Wastewater pump clog resistance cannot be determined by throughlet size

Modern wastewater requires hydraulics that can handle synthetic fibers and ragging

A wastewater pump's throughlet size is frequently used to specify clog resistance, despite data that demonstrates the irrelevance of this measurement. Clogging is a highly undesirable operational problem in wastewater pumping that drastically reduces pump efficiency and can cause hard clogging, unplanned callouts or even sewage overflows.

This paper will describe the importance of a pump's hydraulic design for achieving clog-free operation. It will also establish how a pump's throughlet size is a misleading parameter in specifying clog resistance.

Modern wastewater

Investigations and studies of modern wastewater have shown that it rarely contains hard, solid, spherical objects with a diameter as large as the inner diameter of the piping system. Objects that are truly solid and hard, such as stone, brick, or steel, are also rare, and these items rarely reach the pump because they will be trapped on a flat horizontal surface where the liquid is stagnant or the carrying velocity is low. By far, the most common solids found in municipal wastewater are organic and often consist of long and stringy shapes, such as fibers.

Modern wastewater also contains a higher amount of synthetic cloth and artificial fibers than ever before. The vast array of household cleaning products, such as tissues, wipes, and dishcloths, are to blame. These products should be disposed of in the trash or compost, but many consumers flush them down the toilet, thus adding synthetic fibers to the wastewater stream.

Figure 1 is conceptual and shows the probability of finding different types of solids in wastewater. The left side shows hard spherical objects (stone, gravel, sand, grit, silt, etc.) and the right side shows objects that are soft and stringy, from short and thin to large and elongated. The distribution curve shows that there is a very low probability of finding large, hard objects compared to small, hard particles and various small and large soft and stringy organic objects.

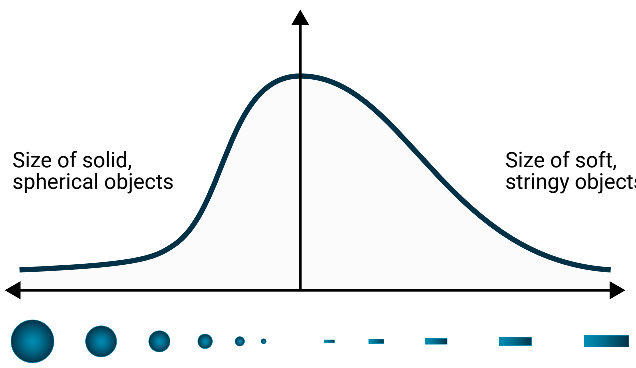

Figure 1: Likelihood of finding various types of solids in wastewater

Throughlet size

The traditional definition of throughlet size refers to the free passage of matter through a pump impeller. Throughlet size is determined by the largest diameter of a hard, solid, spherical object that can pass through the pump. The concept is old, dating back to 1915, and was developed at a time when energy costs were not of significant importance. Pump manufacturers intuitively believed that pump clogging could be avoided simply by having an internal pump throughlet equal to or larger than what the toilet of the day could pass.

Pump manufacturers thought objects would pass through the pump as easily as they did through the pipes. The expectation was that large throughlets would increase reliability and reduce unplanned service calls. These large throughlet size hydraulic designs are referred to as traditional designs in this paper.

The last few decades of research and development, and experience from hundreds of thousands of pump installations, have proven that the simplistic logic of throughlet size is incorrect and misleading, though prevalent in wastewater pump procurement specifications.

How manufacturers achieved large throughlet sizes

The smallest section in a pump is the passage through the impeller. There are two primary impeller design options to maximize the throughlet size:

1. Single-vane impellers (open or closed, valid especially for small pumps)
2. Vortex impellers (also known as recessed impellers or torque-flow impellers)

Figure 2: Example of a single-vane impeller

Figure 3: Example of a vortex impeller

These designs suffer from the following drawbacks:

Single-vane impeller:

- Relatively low efficiency (with more impeller vanes, higher efficiencies can be achieved)
- Significant rotating radial forces (this causes high shaft and bearing loads as well as increased vibration and noise)
- Difficulty in balancing (the impeller is water-filled during operation)
- Impeller trimming leads to further imbalance

Vortex impeller:

- Very low efficiency

How traditional hydraulic designs are affected by modern wastewater

Stringy objects tend to get caught in traditional impeller types even if the throughlet size is large. As shown below, the problem point is the leading edge of the impeller vanes. All impeller designs have one or more leading edges.

Figure 4 and 5: Accumulation in a single-vane impeller

Figure 6 and 7: Accumulation in a vortex impeller

Soft, stringy, and elongated objects in wastewater are continuously fed into the pump; some of these will meet a leading edge on one of the impeller vanes. The fibers tend to wrap around the edge and fold over on both sides of the vane.

