AHEAD OF THE CURVE A guide to sizing and selecting the right pump for the job

Pumps are mechanical devices that add hydraulic energy to a fluid, increasing fluid pressure at the pump discharge and creating flow through piping systems. While a wide variety of pump designs can accomplish this task, they fall into two general categories: Kinetic and positive displacement. Centrifugal pumps, a type of kinetic, are the most common in industrial applications. This article will provide a detailed description of the criteria to consider in centrifugal pump sizing and selection, offer a brief comparison to positive displacement pumps, and provide guidelines for the application of each.

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A centrifugal pump is characterized by the use of a rotating impeller to increase the pressure and flow rate of a fluid, and is the most common type of pump used to move liquids through a piping system. Entering the pump impeller near the rotating axis, fluids are accelerated by the impeller, flowing outward or into a diffuser or volute chamber before exiting into the downstream piping system. Typically used for higher flow rates, centrifugal pumps are commonly utilized in water, sewage, petroleum, petrochemical, and boiler feed applications, among others.

Among centrifugal pumps there exists a vast array of pump types, including submersible, end suction, split case and column pumps, for example. The varying designs handle different fluids, pressures, flow capacities and other system conditions, and the selection of a pump should take into account all of these factors.

Manufacturers typically present pump head and capacity information in the form of a pump performance curve, which represents performance characteristics over the operating range of the pump. To properly select a pump and evaluate system performance, one should consider a number of factors, outlined in the following section.

Selecting the proper centrifugal pump for your application requires careful evaluation of the pump curve, Net Positive Suction Head, fluid viscosity, pump affinity rules, and pump power calculations.

Pump curve

The pump curve is developed by testing the pump according to industry standards and consolidating the resulting head and flow rate data into a curve. Pump manufacturers often provide a performance curve for a single impeller size and speed, or multiple curves for a range of impeller sizes or speeds. Elements found on the pump curve include:

- *Total Head:* The energy content of the liquid, imparted by the pump, expressed in feet of liquid.

