ELECTROMAGNETIC LEVEL PROFILE MEASUREMENT SYSTEM AT VALE ONÇA PUMA FERRONICKEL SMELTER IMPROVES SAFETY AND ENHANCES PROCESS CONTROL DECISION MAKING

[1]N. Brogden, [1]P. Jakobsson, [1]P. Bloemer, [1]A. Lyons, [2]C. Doyle,
[2]R. Aquino, [3]R. J. Dijkhuis, [3]E. Floch

[1]AGELLIS Group AB, Tellusgatan 15, 224 57 Lund, Sweden
[2]VALE ONÇA PUMA Mineração Onça Puma, Ourilândia do Norte, Para, Brazil
[3]SMS Siemag AG, Eduard-Schloemann-Strasse 4, Dusseldorf D-40237 Germany

ABSTRACT

Reliable and accurate data about matte and slag levels during the melting process is invaluable for good decision making and furnace optimization, while obtaining such information safely on a regular basis is of paramount importance.

Vale Onça Puma Brazil is one of the largest ferronickel smelting plants in the world with twin 85MW SAFs. International safety regulations IEC 60519 means that power must be off when taking bath level measurements and Vale Onça Puma do not allow personnel to be on the furnace roofs as a precautionary measure. The current method for determining metal/slag levels is through the use of sounding bars that can only be operated from the furnace roof area or the level above and as a result furnace levels can only be confirmed once per day.

This paper will show how this problem was identified as a concern to the furnace suppliers SMS-Siemag and the Vale Onça Puma management, how a solution was sought, how a real-time electromagnetic measurement system was tested and how safety, furnace control and decision making can be improved in the future.

To test alternative measurement systems, SMS-Siemag arranged a trial to be conducted by Agellis Group AB at the Vale Onça Puma plant in April 2012. The trial was intended to see if the Agellis EMLI-ELP system could be effective in ferronickel producing SAFs to accurately determine levels of metal and slag. Specifically of interest was whether the Agellis system could operate in the furnace when it was powered. If successful, this system would then have the potential to reduce operator time spent on the furnace roof while simultaneously improving the frequency, accuracy and reliability of furnace level measurements.

In conclusion the paper will discuss potential overall safety and production improvements, maintenance cost savings and integrating the generated data with the furnace control system.

KEYWORDS: *Melting process, matte/slag levels, accuracy, reliability, process control, sounding bar, lance carriage mechanism, electromagnetic measurement.*

INTRODUCTION

In the production of ferronickel, the pyrometallurgical process in recent years has made many advances with more efficient furnace design, shielded/immersed arc modes of operation, improved heat delivery/circulation/regulation, use of furnace gases to dry ore, better cooling, improved feed systems and of course modern comprehensive control systems. It therefore seems strange that today's state of the art furnaces are still recording material levels using the somewhat crude sounding bar method, with all of its well-known shortcomings.

Sounding bar readings are notoriously suspect as they dependent on operator skill and interpretation. Furthermore they require operators to work in unsafe areas on and above the furnace.

As reliable and accurate data about matte and slag levels during the melting process is invaluable for good decision making and furnace process optimization, a modern and safe method of obtaining this data is a priority. In order to bring this part of the furnace in line with all the other advances, Agellis Group AB of Sweden have used their knowledge and years of experience in the field of electromagnetics to produce a system capable of recording the working material levels in a furnace reliably, accurately, rapidly and above all safely, at any time during the melting process.

BACKGROUND

During a meeting with Agellis Group AB in late 2011, SMS Siemag explained that the benefits to be obtained in using an automated/semi-automated system at the Submerged Arc Furnaces at Vale Onça Puma are potentially significant. Today, for safety reasons, the power to the furnaces must be turned off when any measurements are taken. This means that there is a high cost when performing sounding bar activities because of production interruption. If measurements are required twice in 24 hours and 30 mins is the usual time required to undertake a manual measurement, lost production time could be up to one hour per day. This could be changed with the installation of a full lance carriage measurement system.

