Best Practice Pump Control

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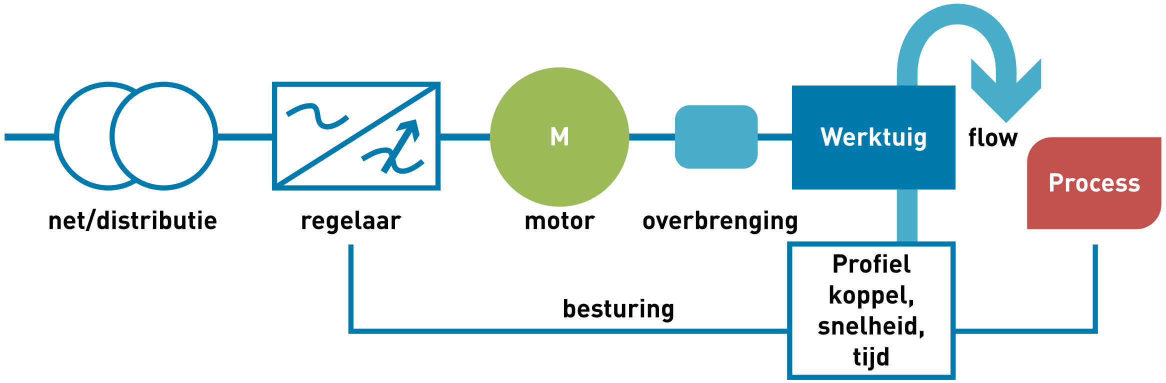
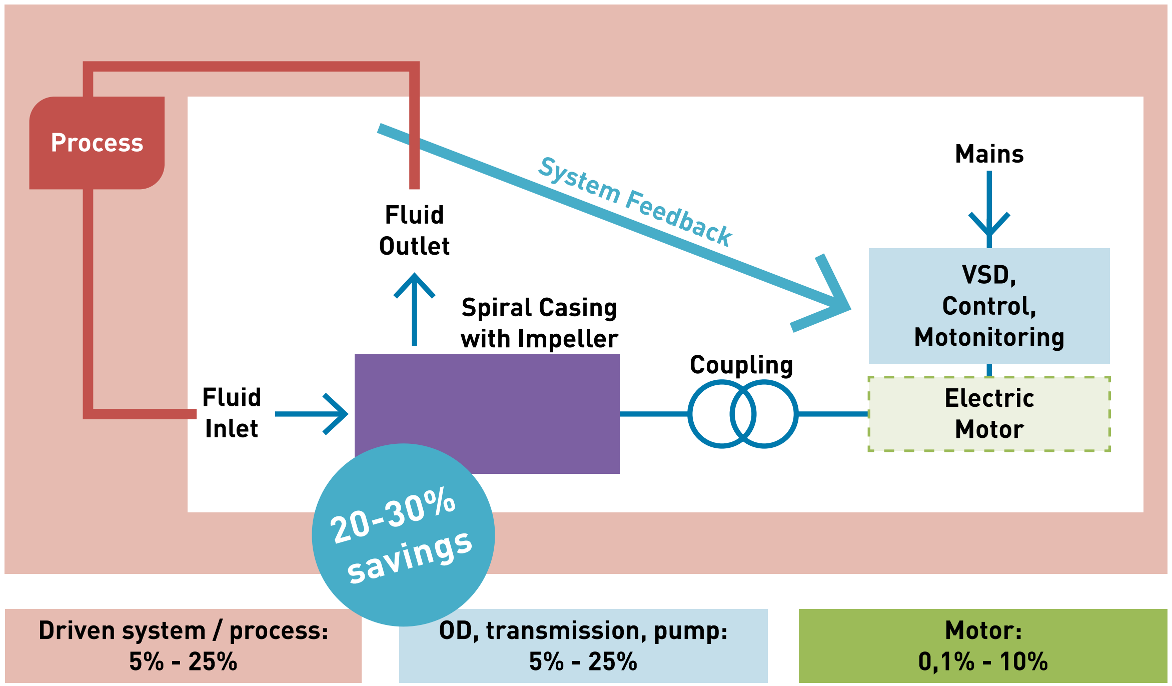




Motor driven systems

Pumps are part of a motor driven system, comprising the pump, the motor, the coupling between them and the capacity control system.

When looking for an optimum in performance and energy efficiency one should always look at the total system for the best cost effective solution.

Savings in the order of 20-30 % on the energy efficiency are possible.

