Pump ED 101

Centrifugal Pump Efficiency – Part 2 Specific Speed

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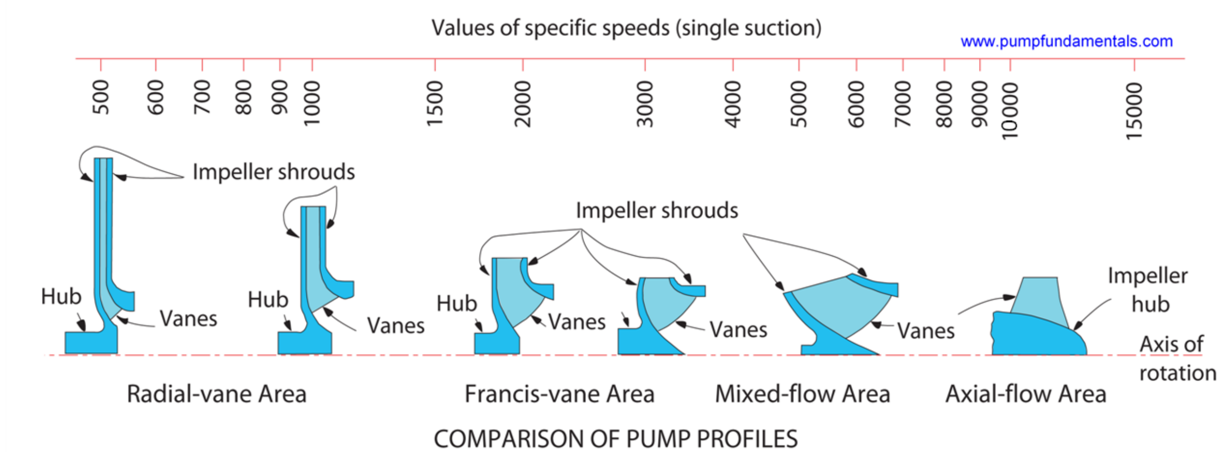
Early centrifugal pump design was heavily influenced by turbine technology during the mid to late 1800's. Specific speed was first applied to centrifugal pumps in the latter part of the century and was a modified version of the one developed for water turbines. Many pump designers see specific speed as the most important contributor to centrifugal pump design. It allows the use of existing design and test data in the design of higher and lower flow pumps of similar design. The reason is that the specific speed of a pump is independent of size.

As Terry Henshaw stated in his September 2011 Pumps & Systems article, the definition of specific speed can be confusing and it is best to think of it as an index number that can predict certain pump characteristics. If we view it in this manner, it can be extremely useful when selecting a pump for a particular application and predicting premature failure due to off BEP operation. Figure 1 (courtesy of pumpfundamentals.com) shows the relationship of the numerical value of specific speed to an impeller's geometric profile.



The lower values (500 to 1500) on the left describe the geometry of the radial vane impeller while the higher values (9000 +) on the right equate to true axial flow impellers (propellers). A radial vane impeller discharges 100% of its flow perpendicular to its suction and usually has a low flow to head ratio. An axial flow impeller discharges 100% of its flow along the same axis as its suction and has a high flow to head ratio. Mixed flow impellers (4000 to 8000) exhibit both radial and axial characteristics and discharge between the radial and axial angles. They have a high flow to moderate head ratio. Those in the range between radial and mixed flow (1700 to 3500) are known as Francis vane impellers. This design discharges radially but the transition from inlet to outlet is more gradual and results in the highest efficiency. The cross sectional pictures on the chart show that, as specific speed increases, the impeller inlet or eye diameter increases and eventually approaches or equals that of the vane outlet. The flow passages also increase in size at a corresponding rate.

