# Strategies to Improve Pump Efficiency and Life Cycle Performance

**By Mike Pemberton**

In today's business environment, paper companies are looking for new avenues to lower energy and operating costs. There is a growing awareness that centrifugal pump optimization can significantly reduce electrical energy demand while improving pump and process reliability. Proper pump selection, sizing and operation are important to mill economic performance. Historically, pump design has focused on mechanical performance; today, the focus must shift to pump system performance in order to achieve available life cycle cost savings. These potential savings are a significant portion of mill operating cost. Motor and valve performance improvements can have a major impact on the bottom line.

**Thinking Outside Traditional Process Design**

When deciding to build a new facility or modernize an existing one, initial design considerations are focused on sizing the major capital equipment items. Once mass balances are determined, the reactors, vessels and other capital equipment items are selected. The next phase typically includes sizing the pipes and motor driven systems, in our case, centrifugal pumps, to meet production targets.

In anticipation of future load growth, the end-user, supplier and design engineers routinely add 10 to 50% "safety margins" to ensure the pump and motor can accommodate anticipated capacity increases. Once the piping isometrics and pump sizing are completed, near the final design phase, process control engineers select the instruments and valves needed to implement process control strategies. As each design phase progresses, the various engineering disciplines rarely collaborate on the subtleties associated with pump, pipe and valve sizing to consider their overall impact on operating stability. As a result, optimum process control is seldom achieved at plant startup. Furthermore, as control loop performance is known to decay over time, unless addressed, the performance gap will continue to widen over the life of the plant.

| Industry | Pumps |
|---|---|
| Pulp & Paper Mill | 100 – 1000 |
| Petroleum Refinery | 500 – 5000 |
| Chemical Plant | 100 - 8000 |

Table 1: Typical Pump Populations in the Process Industries
Source: IIT Industries Fluid Technologies

In 1996, a Finnish Technical Research Center report entitled "Expert Systems for Diagnosis and Performance of Centrifugal Pumps" revealed that the average pumping efficiency, across the 20 plants and 1,690 pumps studied, was less than 40%, with 10% of pumps operating below 10%. Pump over-sizing and throttled valves were identified as the two major contributors to this sizeable efficiency loss. Besides hindering overall plant efficiency, poor pump performance results in lower product quality, lost production time, collateral damage to process equipment and inordinate maintenance costs.

Pump and motor manufacturers have made substantial improvements in mechanical efficiency over the years. Yet, once the pump is installed, its efficiency is determined predominately by process conditions. The major factors affecting performance include efficiency of the pump and system components, overall system design, efficient pump control and appropriate maintenance cycles. To achieve the efficiencies available from mechanical design, pump manufacturers must work closely with end-users and design engineers to consider all of these factors when specifying pumps. In the future, pump selection and sizing should be considered in the context of the overall system, not just the efficiency of the individual components.

The vast majority of pumping systems run far fron their best efficiency point (BEP). For reasons ranging from shortsighted or overly conservative design, specification and procurement to decades of incremental changes in operating conditions, most pumps, pipes and control valves are too large or too small. As a result, pumping systems fail to convert the electric power they consume into fluid motion with anywhere near the economy, reliability and control inherently available in the finely engineered individual components.

**Design Considerations for Improve Pumping Efficiency**

In the process industries, the purchase price of a centrifugal pump is often 5 - 10% of the total cost of ownership. Typically, considering current design practice, the life cycle cost (LCC) of a 100 horsepower pump system, including costs to install, operate, maintain and decommission, will be more than 20 times the initial purchase price. In a marketplace that is relentless on cost, optimizing pump efficiency is an increasingly important consideration. Centrifugal pumps consume, depending on the industry, between 25 and 60% of plant electrical motor energy.

| INDUSTRY | PUMP ENERGY (% of Total Motor Energy) |
|---|---|
| Petroleum | 59% |
| Pulp & Paper | 31% |
| Chemical | 26% |

Table 2. Pumping Systems are Energy Intensive
Source: Bureau of Economic Analysis, 1997

Based on current design practice, energy accounts for about 50% of life-cycle costs (LCC), with maintenance averaging around 20%. In poorly designed systems, maintenance may reach as high as 40% of LCC, even more.

