Output
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Project Management – a matter of trust?

Author: Jonathan Trope

Project Management in the minerals processing industry has undergone a remarkable transformation over the past 15 – 20 years. This used to be the domain of engineering oriented professionals drawn from a multiplicity of backgrounds – fabrication shops, plant and process engineering, drawing and drafting departments, etc. The success or failure of a project was heavily dependent on the ability of these Project Managers to correctly select, inspect and deliver the goods on time and on budget. Moreover, there was a requirement to work closely with suppliers and customers and this was conventionally achieved through development of relationships within the entire supply chain.

Purchase orders contained a clear explanation of the supply scope, schedule, a brief specification, pricing data and some warranty definition. The level of trust between the parties made it unnecessary to generate reams of paperwork, although good quality documentary evidence has always been a prerequisite to enable the ultimate face-to-face negotiations to be concluded at the culmination of contracts.

Those days are gone……..

In the current environment, Project Management has undergone a metamorphosis, principally because the Industry has correctly reacted to the provision of substandard equipment, dishonouring of warranty requirements and presentation of unreasonable claims by a relatively small number of unscrupulous operators. It has sometimes become more of a paper war than a focussed approach on the procedural execution of a set of work instructions. The volume of correspondence that evolves during the execution of the project, not to mention the information in completed manufacturer's data reports, is testament to this fact. The current practice of generating specifications by the "cut and paste" method has also helped this "explosion". This has potentially serious project ramifications, as purchasing agents, who do not necessarily have the engineering skills to make an appropriate assessment of what is indeed relevant, can unwittingly generate conflicting information in two or more sets of specifications.

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Conformed documents, which fully and accurately define the negotiated scope, terms and conditions prior to order placement, are sometimes overlooked in the interests of maintaining the programme and this can later lead to disagreements about the agreed scope. It is not unusual, in the current fast-track environment, for contracts to be kicked off many weeks before the actual order document is placed in the hands of the technology or equipment supplier.

Due to the extent of liabilities in modern-day contracts, Project Managers on both the supplier and client side often require support from legal counsel. This has the roll-on effect of inviting responses in the same legalistic vein.

Thus it is apparent that there is a paradigm shift in the dynamic of handling projects. Project Managers have now become much less focussed on getting the job done and more so in keeping the documents flowing, an altogether unsatisfactory outcome. The “hands-on” aspect where the Project Manager spends time reviewing manufacturing quality, schedule and coordination is lost to third party inspectors and expeditors, most of whom have little real understanding of the whole picture. A significant part of the experience brought to the project falls away.

Is it possible in this litigious society to develop a methodology that will enable companies to align themselves more closely, limit the potential for price gouging, yet still achieve the desired outcome of a project completed on time and on budget? There is considerable benefit in jointly contemplating a model beneficial to all parties, while still minimising capital costs and maximising returns for all concerned.

The following briefly outlines some of the many models which exist - all of which have certain advantages and disadvantages.

1. The most basic of models is the Cost Plus approach, where project costs and subcontractor selection are visible to both parties, with the Contractor receiving an agreed mark-up percentage. If speed is essential, this relatively simple model is quickly and easily implemented. However, one of the downsides includes lack of protection from escalating sub-contractor prices (very topical in today’s mining boom). A certain level of trust is also a prerequisite, as the Customer must be confident the Contractor has found the optimal supplier and pricing.

2. The next level to the Cost Plus approach is the Cost Plus Guaranteed Maximum model. All the basic elements remain the same, however, a maximum fixed price is agreed from the outset, allowing the Customer to budget accordingly. Again, there is a risk of exposure to higher prices, although the exposure would be limited to the maximum price. Potentially, also, there would perhaps less ‘shopping around’ by the more unscrupulous Contractors.

3. In the Open/Closed Book model, the Customer has the benefit of complete cost transparency in the Contractor’s pricing structure and can negotiate on the forecast profit margin. Once the book is closed, the Contractor can negotiate with subcontractors and suppliers to increase his profits with the proviso that minimum specifications are adhered to. The Customer has the right to veto the final selection of subcontractors, if these differ from those utilised in the Open Book phase. This model provides the Customer with benefits similar to the traditional fixed price contract.