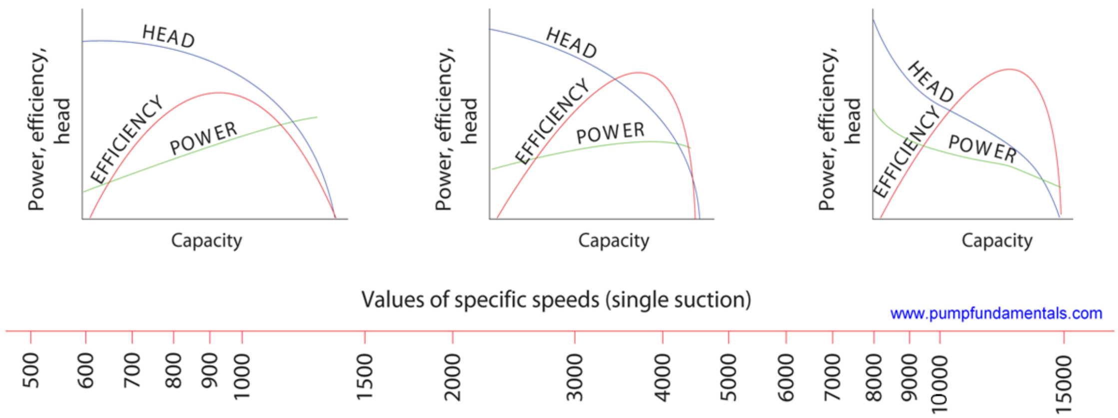
I think you will agree that while this is a nice comparison, what use is it to the pump designer? Well, an equation was developed that relates specific speed and its corresponding geometry to those real application values of head, flow, and rotational speed. That equation is:

$$N_s = n \times \sqrt{Q} / H^{0.75}$$

Where N_s is the specific speed, n is the pump rotational speed in RPM, Q is flow in GPM, and H is head in feet. We can use this equation to determine which impeller design can best match the requirements of a particular application.

Suppose, for example, we need an impeller that will produce 900 GPM at 190 feet of head. If we enter these values in Q and H and also enter a motor speed of 3600 rpm we obtain a specific speed of 2110. The impeller would have a geometry that is similar to the Francis vane impeller seen on the chart at the 2000 point. If you lower the motor speed to 1800 rpm, an impeller with a specific speed to 1055 would be required to produce the same flow and head. Its geometry would be similar to the radial vane impeller shown beneath the 1000 point. At 1200 rpm specific speed is 703 and the impeller would look like a hybrid of the two impellers seen to the left of the chart. Specific speed is directly proportional to rotational speed when head and flow remain constant, however, the specific speed of a single impeller design does not change with a change in rotational speed. The reason it remains constant is because flow and head change in accordance with the affinity laws.

Figure 2 illustrates how specific speed can provide us with predictions as to the performance of a particular impeller design. Experience has taught us that a pump's efficiency reaches its maximum at specific speeds between 2000 and 3000 although favorable efficiency can occur at almost any specific speed. Also the area around the Best Efficiency Point (BEP), or design point, tends to be flatter and broader as specific speed decreases. Pump efficiency also increases with pump rotational speed, especially high speeds, but that increase is not as pronounced at



speeds of 3600 rpm and below. Specific speed also affects the shape of the head-capacity curve. Low specific speeds (500 to 1500) produce relatively flat curves while high speeds (6000 +) produce extremely steep curves. Intermediate speeds produce curves that fall in between these extremes. We will discuss curve shape in more detail in a later section. Finally, specific speed provides us with one more prediction - - the characteristics of the power curve. At specific speeds below 4000, power drops as flow is reduced and is at its minimum at shut off head. The power curve remains relatively flat, across the entire head-capacity curve, between 4000 and 4500 and rises towards shut off at specific speeds at 5000 and above. At speeds above 9000 the power curve becomes extremely steep and almost parallels the head-capacity curve.

Once a particular impeller geometry is chosen, the pump designer can go through a comprehensive mathematical analysis that will allow him to derive all of the impeller dimensions and angles necessary to meet the design point. To say the least, this is an arduous task. If you would like to review a comprehensive example of how this is done, see pages 2.23 - 2.31 of the second edition of Pump Handbook (McGraw-Hill).

The various Ns ranges that I have cited in this column are not cast in stone. They can be slightly narrower or wider and can vary based upon the design characteristics of a particular pump. They are, however, a good rule of thumb.

Another great book on centrifugal pumps was written by John Richards in 1894. He was the editor of the San Francisco based journal “Industry” and was the first writer to point out that centrifugal pumps do not operate via centrifugal force since there is no such force in nature. “Centrifugal Pumps – Their Construction and Operation – and - Some Account of Their Origin and Development” is available as a free download at Google Books. Some of the knowledge about impeller vane shape from the 1850’s is amazing.

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.