

Minjng Magazine



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Ten MillMAX 20/18 high-pressure pumps in two lines of five at a Chilean copper mine



Going with the flow

Paul Moore reviews some of the pump types used in mine slurry transport and the models available from key manufacturers

BOTH centrifugal and positive displacement pumps are used in mining and mineral processing applications in a wide range of slurry-handling situations, with many designs and configurations. In general, centrifugal slurry pumps have a lower initial and maintenance cost, so wherever possible they are used instead of positive-displacement pumps. Piston and diaphragm pumps have their own niche markets where they have an advantage; eg they can operate at higher pressures, but they are sometimes limited as to the size of solids and flow rate they can handle.

Jeff Crawford, director of pump sales at FLSmidth Krebs, tells *Mining Magazine*: "Slurry pumps have been successfully applied to the hydro-transportation of solids for transfer from the mine face to the process plant; in the milling circuit; through separation and flotation; concentrate to filters; tailings to thickeners, and then on to tailings storage facilities. Final concentrate is then transported from the mine to the smelter/shipping area; this is usually done using positive-displacement pumps."

Transport inside the processing plant (intra-processing plant slurry transport) can create some of the biggest challenges in slurry pumping. Mine

concentrator plant ore-milling circuits, followed by classification and separation (cyclone feed), are often considered the most severe and critical of slurry pumping services. Filter-feed pumps, for example, start with a high-flow low head, and as the filter fills the pressure increases and flow reduces. The result is a constantly moving duty point in this type of application, which requires special system controls.

Bill Schittler, business development manager – pump solutions, at Metso comments: "Froth pumping can also be a challenge as pumping air-entrained slurry requires special application corrections to adjust volumetric and power requirements. This type of pumping can be achieved with both horizontal and vertical pumps. Removing as much air as possible from the slurry before it is pumped is always beneficial in these types of application."

Tailings transport, especially in areas such as oil sands, is a rapidly growing market. Tailings disposal is a major concern for most mining applications and requirements are becoming more difficult with water management constraints, hence the move towards thickened tailings – both thicker slurries and pastes.

In commodity terms, the main markets for slurry

pumps include alumina/bauxite, oil sands, coal, iron ore, copper, gold, nickel, phosphates, potash and other industrial minerals.

WHAT IS SLURRY?

The definition of slurry itself is often given as the American National Standards Institute ANSI/HI Standard 12.1-12.6, which is part of the 2005 Rotodynamic (Centrifugal) Slurry Pump Standard. It defines the terms as follows: "Slurry is a mixture of solids (specific gravity greater than 1) in a liquid carrier, usually water. It is often used as a means to transport solids. Slurries also occur when solids are present as an incidental part of the process. The properties of the solids and liquid, as well as the amount of solids, are variable. The solids may vary from a few micrometers, often referred to as microns, up to hundreds of millimetres, and the solids may settle below a certain transport velocity. The properties of slurry, therefore, are highly variable. Slurry may behave like a Newtonian or non-Newtonian fluid. It may be abrasive and/or corrosive, depending on the composition. Slurry pumps are usually employed to move slurries with solids concentrations between 2% and 50% by volume, and specific gravities of the slurry up to 5.3."

The point at which slurry becomes a 'paste' is hard to determine in terms of pump performance. Mr Crawford explains: "The only way to define these criteria is by trial, to find the limit of a centrifugal pump's capability of pumping a particular product, as there is no specific criteria in which one can define this transition. A rule of thumb is: if slurry flows under gravity into the suction of a centrifugal slurry pump it can be pumped."

GIW centrifugal pump, Alberta oil sands



→ Dr Aleks Roudnev, manager, R&D – applied hydraulics at Weir Minerals North America, says: "Pastes are non-Newtonian, and in many cases Bingham Plastic slurries with a yield stress which must be overcome in order to flow."

