Operating

Optimizing process speed and efficiency

Jeremy Salisbury shows how ensuring that a process pump operates at optimum speed and efficiency is key to maintaining productivity, reducing energy consumption and maximizing product life. He examines the technologies available to optimize operation and reliability, and the paybacks achievable through investment in appropriate control.

Centrifugal process pumps may perform a relatively straightforward task, but they are often working in hostile and stressful operating conditions. As a result, they can fail prematurely – resulting in lost productivity from unplanned downtime.

Improved pump reliability, reduced maintenance and lower energy consumption can all be achieved by ensuring that a process pump operates at optimum speed and efficiency as much as possible.

Common problems

One of the main problems that can occur in engineering components is cavitation, which is a significant cause of wear - notably where pressurized liquids are being handled. This makes pumps highly susceptible, especially if they are required to start quickly.

The problem occurs when a liquid is subjected to rapid changes of pressure, causing the formation of cavities in the lower pressure regions of the liquid. When entering high pressure areas, these bubbles collapse on a metal surface continuously, causing cyclic stressing of that surface and resulting in surface fatigue. Cavitation in pumps generally occurs in one of two forms: suction cavitation and discharge cavitation.

Suction cavitation occurs when the pump suction is under a low-pressure/high-vacuum condition where the liquid turns into a vapor at the eye of the pump impeller. This vapor is compressed back into a liquid by the discharge pressure. This imploding action occurs violently and attacks the face of the impeller. An impeller that has been operating under a suction cavitation condition can lose either large chunks from its face or have small bits of material removed, which will cause it to look sponge-like. Both cases will cause premature failure of the pump, often through bearing failure. Suction cavitation is often identified by a sound like gravel or marbles in the pump casing.

Discharge cavitation occurs when the pump discharge pressure is extremely high, normally when a pump is running at less than 10% efficiency. The high discharge pressure causes most of the fluid to circulate inside the pump instead of being allowed to flow out. As the liquid flows around the impeller, it must pass through the small clearance between the impeller and the pump housing at extremely high velocity. This causes a vacuum to develop at the housing wall, which turns the liquid into a vapor. A pump that has been operating under these conditions shows premature wear of the impeller vane tips and the pump housing. In addition, because of the high pressure conditions, premature failure of the pump’s mechanical seal and bearings can be expected. Under extreme conditions, this can break the impeller shaft.

Unscheduled stoppages

Rapid pump stoppage – or pump failure through poor maintenance – can also create significant problems. A sudden reduction in flow can mean a valve closes rapidly, resulting in water hammer, whose ramifications for entire systems can be extremely serious.

Water hammer – also known as fluid hammer or hydraulic shock - is a pressure surge or wave resulting when a fluid in motion is forced to stop or change direction suddenly. It commonly occurs when a pressure wave propagates in a pipe and can cause major problems, from noise and vibration to blown valves, leaks and even pipe collapse if the system is under very high pressure.

Meanwhile, vibration resulting from component wear or misaligned and poorly balanced shafts can also increase...
energy usage and maintenance costs, and even result in product failure.

Optimizing pump efficiency

Variable speed drives (VSDs) – also known as inverters - are proven in their ability to reduce energy usage in many pump applications as well as helping to optimize reliability and close the loop with regard to proportional–integral–derivative (PID) functionality.

For example, using a VSD to reduce by just 10% the speed of a 22 kW pump operating 24 hours a day for 300 days each year can pay for itself in terms of reduced energy usage in as little as eight months - depending on electricity costs. The issue of energy is crucial when it is remembered that many pumps are specified larger than actually needed for the application. This is because a small increase in speed to up the flow rate has the potential to significantly increase power demand, meaning that contingencies are successively built into the design process. However, the fitting of a VSD delivering a 4% decrease in speed will typically pay for itself in around two years through reduced energy costs.

The only rider to the use of VSDs to control pump speed is that they cannot be fitted to pumps operating under high head pressures. This is because the pressure varies in proportion to speed according to the pump affinity laws. In these cases, varying the speed using any method is not advisable without due caution.

