

Selection guidelines for applications that suit both multi-stage centrifugal and positive displacement (PD) pumps

Introduction

Material and mineral transportation in the form of slurry continues to offer economical solutions for both short and long-distance pipelines. With the increasing use of high-density slurries, pipelines also offer environmental advantages. The following guidelines can be used to select the most appropriate and economical type of pumping equipment depending on the slurry properties and the length of the slurry pipeline.

Typical applications for slurry transportation include the following:

- Long distance pipelines
- Mine dewatering or backfill
- Mine tailings disposal
- Ash disposal
- Hydraulic ore hoisting
- Autoclave or digester feed
- Co-disposal systems of fine and very large particles.

The development of centrifugal pumps to handle higher pressures and slurries with increased density and viscosity have broadened their range of application into the traditionally positive displacement pump fields. Similarly, the development of positive displacement (PD) pumps that can handle higher throughputs and larger solid particle sizing means that they can be used where a centrifugal pump may have traditionally been selected.

As a consequence of the increased overlap of the application of centrifugal slurry and PD pumps, the type of pumping equipment needs to be evaluated more thoroughly than in the past to achieve the most economical solution.

The new generation of centrifugal pumps with flow-inducer style impellers are also better able to be used effectively as a feed pump for a positive displacement pump that is handling high density and paste type slurries.

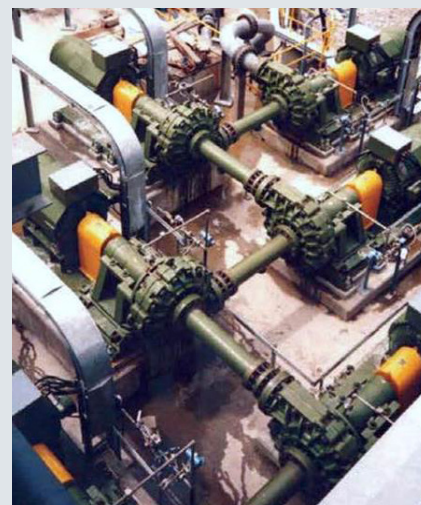
The selection of either a centrifugal slurry pump or a PD pump depends on a variety of factors, which will normally be case specific. The factors and their limitations applicable to each type of pump are further discussed in the following sections as well as summarised in Table 1.

Slurry properties

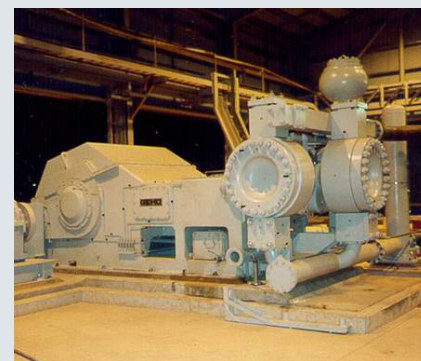
For slurries with fine particles, both types of pumps are normally suitable, but in the range of particle sizes of above 200 μm to 2 mm, the PD pump requires more careful evaluation as large particles can cause the valves to stick open and reduce their life. A centrifugal pump is well suited to handling mixtures of fine and coarse particles e.g. co-disposal.

Deep cone thickeners have been developed in more recent times to thicken slurries to higher densities, which offer a more sustainable solution for slurry disposal such as tailings. The main advantages are:

- Higher density so less volume to pump
- Lower water content, and in some cases very little water drainage from the tailings deposit and therefore little or no water to return to the minerals plant
- Less tailings dam volume required over mine life
- Less potential for catastrophic dam failures or extensive ground water contamination



Warman® 10/8 TAHPP centrifugal slurry pumps



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- Size distribution can be better controlled so that tailings settle out in a stable deposit which can be driven-on shortly after being deposited
- Consolidated tailings hold together with far less dusting when they are dry

Slurries which have a high percentage of 75 μm or finer particles can result in the slurry exhibiting a yield stress. This yield stress can increase markedly over a few percentage points increase in slurry concentration. The higher the yield stress, the harder the slurry is to pump. A yield stress slurry typically causes a problem at the intake of a centrifugal pump and for the intake and valves on a PD pump. Various methods can be used to enhance the pumps suction conditions e.g. the latest generation of Warman® centrifugal pumps can be fitted with a flow-inducer (QU1 style) impeller to increase the shearing and lower the NPSH required at the pump intake.

The slurry rheology should be established by a series of tests to cover the range of expected variables as follows:

- Range of particle distributions
- Range of densities for pumping
- Range of density possible from thickener
- Yield stress for the range of slurry mixes (preferably measured with a rotary viscometer)
- Plastic viscosity (coefficient of rigidity)
- Slump plate reading
- Maximum density for critical yield stress
- Pressure drop (from test loop measurements)
- Miller number (important for PD pumps to gauge the abrasiveness of the slurry particles)
- Time dependency of slurry viscosity and its shear history

The slurry test results can be used to fit co-efficients to relatively simple slurry models to allow the prediction of their behaviour over the range of intended operation. These models assist with the selection of the pumps and can also be used to predict the total system performance (i.e. pumps and pipelines).

