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Frozen charge detection and automatic loosening with gearless mill drives

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Abstract

A Frozen Charge is traditionally a challenge for the mill operators, as it usually involves considerable downtime of the mill to remove it. If the Frozen Charge is not detected during starting of the mill, it can even lead to major damages with associated repair costs and extended downtime.

The modern SIEMENS GMDs provide not only the possibility to automatically detect a Frozen Charge, but also the patented solution Frozen Charge Shaker™ (FCS), which allows for frozen charges to be loosened in a quick, safe and controlled manner avoiding costly and time-consuming manual loosening activities.

The FCS has been applied successfully on various installations worldwide. Details of the functionality as well as the experience from reference operations are provided in continuation.

Keywords

Gearless Mill Drive, GMD, Frozen Charge, Backed Charge, Frozen Charge Protection, Frozen Charge Shaker, Grinding Mill

Introduction

A Frozen Charge – also referred to as locked, cemented or baked charge – describes the solidification of the mixture of ore, steel balls and water in a horizontal grinding mill. Despite its name this solidification not necessarily involves temperatures below the freezing point, but occur mostly due to the mixture of water and the sedimentation of the fine grind ore on basis of the different density of the charge (density of water 1.0, ore – depending of the ore type 2.5-3.0, steel balls 7.8) upon certain time of standing still. Gradually the charge becomes a sticky and hardening mass – especially when containing clay – unable to slide or cascade while turning the mill.

The consequences of a Frozen Charge can be from just causing some misalignment of the mill and the drive system over to more serious damages to the mill bearing pads or even literally breaking apart of the mill shell into two or more parts as has been suffered by some mines in the north of Chile in the past. This really means a catastrophic failure. The consequences of such an occurrence are intensive repair works involving an extended shutdown period and therefore always cause a significant loss for the year's production revenues – apart from considerable direct costs. A detailed example has been published by De Beer, Lombaard, Warner and van Zyl (2011) mentioning 112 hours of downtime on a 14 MW SAG Mill in Ghana generating a production loss of USD 8.9 Mio and direct costs of USD 200 k.

Frozen charge protection

The Frozen Charge Protection (FCP) works on the basis of monitoring the expected torque characteristic of the mill load during start-up. At a normal start the torque increases until the material starts sliding or cascading – usually at a mill turning angle of between 40° and 70°. This cascading leads to a torque decrease and a slow transient oscillation of torque as shown in figure 1. This decrease in torque is monitored and used by the FCP to stop the mill before a dropping frozen charge damages the mill.

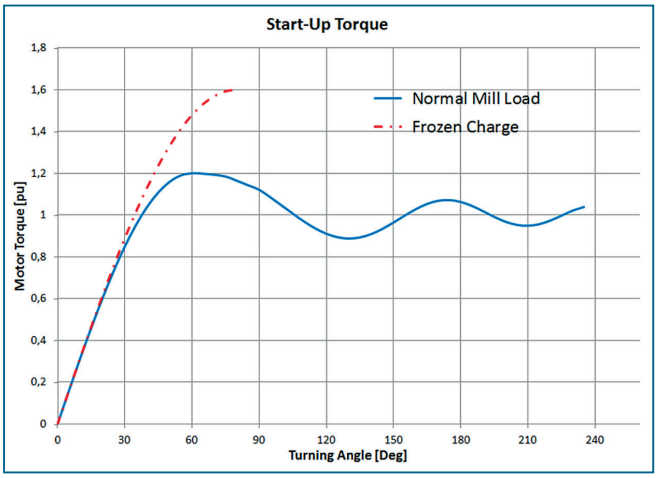

Figure 1: Chart of the load behavior of a horizontal grinding mill for normal start and for a Frozen Charge

To identify a Frozen Charge condition the protection is monitoring the load torque over time at an adjustable angle set to be above the usual cascading angle. This angle can be mill specific adjusted between 45° and 85° and is set at 80° in figure 2. At the selected angle setting, the FCP compares the actual value of the torque with its maximum of this specific starting procedure. If the actual value of the torque is lower than the recorded maximum value then the mill load cascaded, meaning the operation is normal as expected and start-up is continued. If the actual value of the torque is still equal to the maximum value, a frozen charge condition exists and the Gearless Drive is switched off allowing the mill to safely oscillate. An alarm (via HMI) alerts the operator and informs about the cause of the shutdown as described by Oyarzun and Smits (2014). The diagram in Figure 2 displays this procedure as an overview.

