Considerations in selecting a positive displacement slurry pump

Mining offers many challenges when selecting the proper slurry pump, not only because of the demands of the harsh environment, but also due to the nature of the material being pumped. Rick Kesler, a sales manager for ABEL Pumps based in Golden, Colorado, discusses some of the factors to be considered in making such a selection.

There are many (often conflicting) factors that need to be taken into consideration when choosing a positive displacement slurry pump. Such units are not only expensive but bulky, and once installed, form a pivotal and critical link in the whole production chain. They are certainly not “install-and-forget” units, but once they have been piped into the fabric of the operation, they are not easily (or cheaply) swapped out again. Time spent weighing up the duties that such pumps will be required to perform and options available, is rarely considered to be time wasted.

**ABRASIVE WEAR**

Mining slurries tend to be abrasive with solid specific gravities of 2.65 or more and slurry specific gravities of 1.65 or greater at solids concentrations as high as 70%. Abrasive wear varies with velocity. Consideration should be taken in pump selection to allow for the effects of abrasive wear.

Centrifugal pumps can have the lowest capital cost. However, velocities are high and special materials need to be selected when choosing the proper centrifugal pump.

An alternative is offered by positive displacement (PD) pumps which operate at slower speeds and are very effective in the transport of mineral slurries. Progressive cavity and rotary lobe designs have much utilisation in industry, however, the path of the slurry goes through some tight places (ie rotors and stators or lobes). These designs are unfavourable to abrasive wear in the more intense applications and should never be run dry.
One of the best pump options for such duties are piston-diaphragm designs which can run dry and are highly resilient to abrasion. Slurry does not pass through tight constrictions. Instead, elastomer diaphragms are employed and are relatively passive in displacing the slurry. Thus the fatigue limit of the diaphragm determines the diaphragm life rather than abrasion.

GENERAL PUMP SELECTION
Several factors go into the selection of a pump for applications in mining. These include (but are not limited to): flow rate, pressure, particle size, percent solids of the slurry and abrasiveness.

Centrifugal pumps operate along a pressure/flow curve with a best efficiency point in the center part of the curve. This efficiency may be 75% or higher at the best efficiency point (BEP). There is a maximum pressure of up to about 100psi, sometimes more. Steady operation near the best efficiency point is desirable. Variable flow rates can induce cavitation or recirculation on either end of the performance curve. These pumps often require gland seal water to operate. The pumps often operate at speeds of between 1,200 and 1,800rpm, so abrasive wear is enhanced. Centrifugal pumps generally have higher solids size capability than most positive displacement designs.

If total dynamic head, abrasiveness, and variability of flow limit the usefulness of centrifugal pumps, positive displacement pumps may offer a better solution.

Up to about 100psi, rotary lobe pumps can be used, and when operating at 200psi or more, progressive cavity pumps are functional. Again, these pumps should not be run dry. The more abrasive slurries may inflict rapid wear on rotating components. Piston diaphragm designs offer dry running capability and will not suffer near the adverse effects of abrasive wear. Efficiencies are higher with these designs, although capital costs are generally more.

Above +300psi, the piston diaphragm pump design is the preferred method of pumping slurries at high pressures and flows up to around 2,000gpm.

STAGED CENTRIFUGAL VS POSITIVE DISPLACEMENT
Some applications such as mine dewatering allow a choice between staging centrifugal pumps and use of a high-pressure positive displacement pumps, which can accomplish the pumping task in one stage. Lowest initial capital cost favours the staged centrifugal pumps in most cases. However, other factors enter into the decision process, such as: wear, maintenance, efficiencies, use of gland seal water, placement of centrifugal stages etc.

Wear is a consideration in high-pressure slurry pumping. Velocities of centrifugal pump impellers accelerate wear compared to the slower stroke rates of positive displacement pumps. Piston diaphragm pumps are designed near 60 strokes per minute or less.

Maintenance of centrifugal slurry pumps may turn out to be considerable as compared with positive displacement pumps, which usually only require maintenance on an annual or semi-annual basis.

Efficiencies of positive displacement pumps may run as high as 90%. Centrifugal pumps have a peak efficiency at their best efficiency point, but actual efficiencies may be considerably lower.

Let us consider 55% efficiency for the following example:

Six centrifugal pumps are placed in series to pump a tailings slurry at 55% solids with a combined discharge pressure of 1,022psi. Capacity per pump is 910gpm. Assume efficiency per pump is 55%. Power consumption per pump is 165hp or 123kW. So for 6 pumps, the total power consumption is 738kW/hr or 6,108,000kW/year. A positive displacement hydraulic membrane pump operating at 90% efficiency, consumes by comparison some 3,733,000kW per year. Savings, assuming $0.10/kW, equates to approximately $238,000 per year.

The 6 centrifugal pumps each need gland seal water. Assume each gland seal water pump uses 30gpm of water, pumping at 750psi and consuming 18kW per gland seal water pump or 107kW for the 6 pumps. The pumps run 8,300 hours per year.

Water cost approximately $0.25 per 100 gallons, power cost $0.10/kW, cost of water plus energy per year for gland seal water is approximately $310,000. This represents a savings for positive displacement pumps which do not use gland seal water.

Also consider that positive displacement hydraulic membrane pumps can pump media with solids concentrations up to 70% vs lower concentrations possible for centrifugal pumps. This results in less slurry volume pumped, inherent improved efficiency and higher throughput.

Total savings per year using positive displacement pumps amounts to some $238,000 plus $310,000 (ie $548,000 annually). Adjust the costs to fit your local parameters but the cost of centrifugal positive displacement can be deceptive.