Figure: Vale Onça Puma Ferronickel Plant Brasil

Vale Onça Puma Brazil one of the world's largest ferronickel production plants. Each of its twin SAFs has an optimal maximum power rating of ~85 MW. Power is delivered to each furnace through 6 inline Söderberg electrodes. International safety regulations IEC 60519 means that power must be off when taking bath level measurements and as a precautionary measure, Vale Onça Puma do not allow personnel to be present on the furnace roof area when the electrodes are powered. This is due to the risk caused by the high power electrodes and the unlikely case of abnormal furnace conditions which restricts furnace roof operations. At present the method of determining metal and slag levels is through the use of two heavy sounding bars on each furnace that can only be operated from the roof area or just above. As a result, at this time, furnace levels are measured once or twice per day.

In order to test alternative metal and slag level measurement systems, SMS-Siemag arranged a trial to be conducted by Agellis Group AB at the Vale Onça Puma plant. The trial was intended to see if the Agellis EMLI-ELP system could be used effectively in the SAFs to accurately determine the levels of metal and slag. Specifically of interest was whether the Agellis system could operate in the furnace when it was powered on. If successful, this system would then have the potential to reduce operator time spent on the furnace roof while simultaneously improving the frequency, accuracy and reliability of furnace level measurements which in turn leads to improved operation and less downtime. In April 2012 Agellis and SMS engineers, together with Vale operational staff, performed a week's trial at the Vale Onça Puma facility, during which time a number of successful measurement operations were undertaken on furnace 2.

SYSTEM INSTALLATION

The Agellis EMLI-ELP System is designed to be used in combination with a full lance carriage mechanism which provides an easy to operate, accurate and very reliable delivery system for any furnace measurement probe. See figure 1 below.

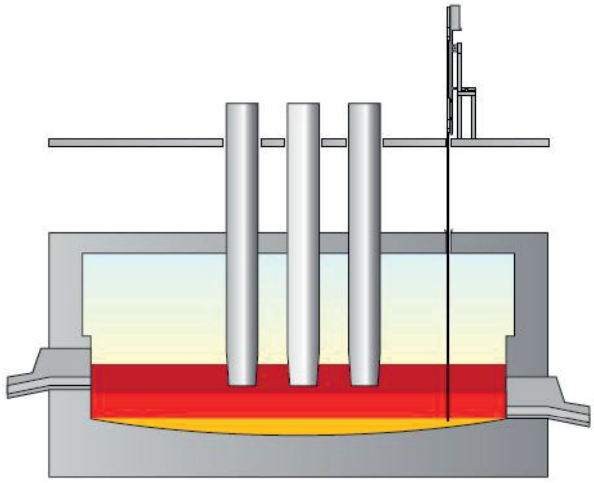

Figure 1: Agellis EMLI ELP Lance System

Further benefits can be obtained when using a lance carriage mechanism to deliver the Agellis EMLI-ELP level probe. Slag thickness, bottom build up, temperature and the ability to take metal samples are all potentially possible. However, the trial system instead consists of a lance, complete with a sensor probe, which can directly replace any sounding bar system. It has a draw-wire position encoder unit attached as part of the measurement loop to be able to ascertain the distance the lance travels into the furnace (figure 2).

This was sufficient to provide metal level detection only, as all other measurement capabilities require the full lance carriage implementation. The length of the lance was decided based on discussions and inspection of drawings/photos of the furnace. An exchangeable, specially designed, electromagnetic sensor was installed in the lance tip and a high temperature cable connected the sensor to the control unit. This cable also supplied the sensor with power. The Agellis EMLI-ELP lance was protected from high furnace temperatures by a set of disposable shields. In all other respects, the lance was operated in the same way as a traditional sounding bar.

Furnace 2 was used for the trial as it was running at higher power, hopefully reducing the risk of a hard slag crust. Also its constantly changing levels would provide opportunities to measure differences.

The trial equipment was installed, including the position encoder unit which would provide an output signal denoting the distance the sensor had travelled into the furnace. The lance was assembled to allow easy removal of the ceramic sensor cover and the lowest of the three paper shields. The Agellis EMLI-ELP Control Unit (CU) was powered up and checked together with the Management Unit (MU). When furnace 2 was powered down the existing sounding bar was removed and replaced by the Agellis EMLI-ELP trial lance.

SENSING TECHNOLOGY

The principle of measurement used in the Agellis EMLI-ELP system is the effect of the presence of conductive materials on an electromagnetic field. The operation of an Agellis EMLI-ELP lance in its winched format is similar to the operation of a sounding bar. The lance, fitted with protective covers, is lowered into the furnace at a steady rate and then raised once the bottom has been reached. The level readings are extracted digitally by the CU and based on the logged changes in electromagnetic conductivity encountered during immersion. Measurements generated in this way are both accurate and precise since they do not rely on subjective evaluation by operators. This gives better accuracy, repeatability and reliability than traditional sounding bar operations and leads to improved furnace process control.