Initial process design considerations help identify opportunities to improve pump system efficiency. The following criteria offer the highest potential for efficiency improvements:

- Reduced load on the motor through optimum process design
- Best match between component size and load requirement
- Use of speed control instead of throttling or bypass mechanisms.

Among all rotating assets in a process plant, centrifugal pumps typically have the best overall potential for electrical energy savings. In addition, the excess energy in fixed-speed systems, not used for moving fluid, is often dissipated into the infrastructure and contributes to noise, vibration and lower equipment reliability, i.e., instruments, valves, pipes and the pumps themselves.

| Energy Savings Method | Savings |
|---|---|
| Replace throttling valves with speed controls | 10 – 60% |
| Reduce speed for fixed load | 5 – 40% |
| Install parallel system for highly variable loads | 10 – 30% |
| Equalize flows using surge vessels | 10 – 20% |
| Replace motor with a more efficient model | 1 – 3% |
| Replace pump with a more efficient model | 1 – 2% |

Table 3: Techniques to Lower Pump Energy Consumption
Source: DOE Office of Industrial Technology, United States Motor Systems, Market Opportunities Assessment, 1998

In addition to energy cost reduction, a top priority is to solve and eliminate recurring operating problems experienced by mill production, maintenance, and engineering departments. Typically, the asset group with the highest failure rate is centrifugal pumps, with seal leakage being the fault that causes the highest downtime and maintenance cost. Pumping system optimization helps minimize unscheduled downtime and contributes to productivity improvement.

**Growing Use of Variable Speed Drives**

Pump over-sizing causes the pump to operate to the far left of its best efficiency point (BEP) on the pump hear-capacity curve. Variable speed drives, assuming a low static head system, allow the pump to operate near its best efficiency point (BEP) at any head or flow. In addition, the drive can be programmed to protect the pump from mechanical damage when away from BEP -- thereby enhancing mechanical reliability.

| Flow Rate (gpm) | Duty Cycle (% of time) | Control Valve Head Loss (psid) & Pump % of BEP | | VFD RPM & Pump % of BEP | |
|---|---|---|---|---|---|
| 400 | 10 | 1 | 86% | 1750 | 87% |
| 280 | 30 | 17 | 31% | 1225 | 86% |
| 120 | 50 | 30 | 26% | 508 | 90% |
| 80 | 10 | 31 | 17% | 315 | 95% |

Table 4. Flow Demand vs. Required Control Valve or VFD Settings
Source: Pumps & Systems Magazine, November 2002, Optimizing Pumping Systems to Maximize First or Life Cycle Cost; Judy Hodgson, DuPont, and Trey Walters, Applied Flow Technology:

Furthermore, excessive valve throttling is expensive and not only contributes to higher energy and maintenance cost, but can also significantly impair control loop performance. Employing a throttled control valve, less than 50% open, on the pump discharge may accelerate component wear, thereby slowing valve response. Because of increased stiction and backlash, operators often lose confidence in valve performance and switch the control loop into manual mode.

