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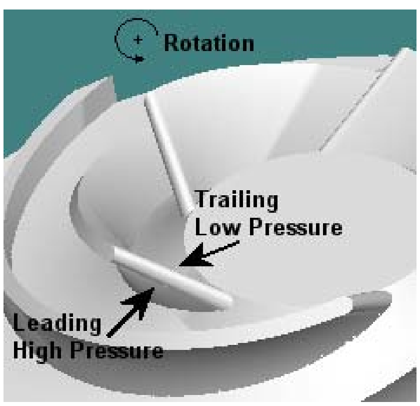
This is the second in a two part series discussing the topic of shaft misalignment. Shaft misalignment is perhaps the largest contributor to premature mechanical seal failure. In our August 05 Issue we discussed some causes and remedies for static shaft misalignment. In this issue we will discuss misalignment that results from hydraulic and mechanical forces encountered during pump operation (dynamic misalignment).

Dale B. Andrews – Editor

Dynamic misalignment may result from shortcomings in a pump's design, installation or operation. Some common causes for dynamic misalignment are cavitation, gas entrainment, impeller imbalance, and radial shaft deflection.

Cavitation



The side of an impeller blade (vane) that acts to accelerate the fluid is the leading side. The fluid on the leading side of the impeller blades is at a higher pressure than the fluid that is entering the pump. The opposite side of an impeller blade is the trailing side. Fluid on the trailing side of the impeller blades is at a lower pressure than the fluid at the pump inlet. If the localized low pressure on the trailing side of a particular blade drops below the vapor pressure of the fluid, a portion of that fluid will vaporize, i.e., vapor bubbles will form. As these vapor bubbles are subsequently condensed by the surrounding fluid, they will collapse violently. This phenomenon is known as cavitation.

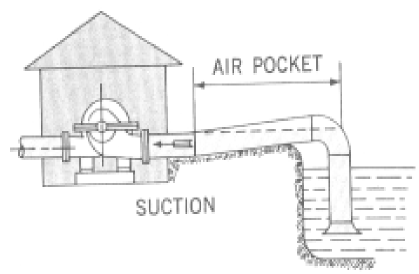
Severe cavitation (wide spread vapor bubble formation and collapsing) will restrict flow in an impeller passage, and result in diminished, or even no flow, from that impeller passage. As flow from an impeller vane passage becomes diminished, fluid discharge from the unblocked impeller passages creates an unbalanced radial load on the impeller, deflecting it and the shaft in the direction of the blocked passage. Shaft deflection from cavitation, is random in direction, and is often severe in magnitude. The amount of blockage in any single vane passage is unpredictable, resulting in random loading and unloading of the vane passages. The degree to which mechanical seal and bearing life will be shortened is dependent on the severity of the cavitation and the horsepower of the pump. However, in all cases, cavitation will result in higher maintenance costs.

Cavitation may be eliminated by increasing the suction pressure available to the pump; modifying the pump so as to require less suction pressure (see our July 2004 newsletter on Inducers); or, by decreasing the vapor pressure of the fluid being pumped.

Gas Entrainment

Gas entrainment has symptoms similar to cavitation, and it causes rapid random loading and unloading of impeller vane passages that in turn cause shaft deflections and result in premature seal and bearing failure. However, gas entrainment results from circumstances completely different than those causing cavitation. Cavitation occurs as a result of fluid vaporization under low pressure. Gas entrainment occurs when gas bubbles become trapped and collect in the suction piping or the impeller eye.

Gas that collects at the low pressure areas of the pump inlet, or at high points in the suction piping, restricts fluid flow into the impeller. This creates a flow blockage very similar to that described for cavitation. Centrifugal pumps can typically handle about 3%-5% maximum gas entrainment before they cease to pump. Some specialty designs have been successfully tested with gas concentrations of over 30% by volume.