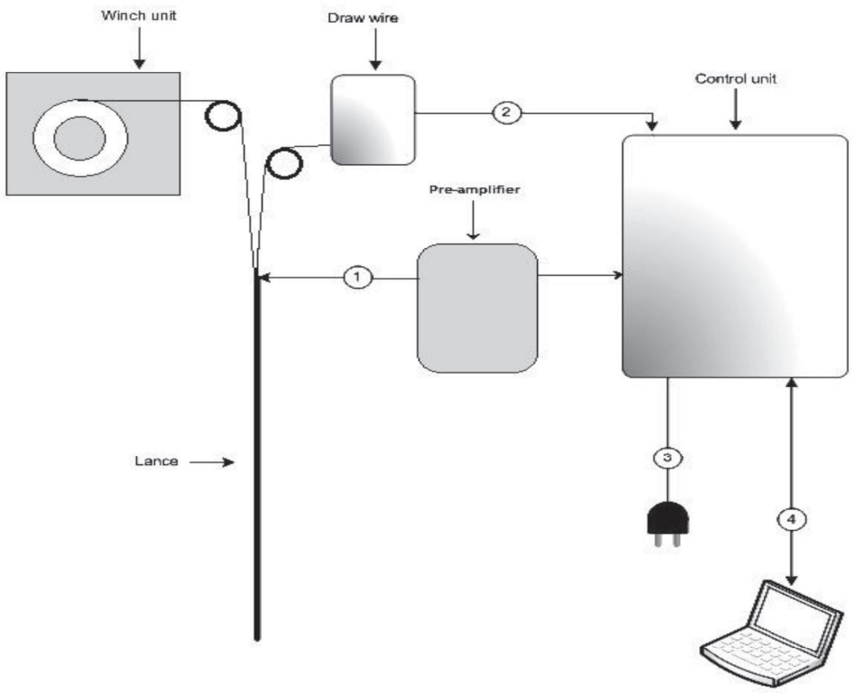

Figure 2: EMLI ELP Lance System configuration

TRIAL

Due to the lance resting position close to the roof the furnace had to be powered down for the first measurements. At the same time as the sensor trial dips were taken, traditional sounding bar dips were also made at the other access port and would later be used as a reference level in the analysis of measurement results.

Preliminary log analysis showed that the first Agellis EMLI-ELP lance dips taken had in fact been successful in detecting both slag and metal in the furnace with good, strong and very clean signal response.

As further dips were made, new detection parameters were set based on the previous dip experience to ensure good automatic detection of both metal and slag. It became clear that there were sometimes conditions when there was a hard slag crust which was too thick to penetrate with the light trial lance and so it was decided to stop the dipping attempts, resuming only with reduced calcine levels in the area of the furnace where the test probe was to be inserted. To avoid further lance damage a request was made to Vale Onça Puma production staff to modify furnace feeding.

Further successful lance dips were performed with the ceramic sensor covers and lower paper shields being replaced before each dip. All of these were performed with power off. The actual dipping procedure took ~35 seconds to perform with the available winch speeds and changing protection covers generally took ~15 seconds. It was noted how quick and easy it was to replace the EMLI-ELP lance protection covers compared to the cleaning procedure required after a sounding bar dip is made.

The CU logs showed that the data was correctly collected and measurements were checked to verify that the sensor levels compared well with known levels in the furnace. New offsets for the detection algorithm parameters were determined to allow the system to automatically generate numerical level readings during dips. It was immediately clear that the strong and consistent metal detection signal response to the metal in the furnace was ideal and it also looked very promising for the slag level measurements.

For the final part of the trial the ELP lance winch controls were moved, for safety reasons, up to the next level above the furnace roof to prepare for a measurement attempt with power on. A successful dip was performed providing very good log data. It was certain that the furnace power had minimal effect on the metal detection sensor. The slag detection sensor was more susceptible to interference from the electrodes, but this interference was easily handled by special signal analysis software and accurate measurements were still possible.