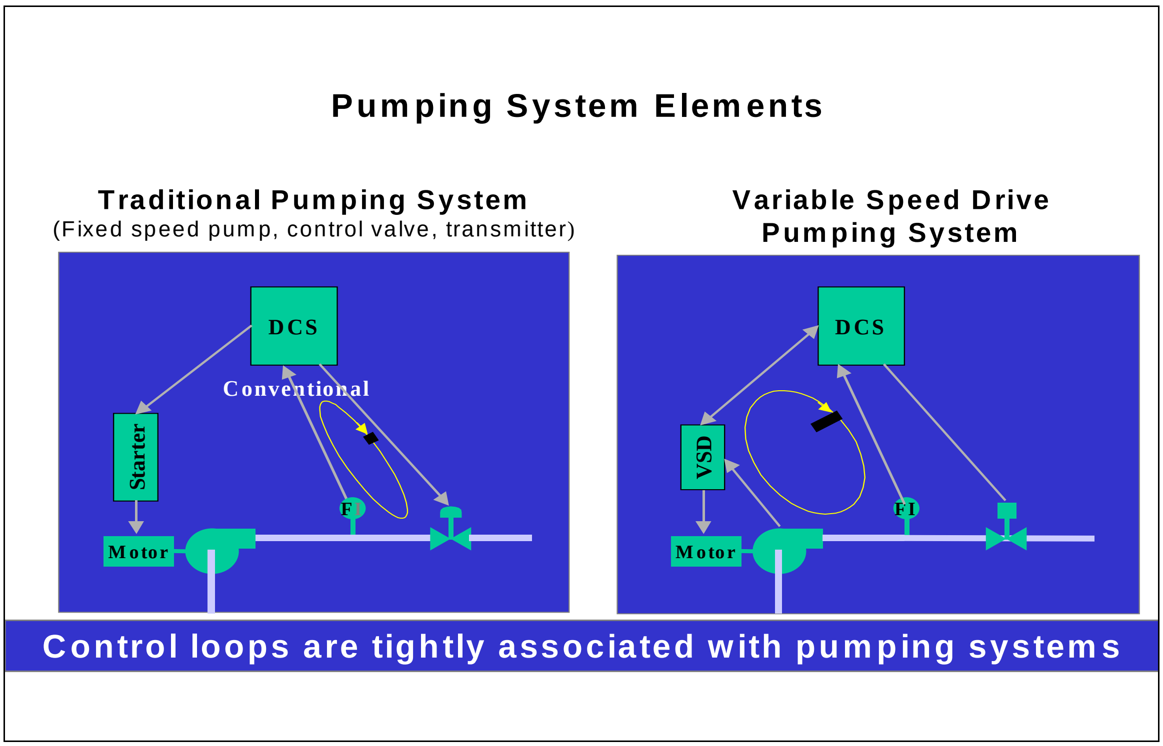


Figure 5. Pumping System Elements

VFDs allow pumps to run at slower speeds with for further contributions to pump reliability and significant improvement in mean-time-between-failure (MTBF). In new applications, variable speed drives are often less expensive to purchase and install than flow control valves and motor starters. Capital costs are also reduced by downsizing the motors, pumps and pipes, in some cases, and eliminating the need for more expensive medium voltage power equipment. Considering the capital and operating cost savings, the total LCC of a given pumping system can be significantly reduced.

Today, there is a growing use of pump intelligence in variable frequency drives to improve pumping system performance. The added intelligence can contribute to smoother startups and production changes, tighter control during continuous operation, and faster diagnosis of potential system problems before product quality or process operation is negatively affected.

**Pump Intelligence – Enhancing Mechanical Reliability beyond Variable Speed**

Intelligent pump performance provides value beyond a traditional variable frequency drive (VFD). While similar energy savings can be achieved by employing a standard VFD, there is no assurance of decreasing the various failure modes of a centrifugal pump. An intelligent drive utilizes variable speed as a method for delivering enhanced pump reliability.

For academic purposes, assume variable speed is being used for flow control. A flow meter provides the process value to either an intelligent drive or standard drive to adjust speed to deliver 100gpm. Now, assume a control valve is closing on the discharge side. What happens? The standard drive speeds up to "compensate" for increased resistance. An intelligent drive will do the same. However, what happens when the valve closes to a point where less than 10% of the 100 gpm is being delivered. A standard drive will continue to ramp up to full speed (running against a closed valve); whereas, the intelligent drive can identify that a detrimental condition is occurring and notify the user. Furthermore, the intelligent drive can intervene to slow down the pump or turn it off, with periodic attempts to restart, and thereby avoid a premature failure.