Gas entrainment usually occurs from one of the following sources:

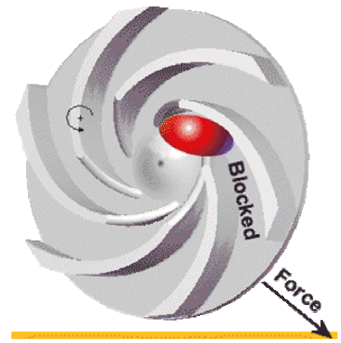
- Improperly designed suction piping
- Air leaks in suction piping that is under vacuum
- Vortices that propagate from the suction inlet to a free surface in a sump or vessel
- Gas carried into a suction pipe by the discharge of fluid into the sump or vessel adjacent to the suction pipe
- Dissolved gas that comes out of solution when entering the low pressure regions of a pump

Free Surface Vortex

The first four items are mechanical in origin and may be corrected by physical changes to the system. Problems related to dissolved gas may be corrected by increasing the suction pressure to the pump, changing the pump to a more gas tolerant design, or changing the fluid properties.

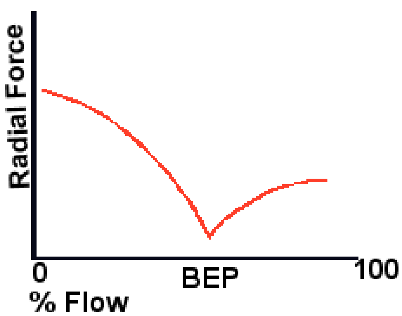
Impeller Imbalance

Impellers are typically dynamically balanced as part of their original manufacturing process and should always be rebalanced following any repair. An out of balance impeller will cause unbalanced centrifugal forces causing the rotating shaft to move in an orbital pattern.

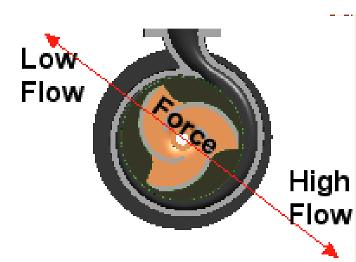


Probably the most severe form of imbalance occurs when some of the vane passages become obstructed by solids. This circumstance creates not only a mass imbalance, but also a hydraulic imbalance resulting from radial discharge forces of the unblocked passages. Both of these imbalances combine to deflect the impeller and shaft in the direction of the blocked passage. The radial deflection rotates with the impeller, creating an orbital shaft motion within the seal chamber.

Radial Load



Single spiral volutes are the most common style of pump casing. They improve the pump performance characteristics and are easy to manufacture. Spiral volutes are designed to match the hydraulics of the impeller. In a well designed pump, operating at its best efficiency point, radial impeller loads are at their lowest level. The amount of radial load depends on the exit area of the impeller vane passages and the amount of pressure being developed by the pump. When a pump is operated away from its best efficiency point, unbalanced forces are set up in the volute that can create high side loading and shaft deflection.



When a pump is operated at a low flow rate, liquid is prevented from discharging and recirculates within the casing. This increases the flow velocity and thus lowers the pressure in the smallest area of the volute, adjacent to the cutwater. The relative lower pressure in this area results in shaft deflection towards the low pressure zone.

As the pump moves out on its curve, the direction of radial thrust reverses. When the pump is operated at a higher than design flow, fluid exits the pump at a flow rate greater than the impeller is designed to supply. This increases the fluid velocity as it approaches the pump exit, reducing pressure at this location, and results in the shaft deflecting toward the low pressure zone.

Bearing and seal problems, in a high flow, high head application, are potential indicators of radial load issues in a single volute pump; especially if the pump is operated off design. Dual volute or diffuser style casings can mitigate this problem, but both add to the initial capital cost, and usually restrict the maximum solid size relative to what a single volute pump can pass. This type of problem is best avoided through close collaboration with the pump manufacturer, when selecting the pump, to ensure there is a thorough understanding of the actual operating conditions as well as the design options available.

Many older pumps, that were originally designed to use packing for shaft sealing, have inadequate shaft stiffness to provide a satisfactory operating environment for mechanical seals if any significant side loads are present. Fortunately, many manufacturers offer retrofits to older pumps that offer stiffer shafts and improved sealing arrangements without having to change the pump end or interconnecting piping.

In Closing

Cavitation, gas entrainment, impeller imbalance and radial shaft deflection usually are traceable to some mechanical, operational, or environmental problems that are correctable, if identified. Mechanical seal failures are usually a symptom and not the cause of high maintenance costs. If a mechanical seal fails too often, get the pump manufacturer involved, working with the seal vendor and plant personnel to help identify the root cause of problem and provide solutions that will provide operational cost savings.