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Mining Mill Braking Technologies

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Mining Mill Braking Technologies

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Figure 1: Sossego 38' x 23' Long SAG Mill

Figure 2: Sossego Mill Braking System

Introduction

Since the early 1990's grinding mills have become larger to offer greater economy of scale with increased throughput. It is not unusual to find SAG mills up to 40 feet in diameter and Ball mills of 26 feet. Motor power is ever increasing with current designs producing upwards of 20MW. For these large drives the solution has been to introduce low speed ring motors "wrapped" around one end of the mill.

Such designs however, whilst giving great flexibility in the control and drive system, do limit the options for safety and static control in the event of total power failure for example. The only option has been to consider fitting a braking system around the opposite end of the mill.

The brakes can be used to stop a mill from full speed in just a few seconds, to protect the bearings, or simply to support the offset weight of the charge following a crash stop. In all cases such brakes offer complete control of the static holding of the mill, even at holding angles of up to 40 degrees. These requirements demand a static torque of many million Newton-meters. The largest systems installed can produce a static torque of 24 million Nm.

The normal control modes for a mill achieve these functions electrically using the flexibility and power of the motor. The braking system can be used in conjunction with the motor but does offer a back up safe mode in the event of power fail.

This article reviews the design and benefits of a new brake system designed to meet these exacting requirements and in particular shows the first system installed in CVRD's open pit copper mine, Sossego, located in the Carajas region of Brazil (Figure 1).

System Description

A typical braking system consists of one or more brake calipers, mounted onto two pedestals, one each side of the mill, symmetrical about the horizontal mill centerline.

Brake operation is controlled by a hydraulic power pack designed to meet each individual application. This unit offers an advanced and flexible means of brake control and monitoring, providing both local and remote operation for inching and creep modes of mill control, interfaced through the main plc.

Brake Pedestals

Figure 2 shows one of the two pedestals installed at Sossego, in this instance with two calipers installed. The pedestals are manufactured from 100mm plate and incorporate full hydraulic and electrical wiring and monitoring.

Isolation valves are provided for the complete pedestal and for each individual caliper. This enables one unit to be isolated and removed for maintenance purposes. The system can continue to operate, albeit at reduced capacity and performance with one unit isolated.

Other features include a pressure filter and a pressure transmitter to eliminate contamination from the pipes and to provide complete monitoring of the operation of the unit.

For example when the brake is operated a loss of pressure at the pedestal would indicate a failed pipe or leaking joint in the system.

Brake Caliper

The VMS-DP brake caliper (see Figure 3) weighs 1850kg and is capable of producing a braking force of 737kN each (940kN clamping force). It is a spring applied, hydraulically released unit which requires the mill flange (braking surface) to be at least 7.6m diameter with a path at least 300mm wide.

The active part of the caliper consists of two spring packs, pistons and pads installed into a common housing. The spring modules are bolted to a reactive back plate the assembly of which allows the unit to “float” with an axial free play of +/- 10mm from the nominal center. This allows the brake to adjust its position as the mill moves due to thermal and other load cases.

The “float” is facilitated by slide bars clamped between two supporting brackets and this feature incorporates bearing supports in a cast boss integral with the reactive backplate (see Figure 4).

As seen in Figure 2 & 3 the two supporting brackets are mounted symmetrically on either side of the pedestal. In this way the braking force generated by the brakes acts along the web of the pedestal. This prevents bending and distortion to guarantee alignment of the pads to the flange of the mill as the brake is operated.

The VMS-DP caliper has been designed to provide a range of braking forces which are controlled by a combination of the air gap setting and thickness of the shim pack fitted. The brake rating can be varied by removing / adding shims in the spring module or by using the hydraulic back pressure during braking (see Table).

Shim Pack Thk. (mm)	Disc / Pad Air Gap (mm)	Braking Force (kN)	Hyd. Pressure Full Retraction (bar)
0	2	590	169
1	2	639	181
2	2	688	192
3	2	737	204

Changing the shims can be carried out in place without removing the brake calipers to adjust the force more precisely to exact site conditions. Increasing the number of shims will increase the precompression of the spring pack, which in turn will reduce the operating fatigue life of the springs.

The fatigue life ranges from > 1 x 105 to < 2 x 104 cycles for a 2mm pad air gap depending on the shim pack setting (see Figure 5). The total (maximum) thickness of shims, which can be fitted to the VMS-DP caliper, is 3mm.