Aker Wirth area sales manager Paul Geraedts says: "As soon as you are talking about a weight percentage of solids you can talk, in our view, about slurry. Mine dewatering with solids-weight percentages of approximately 2-10% are handled with slurry pumps and are already viewed as slurry duties. The typical solids concentration by weight for slurries and paste being handled by our piston and piston diaphragm pumps would be in a range up to 75%."

He continues: "The difference between a slurry and a paste cannot be related to solids content or viscosity. This is based on the fact that viscosity and yield stress or rheology depends, at a fixed concentration by weight, on grain size, mineralogy and surface chemistry. Slurries are further typically subdivided according to the extent of thickening into low, medium, high and possibly very high density slurry. The term 'paste' is, in general, applied to ultra-high density, thickened slurry. To generate a paste-type material you require sufficient fines, typically a minimum of 20% by weight <20-45 micron."

PUMP TYPES

Slurry pumping therefore encompasses a vast range of handling applications. It is distinct from waste-water pumping and dewatering up to the point where the solids content increases to a degree where the material can be defined as slurry, so in the lower solids area there is some overlap.

Most of the major suppliers of dewatering pumps therefore also offer slurry-pump solutions. Sweden's Grindex, for example, is known for its INOX and other dewatering pumps, but has supplied the Bravo range of slurry pumps since 2004. The next generation of the Bravo products is due to be launched at the Bauma show in April.

Likewise, ITT Flygt supplies the 5100/5150 and 5500 slurry pumps, but also offers a wide range of dewatering products. The Bravo and ITT 5100/5150/5500 are all electric, submersible pumps with agitators that can handle elevated levels of solids, but are not aimed at the most severe slurry applications.

Godwin Pumps is primarily a dewatering player, but has supplied its electric-drive HL160M pump to move mine water laden with coal fines and sand from underground to a frac tank.

However, the principal pumps for very heavy-duty slurry applications in mining are centrifugal pumps and several types of positive displacement pumps, including piston, piston diaphragm and hose diaphragm pumps, although the latter group of products also extends into the paste market.



Dr Roudnev at Weir Minerals North America tells *Mining Magazine*: "In general terms, centrifugal pumps are best suited for high-volume flow, lower head applications, although they may be staged to increase overall head, and for handling slurries with large size particles. Positive-displacement [PD] pumps are best suited for low-volume flow, high head applications. PD pumps are typically used with centrifugal pumps as boosters. When handling viscous slurries, especially pastes, centrifugal pumps are best suited for lower density, lower yield stress, lower viscosity applications and shorter distance transfers. Positive-displacement pumps are best suited to higher density, higher yield stress, higher viscosity applications and long-distance transfers."

Positive-displacement pump installations typically require higher capital investment up front and therefore are a better fit for long-term projects where higher efficiency savings can be fully realised. Crankshaft-driven piston and piston-diaphragm pumps are limited in their ability to handle high and very high density slurry, and paste-type material based on the self-acting valves used in the pump design. A rule of thumb would be a maximum of 200Pa yield stress at a 0.2Pa s (plastic viscosity). Above these values, the use of a hydraulic-driven piston pump is required.

Some of the main centrifugal products are supplied by Metso, GIW, Weir Minerals and FLSmidth Krebs, all of whose product ranges are covered in more detail below. Additionally, ITT Flygt owns

Goulds Pumps, which supplies the

Goulds 5500, a hard-metal, centrifugal product, aimed at the most abrasive slurries, and the SRL series of rubber-lined centrifugal pumps, designed specifically for handling abrasive and corrosive slurries. Sulzer is also a major supplier of centrifugal-pump solutions.

For centrifugal slurry pumps specifically, there are two main types of construction. One type, referred to as a lined pump, consists of an outer ductile-iron casing with internal, wear-resistant liners of either elastomer or white iron. The outer

ductile-iron casing supports the internal pump-pressure loads, as well as piping loads. Even with fully-worn internal liners the pump retains its original pressure rating and load-bearing capacity.

