

Understanding sustained efficiency in non-clog pumps

A review of pump efficiency and the benefit of self-cleaning hydraulics in wastewater pumping

Sustained efficiency is a pump's ability to maintain its initial efficiency over time, when operating in the intended application.

Increased environmental awareness and legislative pressure to lower energy usage, coupled with the always-present desire to find ways of lowering operational costs, have driven the wastewater pump industry to better examine true operational efficiencies. Unfortunately, pump efficiency in wastewater is not always what it appears, nor what has been stated in the pump manufacturer's documentation.

Engineers of Flygt pumps have found during site visits that operators are often unaware of the actual efficiency they are getting from their equipment. Sustained efficiency is expected, but often not delivered. Controlled laboratory tests and extensive measurements in the field have shown that with traditional non-clog pumps, end users' actual efficiency is typically 20 to 30% lower than the published efficiency in on-off pump operation, and often worse for pumps with long duty cycles or in continuous-duty operation.



Figure 1: A fully clogged pump (pictured) is easy to detect, while a partially clogged pump is rarely detected when a pump is inspected.

Understanding pump efficiency

Pump efficiency is defined as hydraulic output power (water power) divided by pump shaft input power. It cannot be directly measured but is derived from a simple calculation of measured pump shaft power, flow, and head.

Historically and currently, clean water pumps and non-clog pumps are both tested for efficiency with clean water. This is done for practical reasons, and the documented pump performance (flow, head, and input power) is that clean water performance. While this published efficiency may be delivered by clean water pumps in their intended applications, non-clog pump operating environments immediately challenge pump performance. The type and amount of soft solids being transported impacts the performance of the pump, and the actual efficiency will likely vary widely from the factory-tested efficiency.

The effect of clogging on pump efficiency

For non-clog pumps, also referred to as solids handling pumps, the key criterion is the ability to pass all solids present in the contaminated pumpage without clogging the pump.

There is a broad array of applications for non-clog pumps – including wastewater collection, headworks pumping, sludge pumping, stormwater pumping, land drainage, and pond dewatering – but only a few fundamentally different types of solids. The solids typically contained in the pumpage can be divided into organic, inorganic, abrasive, and stringy.

Organic wastewater solids are fundamentally soft and often consist of fibrous and stringy material, in small or large accumulations. Inorganic solids are hard, often sharp, and of smaller particle sizes. The presence of screens, strainers, and other such devices serve to limit the maximum hard solid size that can enter a pump inlet. Soft solids tend to find their way past these devices irrespective of their size.

Clogging can consist of a full or partial clog of the impeller or volute. A full clog (or hard clog) exists when the pump has ceased pumping; this condition is easy to detect and highly undesirable. An immediate service call is needed to manually clean out the clog.

A partially clogged pump is harder to detect and most often goes unnoticed because the pump still delivers flow, though the flow is reduced. Going unnoticed for long periods of time, a partial clog (or soft clog) wastes substantial amounts of energy. If the pump is operated continuously, the pump efficiency will tend to decrease dramatically (Figure 3a).

Laboratory and field tests have shown that traditional non-clog pumps collect soft solids as they are operated. Solid matter tends to cling to the leading edge(s) of the impeller. Vortex pumps tend to clog in the rotating element and parts of the volute. Certain parts of the pump's cavities can also collect soft solids. Some soft solids tend to clog the gap between the rotating impeller and the stationary volute wear ring.



Figure 2: Partial clogging on a single-vane impeller (left) and vortex impeller (right)

Only when the pump is turned off will some (or all) of the accumulated solids be flushed through the pump's suction opening and back into the pump sump. This flushing phenomenon occurs in systems both with and without check valves and will temporarily restore pump efficiency (Figure 3b). When the soft solids have become hard-packed onto the pump's internal hydraulics, however, this naturally occurring back-flush will not be sufficient to remove all debris. The result is a lower operational efficiency when the pump is restarted.

The material that is back-flushed into the pump sump can be described as "rag balls." These "rag balls" can be of different sizes and the soft solids in them are often packed hard together into an aggregate of circular shape. Many users have experienced an increase in pump clogging as the collection of "rag balls" in the pump sump grows. A manual sump cleaning may be required to restore pump performance, an added operational cost.

