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Global Wastewater Challenges Place Pressure on Aging Infrastructure

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Part 4 of 6

Shifting trends in water use and a changing sewage composition cause complex problems for the world's sewer systems.

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Fourth of Six Parts

Just 20 years ago, many professionals did not consider using variable frequency drives (VFDs) in wastewater applications. Frequency converters were relatively expensive, and experience using them had not been very successful in light of the special conditions and requirements in wastewater.

Today, VFDs are often used in sewage transport, even though some operations do not favor using them. However, flow control is necessary, and plants desire energy savings as well. While some plants have experienced trouble-free operation of these systems, sometimes detailed knowledge of how to use this equipment for a specific design or existing operation in wastewater is missing. With correct usage, VFDs can support trouble-free operation, but they also can disturb proper functioning of a well-designed pumping station.

Because of the increase in wipe usage and the new challenges in sewage (as discussed in Part 1 of this series, Pumps & Systems, November 2015), it is even more important to consider the right exertion. Since 2010, there have been reports on the usage of VFDs and backward operation as a de-ragging method. In some cases it makes sense to use these tools, but they have some limits.

Checking Velocities

Often the question arises of what the maximum reduction of frequency would be for the motor on a submersible wastewater pump. For wastewater, the limits for the motor by itself are not relevant because the impact of the hydraulic limits occur much earlier. Many motors can be reduced in speed to half the nominal frequency without any problem. But the fluid dynamic would be in bad shape if the wastewater is pumped at the corresponding velocity for a longer operation time in the system.

The necessary minimum velocity of the sewage initially limits the reduction of frequency for trouble-free operation. Depending on the kind of wastewater and the content, it is necessary to transfer enough energy into the liquid to transport the solids and fibers as well. The pump's tip speed (speed outside of the impeller diameter), the velocity in the vertical pipe and the horizontal pipe, and the necessary velocity to open the check valve are important parameters to program into the VFD to ensure the velocity during operation is not too low. Exact detailed values generally cannot be given mathematically. The different loads over time and in different stations create a gray area. However, they are good enough for raw sewage in the first implementation to prevent breakdowns. If the velocities in operation are not below the recommended minimum velocities, the risk of blockages is minimized.

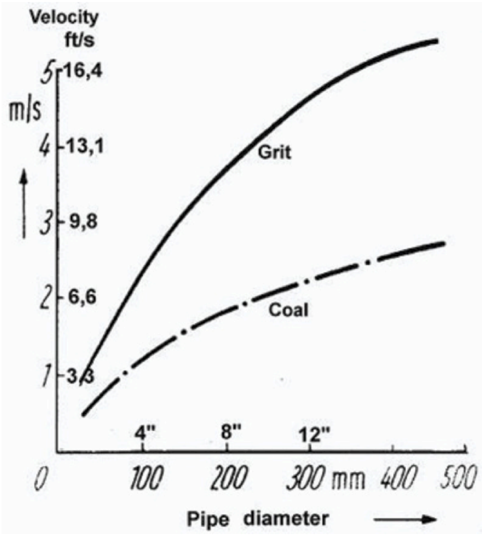

Figure 1. This shows average values from the practice of transporting grit or coal in horizontal pipes in a mixture 20 to 25 percent per volume. Necessary velocity is a function of the pipe diameter. (Graphics courtesy of KSB)

The fluid velocity must be higher than the settling velocity (sink velocity) of the solids (see Figure 1). To avoid sedimentation, the velocity in the pipe should be 0.3 to 0.5 meters per second (m/s), or 0.984 to 1.64 feet per second (ft/s), higher than the settling velocity. Settling velocity depends on specific gravity, shape and size of the solids. The concentration of solids also must be considered.

For wastewater, no exact values are available (size, gravity, shape or concentration), and they change continuously. However, values based on daily experience are good parameters to use.

So far, the first important step to using a VFD for wastewater is to calculate the expected velocity from the minimum flow requested and the planned diameter of the vertical and horizontal pipe. Compare the calculated velocity with the recommended minimum velocity. If the calculated velocity is lower, consider ways to increase it to at least the minimum recommended velocity. For example, to have a higher flow, use the sump volume and the max switch frequency of the pumps to pump the same average per day but with higher minimum flow. Then the corresponding frequency for this particular flow can be programmed into the VFD.

Low velocities that increase the risk for sedimentation and clogging can be avoided.

