WORLD CEMENT May 2015

WORLD CEMENT®

May 2015

IN TOUCH EVERY DAY
mondi

GOOD VIBRATIONS

KARL S. GUGEL, PH.D., DIGITAL CONTROL LAB, LLC, USA, PRESENTS THE RESULTS OF VIBRATION/SIGNAL PROCESSING TECHNIQUES USED FOR AUTOMATED BALL MILL CONTROL.

Introduction

Traditionally, mill power, sound, elevator amps and bearing pressure have been used as the main control variables for automated mill control. However, due to vast improvements in digital signal processing (DSP) devices and affordable wideband high sensitivity accelerometers, vibration sampling and analysis can yield superior

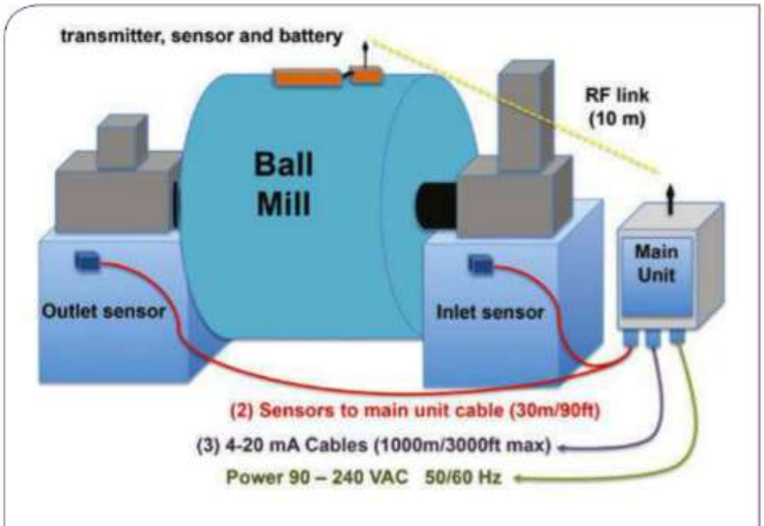

Figure 1. Typical vibration sensor placement.

Figure 2. Bearing housing sensor.

control results. Spectrum analysis of vibration signals taken from the mill support structure and/or those taken from the actual mill shell can be filtered, analysed and used to generate a very responsive mill fill level signal. This signal can then be used manually to control the mill feed or as a primary variable for automated feed control. This article will present results from five case studies that show that when a vibration generated fill level signal is used for control, increased material throughput can be observed for both finish and raw ball mills, as well as reduced specific energy consumption and improved material quality.

Sampled vibration vs microphone sound for mill control

The steel balls inside a raw, finish or coal mill generate a tremendous amount of vibration energy on the mill shell when the mill is rotated. This in turn results in generating sound that is similar to hundreds of hammers striking a large metal drum. Traditionally, this sound has then been used to yield a fill level signal picked up by a microphone or similar magnetic transducer that responds to increases and decreases in sound pressure levels obtained from a position close to the mill shell. Sound coming from a mill, however, can be greatly effected by nearby mills (crosstalk) and other large equipment. Other issues are frequent dust removal and sensitivity to humidity and temperature. To circumvent these problems, a custom wide bandwidth sensor can be placed on the mill support structure or shell (Figure 1).

One sensor is placed on the inlet mill support structure and another is placed at the outlet support structure. Note: there are many other additional spots where vibration can be sampled, such as cement cut-outs for support bolts and other fixed positions. The best spot is determined by looking at the actual vibration spectrum generated at a particular candidate spot via PC software when the mill is in normal operation. Figure 2 shows a common placement on the bearing housing.