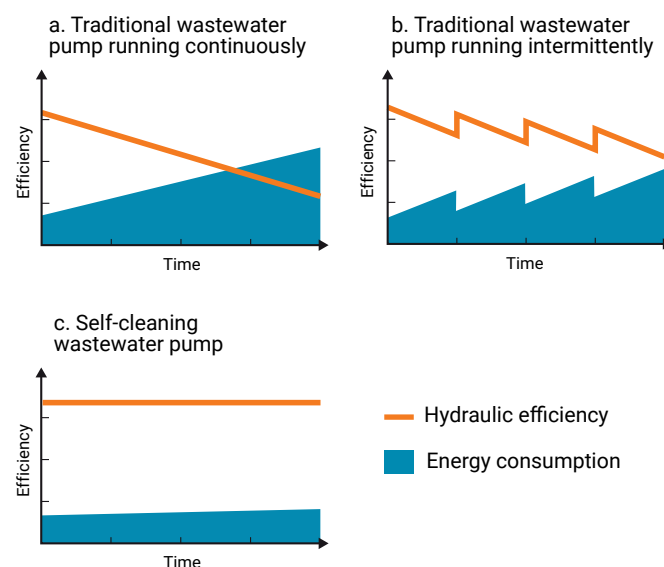


Figure 3: Traditional non-clog pump performance under two different operating scenarios compared with a self-cleaning N-technology wastewater pump

The most demanding scenario is the traditional non-clog pump operated on a variable speed drive. Very often, the pump control software will operate the pump(s) at reduced speeds for long periods of time (hours and days). This lack of pump cycling means the pump does not benefit from the back-flush that occurs each time the pump is stopped. Compounding the issue for the pump, the control software is often programmed to perform a "soft stop" in addition to a "soft start." This means that the pump speed is gently brought down until the pump is stopped. The "soft stop" is programmed because it aids in a quiet closure of the check valve and can help prevent water hammer. The downside is that a clogged pump will not benefit from the important flush generated at a hard pump stop, and the pump is less likely to regain its original efficiency.

For traditional non-clog pumps, the manufacturer's stated pump efficiency generally falls within the range of 50 to 80% efficiency. As non-clog pumps operate in

In a pump test facility, efficiency is an instantaneous measurement with clean water. Sustained efficiency is the pump's ability to maintain that measured efficiency over a long period of time when operating in its intended application.

their intended environment and experience the situations described above, their actual operating efficiency can be 20 to 40% lower than the stated test efficiency.

For the end user's energy consumption, the importance of delivering sustained efficiency is about 10 times greater than specifying a more efficient electric motor, such as an IE3 motor, that may offer a few percentage points up over a standard motor.

Traditional non-clog pump hydraulic design

The early non-clog pump designs were based on unsuccessful applications of clean water pumps, which when pumping liquids with solids would experience a complete clog due to the small impeller channel openings and generally fine pump clearances.

Intuition said that impellers with large throughlets would eliminate clogging. The resulting pump designs had closed channel impellers with large free passages. While high-capacity pumps could maintain a large throughlet size with multi-vane impellers, small- and medium-sized pumps were fitted with single-vane impellers to maximize the throughlet size. Due to their asymmetrical geometry, however, single-vane designs suffered from imbalance, resulting in high pump vibrations, rough-running pumps, and shorter bearing and seal lifetimes.

In different parts of the world, user standards were developed that would dictate a certain minimum impeller throughlet size, often in the 75 to 100 mm range. These requirements drove manufacturers to produce compliant products. In the smallest pump sizes it was not possible to create such large throughlets with a closed impeller. For this and other reasons, manufacturers utilized alternative impeller designs such as vortex impellers and screw impellers. Grinder and chopper designs that reduced the size of the solids before pumping were also developed for small pump sizes.

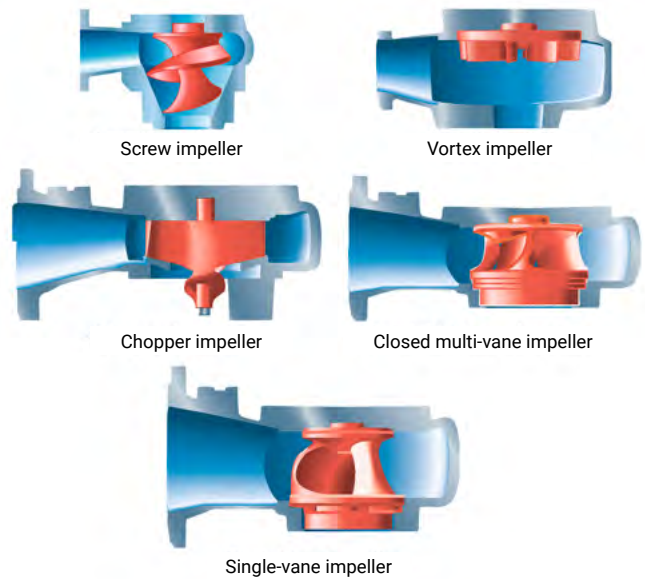


Figure 4: Five traditional non-clog impeller designs

The large throughlet sizes, single-vane designs and other hydraulic considerations resulted in low pump efficiencies, sometimes as much as 20 to 30% lower than their clean water counterparts. However, the key function for pumping wastewater was improved: there were fewer complete clogs of the pumps. Later variations on these hydraulic designs offered better efficiencies in clean water, but not sustained efficiency for wastewater.