The second type, referred to as an unlined pump, has a single walled casing made from wear-resistant white iron, which is typically a chrome or nickel alloy. The wall thickness of the casing decreases throughout the service life of the pump, so its ability to withstand both internal pressure loads and impacts and external pipe loads also decreases. The hard, erosion-resistant white irons have a very low fracture toughness compared to ductile iron. Consequently, as the casing thickness is reduced with wear, the risk of failure due to impact or pressure loads increases.

Dr Roudnev comments: "Lined slurry pumps with either elastomer or hard-metal liners contained in an

CIDRA – SLURRY FLOW ANALYSIS

CIDRA's SONARtrac flow technology is a new class of industrial flowmeter, and uses measurement principles distinct from other flowmeter technologies operating in the mining industry.

SONARtrac non-intrusive flow-monitoring systems do not make contact with the liquid or slurry, and can be removed and reinstalled without process interruption.

For monitoring bauxite slurry flow, CIDRA Minerals Processing, together with Krohne Australia, recently announced the successful completion of a trial at BHP Billiton's Worsley Alumina Refinery, one of the world's largest and most efficient alumina refineries.



CIDRA slurry flowmeter, Worsley Alumina

The trial was conducted by Worsley's Engineering Tech team, who chose CIDRA's SONARtrac flow-monitoring system to measure the bauxite slurry flow and entrained air in a classifier feed line.

According to CIDRA, the accuracy and repeatability of the SONARtrac system has enabled the team to optimise the grind strategy to maintain linearity between the circulating load and mill feed. This refined grind strategy ensures an optimal feed rate to maximise throughput while avoiding mill overload.

Achieving a high level of process control without significant human labour requires instrumentation that is precise, reliable and robust. CIDRA states that its SONARtrac systems were chosen because of the non-intrusive, volumetric flow technology that is immune to scaling effects, and eliminates human interaction in potentially dangerous liquor and slurry applications. Krohne Australia is CIDRA's exclusive representative in Australia, supported by CIDRA's headquarters in the US.

CIDRA has also been awarded, through Bechtel Chile, an additional contract to supply SONARtrac process-monitoring systems to Minera Los Pelambres in Chile, the world's fifth-largest copper mine. CIDRA has been involved in all phases of the expansion project at Los Pelambres, and will now be providing critical-flow measurements on tailings lines within the Mauro tailings dam, and also on critical slurry lines within the concentrator plant.

→ outer ductile-iron or steel casing are the preferred option for multi-stage or high-pressure pipeline applications to reduce the risk of catastrophic casing failures. A lined slurry-pump design is also preferred in process-critical applications where impact damage from mill balls or other large objects is possible. Centrifugal slurry pumps of lined construction represent a large portion of Weir Minerals' product offering."

DESIGN CHALLENGES

In general, slurry pumps are usually designed for specific applications. When this involves transporting large solids in a high concentration, component wear can be a major factor, and must be considered in the selection of the pump and configuration of the pump installation. Abrasive properties of solids directly relate to the pump's ability to maintain sufficient pressure as centrifugal-pump impeller and casing wear increases with length of time in operation. Slurries may also be corrosive in their chemical composition, which creates an 'erosion-corrosion' wear condition. This can be much more aggressive than either erosion or corrosion acting separately.

Graeme Addie, consultant at GIW Industries, comments: "There are many challenges. Wear costs can approach half the total operating cost in the case of high solids concentration, large-sized solids transportation cases, so abrasivity is important. Solids size increases wear dramatically and, of course, a



Metso Orion model heavy-duty, hard-metal slurry pump

pump must be able to pass the largest solids. The materials of construction must also provide a economic life for the parts. This is a major challenge in always trying to provide the most cost-competitive materials. Slurry pumps typically use wet end materials that might cost twice what a cast-iron pump might be, but give six times the life."