Nearby equipment and/or mills do not affect the vibration measurement for the frequencies that are being monitored for fill level calculations. Additionally, because the grinding vibration signal is being measured through metal, a much stronger reading can be obtained, compared to that which can be picked up through air pressure (sound). This was proven several years ago when Cemex compared a bearing housing mounted vibration fill level to its best microphone-based system installed on a large finish mill in Tepeaca, Mexico. It observed that the vibration measurement was ~2.71 times more sensitive than the sound-based

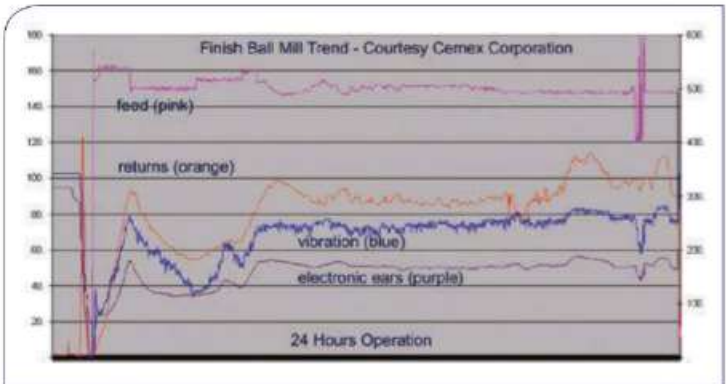

Figure 3. Vibe sensor fill level (blue) vs Cemex's best E. ear fill level (purple).

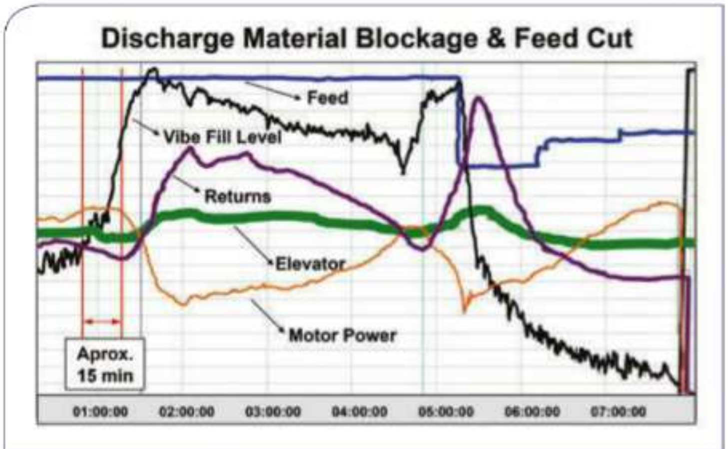

Figure 4. Vibration fill level response vs typical mill process signals.[2]

device.[1] Figure 3 shows an example of vibration fill level versus Cemex's sound-derived fill level signal.

Support structure vibration measurement vs mill shell vibration

A vibration sensor can be placed on a fixed position support structure or on the actual mill shell. However, a sensor placed on the mill shell measures a vertical slice of the fill level in the mill, whereas one placed on the fixed support structure measures the fill level at a particular end of the mill. Thus, it is evident that if the mill bearing oil temperature is kept constant, the best signal is obtained from the fixed position. The shell-based signal is more chaotic and therefore requires slightly more filtering than the fixed position sensor. However, the shell sensor can be employed in lieu of the fixed position sensor if the bearing oil temperature is known to fluctuate. Fluctuations in the oil temperature alter the viscosity of the oil. This in turn alters the acoustic coupling properties of the bearing structure and therefore a more reliable signal is obtained from the mill shell.

Calibration

Whether on the shell or in a fixed position, the vibration signal is constantly sampled and run through a process called a Fast Fourier Transform (FFT) to yield the frequency components (spectrum) of the vibration signature. The frequencies that correspond to mechanical movement, motor and bearing vibration are then removed and the remaining frequency energy is passed through a proprietary algorithm to determine the fill level output. A standard 4 – 20 mA is then used to communicate this information back to the control room where 4 mA corresponds to 0% full and 20 mA corresponds to 100% full. A calibration is performed by taking the mill's frequency signature while in normal operation and then setting this to ~80%. This consists of pressing a couple of buttons and is a two-minute process. After performing this calibration a couple of times to make simple adjustments to signal sensitivity, the calibration is saved to memory and new calibrations are not required unless new liners are installed or there is a major change in the mill's ball distribution.