4. The Cost Plus with Incentives model can be added to all of the above methods. The Contractor receives an incentive for on-time completion or even an added bonus for early completion. While this appears to be an attractive option, if it is established early in the project that the “bonus” timing is unlikely to be achieved, the incentive (and commitment of the Contractor in some cases) disappears. To address this, a variation of this model which combines both an incentive for on-time/early completion and a disincentive for late completion can be employed. In the latter case, the Contractor is driven to maintain momentum, despite the fact that his labour costs may exceed his budget costs. Both options open the door to claims for time extensions by the Contractor to protect his position.

The current trend towards excessive definition, specification and litigation is unhealthy for the Industry. It sometimes results in the parties constructing an agreement which does not necessarily mean a project will run smoothly, on time and to budget. To overcome this, what is needed is a high degree of alignment between all parties and agreement on a sensible working model – ultimately, it's a matter of common sense and trust.

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Previous roles include executive management, sales and marketing, project management, belt and pressure filter development and engineering design. His experience and expertise includes effluent treatment, process development and construction of phosphoric acid, sulphuric acid, ammonia and urea plants. Industries where Jonathan has been involved include chemical, mining and minerals processing, water and wastewater treatment.

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Pulp Level Control in Flotation Circuits

Author: Otso Tiili

One of the most important control parameters in flotation processes is the froth bed depth of a flotation cell. Often it is used in parallel with the aeration rate to adjust the metallurgical recovery and the concentrate grade of the flotation unit. The adjustment of levels allows the operator or flotation control system to keep a flotation circuit in balance and in optimal metallurgical performance with changing feed grade.

The precision of the level control has a direct effect on the consistency of the metallurgical results. Due to the nonlinearity of the process, random variation in the froth bed thickness will result in a decreased metallurgical performance. In scavenger flotation systems with thin froths, the metallurgy is especially sensitive to the variation of a cell's pulp level.

Traditionally, standard feedback controllers manage the pulp levels in flotation cells. The level is affected by manipulating the outflow of the cell with a control valve. The control actions are typically calculated with a PI algorithm (Proportional, Integral) from the control error (setpoint – measurement value).

In general, the pulp level control task has two main characteristics that differentiate it from other typical flotation control tasks and make it significantly challenging. Let's first study this system theoretically.

The following equation represents the volumetric flow (Q) through a control valve

$$Q = C_v(x)\sqrt{\frac{\Delta p}{G}}$$

Where C_v is the valve characteristic curve as a function of the valve opening (x), Δp is the pressure difference over the valve and G is the specific gravity of flowing material.

If the concentrate flow is assumed to be zero, and the specific gravity is assumed to be constant, the generic dynamic model for the slurry volume in a cell with no incoming circulation flow can be written as follows:

$$\frac{dV_i(h_i)}{dt} = Q_{IN,i} - KC_{v,i}(x_i)\sqrt{h_i - h_{i+1} + h_{STEP}}$$

Where V_i is the slurry volume in a cell (number i), h is the slurry level, h_{STEP} the physical height difference between cells, K is a unit conversion constant and $Q_{IN,i}$ is the volumetric flow from the previous cell

All control valves have a slight nonlinear nature in their characteristic curve but, in addition to that, this dynamic system itself is nonlinear and interconnected with other controlled variables i.e. levels in other cells. These factors make this control task more challenging. As the PI controller is a linear controller, some difficulties are inevitable.

Furthermore, the interconnection between separate controls can be illustrated by replacing the volumetric inflow $Q_{IN,i}$ with the flow through the control valve of the previous cell.

$$\frac{dV_i(h_i)}{dt} = KC_{v,i-1}(x_{i-1})\sqrt{h_{i-1} - h_i + h_{STEP}} - KC_{v,i}(x_i)\sqrt{h_i - h_{i+1} + h_{STEP}}$$

The control actions in a previous cell (i-1) manipulate the valve (x_{i-1}) that causes variance to the inflow of cell i and therefore it can be considered as a source of disturbance for the level (h_i).