Mr Schittler at Metso says: "Every application has its unique challenges. From low-suction pressure conditions, which may create net-positive suction head [NPSH] problems, to high-discharge head

applications that may require series pumping to reduce pump speed and minimise wear, it is important to select the proper pump for the application. Sometimes the biggest challenge is getting accurate information related to the application. Everything in the system is important, from the supply-tank configuration to the end of the discharge pipe, to have a successful pump installation."

Mr Crawford at FLSmidth Krebs echoes this: "The challenge is how to achieve the lowest total ownership and operating costs for transported solids. Many questions need to be answered to ensure optimal selection of the pump, such whether there is a standby pump installed and if there is a variable frequency drive. For mill-discharge pumps with no standby pump, the mill maintenance schedule needs to be known. Accuracy of slurry and system data is also very important."

He continues: "The risks involved are minimised when there is close co-operation between the pump supplier, engineering house and end user. Each of the following aspects must be evaluated for each individual application to ensure consistence hydraulic performance throughout the pump wear life: individual wet-end component life; efficiency; and maintenance of cyclone-feed pressure."

As in all areas of equipment, customers are driven by capital-cost reduction and, in pump terms, want to do more with less; for example, preferring to use one pump on high-head applications where two



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pumps in series might be a better solution. Or, the customer may seek to bunch all the pumps at the beginning of a tailings line instead of having several pump locations along the pipeline. Again, reduction in capital cost is the driver, but this requires higher pressure readings for the slurry pumps.

MANUFACTURERS

The following outlines some of the products and technologies from six suppliers of pumps, which can be used in slurry transport applications in mining and mineral processing.

FLSMIDTH KREBS

FLSmidth Minerals division, FLSmidth Krebs, makes a range of centrifugal slurry pumps under the flagship millMAX brand: hard-metal pumps suited for mill discharge under the slurryMAX brand; the gravelMAX line of severe duty rubber-lined pumps; and the vMAX range of pumps for dredging and large-particle pumping. Finally, the firm offers vertical, cantilevered shaft pumps, which are designed for floor sump and other vertical applications. This range covers the needs of virtually all slurry-pumping applications.

The Krebs millMAX pump is available in discharge sizes of 75-650mm, providing a wide range of capacities and wet-end conversions. The primary applications for the Krebs millMAX pump are mill discharge, crusher slurry or any coarse solids or other severe, abrasive slurries – especially in copper, gold,

“The risks involved are minimised when there is close co-operation between the pump supplier, engineering house and user”

lead-zinc, coal or phosphate plants. The most dramatic savings will be in these applications, although savings can also be realised for fine solids such as iron ore or kaolin.

Advantages of the millMAX pump range include the fact that the horizontal pump range incorporates a unique, patented sealing feature that drastically reduces the suction side recirculation. This feature reduces wear on the suction side of the liner, and reduces energy loss caused by the grinding of solids between the impeller and the suction liner. It also reduces energy loss by restricting recirculation from the high-pressure area to the impeller eye. Overall, the sealing maintains suction capabilities and efficiency on the pumps.

GIW INDUSTRIES

All of the GIW centrifugal pump products are designed for pumping slurries. GIW pumps are generally designed for the toughest service such as oil sands



A standard Aker Wirth design piston diaphragm pump for a tailings application in Peru

hydro-transport, phosphate matrix and hard rock. The firm is also very competitive when the pumps are bigger because of its large foundry capability.

Oil sands is a very tough market, but one where GIW has a strong presence; the other main player being Weir Minerals. The main pipelines are some 26-28in in diameter and transport about 8,000t/h of oil sands as dry solids. The pumps involved are very →



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→ large and arranged in trains along the pipeline, and there can be four, five, six or even seven of them, depending on the distance to the plant. There have even been cases where the pipeline has been built to longer distance than necessary to allow extra mixing. The pressure rating of the pumps is about 750psi.