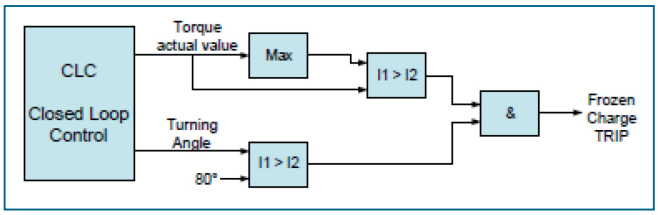

Figure 2: Overview of the Frozen Charge Protection functionality

A big advantage of this configuration of the Frozen Charge Protection is being independent from the level and weight of material within the mill. It also functions effectively at low charge levels with small amounts of frozen charge.

Figure 3 provides the actual values of speed, torque and mill angle for a Frozen Charge trip at a large SAG mill for reference. The speed is following the preset speed ramp until the trip shuts of the motor and lets the mill oscillate. The torque value is constantly growing and the mill angle indicates turning until 85° for Frozen Charge verification followed by the trip.

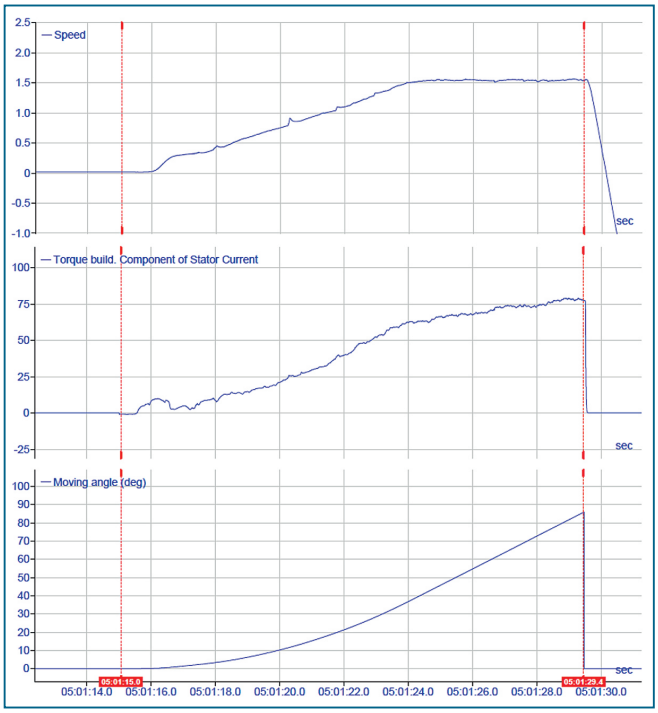

Figure 3: Actual values of a Frozen Charge trip

Stopping the mill on basis of the Frozen Charge Protection prevents damage to the mill, but does not usually get rid of the problem. Now the locked charge needs to be broken up to continue operation. The fasted way is to apply the Frozen Charge Shaker™.