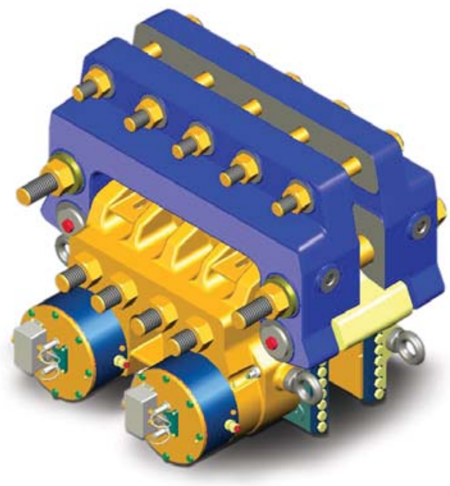


Figure 3: VMS-DP Modular Floating Disc Brake Caliper

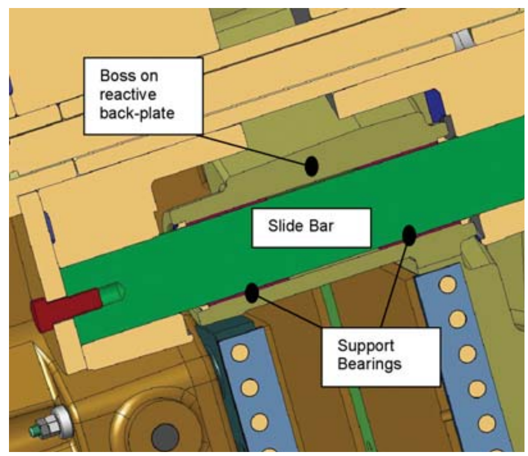


Figure 4: VMS-DP Floating Design Feature

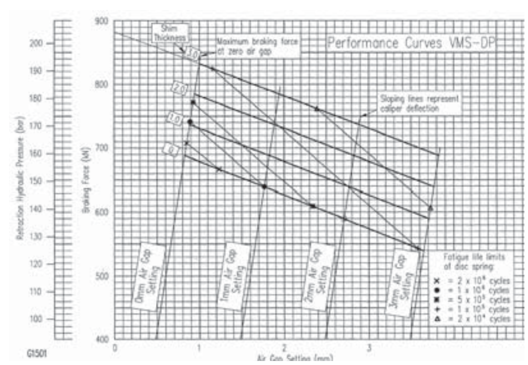


Figure 5: Performance Data

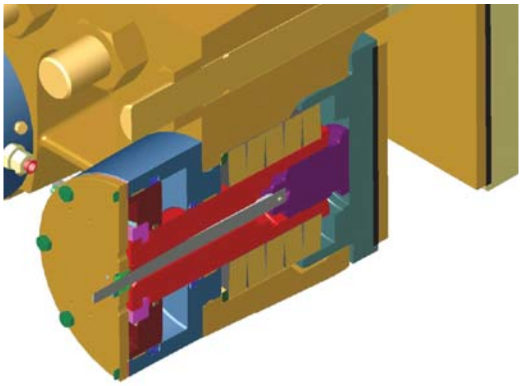
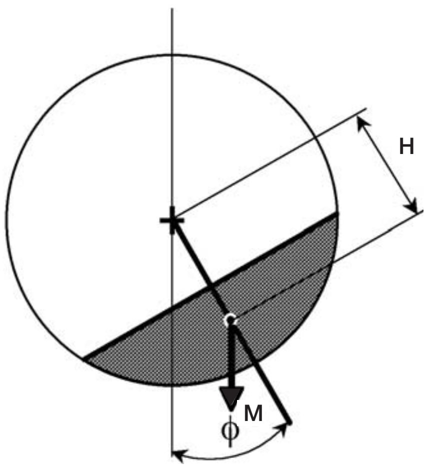


Figure 6: VMS-DP Spring Module (cutaway view)

Figure 7: VMS-DP Caliper Assembly (showing spring module)



Charge Mass M
Charge Angle Ø
Center of Gravity of charge from mill center line H

The out-of-balance torque is therefore given by:
Toob = M . g . H . sin Ø

Based on the following typical data

Mill Charge Mass M = 1100000 kg
Center of mass H = 3.1m
Flange (disc) diameter 12m

The clamping force is applied by two pistons. Each piston comprises a pressure plate operated by a disc spring pack housed in the spring module. When the friction pad is in contact with the brake disc, the module moves back bringing with it the 'reactive' backplate (see Figure 6).

Retraction of the brake is achieved by the application of hydraulic pressure to both cylinders, moving the pistons, which compress the spring packs and bring the friction pads away from the disc/mill flange.

More details of the caliper active half and reactive back-plate are shown in Figures 7 & 8.

