Although the world of pumps is huge and broad, that world is ruled and controlled (everything is their fault?) by people intimately involved with centrifugal pumps. The centrifugal pump is often quoted as the most popular of all the pump types. However, I’m not sure this is strictly true. Centrifugal pumps may be the most popular process pump type, that is, a pump used by industry. If one considers the ‘world’ as being totally inclusive, then the picture may be different.

Consider the motor car; the average car has a centrifugal water pump in the cooling system and may have a tiny centrifugal pump for the windscreen (windshield for our American readers) washers. The washer pump may be a tiny vane pump. The engine will have an oil pump, probably a style of internal gear pump, and the fuel pump might be a vane pump, a screw pump, a diaphragm pump or a piston pump. There may be more than one fuel pump. The automatic gearbox probably has a style of gear pump. Power-assisted steering will have a pump to pressurize the hydraulics; this won’t be a centrifugal pump. Pumps on trucks will follow a similar distribution. I think, in the ‘world’, centrifugal pumps are outnumbered by other pump types, mostly positive displacement pumps.

The centrifugal pump people seldom acknowledge that there might be any other type of pump. In fact, they frequently talk about ‘pumps’ but don’t mean pumps, they mean ‘centrifugal pumps’ – an ideal occasion for ambiguity and confusion. These people know little or nothing of other types. This can cause problems for the pump purchaser. Although there are many pump manufacturers, and there are a few very large pump manufacturing multinational companies, no company manufactures all the pump types. In order to be sure of selecting the most appropriate pump for a specific application, it will be necessary to have discussions with several suppliers. Clarification is necessary regarding pump types. There are two basic types – rotodynamic and positive displacement pumps – but there are some styles that fall outside this categorization.

Rotodynamic pump

A pump design that imparts kinetic energy to the liquid and then diffuses the liquid to convert the kinetic energy into pressure energy, or head. The operating principle is easy to grasp by remembering Bernoulli (see below). The version of Bernoulli shown ignores the changes in elevation between the pump inlet and outlet.

Bernoulli equation

\[ h = h_i - h_e = \frac{v_i^2 - v_e^2}{2g} \]

where:

- \( h \) = head
- \( h_i \) = Initial head
- \( h_e \) = Effective head
- \( P \) = Static pressure
- \( \rho \) = Liquid density
- \( v \) = Liquid velocity
g = gravitational acceleration
and the pump outlet. This distance tends to be small in comparison to the developed head, \( h_2 - h_1 \), but not always; there are some very large, low-head pumps. In some low-head applications, the diffusion conversion process may continue to some distance down the outlet pipe.

The performance of a rotodynamic pump is quoted as ‘flow’ and ‘head’; at a specified flow the pump will develop a corresponding ‘head’. Head is highlighted here because pump people always talk about ‘head’ but mean ‘differential head’. A rotodynamic pump senses the liquid head at the inlet connection and adds the developed head to it. The pressure in the pump outlet is a combination of the inlet conditions and the developed head. The centrifugal pump, also called a radial-flow pump, is the most popular style of rotodynamic pump.

**Centrifugal pump**

A rotodynamic pump style that directs the liquid flow to be radial (hence radial-flow pump), perpendicular to the shaft axis, and relies on centrifugal force to create kinetic energy.

**Differential head**

The ‘pressure’ difference between the pump inlet and outlet connections as measured by normal pressure-sensing instruments. Instruments don’t measure ‘head’.

**An aside**

It is worthwhile digressing here to note the absence of ‘suction’ and ‘discharge’ in the discussion. Suction is a poor term to use in connection with pumps; you can’t suck liquids. Liquids have a very low tensile strength and will ‘break’ easily if a tensile stress is applied. In this context, ‘break’ means form a vapour pocket. Having a vapour pocket in the inlet liquid supply can be annoying (creates noise and vibration), can ruin production (low mass flow), can increase maintenance costs (reduce bearing life, increase wear on mating sliding parts) or can stop production (seize pump). Pumps create suitable inlet conditions so ‘something’ can push the liquid in.

Discharge is a common term for the pump outlet and is much used. However, the rotodynamic fraternity would like us all to stop using it. Power recovery turbines are becoming very popular in an effort to improve process operating efficiency. Why throw energy away, in a throttle valve, when a turbine could usefully recover the energy for something practical! It is possible to run a rotodynamic pump backwards as a turbine. A pump can be a hydraulic turbine; in this case flow enters the ‘discharge’ and exits the ‘suction’. The use of ‘inlet’ and ‘outlet’ removes confusion.