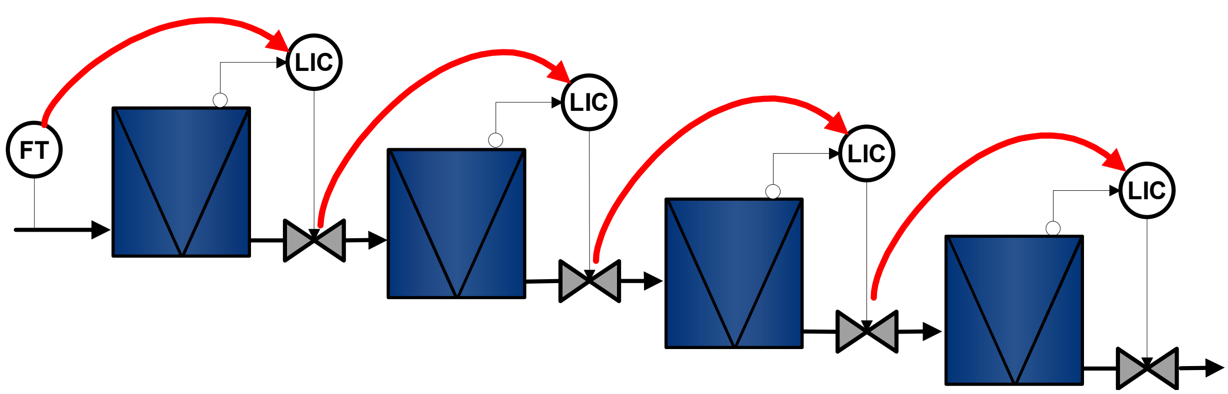
Due to this interconnection, the tuning of pulp level control loops becomes a trade-off. The loops cannot be tuned too fast otherwise there will be problems downstream but letting them react slowly causes poor response time and continuous fluctuation on levels.

The recent trend in flotation cell technology, i.e. the increased use of large cylindrical shaped cells, has improved the kinetics and the dynamics of the flotation phenomena and increased capacities of flotation circuits. However, from the pulp level control point of view, these cells have brought even higher requirements for the controller performance.

A well-tuned and well-maintained PI controller could previously manage pulp level control with reasonable performance, whereas nowadays attention must be paid to the whole package from the level transmitter to the control strategy itself.

Nowadays, the geometry of the cylindrical cell results in a smaller froth area to cell volume ratio. Together with the increased capacity, i.e. higher flow rates, this causes the cell level to be more sensitive to flow variations than in smaller cells. In addition, high flow rates demand large valves. This means that the valve actuator and positioner must be chosen carefully in order to obtain sufficient response time for the valve (time from fully open to fully closed).

To ensure an optimal performance of its TankCells®, Outokumpu Technology has developed an improved control strategy for pulp level controls (EXACT-level control). The basic idea is to monitor the whole flotation line and to react to all measurable disturbances before they affect the levels. The control system is implemented in a modular way; PI loops execute the basic feedback level control, and compensation algorithms make the additional adjustments to its control output.



All measured variables that are correlated to the cell feed flow are used as inputs to the control block. The inputs can be any of the following:

- Actual flow measurement
- Speed of a pump feeding the cell
- Position of the control valve in the previous cell

From the inputs, the algorithm calculates a compensation term that is added directly to the output of the PI loop. It causes the control valve actuator to move if, for instance, there is a change in the previous cell valve and to react to flow changes before they are felt in the level.

With compensation algorithms taking care of most of the flow fluctuations, the PI parameters can be selected for much faster response than with conventional PI control. This has the additional benefit of controlling performance.

The implementation of such a system is straightforward, as the principles remain the same in the system. However, some tailoring is needed due to different operation methodologies e.g. in the case of two slurry valves. Also process interlocks for compensation must be defined separately. An auto-tuning module has also been developed which statistically analyses the control signals and determines suitable tuning parameters.