Other options to control pump speed include V-belts, especially where it is not possible to directly couple an online motor to a pump, although there have been concerns about their performance. However, potential issues such as slippage have been largely circumvented by the latest developments in synchronous belts, which, once fitted and tensioned, do not require regular re-tensioning.

Meanwhile, the latest synchronous carbon belts offer far greater power-carrying capacity than was previously achievable, along with exceptional flex fatigue resistance, enabling them to bend more easily around pulleys and offer a typical 5% energy efficiency advantage over V-belt drives.

VSD or soft start?

The choice between VSD and soft start will depend on the existing conditions of the system itself, the number of starts required, the load on the pump, and how it is currently being started.

As a rule, for smaller pumps, a VSD will be preferable, while a soft start generally becomes economical for pumps of 22 kW or larger. However, there is a crossover area where either method could be used depending on the specific requirements of the application. For example, an application starting just once a month and running at a constant speed will require soft start; however a VSD will be more appropriate if the demand from the pump varies.

Overall performance can also be increased by the fitting of pressure sensors in applications where throughput can vary. At a facility that is only fully operational for part of the time, for example, there may be a temptation to turn down valves at the end of the shift in a bid to save energy. However, this has the potential to cause severe pump damage because of heat build-up and cavitation. In this application, the fitting of a pressure sensor will feed back the reduced flow requirement to the VSD, which will then cause the motor to slow down accordingly, resulting in an energy saving with no risk to the pump.
turn, allows planned maintenance to be undertaken for minor issues or a complete shutdown, if needed, for major work or replacement. The leading innovators in this area have developed software tools that suggest likely causes and prescribe remedial actions, based on the data provided.

Key maintenance points

Pumps should always be placed on a stable base plate with shafts optimally aligned and regularly lubricated in accordance with the manufacturer’s instructions. If either of these conditions is not satisfied, then poor performance and, ultimately, failure are almost inevitable. In addition, as with any other component, simply replacing parts to get it running again with no detailed investigation into the root cause of the problem will not re-establish optimum performance.

When disassembling a pump, the engineer should always check whether the coupling guard was rubbing against the coupling; whether there is grease or oil on the inside of the coupling guard and on the base plate of mechanically flexible couplings; and whether the flexible coupling displays any indication of distress.

Before the coupling is taken apart, a set of shaft alignment measurements should be taken, and compared against previous measurements to see if any change has occurred. The cause of any shift should ideally be identified.

The flexible coupling should then be disassembled, taking into account the presence and condition of any lubricant in the coupling and any signs of excessive wear, compared with a new coupling if necessary. A worn coupling may need to be replaced.

The pump should be visually inspected for problems such as loose foot bolts and pump casing bolts, cracked casings, low lubricant levels, loose shim packs or missing shims, leakage from seals and shaft discoloration.

The amount of shaft free-play should then be established, which will give a clue as to the existence of bearing problems in the pump or driver. A check should also be made for excessive shaft or coupling hub run-out. Both of these can be simply undertaken using a dial indicator.

The level of piping stress on the pump should be checked, with adequate piping supports fitted in the suction and/or discharge piping if the stress is found to be excessive. In extreme cases, the piping may need to be cut and re-fitted. Finally, the piping should be disconnected and a check for excessive ‘soft foot’ problems carried out using an appropriate alignment measurement tool. These can be as severe on pumps as on any other piece of rotating machinery.

Once a pump has been effectively configured and any necessary repairs undertaken, condition monitoring should continue so that any areas for improvement in pump efficiency and productivity can be identified, and ultimate system performance optimized.

Monthly checks

The following points should be checked on a monthly basis:

• Priming speed
• Capacity
• Noise in the pump casing, gaskets and O-rings
• Shaft seal leakage of air and water
• Hose, hose washers and suction strainer

Six-monthly checks

The following points should be checked on a six-monthly basis:

• Impeller wear
• Clearance between the impeller face and the volute
• Shaft seal wear and shaft sleeve wear
• Casing and volute passages to be cleaned

This combination of regular checks and proactive maintenance, coupled with appropriate control methods, will go a long way towards optimizing efficiency, minimizing downtime and reducing whole life costs of pumps.

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