In another example, as above, the pump is operating in flow control. Now, let us assume that the suction pressure (tank level) starts to decrease to a point that causes the pump to cavitate. If suction pressure drops, a standard drive will continue to speed up to meet the flow setpoint. In this case, increasing motor speed will only exacerbate the situation. The intelligent pump can address this problem by notifying the user that the net positive suction head available (NPSHa) has decreased to the point that cavitation exists. In addition, the pump intelligence can decrease motor speed to allow the NPSHa to increase to the point that cavitation is not occurring, and then resume normal operation.

In the future, plant design should consider the pumping system as an integral component of the process control architecture. Pump intelligence can enhance existing reliability-centered maintenance programs. Today, due to a lack of real-time information on process pumps and motors, many of the preventive maintenance checks on pumps, motors and valves are unnecessary.

**Greenfield and Modernization Project Benefits**

Mill management often views process automation as a key to competitive advantage. Over the past 25 years, process automation has dramatically changed the operation of mill processes. Tighter control has reduced cost while providing important productivity and quality gains.

Yet the revolution is not complete. While process automation has produced a wide range of benefits, integrating the pumping system, using VF drives and condition monitoring technology, offers the next tidal wave of automation. To compete in a global economy, pump automation will provide the quantum leaps in technical and economic performance that are needed. Yet, today, while these enabling technologies are readily available, they are not being readily adopted.

In light of ongoing mergers and acquisitions to achieve economies of scale, management has often overlooked the need to invest in new automation strategies to improve productivity. Surveys suggest that mill management is not convinced that automation technology has fully delivered on past promises of large cost reductions. As a result, there has been a lack of spending on process automation and many plants now have aged control systems that are technologically, if not functionally, obsolete.

To remain competitive in global markets the paper industry must become more innovative in their use of process automation technology. New plant designs must incorporate the latest process control and asset management technologies and strategies that will allow them to produce the highest value product and the absolute lowest possible operating cost.

## Conclusion

Pulp and paper manufacturers are increasingly focusing on maximizing return on capital employed to deal with intensifying global competition, industry consolidation, reduction in technical resources, environmental regulations, rising raw material costs and increasingly demanding customers and shareholders.

An important step in improving capital effectiveness is to rethink process design and the role of pumping systems. Optimal design provides major opportunities to integrate all the elements of pumping, control and asset management systems for improvements in operator effectiveness. The growing body of pump optimization knowledge will support effective system design and operation.

In spite of the financial and operating benefits of these design changes, paper companies face many hurdles when implementing motor efficient technologies. Among the major barriers is the lack of awareness among mill staffs, suppliers and design engineers of new technologies and strategies to improve pump and process performance.

When understood, the perceived risk from changing long established operating practices often delays decisions and project implementation. In addition, mills have reduced staffing levels in maintenance, operations, and engineering that limits the time available for evaluating and commissioning new technologies. Considering these constraints, there is a common attitude among plant staffs that “if it ain’t broke, don’t fix it”.

Alternately, on the supplier side of the equation, there are conflicting incentives for promoting efficient systems and practices. For example, pump distributors may have greater incentive to sell additional pumps to meet demand growth, rather than advise customers on how to manage load growth through more efficient pump operation. Interestingly, even when the distributor identifies opportunities and quantifies the potential benefits, many end-users continue to make buying decisions based on initial cost rather than spend the incremental capital required for achieving long cycle savings.

To capture the many benefits of pump optimization, the paper industry, their fluid handling equipment suppliers, as well as their design engineers, must work together to improve process design and capture the significant capital and operating cost savings that are readily available.

**About the Author**

Mike Pemberton is Mgr. of Performance Services, ITT IBG / Pump Smart™ Control Solutions and sponsor of Pump Systems Matter.