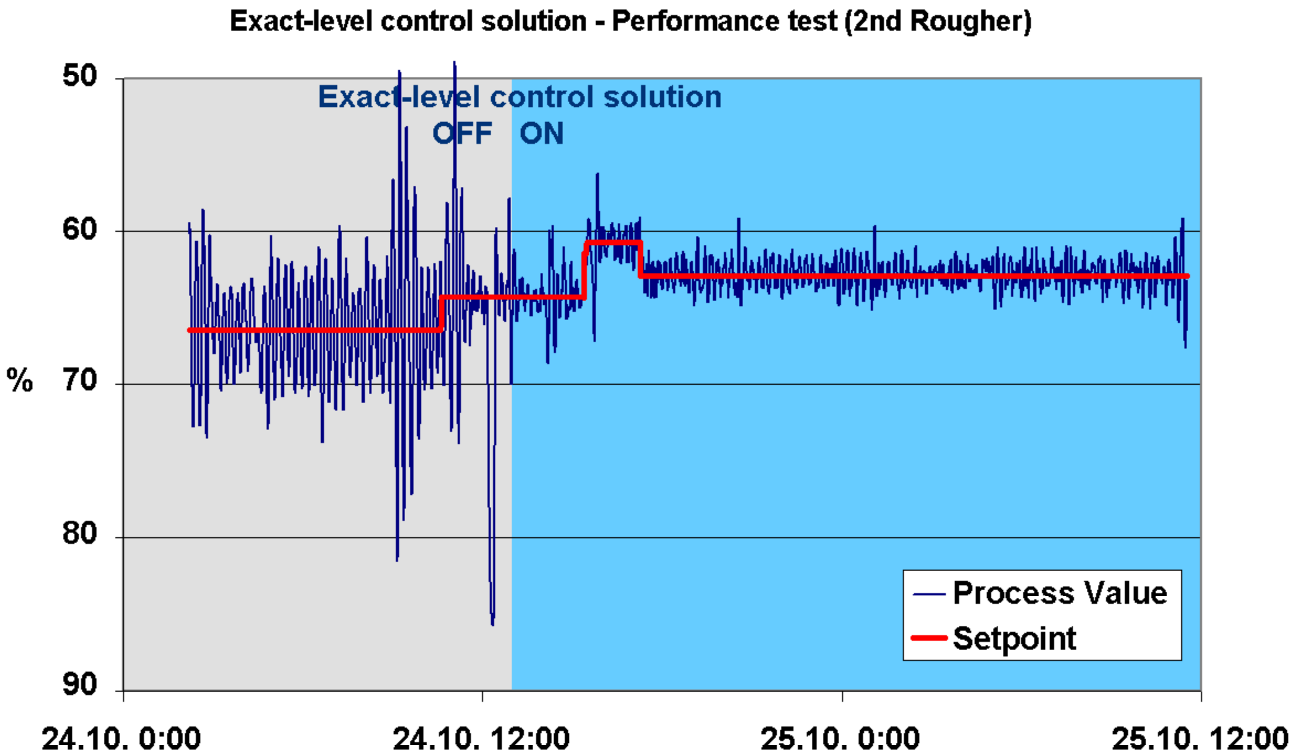
A train of large TankCell® -200 flotation units

This control strategy has been implemented in Russia, India and South Africa. The following example is from a Russian concentrator where the system was implemented in 2003. 24 TankCell®-130s are managed by this control strategy. The system has been running since start-up and several benefits were reported in performance tests. Better level control includes the following benefits:

- About 80% faster disturbance rejection
- More accurate control in normal operation conditions; at the first controller the average absolute control error was reduced ~25%, and in the other cells the reduction was about 60%
- Significantly reduced valve travel, resulting in less maintenance costs

It is also a well recognised and documented fact that better level control leads to less disturbance in the flotation process and flotation conditions are therefore consistent. This leads to optimised froth conditions which has a positive effect on recovery.

The figure below illustrates the difference in control accuracy when the compensation is operating compared to a situation where only conventional PI control is used (PI parameters remained unchanged)



Conclusion

Controlling larger flotation cells presents many challenges. Large flows, coupled with large valves, relatively thin froths, and potentially large flow disturbances, have made the control of pulp level in these cells more difficult. Traditional PI control of each cell or cell bank can now be augmented via a new level control system which incorporates all of the level signals in a cell row, as well as other inputs such as flow measurements and pump speeds.

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Optimising your SAG mill operation

Author: Sanjeeva Latchireddi

Nowadays, the more successful plants are those who have adopted effective and efficient strategies to optimise their plant operation. As the ‘heart of the plant’ could be viewed as the milling/grinding area, one of the key steps in plant optimisation is, therefore, ensuring the mill is operating properly. In the past, when primary, secondary and tertiary crushers fed material directly to large ball mills, the energy efficiency of the concentrator was determined for the most part by the ball mill operation, whereas now the energy efficiency of a plant often rests largely on the semiautogenous grinding (SAG) mill operation. As a result, mines have shifted their emphasis in optimization from ball mills to SAG mills.

The rock load in the mill essentially depends on ore characteristics and the discharge rate of broken particles through the discharge end. The discharge rate depends on how efficiently the discharge pump (grate and pulp lifters) operates. Similar to the impeller design affecting pump capacity, the pulp lifter design affects the discharge capacity (or mill throughput) of autogenous grinding (AG) and SAG grinding mills.

Generally, the discharge from AG/SAG mills consists of one or both of the following components: slurry (water and finer particles) and pebbles (20-100mm). The type of mill discharge and the associated problems in both single stage and multi-stage circuits(AG-Ball-Crusher (ABC) and SAG-Ball-Crusher (SABC)), are briefly summarized in the table below.