The Best Practices for individual parts (high efficiency motors, capacity control and variable speed drives) are given in separate documents

Source: Spice3 workshop SBE September 2014 presentation efficient motor drives

Introduction

In many plants, the capacity of rotating equipment, such as pumps, fans and compressors, is calculated based on the maximum demand of the process; which occurs only part of time. Often the excess capacity is controlled through a control valve; as a result, a lot of energy is wasted. For a good procedure of the system, capacity control is necessary. In order for process capacity or pressure adapted to the demand, various types of control have been developed. This may include mechanical arrangements (such as throttle) or speed control. Given the significant amount of electric power consumed by pumping systems, even small improvements in pumping efficiency could bring very significant savings of electricity.

Source: AkzoNobel

General Recommendations

Energy Conservation Opportunities in Pumping Systems

- Ensure adequate Net Positive Suction Head (NPSH) at site of installation to prevent cavitation.
- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequenced control of multiple units.
- Use booster pumps for small loads requiring higher pressures.
- Repair seals and packing to minimize water loss by dripping.
- In multiple pump operations, carefully combine the operation of pumps to avoid throttling
- Replace old pumps by energy efficient pumps
- In the case of overdesigned pumps, provide variable speed drive, or downsize/ replace impeller or replace with correct sized pump for efficient operation.
- Reduce system resistance by pressure drop assessment and pipe size optimization

Efficient Pumping System Operation

When examining or designing a pump system, the process demands must first be established and most energy efficiency solution introduced. For example, does the flow rate have to be regulated continuously or in steps? Can on-off batch pumping be used? What are the flow rates needed and how are they distributed in time?

The first step to achieve energy efficiency in pumping system is to mark the end-use. For example a plant water balance would establish usage pattern and highlight areas where water consumption can be reduced or optimized. Good water conservation measures, for example, may eliminate the need for some pumps.

Once flow requirements are optimized, then the pumping system can be analysed for energy conservation opportunities. Basically this means matching the pump to requirements by adopting proper flow control strategies. Common symptoms that indicate opportunities for energy efficiency in pumps are given in the Table 1.

Tabel 1: Potential Opportunity for Energy Savings

Sympton	Likely Reason	Best Solution
Throttle valve-controlled systems	Oversized pump	Trim impeller, smaller impeller, variable speed drive, lower rpm
Bypass line (partially or completely) open	Oversized pump	Trim impeller, smaller impeller, variable speed drive, lower rpm
Multiple parallel pump system with the same number of pumps always operating	Pump use not monitored or controlled	Install controls
Constant pump operation in a batch environment	Wrong system design	On-off controls
High maintenance cost (seals, bearings)	Pump operated far away from best efficiency point	Match pump capacity with system requirement

Types of Control

Different types of capacity and pressure control are available:

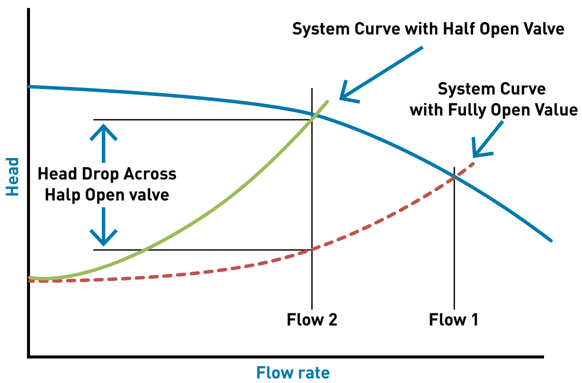
3.1 Stop/start control

In this control method, the flow is controlled by switching pumps on or off. It is necessary to have a storage capacity in the system e.g. an elevated tank. The storage can provide a steady flow to the system with an intermittent operating pump. When the pump runs, it does so at the chosen duty point and when it is off, there is no energy consumption. If intermittent flow, stop/start operation and the storage facility are acceptable, this is an effective approach to minimize energy consumption.
The stop/start operation causes additional loads on the power transmission components and increased heating in the motor. The frequency of the stop/start cycle should be within the motor design criteria and checked with the pump manufacturer.
It may also be used to benefit from "off peak" energy tariffs by arranging the run times during the low tariff periods.
To minimize energy consumption with stop start control it is better to pump at as low flow rate as the process permits. This minimizes friction losses in the pipe and an appropriately small pump can be installed.

3.2 Flow control valve

With this control method, the pump runs continuously and a valve in the pump discharge line is opened or closed to adjust the flow to the required value.
To understand how the flow rate is controlled, see Figure 1. With the valve fully open, the pump operates at "Flow 1". When the valve is partially closed it introduces an additional friction loss in the system, which is proportional to flow squared. The new system curve cuts the pump curve at "Flow 2", which is the new operating point. The head difference between the two curves is the pressure drop across the valve.