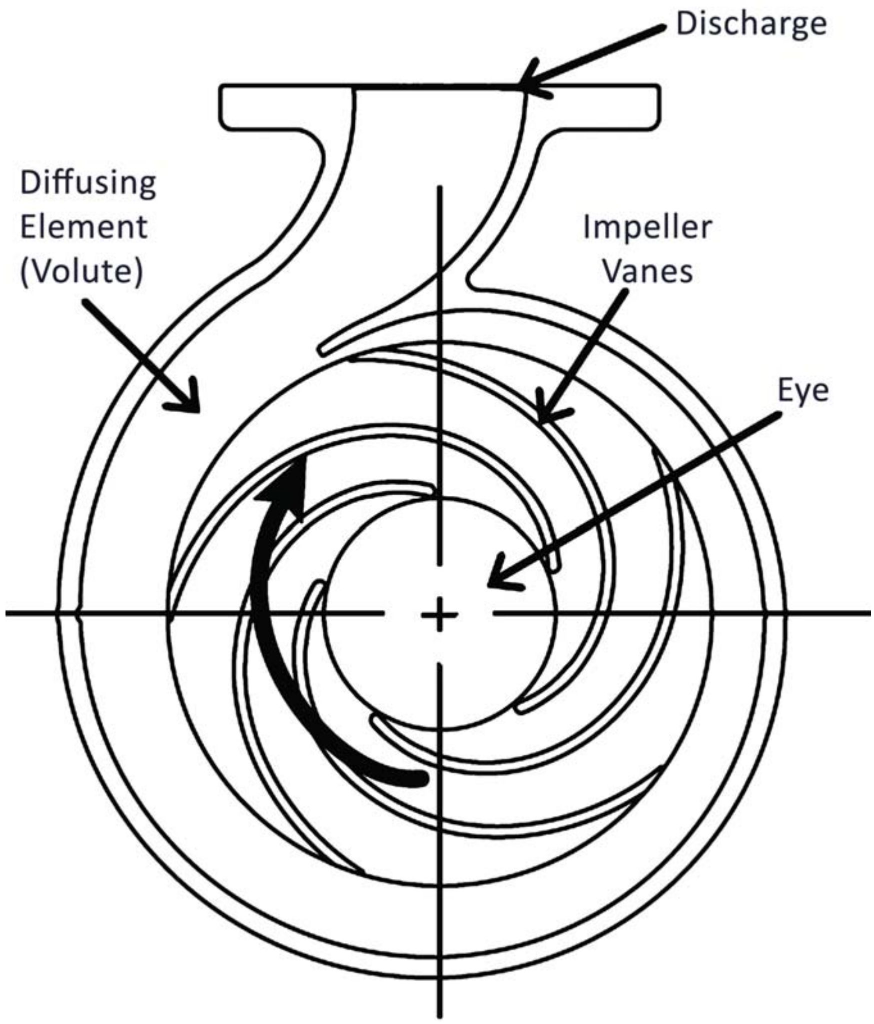

Figure 1: *Centrifugal pump cross section.*

- *Pump Efficiency:* The ratio of the energy supplied to the liquid to the energy delivered from the pump shaft.
- *Shutoff Head:* The head generated at the condition of zero flow where no liquid is flowing through the pump, but the pump is primed and running.
- *Minimum Flow:* The lowest flow rate at which the manufacturer recommends the pump be operated.
- *Allowable Operating Region (AOR):* The range of flow rates recommended by the pump manufacturer in which the service life of the pump is not seriously reduced by continuous operation.
- *Best Efficiency Point (BEP):* The flow rate on the pump curve where the efficiency of the pump is at its maximum. Operating near this point will minimize pump wear.
- *Preferred Operating Region (POR):* A region around the BEP on the pump curve, defined by the user, to ensure reliable and efficient operation.
- *Maximum Flow Rate:* The end of the manufacturer's curve for the pump, commonly referred to as "run out."
- *Net Positive Suction Head required (NPSHr):* The amount of suction head above the vapor pressure needed to avoid more than 3% loss in total head due to cavitation at a specific capacity.

Net Positive Suction Head available

The Net Positive Suction Head available (NPSHa) refers to the head provided by the piping system to the pump suction. It is influenced by the configuration of the system and the properties of the fluid. Properly calculating the NPSHa is essential to ensure that it exceeds the manufacturer's NPSHr and prevents cavitation in the pump.