The Agellis EMLI-ELP system functioned well. The deployed sensor configuration allowed both slag and metal to be detected with ease. Naturally a temporary trial installation like the one used is never able to match the performance, precision and accuracy of a more permanent installation. Nevertheless the results achieved during the trial showed a very high level of measurement precision for the slag level and an even better precision for the metal level. All systems functioned as intended and results were consistent with each other.

MEASUREMENT RESULTS

The exact distance from the reference point to the furnace bottom was measured by the EMLI-ELP draw wire position encoder during the trial and this value was used as the basis for all calculations and calibration constants produced. For this trial the furnace access port cover was used as the reference point. See table 1 for the calculated dip results in mm. Consistent and precise measurements were acquired for slag, metal and build-up levels.

COMPARISON OF LEVELS WITH SOUNDING BAR READINGS

The chart in figure 3 below illustrates the close correlation between the few available sounding bar readings and the measurements made using the Agellis EMLI-ELP system.

The sounding bar readings used in the chart are:

- Day 2 Sounding Bar results – 0cm build-up + 78cm metal + 120cm slag

(2 EMLI measurements made with power off)

- Day 4 Sounding Bar results – 0cm build-up + 80cm metal + 135cm slag

(4 EMLI measurements made with power off)

- Day 5 Sounding Bar results – 0cm build-up + No metal and slag levels

(1 EMLI measurement made with power on)

Please note that no sounding bar measurements could be taken with power on.

Dips 1 – 14 were attempted with power off. Sometimes, due to furnace conditions, the lightweight lance was unable to penetrate slag crust when it formed. In a permanent installation using a full lance carriage system with a more solid lance and power driven immersion, slag crusts become less of a problem.

The final test, dip 15, verified that the Agellis EMLI-ELP system can detect both slag and metal levels with power on, despite the electrode interference present

Dip #	Time Days	Vessel Zero	Slag Depth	Slag Level	Above STH (Slag Tap Hole)	Metal Depth	Metal Level	Above MTH (Metal Tap Hole)	Bottom Depth	Bottom Level	Slag Layer
	2nd day										
1	15:08	550	6817	**1963**	98	7995	**765**	40	8789	-9	**1198**
2	15:18	550	6803	**1977**	112	7981	**779**	54	8775	5	**1198**
	3rd day										
3	11:03					*Could not penetrate slag crust*					
4	11:04					*Could not penetrate slag crust*					
5	14:20					*Could not penetrate slag crust*					
6	14:32					*Could not penetrate slag crust*					
7	14:43					*Could not penetrate slag crust*					
8	14:48					*Could not penetrate slag crust*					
	4th day										
9	10:47	550	6631	**2149**	284	7955	**805**	80	8789	-9	**1344**
10	10:48	550	6618	**2162**	297	7968	**792**	67	8775	5	**1370**
11	10:50	550	6618	**2162**	297	7955	**805**	80	8749	31	**1357**
12	10:52	550	6565	**2215**	350	7955	**805**	80	8749	31	**1410**
13	11:03					*Could not penetrate slag crust*					
14	11:04					*Could not penetrate slag crust*					
	5th day										
15	16:43	550	6803	**1977**	112	7981	**779**	54	8775	5	**1198**