**Hydraulic turbine**

A machine that receives liquid at a high energy level and extracts some of the energy to produce mechanical power available through a rotating shaft. (When installed incorrectly, a rotodynamic pump may run backwards as a turbine. During this condition, the pump may overspeed and damage itself. Some pumps will not run backwards successfully at any speed; damage may ensue.)

**Positive displacement pump**

The other major pump type. Positive displacement (PD) pumps fall easily into two family groups: rotary and reciprocating. Rotary PD pumps are similar, in one respect, to rotodynamic pumps in that both utilize rotating shafts. Reciprocating pumps have oscillating pumping elements, such as pistons, plungers or diaphragms. (If someone tells you a plunger is a long, thin piston, change topics and talk about something else... the weather, for example.) PD pumps operate by physically transferring the liquid from the inlet connection to the outlet connection. The pump might not ‘squeeze’ the liquid; this depends on actual type. PD pumps do not rely on speed and can create very high pressures with hardly any motion. The performance of a PD pump will be described by ‘flow’ and ‘pressure’. In the case of PD pumps, ‘pressure’ usually means outlet pressure, not differential pressure.

**Hydraulic motor**

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Theoretical differences

One way to differentiate, theoretically, between rotodynamic pumps and PD pumps is to consider the former as ‘constant energy’ and the latter as ‘constant flow’. A rotodynamic pump tries to impart a fixed amount of energy to the liquid as it passes through the pump. The pump always fails at this aspiration, but this explains why rotodynamic pumps have a ‘curve’. Rotodynamic pumps can operate over a range of flows described by the performance curve.

The geometry of a PD pump – consider a ‘swept-volume’ parameter for rotary pumps as well as reciprocating pumps – fixes the flow per revolution. PD pumps fail to be ‘constant flow’ machines due to machine design constraints and liquid properties. There are no ideal pumps or ideal liquids! We all live in a ‘real’ world and this includes all man-made machines. PD pumps can operate over a range of outlet pressures and supply a flow of liquid determined by the pump design and liquid properties. But note! Specifying an outlet pressure on a datasheet does not imply ‘all pressures up to and including’. Only the operating conditions described are covered by guarantees and warranties!

Affinity Laws

The Affinity Laws (see box below) are approximate relationships that can be used to predict rotodynamic pump capabilities.

**Generalized Affinity Laws**

\[
\begin{align*}
\text{flow} & = \frac{\text{rpm}_2}{\text{rpm}_1} \times \frac{d_1}{d_2} \\
\text{dh} & = \left( \frac{\text{rpm}_2}{\text{rpm}_1} \right)^3 \times \frac{d_1}{d_2} \\
\text{power} & = \left( \frac{\text{rpm}_2}{\text{rpm}_1} \right)^3 \times \frac{d_1}{d_2} \\
\end{align*}
\]

For a pump with a fixed diameter impeller:

If an inverter salesman or an electrical engineer tells you that you can save a fortune ‘because power is proportional to speed cubed’, ask him to prove it. Ask him to show you how the pump interacts with the ‘system’. Figure 2 shows the same pump curve with two different system curves, the green lines. The pump must operate where the system characteristic intersects the pump curve. Consider the pump is fitted with the full diameter impeller. If the pump speed is reduced, the performance will be reduced and ‘speed’ lines can be drawn just as ‘diameter’ lines are drawn. For example, if the 265 mm diameter line corresponds to 2900 rpm, the 255 mm line could approximate a speed of 2790 rpm.

The system curve marked ‘1’ represents a system that is purely, theoretical, friction resistance; this is an ‘x squared’ law, which goes through the origin. You will notice that this system curve follows the BEP as the pump capabilities are reduced. In this theoretical case, the pump power is proportional to speed cubed, providing everything else remains constant. Curve ‘1’ represents a theoretical special system, a circulation system where the inlet static head is exactly balanced by the outlet static head. This system is theoretical because practical pump systems don’t follow a ‘square law’. The requirement to have valves and fittings and various other flow resistances mean the head-flow relationship is not ‘squared’.

System curve ‘2’ shows a practical system with a significant static head component. It is obvious that this curve will intersect the ‘speed’ lines at a different point. The ‘power cubed’ relationship can’t work for both cases. In order to assess the benefits of any pump control system, the actual system characteristic must be known with a degree of accuracy. The ‘power cubed’ relationship is wildly optimistic in applications such as boiler feed or condensate recovery.

Fan

A rotodynamic compressor that imparts a very small amount of kinetic energy to the gas/vapour. There is no significant change in medium density.

It is very easy to spot someone who doesn’t know much about pumps; they mention fans and pumps in the same breath and think they are related. As mentioned earlier, ‘pumps’ means all pumps. A fan is a special type of compressor.

Contact

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If you would like Brian to review or include a definition in future articles, he can be contacted at: briannesbitt@btinternet.com