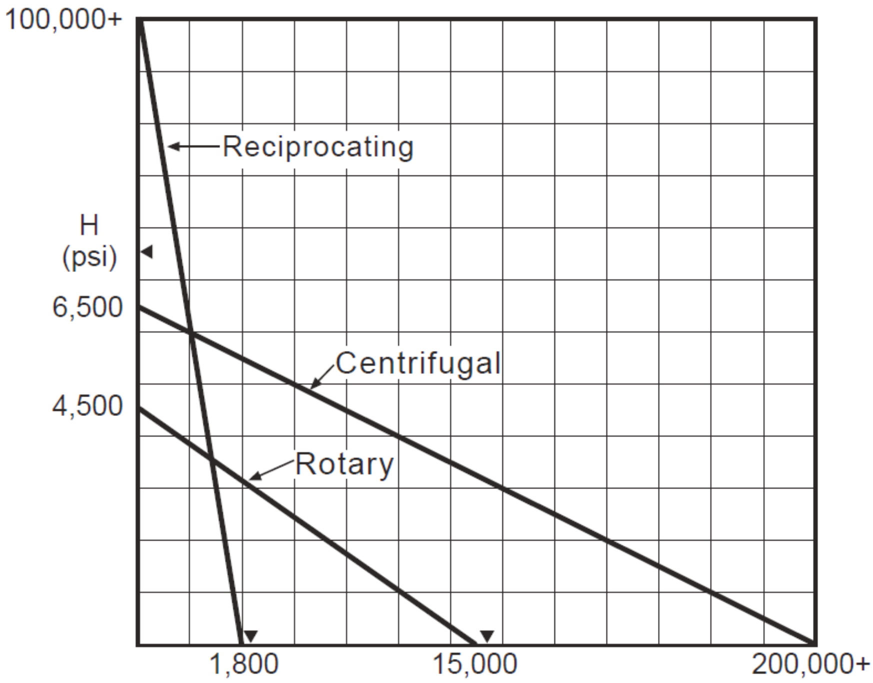

Figure 2: *Head vs. Flow for centrifugal, rotary, and reciprocating pumps.*

System variables can be optimized to increase NPSHa at the pump suction, including:

- *Pump Location:* Lowering the pump suction in relation to the tank will increase NPSHa.
- *Pump Suction Piping:* Minimizing suction pipeline head loss will increase NPSHa. This head loss will be a factor of pipe size, pipe roughness and any components installed in the pipeline. In addition, as flow increases through the suction pipeline, head loss will increase, effectively reducing the NPSHa. For most pumps, NPSHr will increase with flow rate.

- *Fluid Properties:* Fluid properties such as vapor pressure, density, and viscosity vary with temperature. The net effect of a change in fluid temperature on NPSHa should be evaluated.
- *Supply Tank:* An increase in supply tank pressure, elevation or liquid level will increase the NPSHa.
- *Atmospheric Pressure:* Changes in atmospheric pressure can affect the NPSHa.

Viscosity corrections

Most published pump curves reflect the performance of the pump with water as the operating fluid. A more viscous fluid will lead to an increase in required power and a reduction in flow rate, head, and efficiency. Pump performance should be corrected for viscosity to obtain the most accurate representation of operation.

Pump affinity rules

Affinity rules predict pump performance in response to changes in impeller speed or diameter. For example, when a pump's rotational speed is changed, the head, capacity, and power for a point on the pump curve will vary according to the pump affinity rules.

Trimming an impeller will change the vane angle, thickness and impeller clearance. Although these changes will impact pump performance, they are not accounted for by the affinity rules. Therefore, the affinity rules should be used only for small changes in impeller diameters, as increased inaccuracies may occur with larger changes. Interpolation between two known impeller diameters on the pump curve typically provides more accurate results.

Pump power calculations

Pump horsepower can be used to appropriately size a motor for the pump and calculate operating costs based on pump and motor efficiencies.

A positive displacement pump differs from a centrifugal pump in that it moves fluid by trapping a fixed volume in a cavity and then forcing it out into the discharge pipe. Liquid flows into the pump as the cavity on the suction side expands, and it flows out as the cavity collapses, maintaining a constant volume through each cycle of operation.

The two main categories of positive displacement pumps, reciprocating and rotary, add this energy in a periodic, rather than continuous, fashion. Reciprocating pumps use reciprocal motion such as pistons or diaphragms to directly displace fluid, while rotary pumps employ a variety of designs including peristaltic, screw, and gear pumps to displace fluid through the application of rotary motion.

Positive displacement pump applications

The fact that positive displacement pumps add energy by direct force on a fluid makes them a suitable choice for certain applications. They impart little shear force to the fluid, making them suitable for fluids with high viscosity and low-shear requirements, as well as for fragile solids. By directly moving a volume of fluid, they can meet high pressure, low-flow, and precise fluid delivery requirements, as well as offer efficient pumping of two-phase fluids.

Positive displacement pump curve

Positive displacement pump curves are not limited to a flow vs. head relationship. Flow vs. speed and flow vs. discharge graphs are also commonly used. With the exception of slip, capacity in a positive displacement pump varies directly with speed, independent of head. Positive displacement pumps typically exhibit slip, which is fluid leakage from the high-pressure side to the low-pressure side of the pump. At higher pressures and/or lower viscosities, this will result in an increasing loss of capacity through the pump.

Centrifugal vs. positive displacement pumps

While centrifugal pumps are the more common of the two pump types, there are a number of reasons to choose a positive displacement pump in specialized situations.

