CENTRIFUGAL PUMP SELECTION – PART TWO

PULLOUT

This Skills Workshop is part two of a two-part series covering how to select the correct centrifugal pump for a particular design and application. However, keep in mind that proper consideration of pump design considers not just the pump but the entire pumping system, including the supply and demand sides of the system, and how the individual system components interact.

THE SYSTEM CURVE

Developing and analysing system curves can provide insight into how a pumping system will perform.

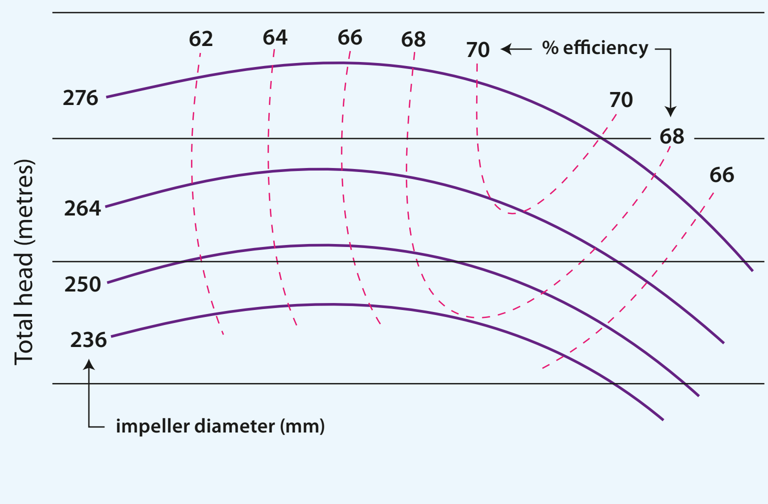
The system curve is a graphical plot of system resistance, i.e. the pressure (head), to be overcome by the pump, versus a range of flow rates. The system curve changes with the physical configuration of the system, including size and extent of piping and fittings, height characteristics, and the pressure drop across connected equipment. These friction losses are a function of flowrate, and increase with increasing flow.

Friction losses are calculated by the designer, and any errors in estimating system resistance will result in an inaccurate system curve. An error in the system curve calculation may result in the selection of a pump that is sub-optimal for the system. The system curve only applies to a fixed piping network. If a system component is changed or a valve is throttled then a new curve is established. Variable flow systems operate over a range of system curves and, for these systems, considering the movement of the pump operating point along the pump curve as flow conditions change is an important component of design.

For systems that are open to the atmosphere (e.g. cooling tower/condenser water circulation), pumps must also provide the energy to lift the water through any changes in elevation. This is in addition to the dynamic losses that are needed to overcome system resistances. The system curve for these applications does not pass through the origin at no flow.

A fixed resistance, like a pressure regulator or flow-control valve, will also shift the system curve away from the origin or zero pressure/flow point by an amount equal to the constant pressure it generates within the system.

PUMP PERFORMANCE CHARACTERISTIC CURVE



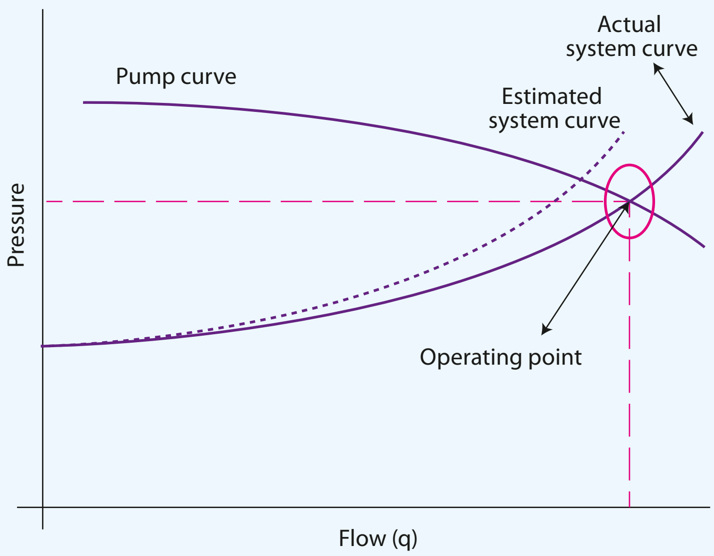
A typical pump characteristic curve.

A pump characteristic curve is the graphical representation of the pump performance characteristics, including the range of pressure and flow capabilities at specified speeds, and the corresponding power input required, and pump hydraulic efficiency. These curves are used in pump and system design, selection, installation, commissioning, operation and maintenance. They are also called pump performance curves, or simply pump curves.

Pump characteristic curves are developed under controlled test conditions with the pump installed with straight inlet and discharge connections. These curves illustrate the relationship between capacity (flow rate), pressure or head, efficiency, and power input of a pump running at a specified speed. A family of curves for different impeller sizes are generally provided for a given size pump operating at a particular speed. Pump efficiency lines, power input lines and NPSH required are often also shown on the same graph as the head/flow curve.

