FOR VERTICAL ROLLER MILLS

by Matthias Authenieth, Thomas Hyttrek and Andreas Reintke, Loesche GmbH, Germany, and Steven McGarel, Senior Consultant, USA
LM-Master for VRMs

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VRMs have become the grinding circuit of choice in cement plants for raw meal, clinker and coal grinding due to their lower capital cost and energy consumption compared to ball mills. Loesche GmbH, Germany, has been a leading supplier of roller mills for over 100 years and in more recent times, has expanded by adding a subsidiary automation company for both hardware and software delivery and project management.

The latest addition to the automation software portfolio, which already includes mill simulator and SCADA solutions, is an advanced mill controller called LM-Master. This provides fully-automatic control and real-time optimisation of the mill process through precise control of mill behaviour according to defined objectives of throughput, energy efficiency and mill availability. The software platform is installed on a PC and interfaces with common PLC systems. With high controller availability the mill is continuously operated close to physical limits yet also with improved stability and reduced vibration levels, ensuring high mill efficiencies for low capital expenditure.

LM-Master mill optimiser

Loesche has unique knowledge of all aspects of roller mill design, operation and automation, allowing the development of detailed and accurate mill control models. These have been incorporated into an advanced control software platform which allows the mill control functionality to be configured and held in-house to protect proprietary knowledge and intellectual property.

The kiln is the equipment that demands the most attention from operators in a cement plant, hence mills are generally operated below optimum capacity to allow for some margin of error due to mill process variations, eg, from feed materials. The development of the LM-Master solution reverses this situation by monitoring and controlling more frequently than any operator and allows for operation at higher capacity and levels of stability than can be achieved by an operator alone (see Figure 1).

New-generation optimisers such as LM-Master use a dynamic model of the actual mill, resulting in improved regulatory control and set points closer to the physical limits of the process.

The control solution monitors multiple process variables and calculates new set points several times a minute to maintain mill performance at very high levels.

Operating at an economic optimum is a challenging control problem since this constantly varies. However, by specifying the overall – and competing – requirements for production rate, product consistency and energy consumption, the optimal combination of set points can be calculated on a high-frequency cycle to drive the process to the economic optimum continuously.

Reduction of vibration levels

Roller mills are constructed of major mechanical components that can be easily damaged by high mill vibrations. It is very important that a mill is operated in a stable manner and that corrective actions are taken to prevent damage to mechanical equipment and mill outages that result in lost production. Unfortunately, high-vibration scenarios arise very rapidly and a mill may trip before an operator even has time to assess the situation and take corrective action. LM-Master is valuable in these situations in that, not only does a mill operate at generally lower vibration levels under LM-Master control – reducing wear on gearboxes and other major components – but the continuous monitoring of the mill process allows for
timely, accurate and rapid control actions to address issues with high vibration and prevent mill trips.

Requirements of VRM operation
Safe, reliable and productive use of a mill plant requires consideration of the following:
• high production rates in the presence of potential limitations in:
  – mill table power
  – mill differential pressure via the mill fan
  – external recirculation system via bucket elevator or other conveyors
  – drying capacity via mill exit temperature control
• low product size variability:
  – balance throughput with stability of mill
  – adjust for changes in feed hardness to promote consistent grinding
• low specific power consumption:
  – reduce variability in the load parameters (mill table power, mill differential pressure, mill fan power)
  – reduce specific power (mill fan and mill table).

Control technology and structure
Traditional PID single input/single output control has some inherent disadvantages in that each loop operates where a single variable set point is compared to the controlled variable. Multiple PID loops are used on a mill circuit, yet these are connected as stand-alone loops with regulatory and operational safety as primary objective. Without coupling of the dynamic relationship between loops, holistic optimisation across the process is basically impossible. In practice, loops are de-tuned to maintain process stability and do not control the process very effectively. In VRMs in particular, highly-interactive variables and rapid process dynamics make PID control difficult while variations in the hardness of mill feed represent a major disturbance to the circuit.
New-generation optimisers such as LM-Master use a dynamic model of the actual mill, resulting in improved regulatory control and set points closer to the physical limits of the process.
The technology selected for the control solution is based on Model Predictive Control (MPC) which calculates the optimum combination of set points to meet multiple objectives of throughput, product quality and process limits simultaneously. The structure of the control scheme is shown in Figure 2.
In addition to a cross-coupled multivariable control structure, the technology has an inherent capability for disturbance rejection which is desirable in grinding circuit control, due to the varying nature of feed streams.
The main features of MPC technology are:
• a dynamic model as opposed to a steady-state model
• true closed-loop control with built-in optimisation
• mathematical basis allows optimal solving for control actions in real time
• computationally efficient, allowing controllers to run at high frequency
• predictive capability as opposed to reacting to process conditions.
The controller will take advantage of stable conditions to increase production, while under upset conditions – such as high vibration – the controller will simultaneously act to reduce vibration, protect process stability, reduce and then restore production while maintaining product quality.
Since the controller solves the optimisation problem online, updates can be made to the objective function (to change the operational behaviour of
the process), to the model (to change parameter values), and to process limits in response to external factors, e.g., tyre wear in a VRM.

These changes are made with the controller running, so the effect of the tuning changes can be evaluated in real time.

Many of the challenges in designing controllers which can handle multiple uncertainties are embedded in this online optimisation routine. This results in controllers which are robust over time and which require less maintenance post-commissioning.

The controller resides on a desktop or rack server and uses an OPC interface to connect to the control network. When online, LM-Master writes set points directly to the PLC and out to the individual field devices. The architecture is shown in Figure 3.

A browser-based interface allows multiple users to access the system and monitor performance. An operator log-on screenshot is shown in Figure 4.

**Project case study**
The development and testing of the LM-Master control solution was conducted on a 500tph mill. This was considered to be already operating well by the customer and therefore represented an interesting challenge in demonstrating how a software-based solution could deliver additional performance benefits over a mechanically-sound, well-operated mill.

The project was structured with discrete steps:
- historical data was analysed to determine mill baseline performance
- important control variables were identified for the mill
- process tests of the main variables were conducted to determine mill response
- controller was constructed and connected to the PLC control network
- calculated control actions were initially checked in Read-Only mode
- variables were activated in Read-Write mode one by one and tuned
- multiple variables were activated in Read-Write mode and interactions tuned
- run time was accumulated in full closed-loop control to fine tune.

By integrating the customer’s operators into the process and promoting close teamwork, buy-in of the concept was achieved and ensured an excellent final solution.

The development and implementation was achieved in 2-3 calendar months and the overall schedule, including planning and post-project evaluation of results was approximately four months as shown in Figure 5.

**Project results**
The project showed impressive results, particularly given the customer’s assertion that the mill was already operating well prior to the LM-Master implementation.
- Production rate was increased almost five per cent, from 505tph to 528tph
- Specific power consumption was reduced almost five per cent
- Mill vibration was reduced by 17 per cent
- Controller utilisation was greater than 90 per cent
- Operators are freed up to better monitor kiln performance
- Reduced CO₂ emissions from the plant (produces its own electric power)
- Project Return on Investment was less than 12 months.

**Conclusion**
The specially-developed roller mill controller LM-Master has been demonstrated to improve the operating environment for control room operators and increase mill performance. The solution leads to better utilisation of personnel by automating the routine control of roller mills and freeing operators to focus on kiln operation.

On the roller mill, the solution delivers higher production rates, lower specific power consumption, more stable mill operation leading to improved product consistency and lower vibration levels. This can have additional benefits such as avoiding vibration trips with a loss of production time and reducing wear and costly damage to major mechanical components such as gearboxes.