Pipeline Design

The main factors influencing the selection of the pipe size are the tonnage, slurry rheology, size distribution and the velocity to keep the solids suspended along the length of the pipeline.

Pipelines should normally be designed to operate at velocities in the transition region between laminar and turbulent or in the fully turbulent region to ensure that there is sufficient flow turbulence to keep the particles suspended as settling solids can block the pipeline. Larger particles can be transported in dense slurry of finer particles, but in this case the velocity may have to be adjusted to suit the larger particles.

The pipeline route is affected by many factors, but normally should be kept as short as practical while avoiding very steep terrain. If the pipe discharge is free to discharge into an impoundment area, the discharge point

position may need to be changed at set times to ensure even filling. Varying pipeline lengths will result in changing pressure requirements for the pumps.

Pipes can be laid on the ground or buried in more environmental sensitive areas. Slurry pipelines normally allow year round operations and can operate independent of weather conditions.

Long distance pipelines will require some form of road access for maintenance, pigging stations or access to outlets for unblocking the pipeline; power and radio control and communication from a central location including any intermediate pumping stations.

Pipe materials and lining will vary depending on the type of slurry, the pressure requirements, erosion and corrosion allowances and the expected pipe life. Lined pipes typically need special preparation at the joints to minimise turbulence and erosion. Periodic pipeline turning can prolong a pipes life, but will need to be considered at the design stage.

The ability to restart a pipeline after a power outage or blocked pipe requires special attention. Pilot studies are normally recommended to ensure that the slurry does not form into hard deposits on the bottom of the pipeline and that the pipeline can be re-started within 24 to 48 hours. Similarly, sufficient run-back storage capacity or other means to scuttle the pipeline maybe incorporated into its design.

PD pumps deliver a fixed volume which is proportional to the pump speed. This fixed flow characteristic helps with the self-cleaning of the pipeline.

Multi-stage centrifugal pump installations require careful analysis of the pipeline system curve and its intersection with each stage pump curve to properly define the possible operating pump ranges. Start-up of the pipeline requires particular attention in order that the motors are not overloaded due to high flowrates and/or to avoid pump cavitation.

Pump operating limitations

The main mechanical differences between centrifugal and PD pumps relate to the maximum pressure rating and maximum flow that each pump type can handle.

Centrifugal pumps are best suited for a maximum of 7 MPa (70 bar) pressure and 7,000 m^3/h flows and can be arranged in series up to a maximum of 8 pumps.

The optimum configuration for centrifugal pumps in series requires a review of the pipeline and inter-stage piping arrangements, foundations loadings and pipe anchors together with maintenance issues e.g. overhead crane access.

PD pumps can handle much higher pressures but reduced flow compared to centrifugals – typically maximum of 30 MPa (300 bar) and 1000 m^3/h .

The optimum configuration of PD pumps is less critical than centrifugals, but still requires a review of the piping and foundations loadings, pipe anchors together with maintenance issues.

The output of both types of pump can be varied with the use of variable speed drives. Variable speed can be also used to change the output depending on the slurry rheology at the time, or to compensate for wear in centrifugal pumps.

Centrifugal pumps can offer further flexibility besides variable speed by allowing the pumping through of some stages without them being driven.

Pipeline starting and stopping is recommended to be carried out with water or dilute slurry. Variable speed drives will assist these operations due to the change in density which affects the pressure drop in the pipeline.

Economic evaluation and transportation cost

Selecting the optimum pumping equipment for specific applications can be relatively straightforward if the application falls clearly within either of the centrifugal or PD ranges. However, for applications where both types of pumps could be suitable, then further evaluation of the capital and operating costs should be carried out. Table 2 can be used as a simple comparison guide to compare the various costs, net present value as well as the overall transportation cost (e.g. \$/tonne.km)

Centrifugal pumps when handling slurry do not produce the same head as when pumping water. However, head and efficiency derating values can be readily ascertained from published information. For the types of slurries considered in this comparison, head reduction would typically be quite small, but high slurry viscosity can reduce the efficiency at low flows which then needs to be considered when selecting the required driver capacity.

The cost comparison should include the cost of the ancillaries, particularly the sealing water equipment required for centrifugal pumps.

Wear of centrifugal pumps is typically light for these types of slurries and all pumps in series normally wear at the same rate. Pump liners and impeller wear life could vary from 6 to 18 months depending on the application.

PD pump wear is normally confined to the valves; with a typical life of approximately 3 to 6 months depending on the slurry and application. If the slurry is acidic, then this will require the selection of corrosion resistant materials.

The civil works for the smaller and lighter centrifugal pumps would normally be lower cost than that required for a single, larger and massive PD pump.

Conclusion

Pipeline transportation of mineral slurries is a viable alternative to other modes of transportation and necessary when terrain is unsuitable for other forms of transport.

Both centrifugal slurry pumps and PD pumps can be used for slurry transport systems. While there are many factors in the selection of each type of pumping equipment, the optimum or most appropriate selection in the overlapping application region really requires a cost comparison of both types.