For raw sewage, several years of experience worldwide indicates 1.5 to 2.0 m/s (4.9 to 6.6 ft/s) is a good minimum velocity in vertical pipes. Depending on the particular load and content, higher velocities can be necessary, but sometimes the station works well with lower ones if solids and rags are rare.

The next step for programming the VFD is to implement a short ramp for the pumps to reach nominal speed. The shorter the better, but 4 seconds or less is recommended. Hold the nominal speed for about 6 to 10 seconds. If the discharge pipe is long and filled with solids and rags, it may be necessary to hold the nominal speed longer. If low flow (low speed) is operating for a longer time, a short ramp up to nominal speed is beneficial. About 10 to 20 seconds is sufficient. This also should be programmed in the converter. To make sure nothing from the solid and stringy content falls back into the pump or sump, program a short ramp up to the nominal speed before the pump will shut off—5 to 10 seconds is sufficient.

In parallel operation, the operating pumps should share the same speed for the total flow. Often one pump runs at nominal speed and the other at very low speed. For a long-lasting, trouble-free system, it is better to share the same speed for the running pumps to get the required total flow.

De-Ragging Function

The above recommendations are the most important for VFD usage in raw sewage and can substantially minimize the risk for clogging. However, additional capabilities are offered by some VFD suppliers. The so-called de-ragging function offers change of speed and/or backward operation of the pump.

One of the main problems with the de-ragging function is the braiding fibers, which can form rag balls. Rag balls up to 24 inches have been common. Avoiding formation of these rag balls at an early stage is critical.

A fast reaction of changing speed or backward operation may be required.

Otherwise, the large rag ball may grow, and even if it could be flushed back out of the pump or pipe, it remains in the sump and cannot be pumped through.

Before the backward-operation function can be used, the pump manufacturer should be consulted for the particular hydraulic to confirm that backward operation will not damage the specific pump.

Avoiding velocities that are too low in the system is the basis for lower risk of clogging. It would not make sense to have a de-ragging (backward) feature without this fundamental concept.

In several tests, just a change of speed helped to dismiss the initial clogging situation. If the speed is on the lowest end and clogging is indicated, it makes sense to ramp up the pump. If clogging is indicated during nominal speed (wipes on the vane), it can help to slow the pump down to get rid of the rag from the vane, then increase to nominal speed.

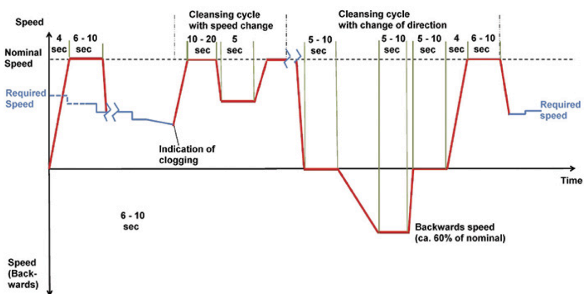

Figure 2. This graph shows the sequences for the described process of de-ragging speed over the time.

If it is not possible to solve heavy clogging, the pump can be triggered to run backward (see Figure 2). Ramp up to nominal speed as fast as possible (a maximum of 4 seconds), and then shut off the pump for 5 to 10 seconds before running the pump backward. Damage from the change of direction must be avoided. If the pump is still running down and gets the impulse to run in a different direction, a very high force will be loaded on the pump shaft and other components.

After the short break, ramp up the speed for the backward run to approximately 60 percent of the nominal speed (in the opposite direction). A short run time of 5 to 10 seconds in the opposite direction is usually sufficient. After the backward run, switch off the pump, implement the break (5 to 10 seconds) and ramp up to nominal speed.

Sometimes one cycle of this procedure is not enough and it should be repeated.

In a few cases, this method cannot solve the clogging problem. For example, so-called jamming may be one of the issues, and an alarm function should be integrated after three unsuccessful cycles of the cleansing de-ragging.

Some VFD programs feature regular preventive cycles of de-ragging, which are triggered by a timer. It can be done this way, but it is not as efficient as triggering de-ragging based on a measured indicator such as amp draw or flow velocity.

Limits of De-Ragging

The clearance between the impeller and the casing normally cannot be solved with the backward run method. Some hydraulics are not suitable for a backward run, especially if they are not symmetrically balanced hydraulics (for example, a single-vane impeller or a screw impeller). The short backward run can create vibration. If large rag balls have formed, it may be possible to get rid of them for the moment, but the problem can be solved only by cleaning the sump.

The next installment will discuss solutions for very heavy cases.