GLAND SEAL WATER PUMP SELECTION
Centrifugal pumps are the industry standard for pumping gland seal water to the large centrifugal pumps on tailings service, ball mill discharge, or other duties. A steady flow is vital to the service life of these large centrifugal pumps even as pressures vary due to gland wear, head tank level changes or other causes.

A positive displacement pump, although initially more costly, provides a steady flow of water to the gland seals. Variations in head tank level or condition of the gland area do not change the flow. The positive displacement piston pump provides a constant flow for a given number of strokes per minute.

A bank of triplex piston gland seal water pumps at a site in Morocco. Each pump provides gland seal water for multiple centrifugal pumps.
PUMPS

AUTOCLAVE FEED PUMPS
Autoclaves are used in circuits such as copper, and molybdenum to oxidize the ore from a sulphide to an oxide to allow further processing. This reaction is enhanced by temperature and pressure. Materials are fed into the autoclave at +200psi. Often the feed rate is about 100 gpm but may vary. Feed temperatures are often ambient but elevated feed temperatures may be required in some processes.

The piston diaphragm pump is preferred for this application as it can best handle the pressure and abrasive slurry.

FILTER PRESS FEED PUMPS
Feed pumps for plate and frame filter presses operate over a range of capacity and pressure. Generally, slurry is initially fed to the press at a high feed rate. As the press fills, the pressure builds up and the feed rate is reduced in steps as the pressure recommended for the press is attained. Feed material may continue to pack into the press for a short time and then the cycle is ended. The pump is stopped. The press is emptied and the cycle repeated.

Centrifugal pumps are a low capital cost option often found in filter press feed applications. Operations range from high-capacity and low-pressure to low-capacity and high-pressure. Little of the operation is at the best efficiency point. Damage to the centrifugal pumps occurs from cavitation or recirculation on either end of the operating range. In some instances the centrifugal pump incurs substantial damage from abrasive wear in just a few weeks.

Piston diaphragm pump operations range from full-capacity and low-pressure to low-capacity and high-pressure, by varying the stroke rate of the pump. Pump efficiency remains constant during this transition. This is accomplished using a pressure transmitter and variable frequency drive.

Piston diaphragm pumps, while having a greater capital cost, can pump to a filter press without experiencing undue abrasive wear, and while maintaining efficiencies greater than 90%.

PULSATION
Reciprocating piston pumps produce a pulsating flow. Pulsations can cause vibrations in piping, excessive acceleration head, and influences on downstream processes. Pulsation can be adequately dealt with by installing and using pulsation dampeners.

One type of dampener is the bladder type. Air or nitrogen is added to the top of the vessel above the bladder at 70 to 80% of the process pressure. The pressure above the bladder does not need to be adjusted, as long as the operating pressure is fairly constant.

With varying pressures, as with a filter press feed operation, the bladder style is inadequate due to the changing pressures. An air cap dampener is preferable. Air within the vessel is compressed by the slurry and the pulsations are attenuated. Air or nitrogen needs to be added regularly to the discharge dampener to replace that carried out by the slurry.

The amount of residual pulsation is a function of the stroke volume of the pump, the operating pressure, the volume of the dampener, and is constant for the pump. As a rule-of-thumb, a 10% residual pulsation is a good value for most applications.

Selecting a residual pulsation, of say 10%, and knowing the other factors stated above, a dampener volume can be calculated. This dampener volume is the volume needed under process pressure. Sizing of the dampener requires the corresponding volume to be at atmospheric pressure. If the dampener volume is calculated for an operating pressure of 30bar, then the calculated volume needs to be multiplied by 30 in order to calculate the volume at atmospheric pressure. Thus dampener size calculated in this manner can become unwieldy at higher pressures.

Therefore, above a certain pressure, the dampener design reverts to a bladder style with stout construction to withstand the operating pressure.
On the suction side, acceleration head is a factor not occurring in non-reciprocating machines. Acceleration head affects the net pressure suction head available (more commonly referred to as “NPSHa”). Actual acceleration head is a function of specific gravity, pipe length, flow rate, and stroke rate divided by pipe diameter squared, and a factor “Z” for the pump configuration. Suction dampeners are standard on larger piston diaphragm pumps. On lower pressure systems, if the suction pipe length exceeds 10ft, a pulsation dampener is recommended.

**PISTON VS PISTON DIAPHRAGM PUMPS**

When transferring solids such as thickened tailings, or paste, hydraulically actuated piston pumps are often employed. These machines have two reciprocating pistons. No diaphragm is used. Material is fed to the machines by an auger. Efficiencies are typically less than a hydraulic piston diaphragm pump but they are capable of handling thicker solids than could even be fed into a hydraulic diaphragm pump.

Piston diaphragm pumps (sometimes also called “hydraulic membrane pumps”) operate typically at efficiencies near 90%. Materials need to be fluid enough to flow into the pump. Some materials are thixotropic and can be sheared with an auger, so that they will flow into a piston diaphragm pump.

The dividing line between piston and piston diaphragm selection is near 70% solids for many mineral slurries. One rule-of-thumb suggests that if the slurry is less than 45% solids by weight it may be amenable to flow into a piston diaphragm pumps. Laboratory testing is recommended to confirm which style of pump to select.

**CONCLUSION**

We have examined several mining applications and discussed some considerations in slurry pump selection. Centrifugal pumps are the most common pumps and generally have the lowest capital cost. However, when one considers efficiency, abrasive wear, pressure per stage, water usage, energy consumption, down time and other factors; positive displacement pumps, and more specifically, piston-diaphragm pumps, are the better choice.

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