Energy Tips – Pumping Systems

Pumping Systems Tip Sheet #7 • September 2006

Industrial Technologies Program

Suggested Actions

Consider impeller trimming when any of the following apply:

- The head provided by an oversized, throttled pump exceeds process requirements.
- System bypass valves are open, indicating excess flow rate.
- The pump is operating far from its design point.
- The operating head and (or) flow rate are greater than process requirements.

Resources

Improving Pumping System Performance: A Sourcebook for Industry, DOE and Hydraulic Institute.

Hydraulic Institute—HI is a non-profit industry association for pump and pump system manufacturers; it provides product standards and a forum for the exchange of industry information for management decision-making. In addition to the ANSI/HI pump standards, HI has a variety of energy-related resources for pump users and specifiers, including training, guidebooks, and more. For more information, visit www.pumps.org, www.pumplearning.org, and www.pumpsystemsmatter.org.

U.S. Department of Energy—DOE's Pumping System Assessment Tool (PSAT) can help you assess pumping system efficiency and estimate energy and cost savings. PSAT uses pump performance data from Hydraulic Institute standards and motor performance data from the MotorMaster+ database.

Visit the BestPractices Web site at www.eere.energy.gov/bestpractices for more information on PSAT and for upcoming training in improving pumping system performance and in becoming a qualified pumping system specialist.

Trim or Replace Impellers on Oversized Pumps

As a result of conservative engineering practices, pumps are often substantially larger than they need to be for an industrial plant's process requirements. Centrifugal pumps can often be oversized because of "rounding up," trying to accommodate gradual increases in pipe surface roughness and flow resistance over time, or anticipating future plant capacity expansions. In addition, the plant's pumping requirements might not have been clearly defined during the design phase.

Because of this conservative approach, pumps can have operating points completely different from their design points. The pump head is often less than expected, while the flow rate is greater. This can cause cavitation and waste energy as the flow rate typically must be regulated with bypass or throttle control.

Oversized and throttled pumps that produce excess pressure are excellent candidates for impeller replacement or "trimming," to save energy and reduce costs. Trimming involves machining the impeller to reduce its diameter. Trimming should be limited to about 75% of a pump's maximum impeller diameter, because excessive trimming can result in a mismatched impeller and casing. As the impeller diameter decreases, added clearance between the impeller and the fixed pump casing increases internal flow recirculation, causes head loss, and lowers pumping efficiency.

For manufacturing standardization purposes, pump casings and shafts are designed to accommodate impellers in a range of sizes. Many pump manufacturers provide pump performance curves that indicate how various models will perform with different impeller diameters or trims. The impeller should not be trimmed any smaller than the minimum diameter shown on the curve.

Net positive suction head requirements (NPSHR) usually decrease at lower flow rates and can increase at the higher end of the pump head curve. The NPSHR at a given flow rate will normally be greater with a smaller impeller, but engineers should consult with the pump manufacturer to determine variations in NPSHR before trimming the impeller. Manufacturers can often provide trim correction charts based on historical test data.

How Impeller Trimming Works

Trimming reduces the impeller's tip speed, which in turn reduces the amount of energy imparted to the pumped fluid; as a result, the pump's flow rate and pressure both decrease. A smaller or trimmed impeller can thus be used efficiently in applications in which the current impeller is producing excessive head. Pump and system curves can provide the efficiency or shaft power for a trimmed impeller. If these curves are not available, affinity laws can be used to predict the variations in pumping performance with changes in the impeller diameter:

$$
\begin{aligned}
Q_2 / Q_1 &= D_2 / D_1 \\
H_2 / H_1 &= (D_2 / D_1)^2 \\
bhp_2 / bhp_1 &= (H_2 Q_2) / (H_1 Q_1) \\
&= (D_2 / D_1)^3
\end{aligned}
$$

where

- Q = pump flow rate, in gallons per minute (gpm)
- H = head, in feet (H_1 is head for the original impeller; H_2, for a trimmed impeller)
- bhp = brake horsepower
- D = impeller diameter, in inches

In practice, impeller trimming is typically used to avoid throttling losses associated with control valves, and the system flow rate will not be affected.

Note that, in contrast to centrifugal pumps, the operating regions of mixed-flow and axial-flow pumps are limited because of flow rate instabilities. Therefore, consult with the pump manufacturer before changing the impeller diameter. Removing stages is often advisable for a multistage centrifugal pump that is oversized for current operating conditions.

When a pump serves a critically important process, it might not be possible to wait for the impeller to be trimmed. In that case, consider ordering another impeller and continuing operation until the new impeller can be installed.

Example

A double-suction centrifugal pump equipped with an impeller 14 inches in diameter is throttled to provide a process cooling water flow rate of 3,000 gpm. The pumping system operates for 8,000 hours per year with a head of 165 feet (ft) and pump efficiency (η) of 80%. The pump requires 156 bhp. Pump and system curves indicate that a trimmed impeller can supply the 3,000-gpm required flow rate at a head of 125 ft. From the affinity laws, the diameter of the trimmed impeller is approximately as follows:

$$(H_2Q_2) / (H_1Q_1) = (D_2 / D_1)^3$$

Holding Q constant,

$$\begin{aligned} D_2 &= D_1 \times (H_2 / H_1)^{1/3} \\ &= 14 \times (125 / 165)^{1/3} \\ &= 12.76 \text{ inches} \end{aligned}$$

Assuming that the pump efficiency remains unchanged, installing a $12^3/_4$-inch trimmed impeller reduces input power requirement to the following:

$$\begin{aligned} bhp_2 &= (H_2 \times Q_2) / (3{,}960 \times \eta) \\ &= (125 \times 3{,}000) / (3{,}960 \times 0.8) \\ &= 118.4 \text{ bhp} \end{aligned}$$

Estimated energy savings, assuming a 94% motor efficiency, are as follows:

$$(bhp_1 - bhp_2) \times 0.746 \text{ kW/hp} \times 8{,}000 \text{ hours/year} / 0.94 = 238{,}720 \text{ kWh/year}$$

At an electricity cost of 5 cents per kWh, total cost savings are estimated to be $11,936 per year.

Reference

Match Pumps to System Requirements, U.S. Department of Energy Pumping Systems Tip Sheet #6, 2005.

FOR ADDITIONAL INFORMATION, PLEASE CONTACT:

EERE Information Center
1-877-EERE-INF
(1-877-337-3463)
www.eere.energy.gov

Industrial Technologies Program
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, DC 20585-0121
www.eere.energy.gov/industry

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DOE/GO-102006-2226
September 2006
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