



Variable Speed Pumping In Parallel

Variable speed (VS) pump operation is common for most water and wastewater treatment plants and pumping stations that I visit today. When asked why they are using variable speed pumps, the usual answer is to control flow; rather than to save power. In fact, variable speed pumping can do both, if set up correctly.

With the popularity today of variable speed drives (VFDs), pumps are now being asked to operate at a greater range of flows and pressures, which is causing some problems in the field. I would like to take this opportunity to highlight a couple of these problems with which I have been associated that are quite typical of many others I see.

First, let us lay some groundwork. A parallel pumping situation occurs when more than one pump, separated

by check valves, pumps into a common discharge header at the same time. As each pump is started up, the increase in flow causes a greater increase in friction losses. As these losses increase, so too does the pressure that each pump must overcome. From a pump curve standpoint, this moves the pump operating point to the left, farther away from its sweet spot (known as best efficiency point (BEP)) and closer to its not so sweet spot (known as minimum continuous stable flow).

In short, this moves the pump from smooth operation towards rougher operation. The system curve determines how fast this transition occurs. We all know how uncomfortable extreme air turbulence can be when flying on an airplane. With continued turbulence, the pilot has

the ability to make adjustments to get away from the turbulence. A pump is no different, except there is usually no pilot to make the change.

Quite often, a full speed pump is operated with a variable speed pump at the same time. Many people do this to 'trim' the flow required for various operational reasons. This causes the variable speed pump to operate to the left of its BEP. The amount of trim and system curve determines how far to the left it will operate.

The first sign of trouble shows up in high vibration, noise and/or cavitation issues. These issues, if not addressed, can lead to extensive problems and repairs.

After repairing many pumps over the years, I have the advantage of actually seeing the damage that is caused by these operational issues. The following two examples are typical of what I see.

Figure 1 shows cavitation damage on a bronze impeller. This impeller was taken from a multi-stage high lift vertical turbine pump in the Belleville Water Treatment Plant.

The customer has five identical high lift pumps, where three are variable speed and two are constant speed. After many years of operation, it was decided to operate one variable speed pump with one full speed pump in parallel. This went on for several years until the variable speed pump performance deteriorated and had to be overhauled. The damage you see was discovered when the pump was dismantled.

Notice the severe cavitation damage on the leading edge of the suction vanes and on the inside diameter of the eye. This cavitation damage is known as recirculation cavitation and is caused by running a pump too far to the left of BEP. All seven impellers of this multi-stage pump suffered similar damage to what is seen here.

Figure 2 shows a set of vibration plots for a large variable speed sewage pump installed at the City of Brockville, Pump Tag P2.

FIGURE 1 – Cavitation damage on a bronze impeller



Figure 3 shows a set of vibration plots for a large variable speed sewage pump installed at the City of Brockville, Pump Tag P3.

To orient you, the X axis is the revolutions per minute (RPM) of the pump and the Y axis is the vibration velocity in inches per second. Vibration velocity is an indicator of vibration severity where 0.2 would be considered smooth to rough and the highest level shown of 0.7 would be considered quite rough. (i.e., turbulence that should be avoided)

Both of these pumps operate together on a VFD. The operating system calls for both pumps to operate at the same speed, moving the speed up or down depending on wet well levels. At 975 RPM, P3 operates at low vibration and P2 operates at high vibration. At 1055 RPM, P2 operates at low vibration and P3 operates at elevated vibration levels. With all the possible combinations, it is easy to see one of these pumps is going to operate at very high vibrations for some period of time.

Every pump design has a range of operation to the right and left of BEP where it can operate trouble free. Sewage pumps are designed to operate typically between 50% and 120% of BEP. High lift vertical turbine water pumps are designed to operate typically between 80% and 110% of BEP. This is a function of the suction specific speed of a pump.

The root cause in both of these cases is running off BEP. In Belleville's case, they were trimming a variable speed pump too far back against a constant speed pump and causing recirculation cavitation in the variable speed pump. In Brockville's case, they were running pumps with mismatched curves, thus causing one of the pumps to run off BEP. Brockville also has some other issues with the pumping station that further complicated the situation.

In each of these cases, the problems and solutions are far more complex than can be discussed in this article. However, there are a few things you can do to help your situation:

- Find out where each pump is operating on its curve at all times.
- If you must trim a variable speed pump with a full speed pump, check with your pump manufacturer and work out how far back you can go. If you are not sure, then use vibration analysis to check.

