



“Screw Centrifugal Impeller Technology And Its Advantages For Sludge Pumping”

Introduction

The screw centrifugal pump design (See Figure 1 “Screw Centrifugal Pump Cross-Section”) offers unique technological advantages that are well suited to certain municipal and industrial sludge pumping applications. Use of these pumps for specific sludge services is quickly growing throughout North America as a result of advantageous hydraulic characteristics, solids handling capability, and high efficiency.

Services such as Return Activated Sludge (RAS), Waste Activated Sludge (WAS), and Digested Sludge Recirculation or Mixing often involve short pipe runs and relatively little static head, resulting in low overall total dynamic head (TDH). Required flows, however, can be high especially when large tanks are being recirculated or mixed. This high flow/low head hydraulic requirement is difficult to obtain with conventional centrifugal “non-clog” pumps but matches the performance characteristics of the screw centrifugal impeller very closely.

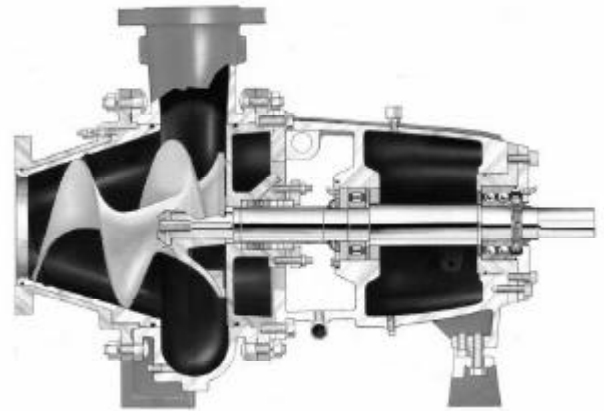


Figure 1: Screw Centrifugal Pump Cross-Section

Solids such as rags, hair, and/or clusters of stringy material are often encountered in RAS, WAS, and digested sludge applications. This material hangs up on the leading edges of conventional “non-clog” impellers causing unbalance and eventual clogging. In order to pass such solids, screw centrifugal impellers feature a single spiral vane which creates one large, smooth passage without abrupt redirection of the fluid. Specially designed cutting grooves further ensure that any material caught in the close clearance between impeller and cone is sheared off and re-introduced into the flow.

On some sludge services, variations in solids concentrations can be experienced - ranges between 2-7% are common. In these circumstances, consideration must be given to changes in NPSH available, TDH, and power consumption which can result in problems such as cavitation, loss of flow, and motor overload respectively. The positive displacement action of the impeller’s “screw” section acts as an inducer which provides very low NPSH required. Screw centrifugal pumps also exhibit steep head-capacity curves that are typically non-overloading at a given speed making their performance relatively insensitive to changes in TDH. These design characteristics make screw centrifugal pumps extremely accommodating under varying sludge conditions.

Resistance to abrasive wear is often a concern with pumps for sludge handling services. To resist abrasion, all wet-end components including impeller, casing, and suction cone can be manufactured in wear resistant materials such as high-chrome iron with a minimum hardness of 450 BHN. Furthermore, it is particularly important to maintain the pump’s close running clearances in order to ensure optimum performance. The impeller clearances can be externally adjusted on screw centrifugal pumps without the need to disconnect piping or remove the pump.

Operational Improvements In Detail

When the hydraulic characteristics of a pump and system are well matched, equipment selection can be made to facilitate operation at a reliable speed close to its best efficiency point - where bearing loads and shaft deflections are at a minimum (See Figure 2 “Radial Load vs % of Best Efficiency Flow”). In order to meet the low head/high flow conditions of many sludge transfer, mixing, and circulation services with conventional non-clog pumps, a trade-off is required between running the pump too far out on the curve and operating an oversized pump at low speed. Operation of the pump too far out on the curve increases the likelihood of frequent bearing and seal failures from high shaft and bearing loads. On the other hand, operation at too low an RPM indicates that the pump is oversized, with fluid velocities



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that are insufficient to move solids through the pump before settling and fouling occurs. Screw centrifugal pumps are designed to operate in the optimum performance range (ie. within approximately 75% to 125% of the BEP) under high flow/low head conditions.

