Tip Sheet

Control Strategies for Rotodynamic Pumps with Variable Flow Rate Requirements

Suggested Actions

- Flow control can be achieved by using ASDs, trimming impellers, installing multiple pumps, or adding a multi-speed motor.
- Consider ASDs as an option when pumps operate at least 2,000 hours per year and process flow rate requirements vary by 30% or more over time.

A rotodynamic (centrifugal, mixed flow, axial flow) pump always operates at a point that corresponds to a system characteristic. In pumping applications with variable flow rate requirements, adjustable speed drives (ASDs) are an efficient control alternative to throttling or bypass methods. ASDs save energy by varying the pump's rotational speed. In rotodynamic pumping applications with no static head, power requirements vary as the cube of the pump speed and small decreases in speed or flow rate can significantly reduce energy use. For example, reducing the speed (flow rate) by 20% can lower input power requirements by approximately 50%.

Due to drive inefficiencies, however, ASDs do not save energy in applications that operate close to fully loaded most of the time. For example, ASDs are seldom cost-effective in fluid transfer pumping systems with on/off control when static head is a significant portion of the total head. In moving a fixed volume of fluid, increases in operating hours can offset the power savings resulting from reducing flow rates.

Developing a system curve is the first step in understanding a given pump system's characteristics at various flow rates. Then, process requirements can be displayed in histogram, flow rate duration curve, or load-duty cycle format. The load-duty cycle is a frequency distribution indicating the percentage of time that a pump operates at each system operating point; it can be useful in calculating potential energy savings. You can obtain the load-duty cycle by using historical measurements of fluid flow rates or using a recording watt-meter to monitor the electrical power input to the pump motor (see Table 1).

Table 1. Load-Duty Cycle for an Existing Rotodynamic Pump with Throttle Valve Control

Operating Point	1	2	3	4	5
Operating Time (hours)	500	1,000	1,500	2,000	1,500
Flow Rate (gpm)	400	600	800	1,000	1,200
Head (feet)	160	155	145	134	120
Pump Efficiency (%)	63	76	82	82.5	80
Power (bhp)*	25	31	36	41	45

*Brake horsepower.

After establishing values for flow rate and head, you can extract the pump efficiency and shaft horsepower required from the pump curve. Using weighted averages for power at each operating point, factor in the motor's efficiency to calculate weighted input power (see Table 2).

Perform similar calculations to obtain the average input power for the same pump when using an ASD to control flow rate. Affinity rule equations used in conjunction with the system curve can help you calculate pump shaft horsepower requirements at each flow-rate point. (Affinity rules are valid for circulating water pumping applications or fluid transfer applications with little static head.) Factor in motor and drive efficiency at each operating point to calculate weighted input power (see Table 3).

Installation Considerations

- Program drive controllers to avoid operating pumps at speeds which may result in equipment or systems resonances
- Install a manual bypass to keep the motor operating at a fixed speed if the ASD should fail
- Install a single ASD to control multiple pump motors
- Use caution when reducing the flow velocities of slurries.

Table 2. Average Power Requirements for a Rotodynamic Pump with Throttle Control

Flow Rate (gpm)	Duty Cycle (%)	Shaft Power (hp)	Weighted Power (hp)	Motor Efficiency* (%)	Weighted Input (kW)
1,200	23.07	45	10.38	91.4	8.47
1,000	30.77	41	12.31	91.6	10.02
800	23.07	36	8.30	91.6	6.76
600	15.38	31	4.76	91.2	3.89
400	7.69	25	1.92	90.9	1.58
				Total:	30.72

*Based on a 50-hp, 1,800-rpm, totally enclosed, fan-cooled standard efficiency motor from MotorMaster+ 4.0 data. For information on MotorMaster +4.0, go to: www1.eere.energy.gov/industry/bestpractices/software.html

Table 3. Average Power Requirements for a Rotodynamic Pump with ASD Flow Rate Control

Flow Rate (gpm)	Duty Cycle (%)	Shaft Power (hp)	Drive Efficiency (%)	Motor Efficiency (%)	Weighted Input (kW)
1,200	23.07	45.00	95.9	91.4	8.83
1,000	30.77	26.04	94.9	90.9	6.92
800	23.07	13.33	92.1	84.5	2.95
600	15.38	5.62	85.5	70.3	1.07
400	7.69	1.67	53.7	41.1	0.43
				Total:	20.20

References

Adjustable Speed Pumping Applications, DOE Pumping Systems Tip Sheet, 2007

Improving Pumping System Performance: A Sourcebook for Industry, U.S. Department of Energy, 2006

Variable Speed Pumping: A Guide to Successful Applications, Hydraulic Institute and Europump, 2004.

RESOURCES

Hydraulic Institute (HI). Hydraulic Institute, the largest association of pump producers in North America, serves member companies and pump users worldwide by developing comprehensive industry standards, expanding knowledge by providing education and training, and serving as a forum for the exchange of industry information. In addition to the ANSI/HI pump standards, HI has a variety of resources for pump users and specifiers, including Pump LCC and VSP guidebooks, "7 Ways To Save Energy" training program and more. To download FREE executive summaries of HI's "Pump Life Cycle Costs", "Variable Speed Pumping", and an index to ANSI/HI Standards, visit www.Pumps.org and www.PumpLearning.org.

Pump Systems Matter™ (PSM). Developed by the Hydraulic Institute, PSM is an educational initiative created to assist North American pump users gain a more competitive business advantage through strategic, broad-based energy management and pump system performance optimization. PSM's mission is to provide end-users, engineering consultants and pump suppliers with tools and collaborative opportunities to integrate pump system performance optimization and efficient energy management practices into normal business operations.

PSM is seeking the active support and involvement of energy efficiency organizations, utilities, pump users, consulting engineering firms, government agencies, and other associations. For more information on PSM, to become a sponsor, or to download PSM's *FREE Pump System Improvement Modeling Tool*™ (PSIM), an educational tool designed to show pump systems engineers how modeling tools can reduce cost and conserve energy, visit www.PumpSystemsMatter.org.

U.S. Department of Energy (DOE). DOE's Industrial Technologies Program (ITP), through partnerships with industry, government, and non-governmental organizations, develops and delivers advanced energy efficiency, renewable energy, and pollution prevention technologies for industrial applications. ITP has launched the **Save Energy Now** initiative to help the nation's manufacturing facilities continue to thrive during a time of diminished energy supplies and rising costs. As a part of this initiative, ITP is sending DOE Energy Experts to the nation's most energy-intensive manufacturing facilities to conduct 200 Energy Savings Assessments. See www.eere.energy.gov/industry for additional information on DOE's energy efficiency activities.

BestPractices emphasizes opportunities for savings in plant systems such as motor, steam, compressed air, and process heating systems. BestPractices is a part of the Industrial Technologies Program, and offers a variety of resources addressing ways to reduce energy and maintenance costs in industrial process systems. This includes training workshops, software tools, a series of sourcebooks, case studies, tip sheets, and other materials, including several which focus on opportunities in pumping systems. For example, the Pumping System Assessment Tool (PSAT) aids in the assessment of pumping system efficiency and estimating energy and cost savings.

For more information, please contact: EERE Information Center; 1-877-EERE-INF (1-877-337-3463); www.eere.energy.gov/industry/bestpractices.