

Energy efficient pumping Energy conservation with centrifugal pumps

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Over the years, usage of energy-efficient pumps is gaining popularity in the process industry, which in turn is leading to finding new ways for conservation of energy. Most processes in chemical industry involve transportation of liquids and/or transfer from a lower to higher energy level. Pumping systems are one of the major consumers of electrical energy globally. It is thus natural that pumping operation should be the primary target for energy reduction and conservation. The article examines how pumping energy can be reduced by proper selection, sizing, operation and maintenance of centrifugal pumps.

The skyrocketing price of oil has yet again brought the issues of energy consumption and energy conservation to the forefront. Nearly 20% of the world's electrical energy demand is accounted for by pumping systems. Most processes in chemical industry involve transportation of liquids and/or transfer from a lower to higher energy level. In certain industries, pumping takes up almost 50% of the energy usage. It is thus natural that pumping operation should be the primary target for energy reduction and conservation. Among all the rotating machinery in process plants, centrifugal pumps have the bet potential for electrical energy savings. Conservative practices influence pump selection, placing, a high premium on initial investment than life cycle cost. Larger than necessary pumps are specified in the name of safety and reliability, resulting in pump systems that operate sub-optimally.

Revisiting basics:

Centrifugal pumps constitute nearly 80% of the total pumps in the industry. A centrifugal pump transfers mechanical energy from a rotating impeller into the required kinetic and potential energy. The performance of a centrifugal pump is typically depicted by a characteristic curve as shown in Fig. 1. This characteristic is inherent in its design and as the capacity increases, the head developed by the pump has a capacity at which it performs most efficiently. This is called as 'Best Efficiency Point' (BEP).

The actual point at which the pump operates is determined by the intersection of the pump curve and the system curve as shown in Fig. 2. The system curve is a measure of the resistance against which the pump has to work. The resistance consists of two parts – the static head, which is the same irrespective of the flow, and the dynamic head, which varies approximately as square of the flow.

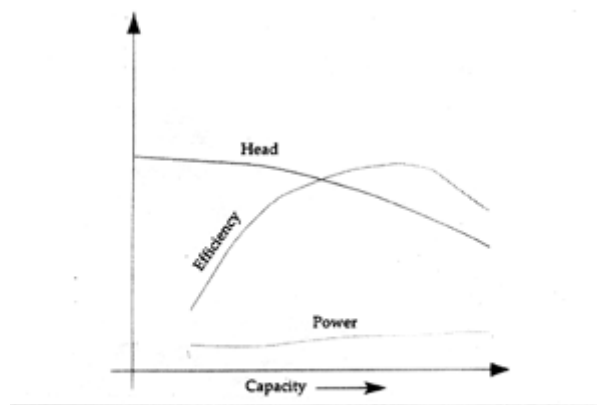
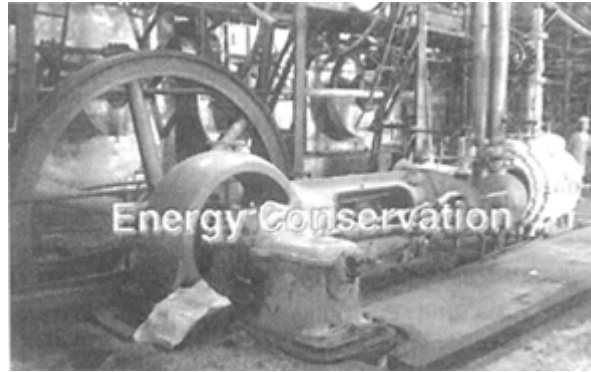


Fig. 1
Pump curves



Process engineers calculate the flow that the pump has to handle and the head it has to develop. The pump manufacturer then selects the pump that meets the process engineer's specification at around its 'BEP'.

Oversizing:

With such a simple and clear approach to pump selection, what goes wrong? The answer is equally simple – oversizing. Process engineers usually add 'safety margins' to the capacity and the head they calculate. There are many reasons why this is done:

- Uncertainties in calculations, due to non-availability of all the details of the pumping system
- Provision for future capacity augmentation
- A perceived notion that oversizing would give higher reliability.