The guidelines presented here, can be used to make the most appropriate pumping equipment selection. Some typical examples are provided in Table 3.

Table 3 - Power consumption comparison for some typical applications		
Slurry Particle Size	Comments	Typical Power Factor to transport 100 tph slurry with 2.65 SG particles at settling velocity
2 to 100 µm	Very economic any distance	1 (base)
150 µm to 0.7 mm (ground)	Normally cheaper than alternate means of transport	20 times
> 2mm (crushed)	Normally equal or higher cost than alternate means of transport. Requires economic evaluation.	50 times
Co-disposal (fines + particles up to 150 mm eg coal refuse)	The fines assist to transport the larger particles. Centrifugal pumps are the only option. Economics depend on the tonnages and terrain. Slurry preparation facilities are generally minimal but no dewatering facilities are normally required, as the deposit is self-dewatering.	Application dependent
Paste for mine backfill operations	Positive Displacement pumps normally preferred due to the high static head, viscosity and / or high pipe friction losses.	Application dependent

Table 1 - Pump Type Selection Factors

Parameter		Centrifugal Slurry Pump (in series)	Positive Displacement Pump
Average slurry particle size	< 50 μm	Yes	Yes
	50 to 200 μm	Yes	Yes
	200 μm to 2 mm	Yes	Evaluate
	> 2 mm and coarser	Yes. Typically up to 150 mm for Co-disposal systems	Evaluate specific cases. Max of 3 mm particles (small pumps) to 6-8 mm for large pumps (up to 75 mm possible with S-tube pump design). Particles could drop out in pump intake.
Slurry pipeline settling velocity		Operate normally at 110% of settling velocity to prevent pipeline blockage.	Not a major consideration
Slurry Density		Upper limit depends on viscosity. Large fluctuations may cause performance changes.	Upper limit depends on viscosity
Slurry Viscosity: Yield Stress		Typically up to 50 Pa with a standard slurry pump, up to 200 Pa with a flow inducer impeller. Higher yield stress will require booster feed into pump suction.	Independent of slurry rheology, provided the pump is feed from an outside source e.g. a centrifugal pump. Typically maximum of 150 Pa for self-actuating valves.
Maximum Pressure rating		Up to 7 MPa (70 bar)	Up to 30 MPa (300 bar)
Maximum Flowrate		20 to 7,000 m^3/h	10 to 1000 m^3/h
Maximum head per stage		80 m fine particles and 55 m coarse particles	What pressure the pipeline requires or to the limit of the pump pressure.
Maximum number of stages		Typically 8	Not applicable
Capital Cost		Low to medium	High
Typical Efficiency		70 to 85 % per stage depending on slurry properties	90 to 95% crankshaft driven
Typical Pipeline per Station		15 to 20 km	Not limited
Typical pipeline topography		Flat or gently sloping will achieve longest pipeline	Flat to steep
Typical number of pump stations		One is normal but booster stations along the pipeline can be used depending on the terrain. Break tanks are an alternative	One or many, but less than centrifugals. Centrifugal pumps can be used as boosters.
Typical drive type		Fixed or variable speed to cater for changes in throughput/wear.	Normally fixed speed.
Pump Output		Continuous	Pulses - requires a pressure damper

Table 2 - Cost comparison guide

Cost component		Comments	Centrifugal	Positive Displacement
Project description: XX tpa of ABC slurry (= xx tph) transported ZZ km			\$	\$
Pipeline	Pipes & Joints	Pipe wall thickness could vary along the pipeline to match the maximum pressure. May include diameter options depending on the application.		
	Transport to site, installation & civil works	May include installation of a spare pipeline or provision for spare pipeline. Pipe maybe buried or in places suspended.		
	Right of way	May include access roadway for maintenance.		
Pumping Stations (including civil works)		Equal spacing generally the best if the topography suits.		
Slurry preparation facilities		Depends on annual throughput and slurry properties required for most economical transport.		
Slurry dewatering facilities		Depends on annual throughput and requirements for use of the slurry end product.		
Equipment	Pumps and interstage piping (where applicable)	Depends on annual throughput as well as consideration of the other factors in Table 1.		
	Motors, starters, gearbox, couplings	Electric motor most common.		
	Ancillaries – gland water pumps, valves, controls, agitated storage tanks.	May also include slurry test loop to check slurry pumpability and ball mills and cyclones at the feed-end and filters or dryers at the discharge-end.		
Operating Costs (fixed hrs pa)	Maintenance	Mainly pumps and valves.		
	Labour	Controls may allow remote monitoring or control.		
	Energy	kWh		
	Spare parts	Mainly wearing parts and valves.		
	Pipeline wear	Normally low if below 1.5 m/s transport velocity. Pipes may require turning to even-out wear.		
Engineering Costs		Including pipeline design and equipment selection.		
Interest Costs				
Total Cost - CC		Add up all the above	CC	CC
Transportation cost		Normally expressed as \$/tonne.km or similar	CC/XX/ZZ	CC/XX/ZZ

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