The VMS-DP caliper has a special operational feature termed the 'parked-off 'position. This is made possible by having a piston stroke long enough to ensure that no internal spring loads exist with the following advantages:

(i) The caliper can be installed without the need for hydraulic pressure.
(ii) The friction pads can be changed in complete safety without fitting the retraction tool and with the hydraulics at zero pressure.
(iii) The spring module, including spring pack, can be safely and easily disassembled and reassembled without the need for special tools.

Each caliper comprises a total of four friction pad assemblies, one fitted to each pressure plate in the spring module and two fitted directly opposite on the reactive backplate.

All calipers are supplied with inductive proximity sensors, which are used to measure the brake status and provide a signal to the main PLC.

Each brake cylinder incorporates one off normally open sensor for brake retraction and one off normally closed sensor for brake applied. (see Figure 7).

The number of brake calipers needed for any particular installation depends on the mass of the charge and specified holding angle.

Based on the selected quantity the stopping time for the mill can also be calculated.

Brake Selection

The number of brake calipers needed to hold at any angle can be calculated. These results are shown in Figure 9 based on the maximum rating for the VMS-DP caliper.

However, it is not possible to use a fractional quantity of calipers, so also shown is the same data using whole numbers of calipers.

This data does not include any service factor. It is not always possible to guarantee performance of a brake. The value of the friction coefficient depends on many factors. These include:

- Localized pressure caused by misalignment of the brakes to the disc. If the pads are not parallel to the disc then edge contact and local high pressure will result in a lower value of friction coefficient being achieved.
- Lack of bedding in of the pads. When new the pad will not sit evenly against the disc and will not entirely conform to the surface topography of the disc face. After dynamic use this will improve to give uniform consistent performance.

- Environmental conditions. During operation of the mill it is likely that dust and debris may collect on the surface of the flange. This will reduce the friction levels achieved. This will not affect the dynamic operation of the brake but can inhibit the static holding characteristics.
- Contamination. Not just dust but also in this case any leakage of oil onto the surface of the disc will of course reduce the friction levels. A service factor cannot truly overcome this affect, unless this is only a minor amount. If such contamination does occur then it will be necessary to clean the disc and also change the pads as the oil will be absorbed by the friction material.

The friction material for the VMS-DP has been specifically chosen to meet the emergency stopping duty and provides excellent friction and wear properties at high nominal pressure, although it will still be affected by the above conditions.

The material incorporates a blend of carefully selected non-asbestos friction modifying elements and a binder system giving a friction coefficient of 0.4 at 300°C.

Typically a service factor of 1.25 is used to account for potential variation following correct bedding in of the pads.

On this basis the number of calipers that would be required is shown in Figure 10.

Further recommendations would suggest that there should be an equal number of calipers at either side of the disc. This is to prevent any increase in loading of the main bearings of the mill.

From Figure 9 it is clear that the net bearing reaction force is given by: M.g - Tr + Tl

Where Tr is the braking force from the caliper on the right
Tl is the braking force on the left

Now, with equal numbers of calipers, Tr is equal to Tl with no net change to the bearing forces. In the orientation shown, with Tr > Tl there is actually a reduction.

However, with the opposite rotation of the mill the charge will be to the left of center with the sign of the braking forces reversed which will lead to an increase in the reaction force.

If equal numbers of calipers are used then the variation with required holding angle (including service factor) is shown in Figure 11.

Having determined the number of calipers required for static holding it is now possible to calculate the stopping time for the mill if the total inertia of the system is known.

It is important in these calculation to include all rotating components such as:

- Trunnions
- Feed Liners
- Ring Motor
- Heads
- Discharge Liners
- Shell
- Shell Liners
- Trommel

In addition, the charge mass itself will have a contribution to the rotating inertia.

The stopping time is simply given from Newton's Laws of motion. It is important to note these calculations should always take into account the instant when the brakes are applied.

For example, if the brakes are applied at full operational speed the out-of-balance of the charge mass produces a force that will assist the brakes. Indeed, for most normal instances the mill will come to rest within 1 – 2 seconds on its own without the assistance of the brakes.