Figure 1: Control of pump flow by changing system resistance by using a valve



It is usual practice with valve control to have the valve 10% shut even at maximum flow. Energy is therefore wasted overcoming the resistance through the valve at all flow conditions. There is some reduction in pump power absorbed at the lower flow rate, but the flow multiplied by the head drop across the valve, is wasted energy. Maintenance cost of control valves can be high, particularly on corrosive and solids-containing liquids. Therefore, the lifetime cost could be unnecessarily high.

3.3 By-pass control

With this control approach, the pump runs continuously at the maximum process demand duty, with a permanent by-pass line attached to the outlet. When a lower flow is required the surplus liquid is bypassed and returned to the supply source.
An alternative configuration may have a tank supplying a varying process demand, which is kept full by a fixed duty pump running at the peak flow rate. Most of the time the tank overflows and recycles back to the pump suction. This is even less energy efficient than a control valve because there is no reduction in power consumption with reduced process demand.
The small by-pass line sometimes installed to prevent a pump running at zero flow is not a means of flow control, but required for the safe operation of the pump.

3.4 Pumps in parallel switched to meet demand

Another energy efficient method of flow control, particularly for systems where static head is a high proportion of the total, is to install two or more pumps to operate in parallel. Variation of flow rate is achieved by switching on and off additional pumps to meet demand. The combined pump curve is obtained by adding the flow rates at a specific head. The head/ flow rate curves for two and three pumps are shown in Figure 2.

The system curve is usually not affected by the number of pumps that are running. For a system with a combination of static and friction head loss, it can be seen, in Figure 2, that the operating point of the pumps on their performance curves moves to a higher head and hence lower flow rate per pump, as more pumps are started. It is also apparent that the flow rate with two pumps running is not double that of a single pump. If the system head were only static, then flow rate would be proportional to the number of pumps operating.

It is possible to run pumps of different sizes in parallel provided their closed valve heads are similar. By arranging different combinations of pumps running together, a larger number of different flow rates can be provided into the system. Care must be taken when running pumps in parallel to ensure that the operating point of the pump is controlled within the region deemed as acceptable by the manufacturer.

3.5 Impeller trimming

Impeller trimming refers to the process of machining the diameter of an impeller to reduce the energy added to the system fluid. Impeller trimming offers a useful correction to pumps that, through overly conservative design practices or changes in system loads are oversized for their application.
Trimming an impeller provides a level of correction below buying a smaller impeller from the pump manufacturer.
But in many cases, the next smaller size impeller is too small for the pump load. Also, smaller impellers may not be available for the pump size in question and impeller trimming is the only practical alternative short of replacing the entire pump/motor assembly.
See before and after impeller trimming fig 3.

Figure 2: Typical Head-flow curves for pumps in parallel

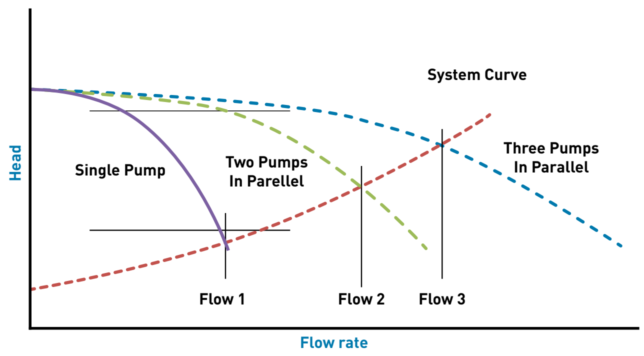
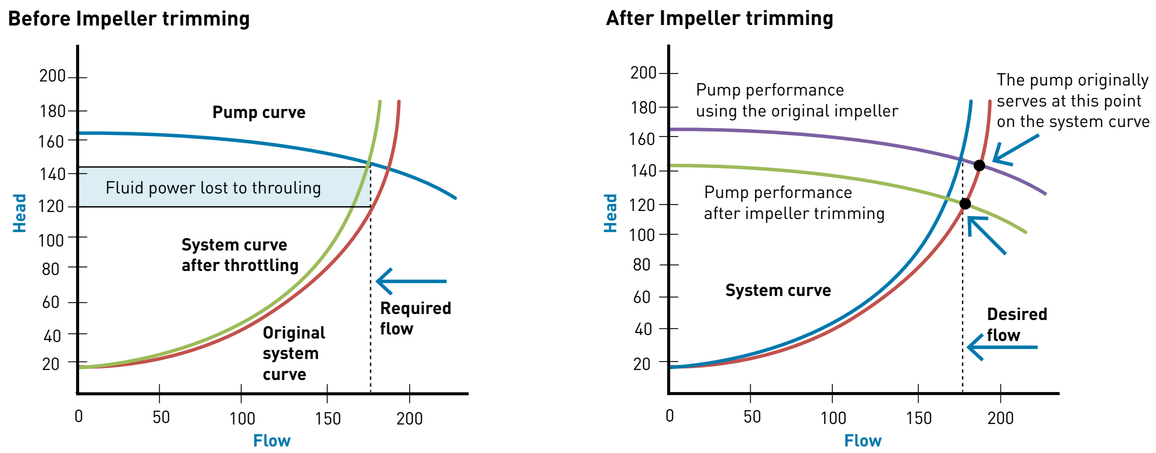


Figure 3: Impeller trimming



Impeller trimming reduces speed, which in turn directly lowers the amount of energy imparted to the system fluid and lowers both the flow and pressure generated by the pump.