Whatever by the reason, oversizing is the single biggest culprit of pumps wasting energy. A centrifugal pump will operate only at a point, which fails on its characteristic curve, and this point is determined by

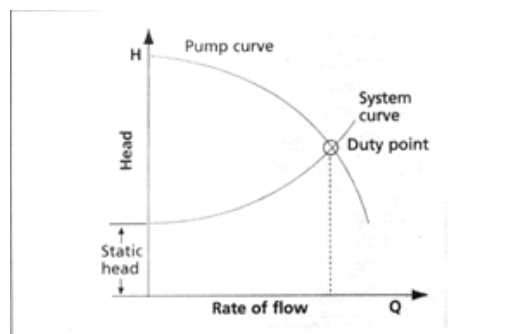
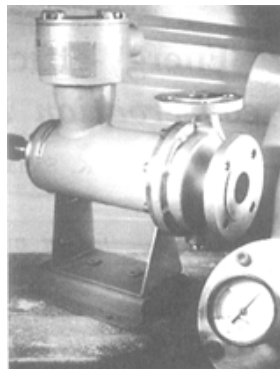


Fig. 2
System curve

the intersection of the system curve. It is the intention of both the process engineer and the pump manufacturer that this operating point nearly coincides with the 'BEP'. However, thanks to oversizing, the reality is far from the intention. The actual operating point is removed from the pump's operating point is removed from the pump's 'BEP'.



Let us say that the process engineer calculates the required pump capacity and the head as 2,700 m³/hr and 55 m. If now following the established traditions, he applies approximately 10% margin on both the capacity and the head, the pump would be selected by the vendor for 3,000 m³/hr and 60 m. In the field however, since the desired delivery rate is 2,700 m³/hr, the pump will develop a head greater than 60 m, or much higher than the required 55 m. This excess head has to be necessarily wasted by dropping it in a throttling valve. As if this were not enough, the operating point of the pump now shifts away from the intended “BEP” leading to further loss of energy. A 5% drop efficiency is not unusual as a result of such oversizing. A 10% margin on the capacity and the head typically ends up in a 20% penalty on power consumption.

System study:

The potential for energy reduction and conservation in a pumping system lies not so much in pump selection as in analysis of the pumping system. Every effort should be made to reduce the system resistance by optimizing the pipe diameter and routing. The frictional loss contributed by various fittings and components in the piping system should be carefully reviewed. The need to apply a ‘safety margin’ should be critically questioned. Providing margins on both the capacity and the head is clearly counterproductive.

Future capacity requirements can be built into the system without sacrificing efficiency significantly by selecting a pump that can accommodate a larger impeller and oversizing the motor. Care should be taken while oversizing the motor, so that current operating needs are met at more than half the rated full load of the motor. The system study should be thoroughly objective and there should be no ‘holy cows’ including capacity. In fact, there exists scope for capacity review and reduction in batch transfers by providing suitable balancing equipment.

Impeller trimming:

A system study should be carried out not only for proposed new installations but also for existing facilities. What about pumps that are already oversized? Fortunately all is not lost and there is an opportunity to bring back the pump’s operating point close to the ‘BEP’ by changing the speed of the pump or trimming the pump impeller. Impeller trimming is also resorted to in new installations to get a closer fit to the system requirement, since impellers come in standard sizes. Impeller trimming decreases tip speed, which in turn reduces the amount of energy imparted to the fluid and pressure generated by the pump. Trimming the pump impeller also changes its operating efficiency in a way that is difficult to predict. Hence, impellers should not be trimmed below 70% of the original size. Impeller trimming is a useful correction tool to pumps that have been oversized through adoption of conservative design practices or in cases where system loads have reduced due to process improvement.

Variable loads:

Often a centrifugal pump is called upon to handle varying flow rates. This might happen due to the process plant operating at varying capacities. But there are other pumping systems in which the demand varies considerably even during the normal course of operation. When a pump application requires several operating points, selecting the pump based on the largest flow and/ or head is the easier but wasteful option. If pumps are selected on the basis of their ability to handle short-term peaks in demand, then they would be oversized for normal operating loads. Such applications should be carefully analysed and the following techniques are available for energy reduction:

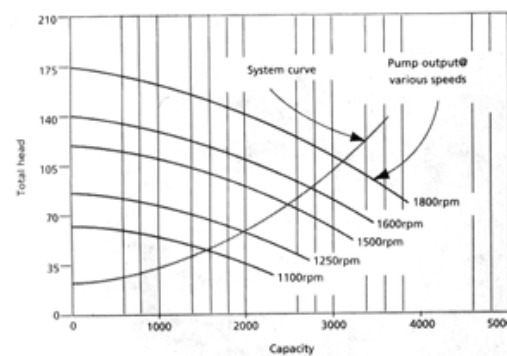


Fig. 3
Effect of speed variation

- Variable speed operation
- Operating pumps in parallel
- Segregating the loads.

Table 1 gives the saving potential possible by adopting various energy saving techniques.

Variable speed operation:

As explained earlier, the capacity delivered by the centrifugal pump is determined by the point of intersection between the head-capacity and system curves. Hence, to vary the pump capacity, profile of either or both the curves has to be changed. The usual practice is to alter the system curve by creating additional friction loss through a throttling valve. This is obviously a wasteful method as energy is unnecessarily expended in the throttling process. The more economical alternative is to change the pump's head-capacity curve, which is possible by changing the speed of the pump.