Figure 8: VMS-DP Caliper Assembly (showing reactive backplate)

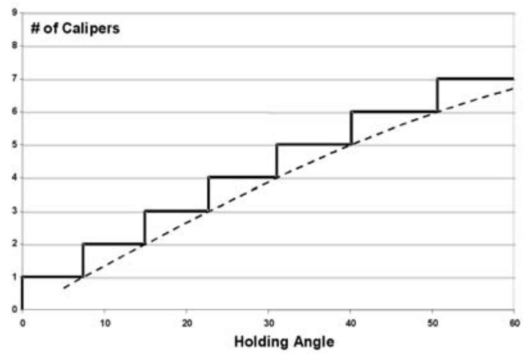


Figure 9: Number of Calipers Required

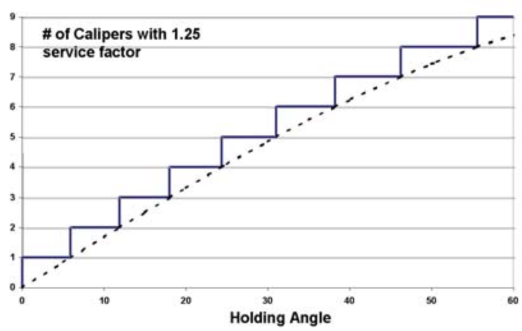
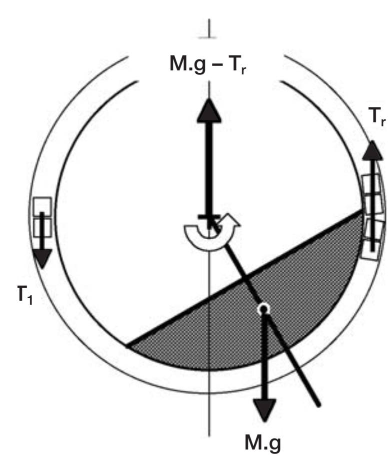


Figure 10: Number of Calipers Required with Service Factor



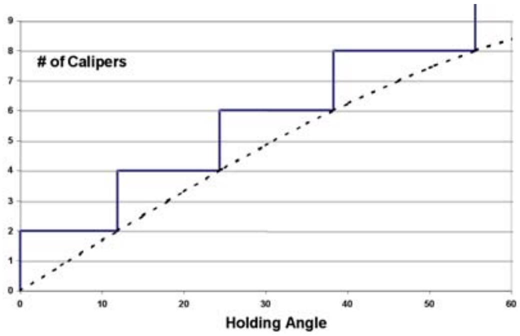


Figure 11: Equal Number of Calipers Required with Service Factor

Figure 12: Hydraulic Powerpack

However, if the mill has stopped and starts to move in the reverse direction then the charge mass will oppose the brakes. The brake torque available to stop the inertia will be the difference between the out-of-balance torque and the available braking torque.

Thus the deceleration will be reduced and the braking time extended. Of course, in this instance, the longer the stop, the more the mill will rotate away from its maximum angle of the charge with the out-of balance torque being lower. In this case the deceleration will increase during the stop.

If the stopping time is too severe adjustments can be made during initial set up using the hydraulic system.

Hydraulic Power Pack

The hydraulic power unit (see Figure 12) has been designed for:

(i) static mode to hold the mill during liner replacement and mill maintenance.

(ii) dynamic mode for controlled application of the brakes to stop the mill rotating at full speed (emergency stop) or quick application to accurately stop the mill during inching and creeping operations.

Power Pack Functionality (see Figure 13)

Brake Release – To release the brakes the NG16 spool valve, Item 1 is energized by an NG 6 pilot valve due to its size (i.e. less power required). Item 2 remains de-energized to close the return line to tank.

This allows flow from Accumulator Item 7, which can lift the brakes without the assistance of the electric motor. This means that a smaller lower power motor can be used.

When the pressure transmitter, Item 6 senses a pressure reduction then a signal is sent to the PLC which starts the motor / pump via the customers contactor to restore normal system pressure.

Normal Mode – In normal mode the mill is considered to be turning at full speed with a full process charge. A controlled stop is required. Item 1 is de-energized. The pressure immediately reduces to the setting of the relief valve Item 3, which is set to a back pressure that means the pads come into contact with the disc. Flow is then controlled by the flow control valve Item 5, which governs how fast the brakes are applied. The orifice Item 4 is an emergency feature and is incorporated as a backup in case Item 5 becomes clogged.

Inch Mode – In the inch mode the mill is considered to be turning at 10 percent of design rated speed with a full process charge.
In this mode quick braking is utilized, i.e., Item 2 is energized and Item 1 is de-energized. Flow then immediately returns to tank.

Creep Mode – In creep mode the mill is considered to be turning at 3 percent of design rated speed with full process charge.
In this mode quick braking is utilised using the same procedure as when in Inch Mode. The mill is assumed to be in an out of balance state with the brakes on. The requirement is for the mill to be lowered to a balanced position.

A ‘Manual Lowering’ push button supplied by the customer is pressed and the brakes are released with the push button to slowly lower the mill to equilibrium.

Manual Operation of Brakes Without Power – The brakes can be manually released without the need for electrical power using the hand pump.

