Pump ED 101

Centrifugal Pump Efficiency – Part 3 Individual Efficiencies

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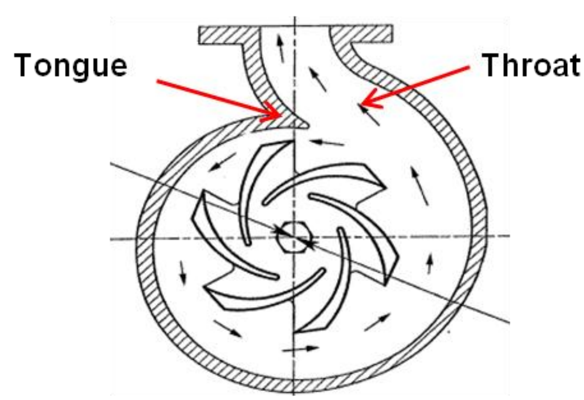
Hydraulic Efficiency

The shape and spacing of the impeller vanes have an effect upon overall pump efficiency. Although the ideal impeller would have an infinite number of vanes, the real world limits us to 5 – 7 for clear water pumps and even fewer for pumps that handle larger solids. Also, flow would always be exactly parallel to the vane surfaces but that doesn't happen either. But oddly enough, if the designer follows some well documented rules, impeller vane efficiency losses remain relatively flat (about 2.5%) across a specific speed (Ns) range of 500 to 7000. Disk friction, which is caused by contact between the fluid and the impeller shrouds and hub surfaces, can reduce impeller efficiency another 4 to 15% at specific speeds below 2000 but decreases to 2% or less at an Ns of 3000 and above. So, depending upon its design, the impeller can reduce overall pump efficiency by as little as 4.5% or as much as 17.5%.

The volute also plays an important role in pump efficiency. At specific speeds below 2000, friction losses range from 1 to 2.5% but losses can approach 10% at an Ns of 5000 and above. Typically, volute design begins with the throat (see Figure 1), as its cross sectional area will determine the flow velocity out of the volute. Flow through the throat and other portions of the casing follows the law of constant angular momentum so the designer will try to avoid abrupt changes in its nearly circular geometry while gradually increasing its volume.



Another critical area of the volute is the clearance between the outer circumference of the impeller and that of the volute tongue or cutwater. As this distance becomes larger, an increasing volume of liquid escapes entry into the volute throat and recirculates back into the volute case. The smallest distance, that does not give rise to pressure pulsations during vane passing, will produce the best efficiency. As a rule of thumb, 5 to 10% of the impeller radius tends to be a safe value. In the next section we will discuss this in more detail when we compare the efficiencies that result from trimming an impeller versus changing its rotational speed.

Volumetric Efficiency

It is debatable as to whether the volumetric efficiency of a centrifugal pump is a function of the volute or the impeller (it is probably both) but I will include its effect here. Volumetric efficiency represents the power lost due to flow leakage through the wearing rings, the vane front clearances of semi open impellers, and the balancing holes in the rear shroud. As a rule of thumb, leakage increases with a decrease in specific speed, flow or a combination of the two. For example at a specific speed of 500 and a flow of 100 GPM, leakage can account for as much as 7% of the total power consumed. At 2000 GPM it is reduced to about 2%. At higher specific speeds and flows volumetric losses can be as low as 1%.

Mechanical Efficiency

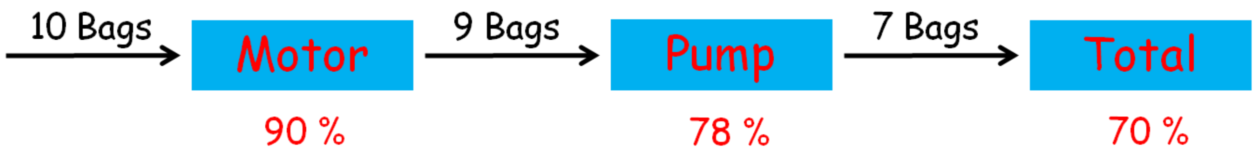
The final piece of the pump efficiency puzzle is that of mechanical losses, although some of these losses are not always included in published efficiency curves. In the case of a frame mounted pump, these losses are caused by the shaft bearings and the mechanical seal or packing. For close coupled pumps, bearing losses are figured into the motor efficiency. Again the rule of thumb follows that of volumetric efficiency, and losses increase as flow and / or specific speed decrease. If we use the same values of specific speed and flow, as in the volumetric example above, we could expect losses of 5% and 1% for a frame mounted pump. At higher specific speeds and flows, mechanical losses can drop below 1%.

Combined Efficiency

When we look at the overall efficiency of a pump, operating in an application, we also have to include the efficiency of the driver and, in many instances, that driver will be an electric motor. When EISA went into effect in December of 2010, it raised the bar on motor efficiency and today, all new motors must meet premium efficiency standards. Obviously, a higher efficiency motor will increase the overall efficiency of a pumping system but, by how much? How do we calculate the combined efficiency of various pumps and motors?

When I ask this question in my hydraulics classes the common sense response is that it is the average of the two efficiencies. After all, the efficiency of two or more pumps, operating in parallel, is equal to average of their individual efficiencies at their operating points. But, when machines operate in series their combined efficiency is quite different. Just as the total efficiency of a centrifugal pump is the product of several different internal efficiencies, so is the total efficiency of a pump and its driver.

The total efficiency of an electric motor and a centrifugal pump (wire to liquid or wire to water efficiency) is the product of the individual efficiencies. Sometimes this is hard to visualize due to the various units of measure used to compute the two efficiencies. Figure 2 simplifies this by using a single unit of measure that can be used to describe the operation of any machine. That unit is a "bag" of energy.



In this example the motor consumes 10 bags and produces 9 bags so its efficiency is 90%. The pump consumes the 9 bags provided by the motor and produces 7 so its efficiency is 78%. Therefore for every 10 bags of energy consumed by the motor, 7 bags are produced by the pump and the total efficiency of the system is 70% (7 bags / 10 bags). This confirms that the product of the two individual efficiencies is the total efficiency of the system (90% X 78% = 70%). If this system is controlled by a VFD, with an efficiency of 97%, the total efficiency will be reduced to 68% (at full speed - 60 Hz). This lower efficiency is the product of the three individual efficiencies.

Next month we will show the efficiency savings that can be achieved by reducing speed rather than trimming an impeller.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pump & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.PumpEd101.com. If there are topics that you would like to see discussed in future columns, drop him an email.