Energy saving method	Savings
Replacing throttling valves with variable speed drive	10 - 60%
Reduce speed for fixed load	5 - 40%
Pumps operating in parallel for highly variable loads	10 - 30%
Flow equalization using surge tanks	10 - 20%
Replace motor with a more efficient model	1 - 3%
Replace pump with a more efficient model	1 - 2%

There are different methods by which speed variation can be achieved:

- Multi speed motors, which however allow only discrete variation in two or three steps
- Hydraulic coupling, which is not a very efficient technique.
- Variable frequency drive, the most commonly used method, adjusts the frequency of the electric power supplied to the motor.

Speed control can keep pumps operating efficiently over a broad range of flows. When the pump speed is reduced, its head-capacity curve and efficiency curve shift to the left. The efficiency response is an icing on the cake, providing additional cost benefit, by keeping the operating efficiencies as high as possible across variations in the system's flow demand. However, the principal energy savings come from the reduction in friction losses by eliminating the need to throttle the flow.

Speed control cannot be applied indiscriminately to all situations. In applications where the system resistance is dominated by static head, reducing the speed can induce vibrations. Speed control devices are expensive, but the energy saves easily pays off the additional investment. In addition to savings in energy, reduced speed operation also decreases hydraulic forces on the impeller, which increases bearing life. Vibration and seal life also improves due to part load operation at lower speed.

Parallel pumps;

Another energy efficient method of meeting varying system demand is to install two or more pumps in parallel. Variation of low is achieved by operating the required number of pumps. Such parallel installations are provided when flow operations are possible over a considerable range. For example, distribution of utilities like cooling water. Meeting 50% of flow demand by operating at half load. In fact, it is possible to take advantage of the non-linearity of the head capacity and system curves and meet 60-70% of the flow demand by operating one 'half capacity' pump. Pumps that operate at reduced load have their life shortened, compared to those that operate close to their 'BEP'. Thus, running only one pump whenever it can handle the reduced demand provides additional benefit.

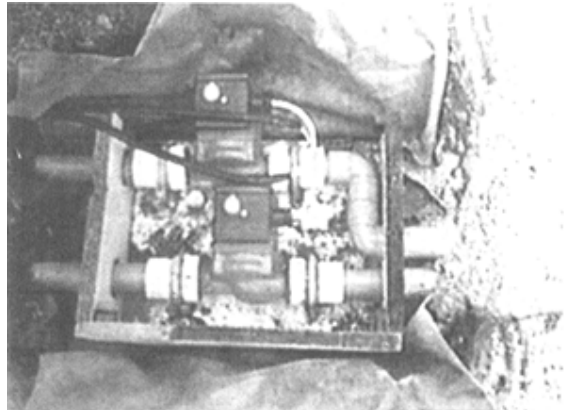
Multiple pumps:

Some pumps cater to multiple users or multiple requirements of the same user. In a multiple user environment, it is often likely that a small number of users are more energy demanding than the majority. For example, one or two condensers located at a very high elevation in a cooling water distribution network or a single large user located at a considerable distance from the pump. In other situations, a single user may impose high demands for a short duration. For instance, backwashing of filters, requires 4-5 times higher flow than the main service flow for 20-30 minutes in a day. Careful

segregation of loads and use of multiple pumps prevent the burden of a few users or short-duration demands falling on the entire system. Booster pumps may be effectively used to cater to small loads requiring higher pressures.

Life cycle cost:

A Life Cycle Cost (LCC) approach should be employed while procuring a pump and it should be extended to the electric motor. Life cycle cost includes cost to install, operate and maintain the pump. The initial purchase cost of an average centrifugal pump is usually not more than 15% of the LCC. Energy and maintenance costs constitute the rest in equal measure. For most applications, there exist in the market high efficiency pumps and energy efficient motors. There are expensive because of their sophisticated design and superior materials. The LCC approach will permit a serious objective examination of these alternatives.



Summary:

Pumping systems offer tremendous scope for energy reduction and conservation. This is possible through:

- Ensuring that the pump operates close to its 'BEP' by proper specification and selection
- Minimizing throttling losses, if not totally eliminating them by adopting speed control and parallel/multiple pump configuration
- Using the LCC approach in procurement of pump and motor.

Selecting a pump with a high 'BEP' and ensuring that it operates close to it under all situations, is the key to energy conservation in pumping systems. Operating a pump close to its 'BEP' not only reduces energy, but also improves the pump longevity.

Reference book:

Indian Pumps
Vol. XXXVII, March 200