The GIW ranges used in mining include the LCC-M slurry pump series, which is a hard-metal, horizontal, end-suction, centrifugal slurry pump. The hydraulic wet end consists of three components – a shell or casing, an impeller that screws on to the shaft, and a suction plate/liner to permit easy assembly and disassembly for maintenance and inspection.

The LCC-R slurry pumps are the corresponding, rubber-lined series, and feature a split-casing design with moulded, replaceable rubber liners. The moulded liner may be specified in a variety of natural and synthetic rubbers. Additional, rubber-lined pumps are in the LSR range, designed for hard-wearing applications. Operating flows can exceed 9,000m³/h.

The products for the most severe applications are the LSA-S slurry pumps, designed for operating flows of 20m³/h to over 14,000m³/h. These high-performance, low-maintenance slurry pumps are applied primarily in ore transport, mill discharge, cyclone feed, tailings and plant processing.

WEIR MINERALS

Weir offers centrifugal and positive displacement solutions. Warman is the world's most comprehensive range of centrifugal slurry pumps for use in mining, chemical and industrial applications. The horizontal and vertical slurry pumps are designed for ultra heavy-duty applications such as mill discharge, process plant and tailings, pipelines and specialty applications. The Warman range also includes axial flow pumps for applications in the salt industry.

GEHO pumps are world market and technological leaders in the design and manufacture of piston, piston-diaphragm and hose-diaphragm pumps for slurry, sludge and paste applications. The pumps handle a range of applications such as long-distance slurry pipeline transport, mine dewatering and backfill, autoclave, reactor and digester feed, gasifier feed and high-density tailings disposal.

Weir states that it has an ongoing commitment to improving the wear life of its products. This includes the optimisation of pump hydraulics using CFD modelling/wear testing, as well as the development of erosion-resistant proprietary hard metals and advanced elastomers for wetted parts.

METSO

Metso slurry pumps are commonly known by their traditional names of the Sala series, Orion series and Thomas series. Metso states that it separates slurries into two classes when related to pumping: settling and non-settling (viscous) slurries. Non-settling slurries are a mixture of liquid and solids that are smaller than 0.04mm (385 mesh). Settling slurries are a mixture of liquid and solids that are larger than this.

Mr Schittler comments: "Metso primarily supplies centrifugal pumps for these types of slurry applications. These generally are the most economical



ITT slurry pump agitator

type of slurry-transport pump and the mining industry is very comfortable with this technology. It is important in viscous slurry applications to confirm that the material will flow into the inlet of the impeller. If the material will flow into the impeller, a centrifugal pump should perform satisfactorily for the application."

The firm's centrifugal pumps fall into a wide range of slurry-transport situations, but also have niche markets. Since Metso offers both horizontal and vertical pumps in a wide range of impeller configurations with both high-chrome metal and elastomer materials, they are applied to mineral processing and aggregate applications from mill discharge through the entire concentration process to tailings pumping. Specialty pumps such as tank and froth pumps are used for applications requiring special technology to move air-entrained slurry. Metso says its products also handle many dredge applications with the Thomas series of centrifugal horizontal pumps.

Metso states that it was the first slurry-pump manufacturer to offer the double-adjust feature to alter the clearance on both the suction and glance side of the impeller in its Orion series of

horizontal pumps. Other companies have since developed their own version of this feature, which extends the life of wet-end components and maintains the highest efficiency in operation.

The Sala series of vertical sump pumps offers the widest range of wet-end configurations and materials in the industry to maintain its position as global leader in vertical, cantilever sump-pump installations.

AKER WIRTH

Aker Wirth specialises in the supply of piston and piston-diaphragm slurry pumps for a range of mining and industrial markets. One area where its products lead the market is in the supply of pumps for high-temperature nickel slurry transport (up to 220°C) for autoclave feed applications.

