

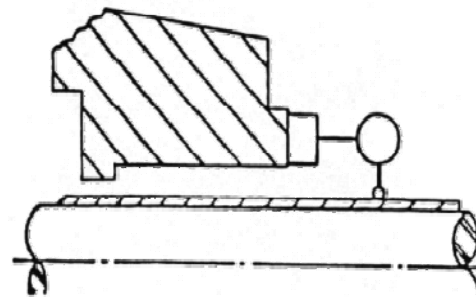
In this 6th installment of The Seven Deadly Sins of Pump Ownership¹ we present the first of a two-part series on misalignment. Misalignment is a common cause of premature pump failure. Causes of misalignment may be static or dynamic in origin. Static misalignment is defined as misalignment that is measurable when the equipment is not in operation. Dynamic misalignment is defined as misalignment that is detectable only during operation. In this issue we will discuss sources of static misalignment and corrective actions that can be taken to improve pump reliability. Static misalignment can be caused by parts that are out of tolerance, static shaft deflection, coupling misalignment, and improper pump installation.

Dale B. Andrews

Dale B. Andrews – Editor

Misalignment at the seal housing can be caused by a permanent bend in the shaft, excessive shaft deflection, or by misalignment between the rotor assembly and the seal housing. Determination of the shaft condition should be a first step when checking for misalignment at the seal housing.

A bent shaft is easy to detect and difficult to repair. To determine if a shaft is bent at the seal housing, mount a dial indicator on a stationary surface, such as the seal housing, and measure the runout on the shaft sleeve while turning the shaft through 360 degrees. Total Indicated Runout (TIR) of more than 0.002 in (0.05 mm) warrants a repair or replacement of the pump shaft.



Shaft Sleeve Runout

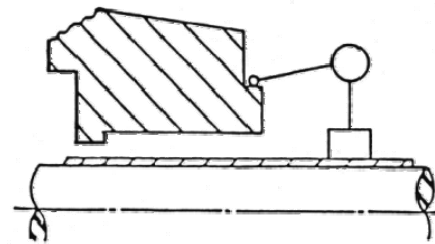
¹ The Seven Deadly Sins: (active links are to past issues)

1. [Off-design operation](#)
2. [Misapplied design \(i.e. wrong type of pump\)](#)
3. [Cavitation](#)
4. [Excess nozzle loads](#)
5. [Poor lubrication](#)
6. Misalignment
7. Neglect

It is possible for the shaft to be bent at a location that will not reveal itself when checked at the shaft sleeve. A shaft should also be checked for straightness if vibration readings indicate an out of balance condition. The detection procedure is the same. Mount the indicator on a stationary surface and take a reading from the shaft while turning it.

In most cases it is less costly and more reliable to replace a bent shaft than to attempt straightening it. Shafts of small diameter may be straightened by mechanical means, but this is more an art than a science and it is often a time consuming, and therefore expensive, process. Some repair shops use heat to straighten a shaft, but this is an unreliable method. Not only can excessive heat affect the physical properties of the shaft, but shafts straightened with heat often bend again as heat induced stresses are relieved.

Misalignment that is indicated by a lack of concentricity or parallelism may be measured by mounting a dial indicator on the shaft sleeve. While rotating the shaft and dial indicator, measure runout on the seal housing bore or register for concentricity and at the seal housing face for parallelism (angularity).



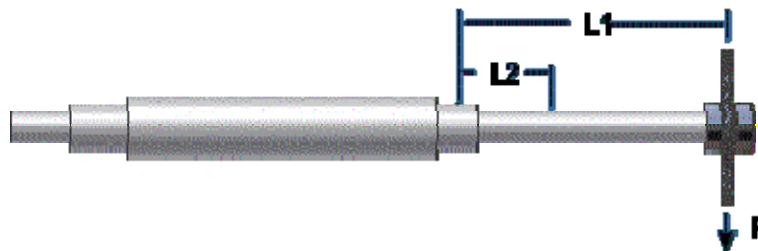
Seal-Chamber Register Concentricity

If the seal housing concentric runout is greater than 0.005 in (0.127 mm), or the face runout is greater than 0.0005 in/in of seal housing bore diameter, further investigation and corrective action is warranted. Potential causes of an out of tolerance seal housing runout reading include excessive static shaft deflection, out of tolerance assemblies and deformation of the pump assembly due to high structural loads.