Control Logic

Monitoring and feedback from a number of transducers and transmitters fitted to the system enable a comprehensive arrangement of control logic functions. These include:

- Maintain system pressure based on feedback from the pressure transmitter installed on the power pack
- Temperature transmitter to enable switching the heater to maintain fluid temperature
- Level switches to monitor the fill condition of the tank
- Filter blocked signals
- Brake release monitoring
  - If the control valve is operated then a brake release signal should be detected from all calipers (can be used in conjunction with brake isolation switch on each pedestal) – see Figure 14.
  - Should also detect the working pressure from the pressure transmitter on the brake pedestals – failure to do so would indicate a broken pipe or fitting.
  - Start up should only begin if the brakes are released.
- Brake On Monitoring
  - If the isolation switch on the pedestals is closed with the brake in the "on" position then start should be inhibited to prevent overheating the brake.

Note that the "on" switch is set with the piston fully forward and the "off" switch set with the piston at the fully retracted position. It is therefore possible that during operation of the brakes there cold be an instant when neither switch is functional, i.e. the brake is neither on or off while the piston is actually moving.

Conclusion

With over a dozen systems now installed around the world the new floating disc brake caliper has proved that modular braking on gearless drives is worth consideration when commissioning new grinding mill equipment.

The ease of maintenance and the simplicity of the system has shown that an operator experiences less downtime and therefore less cost.

The design of the caliper for example means that a spring module can be quickly replaced if necessary (site feedback suggests within 40 minutes) or worked on in place to replace the seals without having to remove the caliper assembly from the brake pedestal.

Consumable spares are readily available from the factory, although keeping spare seals, brake pads, valve coils and filters on site is recommended.

The brake pads are small enough (weighing only 8 Kg each) to carry by hand and install by simply sliding along the disc face into position.

Being predominantly a holding brake with very little dynamic duty the pad life is calculated as being in excess of five years based on an annual usage of 400 brake cycles per year.

Since the hydraulics are a sealed system, experience has shown that very little maintenance is required and any work is confined to just a change of filters and oil every year as a matter of caution.

As the trend towards bigger mills continue then the growth in modular braking systems will increase with the resulting improvements in plant efficiency and cost.

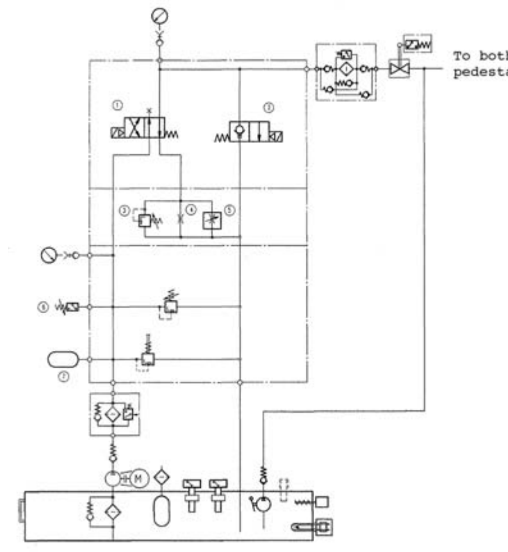


Figure 13: Hydraulic Circuit Diagram

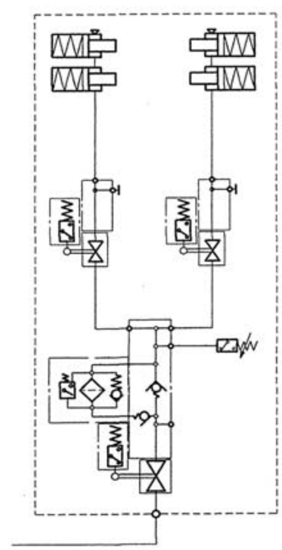


Figure 14: Hydraulic Circuit Diagram for each Pedestal

About Altra Industrial Motion

Altra Industrial Motion (NASDAQ:AIMC) is a leading multi-national designer, producer and marketer of a wide range of electromechanical power transmission products. The company brings together strong brands covering over 40 product lines with production facilities in nine countries.

Altra's leading brands include Boston Gear, Warner Electric, TB Wood's, Formsprag Clutch, Wichita Clutch, Industrial Clutch, Ameridrives Couplings, Kilian Manufacturing, Marland Clutch, Nuttall Gear, Bauer Gear Motor, Stieber Clutch, Twiflex Limited, Bibby Transmissions, Matrix International, Inertia Dynamics, Huco Dynatork, Ameridrives Power Transmission, Delroyd Worm Gear and Warner Linear. For information on any of these technology leaders, visit www.AltraMotion.com or call 815-389-3771.

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