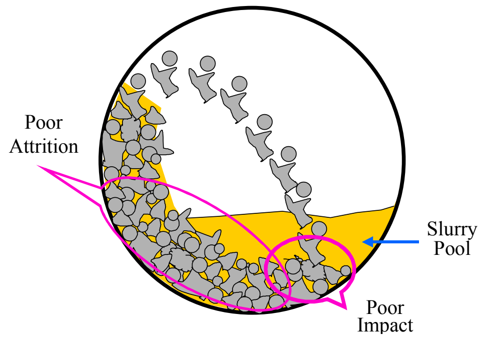
Circuit	Closed circuit with	Mill discharge	Problem
Single stage AG/SAG	Hydrocyclones/ Screens/Sieve-bends	Slurry	Slurry pooling
Multi-stage ABC/SABC	Pebble crusher/screens	Slurry and pebbles	Slurry and pebble pooling

Types of grinding circuits and discharge problems

Material transport problems in single stage AG/SAG circuits:

Single stage AG/SAG mills have to handle large amounts of slurry as they are generally in closed circuit with classifiers whose circulating loads reach as high as 400-500%. The geometry of radial and curved pulp lifters is such that the slurry, once passed through the grate into the pulp lifter, will always be in contact with the grate until it is completely discharged, which makes the 'flow-back' process inevitable. Slurry ‘carry-over’ is another problem which generally occurs at relatively higher mill speeds and/or with increasing slurry viscosity.

Though the impact of flow-back may be of lower magnitude in open circuit grinding, flow-back can make a significant impact when the mills are operated in closed circuit, especially with cyclones and fine screens. The field of breakage diminishes when excessive slurry is present in the mill. The inherent flow-back and carry-over problem associated with radial and curved pulp lifters leads to formation of a slurry pool, which absorbs a significant amount of impact energy instead of being used to cause impact breakage of particles. This inefficient usage of grinding energy reduces the grinding capacity.



Poor impact and poor attrition breakage due to slurry pooling.

Material transport problems in multi-stage ABC/SABC circuits with pebble crusher

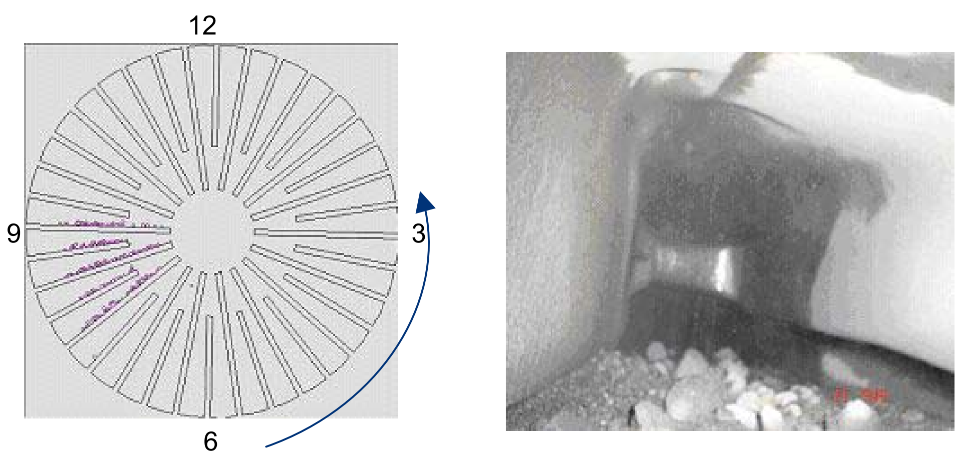
In multi-stage ABC/SABC circuits, the AG or SAG mills are in closed circuit with screens and pebble crushers. The mill discharge from these mills consists of slurry, which goes to the ball mills for further grinding, and coarse pebbles/rocks, which are crushed and sent back to the mill.

To maximize the capacity of these circuits, the general practice is to use grates with pebble ports (reaching 100mm) instead of normal grate openings to increase the pebble removal. In addition, operating mills at relatively higher speeds has become an option to increase mill capacity. The reasoning is because the higher the mill speed, the higher the number of impacts/collisions, which in turn is proportional to higher breakage of particles.