Static Shaft Deflection

Although it is unusual for static deflection by itself to be a problem, calculating the static deflection at the seal housing provides an indication of how much of the total deflection is from the overhung load and how much is from other causes. A single stage overhung shaft can be treated like a cantilevered beam. The impeller creates a radial downward force, “F”, at some distance, “L”, from the nearest support bearing. The deflection can be calculated by the equation

$$y_c = \frac{F L^3}{3EI}$$



Where:

y_C = Shaft deflection at the Impeller centerline

F = Weight of the Impeller

L1 = Overhang from the closest bearing

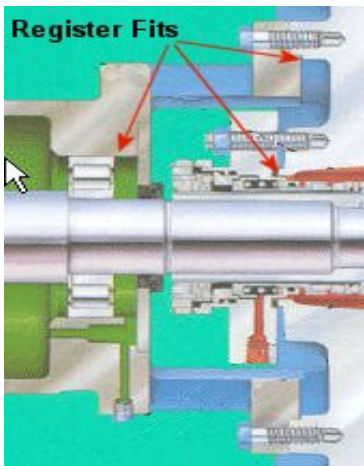
E = Modulus of Elasticity for the shaft material

D = Shaft diameter under the sleeve

I = Shaft moment of inertia ($0.049 D^4$)

Deflection at the Seal housing can be approximated by $L2/L1 * y_C$.

Worn Parts

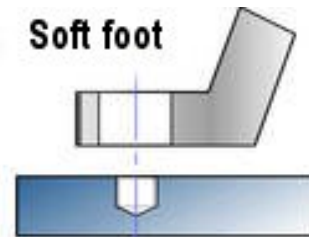


Misalignment that is due to the tolerances of the assembled machined components is harder to detect. There are usually several register fits between the bearing supports and the seal housing. These fits need to be machined concentric and square. Measurements should be done on a machine. Although an individual register may appear to be out of tolerance by only a small amount, it is important to remember that the total misalignment of the assembled parts will be the sum, or stack up, of the individual component misalignments. Register fits are subject to wear and corrosion over time and should be checked as part of any major maintenance.

Improper Installation

Soft Foot

Many pumps have four or more mounting pads for mounting the pump to the base plate. Similar to a chair or table with uneven legs, a pump often does not have 100% contact with all of the base plate mounting surfaces. This is called a soft foot condition.



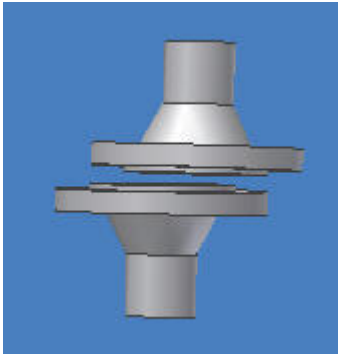
Bolting a pump to a base when a soft foot condition exists may result in misalignment of the pump shaft to the seal housing and place stress on the bearings and other components. To check for soft foot, mount a dial indicator on the base plate and take a measurement from a pump foot horizontal surface adjacent to a hold-down fastener. A change of the indicator of more than 0.002" (.05mm) while tightening or loosening a hold-down fastener indicates a soft foot. Use stainless precision shims between the baseplate and pump to compensate.

Coupling Misalignment

Pumps and drivers are usually joined by some form of flexible element coupling to compensate for small misalignments between the driver and driven shafts. Flexible parts are usually made from springs, stacked flexible discs, or some form of elastomer. Most coupling manufactures promote that their couplings can tolerate large shaft misalignments. These statements are misleading as they are statement of what the couplings can tolerate and not what the interconnected machines can tolerate. Shafts are aligned when the two opposing shafts are coaxial. Misalignment is parallel where the shaft axis are parallel but offset from one another either vertically or horizontally, and misalignment is angular where the axis are no longer parallel to one another. Usually, misalignment is a combination of both and parallel and angular misalignment.

Misalignment should be within 0.02 mm (0.001 in) for parallel misalignment. Angular misalignment should not exceed 0.03 degrees². With the ready availability of relatively inexpensive shaft laser alignment tools, these numbers are easily attainable, even by inexperienced mechanics. For equipment that operates at non-ambient temperatures, shaft alignment should be done hot to prevent misalignment due to thermal growth.

Piping Misalignment



Mating flanges should be concentric and parallel. Bolting of misaligned piping to a pump will cause both the piping and the pump to distort. The amount of distortion is related to the relative size and strength of the pump and piping, as well the distance from the nearest fixed hold down. Pump manufacturers provide allowable nozzle loads by request, or as part of their standard documentation. If mechanical leverage is required to bring the flanges into position then the nozzle loads should be checked.

If the piping connections are suspect for reliability problems, mount a dial indicator so as to check for shaft alignment at the seal housing as described for checking shaft angularity and parallelism. If connecting or disconnecting the piping changes the shaft alignment, then corrective action should be taken. This sometimes requires cutting and field welding to obtain proper nozzle alignment.

This is a very brief guide to the major mechanical causes of excessive static misalignment at the mechanical seal. More detailed information about the requirements for a specific pump can be obtained from the pump OEM service department. While in operation, other forces such as radial loads, impeller balance, and cavitation also affect seal alignment. Next month we will take a look at some of the most common causes of dynamic misalignment and corrective actions than may be taken to improve reliability.

² API 686 Recommended Practices for Machinery Installation and Installation Design, American Petroleum Institute