Theory of operation

The fill level signal generated from the real-time sampled vibration sensor is a relative measurement that is proportional to the volume of material in the mill. Therefore, when vibration is used to control the feed going to the mill (and sometimes the recirculation when this is available), the goal is to maintain a constant volume of material in the mill and mill circuit. In order to maintain a constant volume of material in the mill over several hours of operation, it is necessary to make changes to the feed rate due to changes in fresh feed hardness and density (i.e., hard material: back off the feed to maintain a constant volume; softer material: increase the feed to maintain the current volume of material in the mill). This is why the feed cannot just be set to a constant rate and left for several hours, unless the mill is running in a very under-loaded condition. By maintaining a constant mill volume over an extended period of time, many benefits occur. These include:

- **Increased throughput:** when the mill is run in a more stable manner, it can be pushed closer to the point of overfilling because the operator will know when to back off the feed if the fill level begins to take off.
- **Reduced specific energy consumption (lower kW/t numbers):** by increasing throughput, an

operator can run the mill less to reach the target output numbers, thereby saving power. Higher fill levels can also be run that allow it to be operated at a low mill power value.

- **Improvements in product quality:** keeping the quantity of material constant in the mill allows the operator to zero in on the optimal fill level to achieve the designed target output particle size. Mesh and strength test standard deviation numbers will also decrease as the process becomes more stable.

Control strategy

The vibration fill level signal is very responsive. It reacts to material changes in the mill faster than elevator amps, mill power and bearing pressure. A change in mill fill level can be detected in a matter of a few seconds using vibration processing (Figure 4). The signal is excellent for real-time control of fresh feed. The challenge, however, is to determine the optimal fill level target value to be used initially and/or as a final set point in the auto-control system. This value needs to be determined by looking at the other process variables and quality results and may need to be slightly changed on a daily basis. With this in mind, a simplified control strategy for using the vibration fill level signal is as follows:

- Initially, choose a target fill level value that yields a typical tph feed rate (i.e., a fill level set point that creates a tph rate that matches the typical historical rate).
- Use the fill level signal for real-time control. Depending on whether an operator is above or below the target fill level set point, the feed can be increased or decreased as needed to maintain a flat fill level value that will then yield a constant mill material volume inside the mill. Over time, this will stabilise the amount of material in the mill and also in the mill circuit.
- Incrementally step-up the set point. After achieving a flat fill level signal for an extended interval of time, increase the fill level set point to slowly ramp up the feed. Ensure that the process stabilises after every set point change.
- Use the other process information to determine the optimal set point. Use mill power and lab quality measurements to determine when the optimal fill level set point has been reached.

Case study results summary

CalPortland (Colton CA – R. Moon)

- 13 ft x 21 ft single compartment finish mill with PID control and vibe fill level signal replacing mill power signal. Six months of data using vibration auto-control versus the previous six months of using the original mill power auto-control.
- Vibration control yielded an average drop in kW/t of 6.2%.[3]
- Increased average 325 passing = 0.25%.
- Reduced 325 standard deviation = 60.0%.
- Reduced average Blaine = 4.60%.
- Reduced Blaine standard deviation = 20.0%.
- Reduced 28-day strength standard deviation = 37%.[3]

"When using vibration for control, we have observed flat stable process signals such as mill, elevator and separator power. This increased stability allows an operator to comfortably increase the throughput target for the mill while operating at a lower power point on the mill kW power curve. Hence we can produce more material for less power and thereby significantly decrease historical average kWh/t numbers."[3]

Pricast/Cimpor (Spain – M. Staschower)

- Raw ball mill (75 – 90 tph typical operation) – vibe fill level vs manual control. Test duration: several weeks. Sold out stock; goal is to produce as much material as possible.
- Manual control tph average = 73.8.
- Vibration control = 77.8 tph, which is a 5% improvement.
- Production costs were estimated to also decrease by 4.7% and material fineness standard deviation decreased by 1%.