Example:
A centrifugal pump equipped with an impeller 355mm in diameter is throttled to provide a process cooling water flow rate of 818m3/h. The pumping system operates for 8,000 hours per year with a head of 50.2 m and pump efficiency (ç) of 80%. The pump requires 114kW. Pump and system curves indicate that a trimmed impeller can supply the 818m3/h required flow rate at a head of 38.1m. From the affinity laws, the diameter of the trimmed impeller is approximately as follows:
(H2Q2) / (H1Q1) = (D2 / D1)3
Holding Q constant, D2 = D1 x (H2 / H1)1/3 = 355mm x (38.1m / 50.2 m)1/3 = 324mm

Assuming that the pump efficiency remains unchanged, installing a 324 mm trimmed impeller reduces input power requirement to the following:
P2 = [(H2 x Q2) / (H1 x Q1)] x P1 = [(38.1m x 818m3/h) / (50.2 m x 818m3/h)] x 114kW = 87kW

Estimated energy savings, assuming a 94% motor efficiency, are as follows:
(P1 – P2) x 8,000 hours/year / 0.94 = 230,000 kWh/year

At an electricity cost of 8 cents per kWh, total cost savings are estimated to be $18,400 per year.

3.5.1 Opportunitles for lmpeller Trimming

Most radial and mixed flow pumps in industry are oversized, due mainly to conservatism in assessing system requirements and in choosing the impeller diameter. Inaccurate system analysis can result in the need to throttle flows, which even when the pump itself is operating efficiently leads to energy wastage. However, if in such a system the pump is not throttled, it is in any case likely to be operating at less than its optimum efficiency.
Pump cavitation as a result of operation at excessive flow rates can also lead to energy wastage.

As this Case Study shows, impeller trimming can be very cost-effective. However, there are some important points to remember:

- The axial flow impeller, which is typically found in low head, high flow pumps cannot be trimmed.
- lmpeller trimming is irreversible and, if a return to the original duty is anticipated, the cost of a new impeller must be allowed for. However, this cost will usually be modest in relation to the savings made by trimming.
- Users should always seek advice from the pump maker. If this is not available, a pump specialist should be consulted.

3.6 Variable Speed Drives (VSDs)

In contrast, pump speed adjustments provide the most efficient means of controlling pump flow. By reducing pump speed, less energy is imparted to the fluid and less energy needs to be throttled or bypassed. There are two primary methods of reducing pump speed: multiple-speed pump motors and variable speed drives (VSDs).
Although both directly control pump output, multiple-speed motors and VSDs serve entirely separate applications. Multiple-speed motors contain a different set of windings for each motor speed; consequently, they are more expensive and less efficient than single speed motors. VSDs allow pump speed adjustments over a continuous range, avoiding the need to jump from speed to speed as with multiple-speed pumps.

Variable Frequency Drives (VFDs) are by far the most popular type of VSD. VFDs adjust the electrical frequency of the power supplied to a motor to change the motor's rotational speed. (See Best Practice: Variable Speed Pump System)

However, pump speed adjustment is not appropriate for all systems. In applications with high static head, slowing a pump risks inducing vibrations and creating performance problems that are similar to those found when a pump operates against its shutoff head (zero flow through the system). For systems in which the static head represents a large portion of the total head, caution should be used in deciding whether to use VFDs. Operators should review the performance of VFDs in similar applications and consult VFD manufacturers to avoid the damage that can result when a pump operates too slowly against high static head.

When a VFD slows a pump, its head/flow and power curves drop down and to the left and its efficiency curve shifts to the left.
This efficiency response provides an essential cost advantage; by keeping the operating efficiency as high as possible across variations in the system's flow demand, the energy and maintenance costs of the pump can be significantly reduced. Another system benefit of VFDs is a soft start capability. During startup, most motors experience in-rush currents that are 5 – 6 times higher than normal operating currents.
This high current fades when the motor spins up to normal speed. VFDs allow the motor to be started with a lower start-up current (usually only about 1.5 times the normal operating current). This reduces wear on the motor and its controller.

www.vnci.nl

Source: AkzoNobel