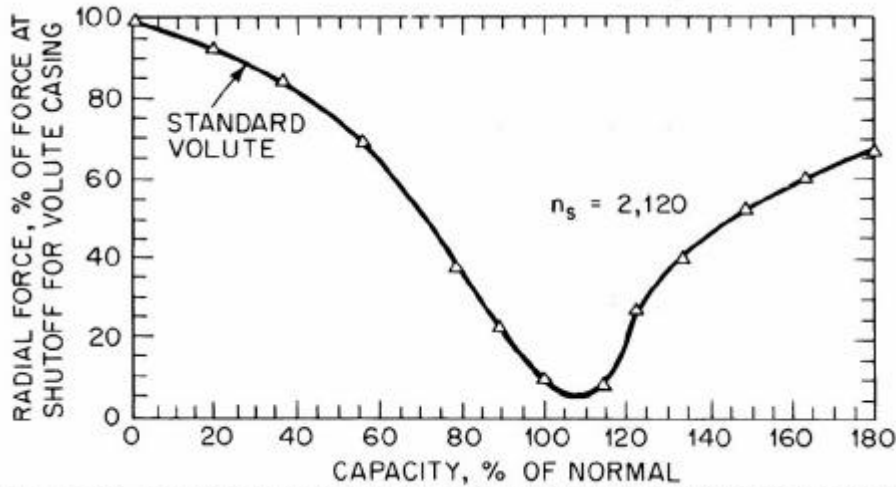


Figure 2: Radial Load vs. % of Best Efficiency Flow

The ability to manufacture a pump in the correct materials of construction for each application can have a major effect on equipment performance. For example, applications involving a moderate level of abrasive material will require a hard metal impeller and suction liner (usually ASTM A532 high chrome iron) to prevent premature wear of these key components. Municipal sludge applications requiring corrosion resistance, such as ATAD sludge, should specify the impeller, suction cone, and casing to be made from ASTM A532 high chrome iron with all other wetted parts to be 316L stainless steel. High chrome iron has good corrosion properties as its chromium content is approximately 25%. Screw centrifugal pumps are typically designed to provide a wide range of construction materials - details can be provided by the specific manufacturer.

Solids handling pumps with close radial clearances between the impeller and casing are susceptible to jamming and performance degradation in this area as the clearance opens up. A major maintenance benefit provided by screw centrifugal designs is the ability to externally adjust this clearance without dismantling or replacing parts of any kind. The suction nozzle is designed with a straight taper so that axial travel of the cone will adjust the clearance evenly along the entire length of the impeller. In order to prevent jamming from occurring in the area between the rotating impeller and its stationary counterpart, the suction cone is designed with spiral cutting grooves that trap material so that the impeller vane can shear it into smaller pieces and move it out of the pump. In comparison, conventional non-clog designs offer no cutting action and require the pump to be removed and dismantled in order to repair or replace worn parts and restore the proper tolerances between the impeller and casing.

Case Studies

1) Digester Mixing

To achieve homogeneous mixing of digesters and sludge storage tanks with centrifugal pumps, high flow rates are required to ensure a sufficient number of turnovers of the tank contents. The TDH of tank mixing systems, however, is typically quite low since the pipe runs are short and elevation differences small between pump and tank. This combination of high flow and low head can be difficult to achieve with conventional centrifugal pumps. Additional challenges of this application include stringy and fibrous material that can cause clogging, and the presence of entrained gases that can cause cavitation and reduction of pump performance.



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The New York City Department of Environmental Protection (NYCDEP) originally selected axial flow “propeller-type” pumps for this service at several of its wastewater treatment plants. This design of pump features a multi-vaned propeller/impeller (See Figure 3 “Axial Flow Impeller”) suitable for the high flow and low head hydraulic conditions inherent in the application.

Although the axial flow design meets the hydraulic requirements, it is vulnerable to fouling around the exposed impeller vanes when handling fluids such as digested sludge containing stringy and fibrous material. Chronic clogging problems with these pumps were experienced by the Coney Island, NY WPCP in their sludge mixing application.

Axial flow mixing pumps at the Coney Island plant also had to contend with gas bubbles (methane) present in the sludge. Axial flow pumps are sensitive to entrained gases because their impellers feature multiple, narrow vanes which impart turbulence on the gas bubbles and allow them to form larger pockets which displace fluid and reduce pumping capacity. These cavitation bubbles can also cause pitting of the impeller. Both impeller pitting and significant variations in pumping volume were experienced.

The screw centrifugal pump offers several features designed to overcome the problems described above and the NYCDEP decided to test the design at two locations (Coney Island WPCP and Tallman Island WPCP).