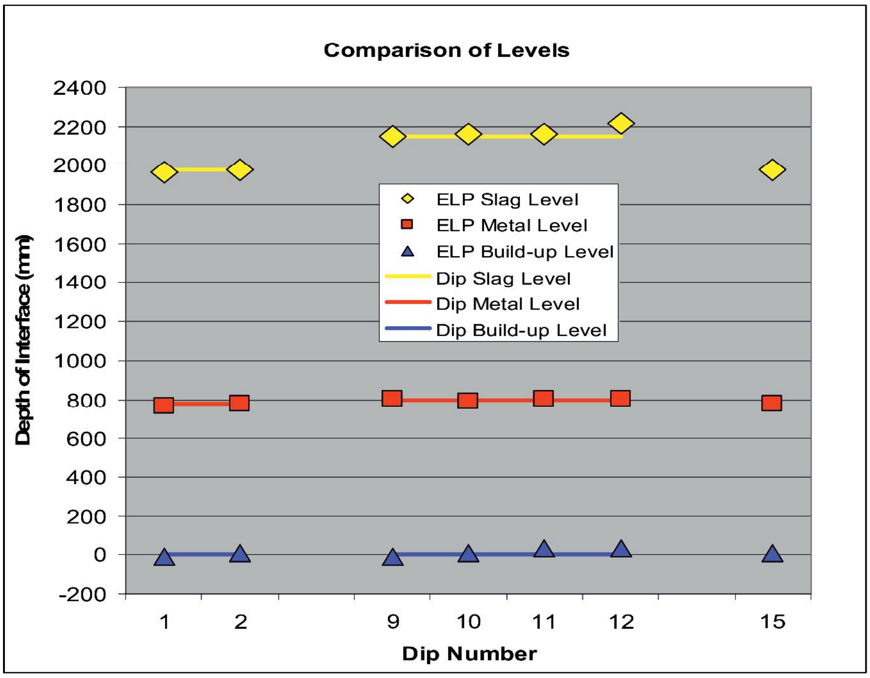

Figure 3: Comparison of ELP results with sounding bar dip readings

Please note that the sensor offsets used in the calculation have been calibrated against the initial sounding bar level values. The graph should therefore only be used to gauge the precision of the EMLI-ELP system. The accuracy is usually set by parameter calibration of the metal, slag and bottom build-up detectors at commissioning time. For this trial, approximate values were instead set and then used in all following calculations to allow comparison between measurements.

As can be seen from the graph, metal detection is very precise while slag detection and bottom build-up measurement precision is slightly hampered by the flexible nature of the trial version lance when encountering physical resistance. Nevertheless, very good and consistent readings were possible even for these level measurements.

MEASUREMENT CONCLUSIONS

During the trial period 7 successful and consistent metal, slag and build-up level measurements with very high precision were taken using the Agellis EMLI-ELP system.

The Sensor system:

- Functioned reliably and accurately.
- Reliably detected the calcine/slag interface in the furnace.
- Reliably detected the slag/metal interface in the furnace.
- Reliably detected bottom of the furnace.
- Signals can be automatically converted to level measurements.
- Levels compare well to available sounding bar measurements.
- Can detect differences in metal levels from day to day.
- Can detect differences in slag levels from day to day.
- Metal detection is not affected by electrode power.
- Slag detection is only slightly affected by electrode power.
- Bottom build-up detection is not affected by electrode power.
- Functions well even when outside its thermal operating specifications.
- Ceramic covers are capable of withstanding the hot metal and slag.
- Protective sleeves are capable of withstanding the hot metal and slag.
- Protective sleeves and ceramic covers are quick and easy to change.

The system has performed very well in the Onça Puma furnace environment, meeting all expectations on metal, slag and bottom build-up level detection under varying environmental conditions. The temporary trial scenario is used more for ease of installation and use over the precision and accuracy of a more permanent installation. The lower trial depth measurement precision and manual lance manipulation do not optimize the performance of the Agellis EMLI-ELP system. The results however demonstrate great performance potential for a full installation. As a result, Agellis, SMS Siemag and Vale Onça Puma consider this trial to have been highly successful.

The installation of a permanent lance carriage mounted Agellis EMLI-ELP system would immediately improve safety for the operators at Onça Puma, who currently spend time at the furnace roof area taking sounding bar measurements. Design of lance carriage mechanisms includes a lance rest position location away from the immediate roof area for safe application and removal of protection sleeves.

Furthermore the ability of a permanent installation to take measurements when furnace power is on provides the immediate benefit of continued production and reduced power usage. Once accurate and reliable measurement data is available to the Onça Puma furnace operators whenever required, it can be integrated into the furnace control system to greatly assist correct decision making and process optimization. Consistent furnace operation may also lead to reduced maintenance requirements and costs.

ACKNOWLEDGEMENTS

This paper is published by permission of Vale, SMS Siemag and Agellis Group AB. The contributions of our colleagues are gratefully acknowledged.

REFERENCES

[1] N. Brogden, P. Jakobsson '7128 – SMS Siemag Vale ONÇA PUMA ELP Trial Report', OPR/REP/02593/AG, Rev A, April 2012.

[2] T. J. Goff, N. Brogden, J.P. Nilsson, P. Bloemer, A. Lyons, 'Implementation of an Alternative Matte Level Measurement Solution at Lonmin Marikana Smelter Division for Improved Process Monitoring', Southern African Pyrometallurgy 2011, March 2011.

[3] R.Degel, J. Kempken, J.Kunze, R. König 'Design of a Modern Large Capacity FeNi Smelting Plant' INFACON XI New Delhi 2007.