With the advent of simulation techniques such as discrete element modeling (DEM), appropriate shell lifters can be designed to operate mills at higher speeds. Shell lifters, an integral part of all grinding mills, are located in the main grinding chamber. However, the inefficiency of pulp lifters increases with mill speed and so does the effect of the following factors:

1. Pebbles carry-over

In ABC and SABC circuits, once the slurry and pebbles pass through the grate into the pulp lifters, the motion or flow behavior of solids will be different to the slurry. At the end of one revolution, all the pebbles are supposed to reach the discharge trunnion. However, a significant amount of pebbles are retained inside the pulp lifters. The problem of pebble carry-over is shown in the picture taken at "9 o'clock" position of a 36-ft diameter SAG mill which was crash stopped using the holding brakes. The DEM simulation on the left shows significant pebble carry-over at the "9 o'clock" position and the picture on the right confirms this.



Pebbles carry-over inside the pulp lifter a) DEM simulation and b) 36-ft SAG mill.

By the time a pulp lifter starts a new cycle from "6 o'clock", all the pebbles reach the bottom of the pulp lifter and occupy significant volume. The presence of these pebbles blocks the outer rows of grate slots and reduces the flow gradient across the grate. In order to maintain the same flow gradient, the load inside the mill increases and the mill draws more power. In turn, this leads to a higher rock to ball ratio, resulting in insufficient grinding energy and a further increase in load inside the mill.

2. Pebbles flow-back

Similar to slurry flow-back, the pebbles flowing back into the mill increase with larger pebble port or grate slot size. As the pebbles flow down and slide across the grate slots, they get an equal chance to go back into the mill. Similar to slurry pool formation, pebbles flow-back would increase the quantity of critical size material in the mill. The amount of pebbles passing through the grate increases with the angle of the grate.

Elimination of material transport problems

It is, therefore, imperative to ensure the efficient removal of both slurry and coarse pebbles (critical size) in order to ensure the efficient operation of AG/SAG mills. Elimination of the above mentioned material transport problems will allow the mill to respond truly in terms of power draw for changes in mill load which depends on feed ore characteristics.

Although curved pulp lifters partially solve the 'carry-over' problem, they cannot eliminate the 'flow-back' problem. This is because once the slurry/pebbles flow into the pulp lifter, they are always in contact with the grate until they are completely discharged out of the mill. However, the curved design necessitates redrilling of the mill head and also requires curved grates, which can be quite complicated compared to a simple radial design.

The best way to eliminate material problems is to use a grate, peripheral discharge trunnion supported mill or use a grate, open-ended discharge shell supported mill. Both these aforementioned mills do not require pulp lifters. The grate, peripheral discharge trunnion supported mill and the grate, open-ended discharge shell supported mill both have inherent structural limitations which makes their commercial application limited. The commercially viable and industry accepted alternate is a grate discharge trunnion supported mill or a grate discharge shell supported mill using pulp lifters. The only way to eliminate the problem of flow-back and carry-over of slurry and pebbles is by optimizing the design of the discharge arrangement.

Outokumpu Technology's patented new design – TPL™ (patent pending), is a result of these material transport problems. As the internal design of the TPL™ approximates a grate, peripheral discharge or a grate, open-ended discharge, it keeps the slurry/pebbles away from the grate once they enter the pulp lifter chamber, thus completely eliminating flow-back and carry-over problems. This efficient

TPL™ system on the left and old radial pulp lifters system on the right.

material transport ensures the best grinding conditions by allowing the particles to stay inside the mill long enough to be broken into sizes smaller than the grate. The TPL™ does not necessitate redrilling of the mill head for retrofitting. From the outside, the TPL™ appears exactly like the conventional radial pulp lifter.

Elimination of material transport problems using TPL™ will bring the following process benefits:

- Allows the mill to operate at maximum capacity
- Ensures good grinding conditions with lower grinding energy per ton
- Efficient operation even at higher mill speeds
- Operator-friendly smooth mill operation
- Significantly improves wear life
- Can be precisely designed to handle the given capacity
- Can be easily retro-fitted to existing mills

CONCLUSION

The optimal performance of AG/SAG mills is the key to successful plant operation. All AG/SAG mills using radial or curved pulp lifters suffer from inherent material transport problems such as slurry and pebble pooling, which decrease throughput and increase energy consumption. The Turbo Pulp Lifter (TPL™) completely eliminates slurry pooling and pebble pooling problems and ensures the best grinding conditions, thus allowing AG/SAG mills to operate at maximum possible capacity with lower energy consumption.

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