"It is important in viscous slurry applications to confirm that the material will flow into the inlet of the impeller. If the material will flow into the impeller, a centrifugal pump should perform satisfactorily for the application"

A general advantage of crankshaft-driven piston and piston-diaphragm pumps versus centrifugal pumps is the higher pump efficiency (reduced power costs), which is also constant and does not have to be corrected based on slurry properties. Additionally, the maintenance costs for the Aker Wirth piston diaphragm pump are limited to the pump valves, resulting in lower overall operating costs.

Centrifugal-pump limitations for specific nickel applications include their lower resistance to the high temperatures and pressures (typically 4-7MPa) involved. Based on the high slurry temperatures up to 220°C and the use of a diaphragm in the standard Aker Wirth pump design, the company uses a dropleg (cooling leg) construction to cool down the slurry in direct contact with the diaphragm to a suitable temperature for the latter. This has to be done without influencing the actual slurry temperature in the system.

Based on the slurry properties (temperature, pH and acid concentration), the use of special materials such as titanium and super-duplex stainless steel is also required for the pump liquid end, which is in direct contact with the slurry. All of this has to be handled within an acceptable wear rate for the pump valves and high overall pump availability of 98% or more.

Three of the company's main pump



ITT Flygt 5100/5150 series slurry pumps



VF 125 peristaltic pump at Anglo Platinum

→ deliveries for nickel slurry were to Goro, Cawse and Ramu. At Goro, the pumps have been operating since the start of this year with the full satisfaction of the customer. Cawse, owned by Norilsk, is currently on indefinite care and maintenance, while two out of six Ramu pumps have been installed and are awaiting final commissioning.

In March 2008, Aker Wirth signed an order with China ENFI Engineering Corp for the delivery of six diaphragm pumps for the Ramu Project in Papua New Guinea. These are triplex diaphragm pumps of type TPM 2200 HS with a cooling leg. The pumps are being used for high-pressure acid-leaching autoclave feed.

Each pump can handle a maximum flow rate of 400 m³/h against a discharge pressure of 5.27MPa. The slurry temperature is as high as 210°C, with the pumps driven by 800kW electric motors with variable-frequency drives. Two pumps parallel feed one of the three autoclaves. Under normal circumstances each pump is operating at 50% of the flow rate of one autoclave, which is also only at 50% of the pump design speed (stroke rate). Only when one pump is down for maintenance will the other be sped up to full capacity at 100% of the pump design speed.

Due to the high temperature of the slurry, it is necessary to equip the pumps with cooling legs. The cooled slurry oscillates in the cooling legs where it is cooled to 80°C to protect the pump diaphragm and operate at a convenient temperature range.

The suction and discharge valve housings, where the heated, 210°C slurry enters, are located away from the pump diaphragms. The main slurry stream is therefore not cooled down and is pumped at the original 210°C temperature into the autoclave. All of the parts in contact with the 210°C slurry are made of titanium, while those in contact with the cooled slurry of 80°C are of super-duplex steel.

VERDERFLEX

Verderflex offers a peristaltic pump range with hose diameters of 5-125mm. Typical mining applications in which they are used include dosing process reagents,

“CiDRA states that its SONARtrac systems were chosen because of the non-intrusive, volumetric flow technology that is immune to scaling effects”

coagulants and flocculants. Process reagents, such as cyanides and acids, are often highly corrosive, but as the chemically-resistive hose of the Verderflex peristaltic pump is the only part in contact with the pumped product, no working parts are exposed to the chemical.

One application in which these pumps have been used is for platinum slurry transport at an Anglo Platinum operation. Three VF125 pumps are being used. An offloading pump transfers slurry concentrate from trucks into a tank – previously this had taken 1hr, 45min to complete, but with the VF125 this has been reduced to 20min. A conditioner pump operates for 10h/d and provides circulation in the process to keep the slurry in suspension, ensuring no sediment can settle. Finally, a transfer-pump takes the (SG 1.7) slurry over a distance of 600m to the filter plant. The pumps are limited to 50m³/h.

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