FIGURE 2 – Vibration plots for a large variable speed sewage pump (City of Brockville Tag 2)

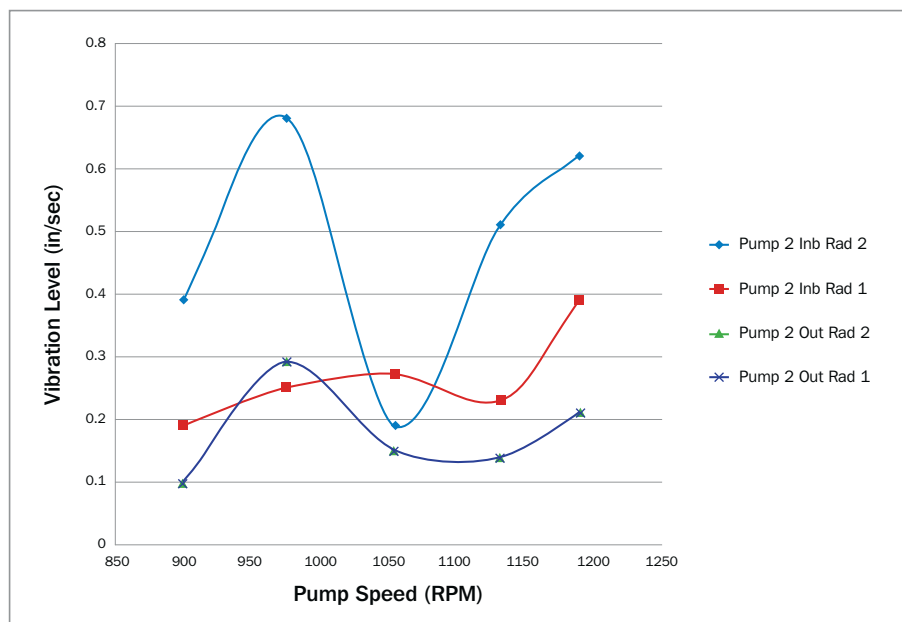
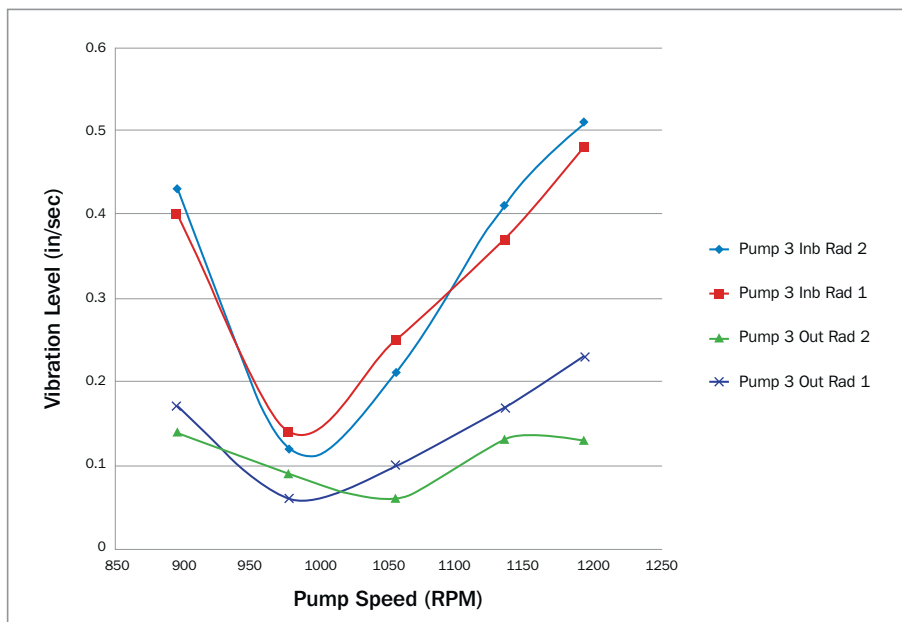


FIGURE 3 – Vibration plots for a large variable speed sewage pump (City of Brockville Tag3)



- Avoid installing pumps with mismatched curves.
- Make sure you check all operating conditions from low to high flows to ensure problems do not occur late at night or on weekends.
- If you cannot obtain good hydraulic data from the pump manufacturer, you can use vibration analysis to see how far off BEP you are operating.
- Consider hiring a consultant to work with your pump supplier to do an optimization study.

Keep in mind that, if you operate each pump as close to BEP as possible at all times and satisfy the flows and liquid levels required for operations, you will be operating as energy efficient as possible. The money invested to get there will provide a payback in energy savings.

Please join me in Toronto at the Annual WEAO Technical Symposium and OPCEA Exhibition in the PWO technical session to review these cases in more detail and observe the actual damaged impellers. ♦