The effect of self-cleaning hydraulics on efficiency

Flygt pump engineers have been studying the phenomenon of sustained efficiency in non-clog pumps since the mid-1990s. Extensive research and a standardized clog test have demonstrated, among other things, the importance of the impeller vanes' leading-edge geometry and degree of sweep in preventing clogs. This led to the introduction of once-radical, now industry-leading hydraulic geometries that deliver higher pump efficiency and sustained efficiency.

A self-cleaning design with substantially backswept leading edges and a relief groove (Figure 5) has proven to be the answer to most clogging problems. Solids that land on the leading edges of the impeller are continuously pushed towards the periphery and out through the pump discharge via a relief groove in the insert ring, preventing accumulation of solids and delivering sustained high efficiency (Figure 3c). This modern, self-cleaning pump design can reduce energy consumption by 25 to 40% or more compared to traditional non-clog pump designs.

For smaller pumps, self-cleaning N-technology hydraulics are aided by two further elements. The first is an integrated guide pin that catches fibers near the impeller hub and allows the blades to push them out through the relief groove. The second is an adaptive technology (Figure 6) that temporarily increases the clearance between the impeller and insert ring to allow bulkier objects to pass smoothly through the pump.

In addition to energy savings, the self-cleaning hydraulic design can generate substantial savings in unscheduled pump station callouts caused by clogging. When combined with intelligent clog detection and pump cleaning functions, self-cleaning hydraulics can reduce the likelihood of clogging to near zero.

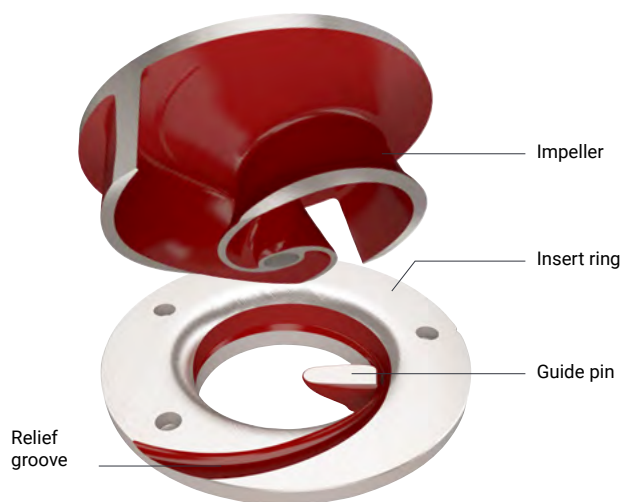


Figure 5: Self-cleaning N-technology hydraulic design

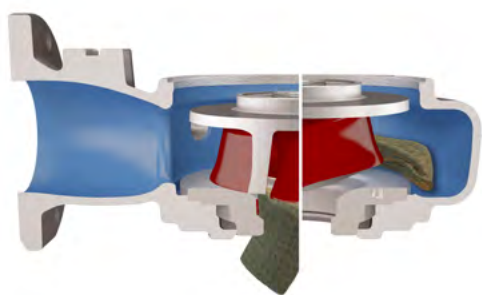


Figure 6: Adaptive N impeller positions during operation

The wastewater transport industry today

Today's end users continue to be hard-pressed to lower operating costs and cannot accept disruptions in service to address a pump clog. While there might be a general suspicion that the operational efficiency of a non-clog pump will be less than the performance curve indicates, the true difference is not well known. Understanding true pump efficiency and its impact on energy consumption, however, can deliver significant operational improvements. With a pump that starts out efficient and stays efficient over long and short duty cycles in wastewater, while also resisting both full and partial clogging, operators can achieve significant energy savings, minimize site visits and reduce equipment wear.

Only modern, self-cleaning pump hydraulics and pumps with cutting functions can deliver sustained efficiency when pumping wastewater, stormwater, and similar liquids containing soft solids.

Changing the industry mindset

Pump specifiers, consulting engineers, industry experts and standard-setting organizations have shown an increasing interest in sustained pump efficiency. Several pump manufacturers have followed Flygt's lead in conducting research in this area and in adopting self-cleaning design trends, but there are still barriers to overcome:

- General lack of awareness of the issues discussed in this paper
- User reliance on minimum pump throatlet size as a criterion for pump selection
- Lack of a uniform and globally accepted clog test standard