To pass solids without clogging, screw centrifugal pump impellers feature an elongated, single, open spiral vane forming a large channel (See Figure 4 “Screw Centrifugal Impeller”). To free material that may lodge between the stationary suction cone and the rotating impeller vane, dual cutting grooves cast into the suction cone, shear off the material and reintroduce it into the flow. Multiple vane edges that can catch on solids, as in axial flow and non-clog designs, are not present in screw centrifugals. Testing and operational experience has proved these pumps to be extremely resistant to clogging on digested sludge.

To minimize cavitation, screw centrifugal impellers borrow from design principals found in suction inducers. Inducers are used to prevent cavitation in pumps and they feature few long vanes rather than many short vanes and their blades typically wrap around 360 degrees - these are also features of screw centrifugal impellers. The principal of an inducer is that a long, smooth passage provides the time and space for the collapse of the cavitation bubbles and for the gradual addition of energy. The inducer is intended to pressurize the flow sufficiently to enable the pump to operate satisfactorily. In effect, the long, spiral screw centrifugal impeller provides a longer fluid stay time within the vane, permitting vapor formation to recondense while still having sufficient vane surface remaining to impart the required head rise to the liquid. To achieve minimum vapor formation in the first place, fluid must pass into the vane with minimum disturbance - the entry into the screw centrifugal impeller is much gentler than that of the multi-vaned axial flow impeller shown in figure 3. As a consequence, the screw centrifugal pumps at the NYCDEP did not exhibit the same performance fluctuations and impeller pitting from cavitation that was experienced with the axial flow pumps.

In conclusion, the screw centrifugal pumps tested by the NYCDEP on sludge mixing did not exhibit the clogging and cavitation problems described above and are now replacing axial flow pumps on this service.

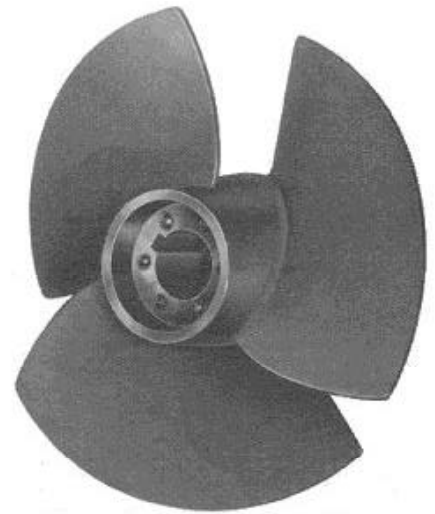


Figure 3: Axial Flow Impeller

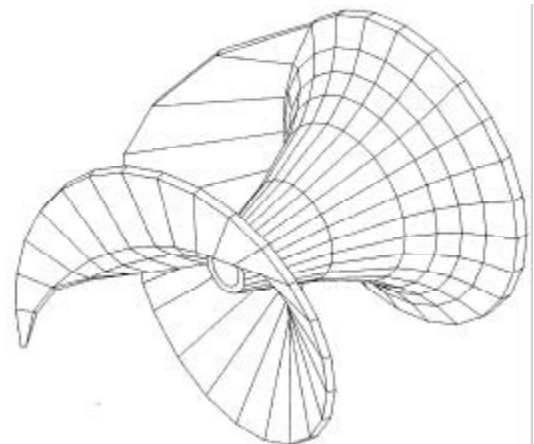


Figure 4: Screw Centrifugal Impeller



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2) Return Activated Sludge

The wastewater treatment plant at the City of Neptune Beach, Florida was experiencing excessive maintenance problems with their non-clog type return activated sludge (RAS) pumps. Approximately 20 hours of maintenance per week was required to repair seal and bearing failures or to free the pumps from clogs.

At Neptune Beach, low TDH (a feature of many RAS applications) caused the non-clog pumps to “run-out” on the performance curve where hydraulic radial loads on the impeller and shaft are high. Excessive radial loads on the shaft increase deflection at the mechanical seal faces which shortens seal life and causes leaking. High radial loads also transmit through to the bearings and can shorten their life. Replacement of bearing and mechanical seals is a major maintenance task. A centrifugal pump should be selected to operate within a range of its best efficiency point (BEP) that is within the manufacturer’s performance curves and mechanical ratings. Ratings such as bearing life and maximum shaft deflection are often qualified for operation of the unit within, say, 50% to 125% of the BEP.

The non-clog RAS pumps also experienced clogging on the leading edges of the impeller (see Figure 5 “Non-clog Impeller”) and between the impeller and wear ring. The close running clearance between the impeller and wear ring is vulnerable to binding with solids but there is no mechanism to cut or otherwise free material from this area.