Holcim/PA Technologies (Altkirch France – E. Serrano)

- Two compartment finish mill, five products (70 – 85 tph typical operation) – vibe fill level vs manual control.[4]
- Manual control tph average = 77.
- Vibration control = 82 tph, which is a 6.5% improvement in production.
- The kW/t values were reported to drop by 5.8%.
- Blaine standard deviations dropped 37%.

According to the plant manager, Luc Cousin, "the sensor part is interesting as it gives a reliable image of the fill level of the two mill compartments."[4]

JK Lakshmi Cement/LNVT (India – A. Kumar)

- Two compartment finish mills (4.6 x 16 m and 3.8 x 13 m) – vibe fill level vs sound control.[5] Test duration = several months.
- Specific power consumption dropped by 4%.
- Average tph throughput increased by 3.4 – 4%.
- Average product particle standard deviation dropped by 15%.
- Silo core strength standard deviation fell by 30%.

"Unlike sound control, vibration control showed a much better ability to adjust to varying mill loading conditions."[5]

Glencore Xstrata (South Africa – J. Schutte)

- Single compartment Ferrochrome ball mill (90 – 100 tph) – vibe control vs bearing pressure/ mill power control in a PID loop system. Test duration = two months.[6]

- Specific power consumption dropped by 9%.
- Produce mesh size standard deviation was reduced by 61%.

"The reduction in the standard deviation can also be attributed to the accurate and constant mill fill level signal provided by the <product name> unit. The precise level signal allowed the PI-controller to effectively control the milling operation at the most stable and efficient conditions possible."[6]

Conclusion

The mill fill level signal derived from vibration is a more responsive signal than those traditionally used. It therefore is an excellent primary variable for real-time control of the feed. When properly implemented, the mill and surrounding circuit can be operated in a very stable and optimal manner. Increased stability enables the plant to produce more material for less money with better quality results than the case where the process is operating in a more chaotic manner. By keeping the mill full for longer periods of time, the liner life will also be extended.

The main challenge of vibration fill level control is to determine the optimal fill level value based on the present mill operating conditions. This is normally performed by looking at the current lab quality results and motor power value. A plant's process control engineers, metallurgists and mill operations are able to determine this optimal target fill level value, which in turn results in typical increases in production of 5 – 6% and significant decreases in specific energy consumption when compared to other traditional control methodologies.

References

1. BECCERA, K., RAMIREZ, J., PARRA, M. and PALACIOS, G. (Cemex Technology Engineering) 'Improvements in Mill Fill Level Measurement via State-of-the-Art Digital Signal Processing (DSP) Technology', Internal Report (April 2002).
2. STASCHOWER, M. (Pricast Spain) 'Using Vibration to Measure the Fill Level of Ball Mills', Internal Report (October 2009).
3. MOON, R. (Cal Portland), and GUGEL, K. (Digital Control Lab), 'Automated Mill Control Using Vibration Signal Processing' *IEEE-IAS/PCA Cement Industry Technical Conference*, Charleston, USA (May 2007).
4. SERRANO, E. (Holcim Cement), 'Improvement of the Grinding Performances at Holcim (Altkirch)', Dossier Congres, *Ciment, Betons, Platres, Chaux* No. 897 – 898 (June/September 2009).
5. KUMAR, K. (LNVT) and GUGEL, K. (Digital Control Lab), 'Mill Control Using MillScan G4', *Indian Cement Review*, Vol. 27 (June 3013), p. 54 – 55.
6. VAN DER WATT, H. (Pro-Op Industries), 'MillScan Installation Report: Glencore Xstrata Ferrochrome (Steelpoort)', Consultant Report (January 2014).

Make sure you're seen

Media planners and advertisers need reassurance too.

An ABC Certificate shows our figures have been independently verified, giving you confidence in our claim.

Ask to see our ABC Certificate.
See it, believe it, trust it.

For more information visit www.abc.org.uk