mass of the pump, base plate and other equipment being supported.
- The foundation should be three inches (75 mm) wider than the base plate, all around, up to 500 horsepower (375 KW) and six inches (150 mm) above 500 horse power (375 KW).
- Imaginary lines, extended downward 30 degrees to either side of a vertical through the pump shaft, should pass through the bottom of the foundation and not the sides.
- Every inch of stainless steel grows 0.001 inch for every 100° Fahrenheit rise in temperature (0,001 mm/mm/50° Centigrade) This thermal growth can cause the impeller to rub the pump casing as well as cause rubbing in many close tolerance clearances such as the wear rings. Carbon steel grows about 30% less than stainless steel.
- Any time the shaft moves there is the danger of parts rubbing. Thermal imaging equipment can detect this rubbing easily. When ever you set tight tolerances be sure to allow for thermal growth and, in the case of A.N.S.I. pumps, impeller adjustment.
- Worn or loose bearings are caused by improper installation or allowing water to enter the bearing cavity. Labyrinth seals or positive face seals are the easiest solution to the water problem. Install bearings by using a proper induction heater to prevent contamination during the installation process.
- The answer to loose hold down bolts is obvious and requires no explanation.

Hydraulic Problem Solutions

- You may be able to increase or reduce the impeller diameter to get close to the pump B.E.P., but if this is not practical your best bet is to reduce the L3/D4 by going to a solid shaft or upgrading the power end to a larger shaft diameter. In some instances you can install a support bushing in the bottom of the packing stuffing box and install a mechanical seal closer to the bearings. Split seals are ideal for this conversion. In a few instances, changing the shaft speed will solve the problem. A closed loop system with a high system head is an ideal candidate for a variable speed pump

- Insure that you have enough NPSH for your application. If there is not enough an inducer or booster pump might solve the problem. Another section in this series explains "Cavitation" in great detail, and offers many solutions to the problem.
- An impeller, running too close to the pump cutwater will cause vibration and damage. An impeller tip to cutwater clearance of 4% (of the impeller diameter) in the smaller impeller sizes (to 14 inch/355 mm) and 6% in the larger sizes will solve this problem. This becomes a problem with most self priming pumps and the only solution is to contact your pump supplier for his recommendation, if he has one. Repaired impellers sometimes experience this problem.
- Internal recirculation problems can be solved by either adjusting the open impeller or replacing the closed impeller with an alternative design. This problem was discussed in another volume of this technical series.
- Air can get into a system through valves above the water line or flanges, but the easiest way for air to enter a system is through the stuffing box of a packed pump. The simplest solution is to replace the pump packing with a balanced O-Ring seal. If vortexing is the problem, consult the "Hydraulic Institute Manual" for information on vortex breakers and proper piping layouts to prevent turbulence in the lines, and at the pump suction.
- Water hammer is not very well understood by our industry, but we know how important it is to keep air out of the piping system.
- It is good practice to use one size larger suction pipe and then use a reducer to connect the piping to the pump. Do not use concentric reducers. Eccentric types are much better, as long as you do not install them upside down.

Solutions to other types of vibration

- The pump, or one of its components, can vibrate in harmony with another piece of equipment located in close proximity. Isolation, by vibration damping, is the easiest solution to this problem. This is a big problem with many metal bellows seal designs because they are lacking an elastomer that functions as a vibration damper.

- Critical speed operation is not a common problem unless you are operating with a variable speed drive. Changing the speed is the obvious solution. If that is not practical, changing the impeller diameter is another solution.

- Seal "slipstick" is a problem with non lubricants such as hot water or most solvents. If you are using O-Ring seals, the O-Ring is a natural vibration damper. Metal bellows seals require that a separate vibration damper be installed, usually in the form of a metal component vibrating and sliding on the shaft.

- Pump discharge recirculation lines can cause a vibration every time the impeller passes the recirculation line "tap off". This vibration will affect the mechanical seal and like all vibration, can be recognized by chipping of the outside diameter of the carbon face and worn drive lugs.

Most of us can not stop all of the vibration that is causing our seal, packing, bearing, and critical clearance problems, so our only solution is to live with it. Unfortunately the standard pump and original equipment seal is not prepared to handle vibration without major modification.

Reference:

http://www.mcnallyinstitute.com/02-html/2-09.html