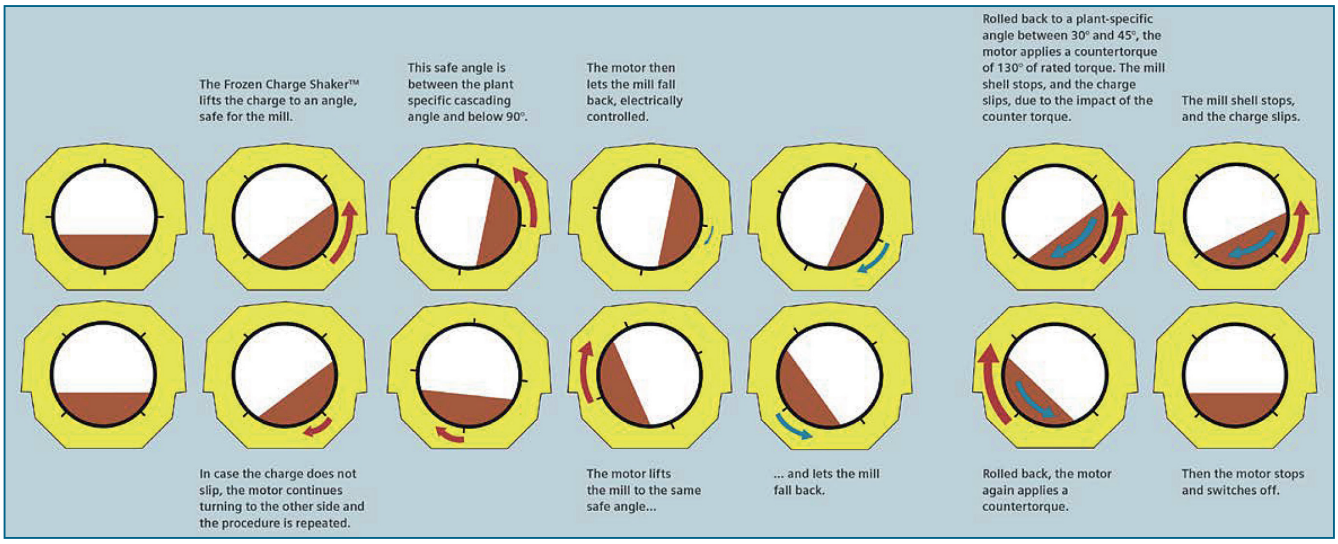

Figure 4: Operating sequence of the patented Frozen Charge Shaker™

Frozen charge shaker

In the traditional way a Frozen Charge had to be loosened by mechanical means like flushing with pressure water jets, or by application of excavators or even jackhammers. In order to avoid these time-consuming measures SIEMENS developed and patented the Frozen Charge Shaker™ (FCS) to break up the cemented charge and remove it from the mill body automatically. The charge is lifted to an angle safe for the mill between the plant specific cascading angle and below 90°, and the mill is then moved back and forth with varying speed and acceleration to displace the charge in a controlled manner. The angle and controlled movements are designed to break up the frozen charge and remove it from the mill body.

Figure 4 provides details of the operating sequence of the FCS and figure 5 indicates torque, turning angle and speed over time of that operating sequence for a partly filled mill (max. torque value for lifting the mill < 100%).

From balanced position the charge is lifted following a predefined speed ramp to a preset risk-free angle between the mill specific cascading angle and 90° (80° in Figure 5). Then the motor changes rotation as displayed at icon 4 in figure 4 respectively after 16 seconds in figure 5 and the mill accelerates electrically controlled reaching an individually set mill angle between 30° and 45° (see icon 6 in figure 4) – 30° are selected in Figure 5 – where a strong counter-torque is applied. This counter-torque of up to 130% (almost 100% in figure 5) stops the mill shell immediately. The charge slips due to its high kinetic energy.

For the case the charge does not slip at the first time, the procedure is repeated turning the mill to the other side. Figure 5 provides such a reference where the charge slips upon the second attempt in the counterclockwise direction shown with the uneven torque behavior due to the loosening of the charge during the time period 55 to 60 seconds. At the end the motor stops in balanced position and switches off.

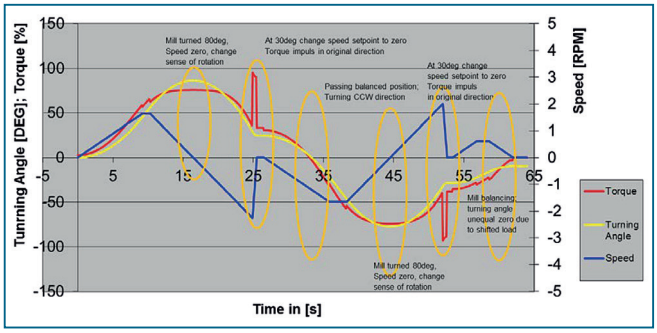

Figure 5: Torque, speed and turning angle over time for the Frozen Charge Shaker application at a partly loaded mill

The FCS is easy to apply from the local control panel and will be initiated by means of a key locked switch. The complete procedure usually requires only 15-20 Minutes to have the mill back in operation again. This compared to multiple hours or days of downtime for loosening a Frozen Charge by mechanical measures, means a significant contribution to the plant productivity. In the following chapter a few examples of this contribution are detailed.

Operating mills with a Siemens GMD not equipped with the Frozen Charge Shaker can be principally upgraded to implement the FCS function right back to the older generation of 32 bit Simadyn D controllers.

Frozen charge shaker – field experience

The SIEMENS Frozen Charge Shaker™ is presently installed at 3 operations throughout the world. The installations are Rio Paracatu Mineração (RPM) with a 38ft, 20 MW SAG Mill in Brazil and Lumwana having a 38ft, 18 MW SAG and one 26ft, 16 MW Ball Mill in Zambia, all three mills put in operation in 2008, as well as Los Bronces, Confluencia in Chile equipped with one 40ft SAG Mill of 22 MW and two 26ft Ball Mills of 16.4 MW commissioned in 2011. In the light of increasing interest in that technology various further Gearless Mill Drives with FCS are presently being erected or are in fabrication phase.