On straight and moderately curved leading edges, the debris will not dislodge; instead debris will continue to build up. These accumulations will create big lumps or bundles of solid organic material (sometimes called rag balls). As these objects accumulate in a traditional impeller design, the following become likely:

1. The flow rate of the pump decreases as the solid objects start to constrict the free passage of liquid. This usually leads to decreased efficiency. This phenomenon is called soft or partial clogging because the pump continues to operate. It will take longer to pump down the sump with a constricted impeller than with a non-constricted impeller.
2. The input power increases when the accumulated objects make contact with the volute and create drag. Drag leads to lower efficiency and to the risk of a stop due to motor overloading. The solids act as a brake which increases the required input power. Once the running current exceeds the trip current, the pump is shut off due to hard clogging.

With decreased pump efficiency, the operational cost for the end user is increased because the pump must operate for a longer time and consume more energy to handle the inflow. A motor overload or pump trip also adds cost for the end user because it requires a service technician to visit the pumping station to clean and restart the pump.

Figure 8 shows the types of solids that can pass through a traditional impeller with a large throughlet. The light blue area indicates objects with a high probability of passing through the pump. The darker area indicates a higher probability of clogging.

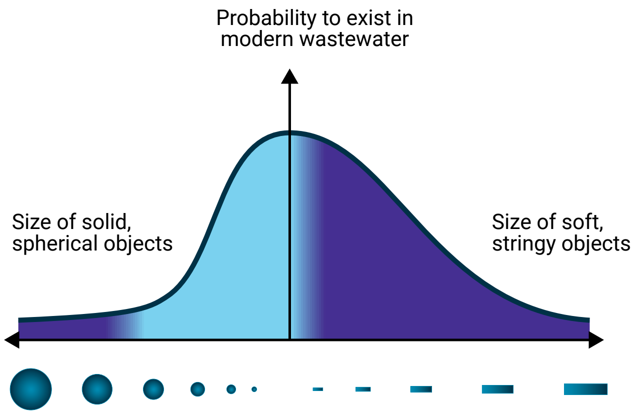

Figure 8: Capability of traditional hydraulic designs

Some hydraulic designers claim that vortex impellers are self-cleaning because after back-flushing, the impeller is free of solids. In practice, this has not been the case. For pumps operating intermittently, back-flushing will occur naturally every time the pump is turned off. This cleans the leading edges of the impeller and flushes the accumulated solids through the pump's suction opening back into the pump sump. This flushing phenomenon may temporarily free the impeller and improve efficiency, but once the pump is restarted, the build-up will resume, leading to a significant decrease in efficiency and higher energy bills. Eventually, the soft solids may also become hard-packed on the pump's hydraulics, and the naturally occurring back-flush will not be sufficient to remove all debris.

Self-cleaning N-technology hydraulic design

Today there are better and more advanced hydraulic designs available to increase a wastewater pump's clog resistance and to maintain pump efficiency over time. A state-of-the-art self-cleaning design, with substantially backswept leading edges and a relief groove, has proven to be the answer to most clogging problems.

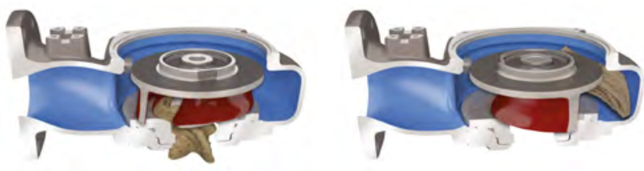

Figure 9: Modern, self-cleaning N-technology hydraulic design

A standardized clog test was developed by Flygt in the late 1990s and has been used to test many existing hydraulic designs as well as new and innovative ideas. This development, carried out for more than 25 years, has resulted in refined wastewater pumps that vastly outperform traditional wastewater pump designs.

The company's knowledge from its large installed base of wastewater pumps has provided data necessary to develop self-cleaning impeller capability that works for all duty points and for reduced rotational speeds. The function of transporting liquid has been separated from the function of transporting solids.

This self-cleaning hydraulic design does not accumulate the typical contaminants present in modern wastewater. Solids that land on the leading edges of the impeller are continuously pushed towards the periphery and out through the pump discharge via the relief groove located in the insert ring.

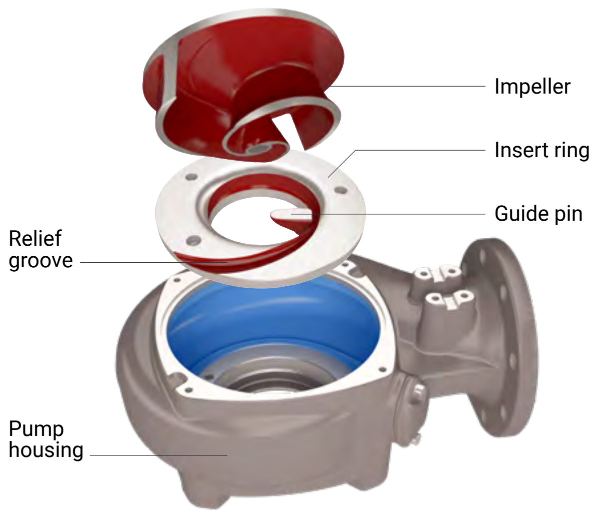

Figure 10: Key components of N-technology hydraulic design

Figure 11 shows what a modern, self-cleaning hydraulic design with backswept leading edges and a relief groove can achieve. The light blue area indicates objects with a high probability to pass through the pump. The darker area indicates a higher probability of clogging. The light blue area is much larger than for a traditional, large-throughlet pump as shown in Figure 8.