SYSTEM OPERATING POINT

When a pump is installed in a system, the effect can be predicted and illustrated graphically by superimposing the system and pump curves. The point where the system curve and pump performance curve intersect determines the system volume flow rate, and defines the system operating point.



This operating point may not be optimum for the proposed pump application, and the system designer should look for a pump with a best-efficiency point that matches the system operating point.

BEST EFFICIENCY POINT

Centrifugal pumps are characterised by the relationship between the flow rate they produce and the pressure at which the flow is delivered. Pump efficiency varies with flow and pressure, and is highest at one particular flow rate. This point is called the best-efficiency point and will deliver the highest efficiency rating possible for that pump in that system.

The benefits of selecting and operating pumps at their best-efficiency point include:

- Minimised energy use
- Smooth operation minimising noise and vibration
- Reduced bearing and seal failure
- Reduced risk of cavitation.

Constant-flow systems

In constant-flow systems, best practice is to ensure that the system operating point or "peak" duty is within at least ±10 per cent of the pump best-efficiency point.

Variable-flow systems

In variable-flow systems, pump selection should be made for within ±10 per cent of the best-efficiency point at the "mean" duty, with the pump capable of operation at the peak duty. This will ensure that the pump is operating at its peak efficiency for longer periods, because most systems typically only operate at the peak duty for less than 5 per cent of the time.

MATCHING CENTRIFUGAL PUMPS TO SYSTEM DUTY

Obtaining a perfect match between the system curve and the best-efficiency point on the pump performance curve is often not practical. Generally, the approach is to vary the pump performance to achieve the closest match with the best operating point. The following methods are used to vary the pump performance:

- Adjust the pump operating speed
- Adjust the pump impeller size (trim)
- Change the impeller design
- Change the system resistance
- Modify the static pressure (head)
- Add system bypass flow route.

Change in pump speed

A common technique when changing the speed of the pump is to use a variable speed drive (VSD) motor. VSD motors provide an efficient and low-cost method of instantaneously varying pump impeller speed and pump performance.

VSDs are more suitable for continuously varying system flows, rather than for matching pump performance to a constant-flow system at commissioning.

Change in pump impeller size

Often called "trimming", the impeller diameter (d) can be reduced to permanently vary the pump performance. The reduced impeller diameter rotating at full speed will apply less energy to the fluid, resulting in a reduced flow (q) or reduced pressure (H), and changed performance characteristic. The changed performance (P) can be predicted using the pump affinity laws:

q is proportional to d;

H is proportional to d2;

P is proportional to d3

Only small permanent performance adjustments are possible with this method. For greater magnitude of changes, the pump impeller can be replaced with a different design or size. Larger impeller reductions can effect efficiency and suction characteristics.

Change in pump impeller design

There are practical limits to how much variation can be achieved by impeller trimming, and if a greater order of magnitude of change is required, a different impeller design may be available for the pump.

Different impellers, casing and diffuser arrangements will all produce different performance characteristics that can be manipulated to help match the pump performance with the system requirements.

Change in system resistance

Increasing the resistance of the system by closing down in-line valves was traditionally a common method of changing the system curve to match the pump performance. This is an energy-inefficient method of design, and both pump speed control and impeller adjustment provide a better energy solution. Speed control is the most efficient option.

Add system bypass

Allowing some water to bypass the circuit/load is another way to deal with a variable load requirement. The bypass deals with the variability, while the pump operates as a constant flow system. Again, system bypass is not an energy-efficient method of dealing with a variable load from a pumping point of view, and is not recommended for new or modified systems.

CENTRIFUGAL PUMP STALL

When a pump operates at reduced flow rates, its performance (flow rate and pressure developed) can be degraded by the inception of a flow instability, called "rotating stall". Stall refers to zones of recirculating fluid within a pump's impeller, diffuser or volute that can cause substantial velocity and pressure fluctuations, which can adversely affect the flow and the pump.

The mechanics of the rotating stall phenomenon are not yet well understood. A percentage of the pumped fluid will always recirculate at the eye of impeller, and that percentage increases as the flow rate drops. In the stalling flow-range of recirculating flow, pump head becomes variable, leading to transient variations in both radial and axial hydraulic thrust. High pump structural vibrations are likely to be present in the stalling flow ranges, with recirculation potentially causing mechanical damage to the pump or driver bearings.

PULLOUT

ACOUSTICS AND NOISE

Pump noise

An important aspect to consider in pump selection and application is the area of pump noise. There are two main sources of noise in pumping systems: the noise associated with water flow in the pipework and fittings, and the noise associated with the motor and drive.

Water turbulence

Water-generated noise can be emitted from the system when water flows through pipes and fittings. The level of noise generated is generally proportional to the turbulence of the flow, more turbulence means more noise. To minimise noise generation due to water turbulence within the system, ensure that the flow is straightened prior to entering the pump volute, and that flow velocities are kept within reasonable limits throughout the system. Selecting the most efficient pump for the application is the best way of minimising this risk.