Los Bronces suffered a Frozen Charge in their expansion plant Confluencia on 10th September 2012 at its Ball Mill No. 2. By applying the Frozen Charge Shaker™ with the described procedure in figure 4 &5 the material broke up and the mill resumed normal operation in less than 15 Minutes – maximum it may take 30 Minutes. No additional flushing or application of any mechanical devices was necessary. The same procedure was applied with equal positive result during further Frozen Charge incidents – for example:

- In July 2012, undergoing a planned shutdown of about 100 hours the FCS was required to be able to turn the mill and go ahead with the relining,
- On 05th September 2013 again on the Ball Mill No. 2,
- On 20th March 2014 on its Ball Mill No. 1 and
- In May 2015 as well.

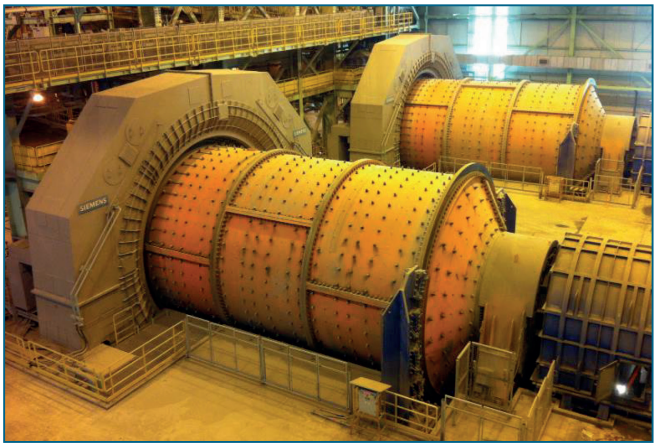

Figure 6: Ball Mills of Los Bronces, Confluencia plant with SIEMENS GMDs

Due to its reliable performance Los Bronces is completely satisfied with the Frozen Charge Shaker™. Especially considering that if Los Bronces, Confluencia would not have had the FCS it would be clearly necessary to send people into the mill to remove the Frozen Charge manually. Los Bronces expects this to take ten to twenty days on every event. Millions of USD lost production would be the consequence for each and every incident.

Patricio Chacana as the plant manager of Los Bronces adds in an interview: "For major shut downs we would need to take special precautions (if not having the FCS), which we know from our other plant and where we sometimes have had major trouble as not counting on the Frozen Charge Shaker (and Frozen Charge Protection). So it's an add on which allows us to operate with improved reliability and to protect our assets"

The next reference Lumwana mine encountered frequently Frozen Charge incidents on their 16MW ball mill during initial phase of production in the years 2009 and 2010. This was often combined with overload of the mill. The Frozen Charge Shaker helped the operation to overcome the Frozen Charges by application of the usual procedure described as per figure 4 & 5 above. On basis of some changes in the concentrator operation and respective maintenance measures the amount of locked charge incidents has been reduced notably (e.g. by grinding out before a planned maintenance shutdown). Presently a Frozen Charge happens approximately once or twice a year and is solved by application of the FCS as expected. Only once in all these years and numerous events of Frozen Charge has the Frozen Charge Shaker not been able to bring the mill up to speed again. Investigating that incident it was found that the mill was overloaded while having the Frozen Charge and consequently the GMD was tripping based on over-current. This means the FCS was not working abnormally but that the mill load was exceeding the acceptable current limits due to overload. Removing the charge by mechanical means made the mill able to resume work after some hours.

Summing up all these facts also leads to the full satisfaction of Lumwana with the SIEMENSs Frozen Charge Shaker function as confirmed by the electrical superintendent for the grinding circuit.

Finally it is worth mentioning that also the RPM plant expressed their satisfaction with regard to the Frozen Charge Shaker function – however without yet allowing for further details.

Conclusions

The Frozen Charge Protection is an important feature to protect the mill from a potentially damaging Frozen Charge. Throughout many years this function is standard for a Gearless Mill Drive now. However, to absolutely minimize the impact of a Frozen Charge the patented Frozen Charge Shaker™ is available to automatically break up the locked charge and to avoid the requirement of time consuming and costly mechanical measures to loosen the charge. The satisfactory operation of the Frozen Charge Shaker is confirmed by all the plants where this feature is installed. For Los Bronces for example the Frozen Charge Shaker is also among the contributors to the benchmark availability of over 95% of their complete concentrator plant Confluencia.

Acknowledgments

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