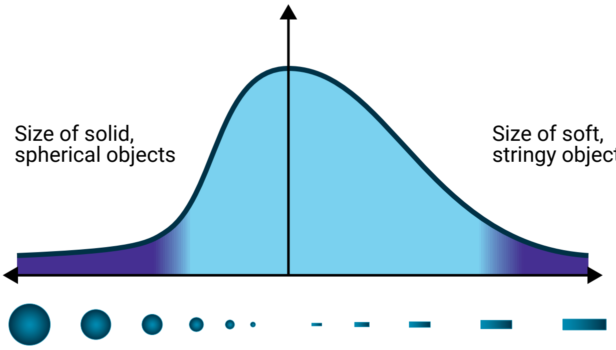

Figure 11: Capability of modern, self-cleaning hydraulic designs

With this increased clog resistance in the face of modern wastewater, true self-cleaning hydraulics deliver sustained efficiency and minimize costs for operation, service, and maintenance.

Clogging and pump lifecycle costs

A clog-resistant pump results in a lower total cost of ownership. The main variables in the lifecycle cost are initial investment, energy costs, and maintenance costs.

The following bar charts illustrate lifecycle costs for different pump sizes depending on the number of clogging events. Figure 12 shows the cost distribution for a pump station with no call-outs. Figure 13 factors in two unplanned call-outs due to pump clogging. This is a fairly common situation for a small wastewater pump station, and the cost of these call-outs equals or exceeds the initial cost of the pumps. Lastly, Figure 14 illustrates a troublesome pump station with 10 call-outs per year. In this situation, unplanned maintenance costs will far exceed installation costs, and in smaller pumps, exceed the energy costs.

Because energy and maintenance costs represent the vast majority of the total cost of ownership, the best solution for the end user is a well-designed pump station with modern pumps that are clog-free, reliable, and energy efficient.

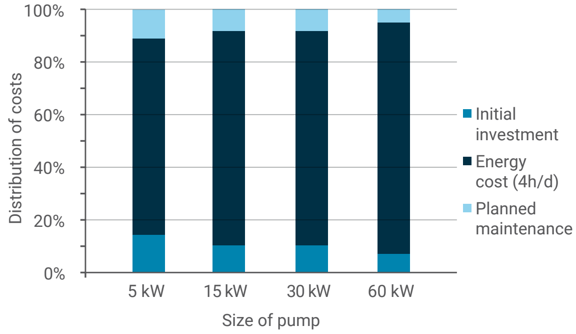

Figure 12: Cost distribution for a pumping station without call-outs

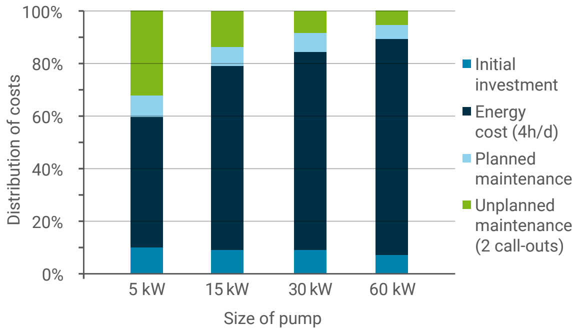

Figure 13: Cost distribution for a pumping station with two call-outs

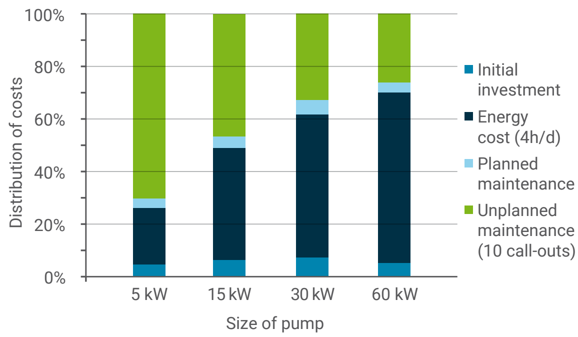

Figure 14: Cost distribution for a pumping station with 10 call-outs

Conclusion

A pump's throughlet size is not a useful parameter for specifying clog-free operation of a wastewater pump, especially for today's modern wastewater systems. The end user of a wastewater pump needs a pump that is reliable and efficient during both short and long duty cycles.

Using modern, continuously self-cleaning N-technology pump hydraulics will yield significant operational savings due to increased clog resistance and the ability to deliver sustained efficiency when pumping wastewater.

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