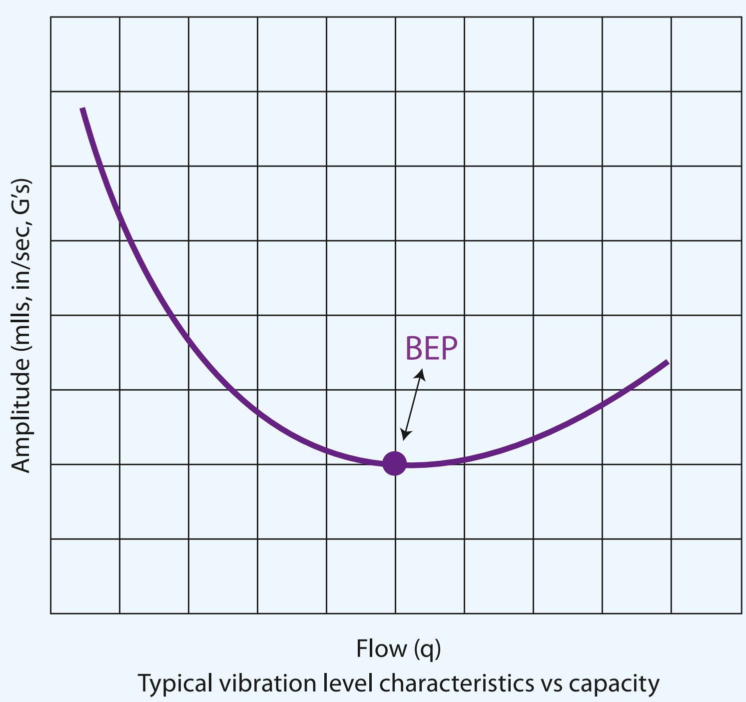
Pump motor noise

Motor noise is generally the main contributor to the overall system noise. In an effort to reduce energy waste, modern, higher efficiency motors have improved designs, reducing the overall noise emitted by the motors. Higher speed motors of comparable sizes will emit higher noise than their slower counterparts, although a smaller high-speed motor may provide better pump efficiency, with only a negligible increase in noise.

VIBRATION

Vibration is defined as mechanical oscillations or the repetitive motion of an object about an equilibrium point. All centrifugal pumps vibrate at some level of intensity throughout their life cycle, and it is the severity of the vibration that is important. Some level of vibration may not be harmful but, as vibration exceeds acceptable levels, it can shorten a pump's life. Vibration is a good indication of a pump's condition, and vibration analysis can be used as a tool for preventive and predictive maintenance.

Many vibration problems are a result of interactions between a system's pump, motor, fluid, piping, and structure. This interactive relationship requires a systems approach to vibration analysis, rather than the investigation of individual components. Neglecting important factors during pump installation can lead to vibration issues that are expensive and time-consuming to resolve. All pump installations must adhere to manufacturers' recommendations in order to avoid system-vibration problems.

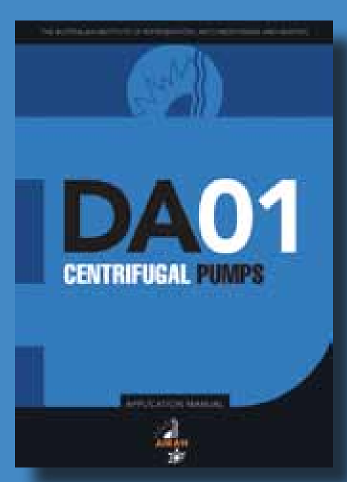


Centrifugal pump vibration versus capacity.

Common causes of vibration in centrifugal pumps include:

- Unbalance in rotating parts, e.g. damaged impellers and non-concentric shaft sleeves
- Misalignment of shaft, coupling, or bearings, e.g. bent shaft, thermal expansion of shaft, misaligned pump
- Rubbing or looseness of parts, e.g. loose bearings, loose hold-down bolts
- Turbulence in the system (non-laminar flow)
- Operating away from the pump's best-efficiency point (BEP)
- Acoustic, mechanical or structural resonance
- Hydraulic forces, e.g. internal recirculation
- Mass of the pump base too small
- Harmonic vibration from nearby equipment
- Operating the pump at a critical speed
- Dirt or contaminants between mating parts.

In order to identify the cause, or causes, of vibration, it is important to know its magnitude, direction, and frequency. Data about the vibration amplitude, velocity, acceleration, spike energy, acoustic characteristics and deflection are all useful in a vibration analysis. ▲



The information in this month's Skills Workshop was adapted from a draft version of AIRAH's soon-to-be-released revised DA01 Centrifugal Pumps, a guideline for the selection and application of centrifugal pumps used in the building services industry for pumping water and other fluids. DA 01 will be available for purchase online later this year, by visiting AIRAH's online store at www.airah.org.au

To pre-order contact Sandra at sandra@airah.org.au

Next month — **Chiller Technology – Part one**