Highly-viscous solutions

As mentioned above, positive displacement pumps are the better choice when handling high-viscosity fluids, as these will dramatically affect the flow rate and efficiency of a centrifugal pump and can result in increased energy costs.

High-pressure applications

While pressure limits can vary with the design of individual pumps, positive displacement pumps are often better able to produce extremely high pressure compared to centrifugal pumps, especially at low flow rates, even when operated in series.

Variations in pressure and viscosity

Debris, pipe corrosion, and even modest changes in valve operation or pressure can greatly affect the efficiency of a centrifugal pump, whereas positive displacement pumps are able to maintain their flow rate.

The information contained within this article has been gathered from Crane's Technical Paper No. 410, first published in 1942 and continuously updated to reflect the evolution of the fluid handling industry, with the most recent revision having been completed in 2009. The complete text provides supplemental theory, equations and charts to further illustrate the concepts discussed herein, and offers a comprehensive suite of online tools and calculators.

Shear-sensitive fluids

As pump speed increases, so does their tendency to shear liquids. Therefore, high-speed centrifugal pumps are typically not the ideal option for shear-sensitive liquids and positive displacement pumps offer a better solution.

Operating away from the middle of the curve

Centrifugal pumps have a specific range on the pump curve at which they operate with maximum efficiency — the greater the deviation from this range, the greater the risk of cavitation, deflection, and pump failure. Positive displacement pumps, however, are able to more efficiently accommodate operating conditions at any point on the curve.

Considerations for pump selection

The process of pump selection can be broken down into a series of distinct steps. First, one must determine the pump capacity — this is the desired pump flow rate, typically measured in gallons per minute. Upon determining pump capacity, users must ascertain the head requirements, ensure that the pump can overcome the static and dynamic head losses of the system. Next, the NPSHa can be calculated by hand.

To specify the best equipment, a selection chart is consulted to create a short list of pumps for evaluation. The curves are then individually considered to find the best fit. Next, users must account for fluid density and viscosity, both of which will impact the shape of the pump performance curve and will need to be adjusted according to the media. Finally, the pump horsepower must be determined. Although horsepower curves may be included on the published pump curve, it can also be calculated by hand.

Whether an application requires a centrifugal or positive displacement pump, there are a myriad of factors to consider in ensuring that systems are compatible and operate with maximum efficiency and minimum costs.

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CASE STUDY: Slurry pump repair with polymeric composites

An Australian producer of nickel and cobalt required a solution for their centrifugal vertical slurry pump.

By Cassia Sanada, Technical Coordinator, Belzona Inc.

The slurry mixture contains approximately 60% solids by volume and has a temperature of 70°C – 80°C. In order to repair the casing that suffered extreme wear on both cut waters, the repair compounds needed to be highly durable, satisfy the need for high abrasion resistance under immersed conditions at high temperatures, and provide excellent mechanical strength. Since the pump is constructed of Ni-Hard, abrasive blasting was conducted to Swedish Standard SA 2½ . Customized templates were affixed to the impeller ring and discharge port openings of the casing to serve as a mould in order to restore the internal diameter and also to ensure correct alignment.

Worn cutwaters reduced by approximately 100mm were repaired with a paste grade ceramic-filled composite: Belzona 1311. Once cured, the cutwaters were shaped to the required dimensions using an angle grinder. Belzona 1321, a ceramic-filled coating, was applied to the entire casing internals as a priming coat to assist adhesion to the Ni-Hard substrate. Belzona 1812, a composite with hard ceramic aggregates closely packed in a polymeric binder, was then applied at a thickness of approximately 6mm utilizing the templates previously installed. A final layer of Belzona 1391 was applied throughout the pump internals to provide additional

External surface protected against high temperature.

heat resistance. From start to finish, the application lasted less than a week and the client could avoid replacement costs in excess of approximately $15,000 USD. The repair solution, proven to be more durable than the Ni-Hard substrate, cost approximately half of this amount and prevented downtime at approximately $77,000 USD per hour.