Plant personnel at Neptune Beach investigated alternative pump designs with the objective of overcoming the problems described above. Screw centrifugal were ultimately selected for a number of reasons.

The low head / high flow hydraulic characteristics of screw centrifugal pumps provided the opportunity to select a pump for this application that would operate close to the BEP (See Figure 6 “Screw Centrifugal vs Non-Clog Performance Curves - Neptune Beach RAS Pumps”).

To address the clogging problem, the screw centrifugal pump features an open impeller with a single, spiral vane forming a large channel. Cutting grooves in the suction ensure that any material entering the close clearance between suction liner and impeller vane is sheared off and re-introduced into the flow. Wear rings and multiple vane edges are eliminated.

The replacement of the non-clog RAS pumps with screw centrifugal pumps completely eliminated the previous mechanical and clogging problems.

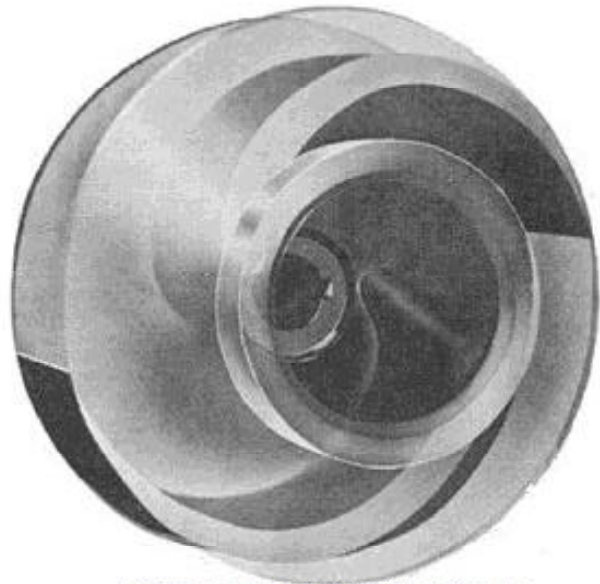


FIGURE 5: NON-CLOG IMPELLER



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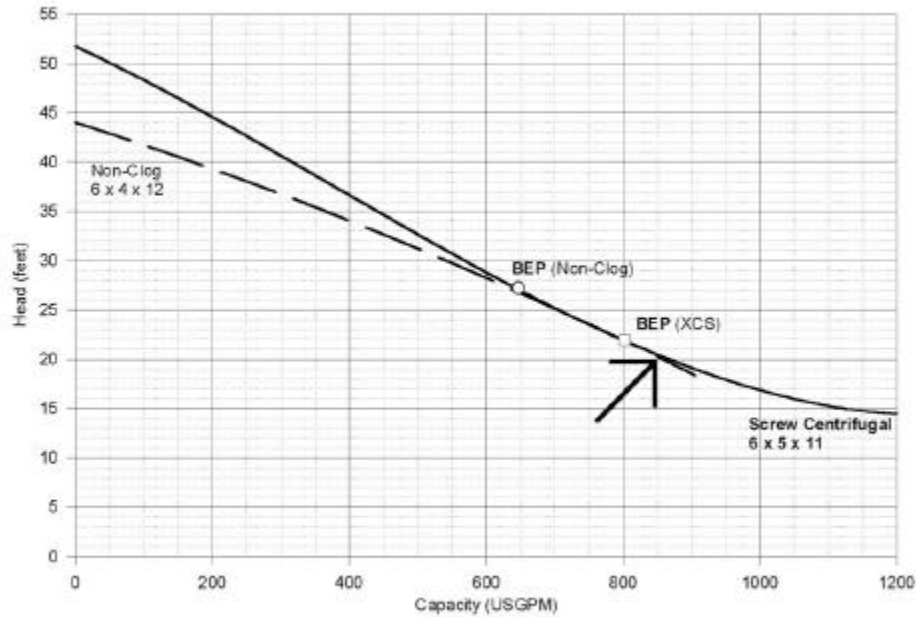


FIGURE 6: SCREW CENTRIFUGAL VS NON-CLOG PERFORMANCE CURVES - NEPTUNE BEACH RAS PUMPS

Summary

Screw centrifugal pumps are being increasingly utilized in new installations and retrofits to address and solve very costly and inconvenient problems due to clogging, wear, and mechanical breakdown. Operational savings can be achieved from reduced maintenance and repair costs and less downtime.

References

Lakshminarayana, B. (1982) "Fluid Dynamics of Inducers - A Review", *Journal of Fluids Engineering*, Vol. 104/411