Online measurement of moisture in coke and other conductive materials

CM100
Conductive materials moisture analyser

Photograph supplied by OneSteel Whyalla, Australia

Author
Kelly Wilding, Scantech International Pty Ltd

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Introduction

Modern steelworks are driven to produce better quality products and to improve upon current practices, which will in turn reduce the cost of their end product. Located in South Australia, OneSteel, Australia's largest producer of steel long products has incorporated the use of a Conductive Materials Moisture Monitor (CM100) as part of their quality control system since 2000.

The CM100 used at OneSteel Whyalla steelworks is designed and manufactured by Scantech and is widely used in the steel making industry to measure the moisture of coke, sinter and iron ore, before it enters the blast furnace. This provides valuable real time feedback to both the blast furnace and coke ovens operators enabling them to adjust their practices accordingly. The measurement of coke moisture allows more precise control of the dry weight of coke being charged to the blast furnace. Variation in coke moisture, which is not accounted/adjusted for, can have an adverse effect on the thermal control of the blast furnace process and also the chemistry of the iron and slag produced. Outlined in this paper are the benefits of having real time analysis for coke moisture in the operation of the blast furnace at OneSteel as well as some technical information on the CM100.

OneSteel Whyalla

OneSteel is the largest manufacturer of steel long products and is the leading metals distribution company in Australia, with revenues of $6 billion Australian dollars. OneSteel has over 200 operational sites in Australia and New Zealand, more than 30,000 customers and employs over 10,000 people (OneSteel.com).

The fully integrated steel works at Whyalla has been operational since 1968. The steelworks operates a single blast furnace with an impressive campaign life record (Tsalapatis and Keil 2005), The current campaign began in 2004.

OneSteel manufactures and distributes structural, rail, rod, bar, chrome plated bar, reinforcing, wire, tube and pipes. The majority of OneSteel's products are used in the construction, manufacturing, housing, mining and agricultural industries (OneSteel.com).

Plant operations

Onesteel Whyalla sources it's iron ore exclusively from several local mines which are all part of the company operations. Iron ore from the local mines is delivered to the pellet plant by rail where it is processed ready for delivery to the blast furnace stockpiles.

Delivery of coal to OneSteel comes in via the wharf, to be stockpiled and blended before transferring to the coke ovens. Each oven can hold approximately 20 tonnes of coal at a time and will keep a temperature of 1000 degrees over an 18 hour period to turn the coal into coke. Once the coke is removed from the oven it is wet quenched. From here the coke is screened to ensure correct sizing, and transported via conveyor to the blast furnace raw material storage bins.

Coke, iron ore pellets, lump ore and fluxing materials are the raw materials consumed by the blast furnace to make molten iron. Utilising a mass balance the amount of raw materials with their respective chemistries is calculated for charging to the furnace. The Whyalla Blast Furnace uses a constant coke base while varying the ore base. Being able to have the moisture included in the mass balance of the blast furnace ensures the correct balance of ore/coke is charged to control the thermal balance and product quality. Once the molten iron is tapped from the base of the blast furnace it is ready for the steelmaking process. While the product quality provides an important feedback into the performance of the blast furnace it is also important for the BOS, so that the variation in treatment requirements is minimised to produce the steel grades required.

Whyalla Blast Furnace

Blast furnace control

For optimal blast furnace performance the chemistry of the molten iron being produced will remain under control and the thermal balance of the furnace will remain as constant as possible. To achieve this the operators need to know that the addition of raw materials (coke, iron lump and pellets) is correct in terms of chemistry and weight, and this incorporates moisture being accounted for. Coke has an ash content, carbon content and also a volatile matter content. The ash chemistry and the carbon content are taken into account in the mass balance. The moisture content is also included in the mass balance to account for its influence on the ore to coke ratio. The Whyalla Blast Furnace runs with a constant coke base and accounts for the coke moisture by adjusting the ore weights to remove its influence.

If there is an unaccounted for step change in coke moisture the following two scenarios will occur:

- Increased moisture - the furnace temperature cools
- Decreased moisture – the furnace temperature heats

If the operators are aware of fluctuations in the moisture of coke being produced by the coke ovens they are in a position to make adjustments to the ore mass charged to account for its influence on the thermal balance of the blast furnace. An unaccounted for increase or decrease in moisture will affect the thermal balance of the furnace, which will alter the consistency of the molten iron chemistry. The worst result arising from not accounting for a large increase in coke moisture is a chilled hearth condition resulting in a significant interruption to normal production. Aside from the thermal control of the blast furnace, the chemistry of the molten iron is important for the steel making department as a deviation from the specifications they require can alter their production plans or cause delays.

The main elements that are varied through the inability to correctly respond to moisture in coke are the hot metal silicon and sulphur. This occurs due to a loss of thermal control, which alters reactions inside the furnace governing the amount of silicon reporting to the iron and the amount of silica reporting to the slag. The result of increased silica in the slag is a reduction in the desulphurisation capability of the slag. The Basic Oxygen Steelmaking (BOS) vessel where the molten iron undergoes further processing can be required to alter its processing of the iron depending on how far the chemistries have drifted. De-sulphurisation of the material is one of the possible outcomes of the chemistry being altered from specification.

In the past, manual coke samples were taken to determine the moisture content of coke entering the blast furnace. One 20 Litre bucket of coke would be collected every 4 hours for laboratory analysis. There were a number of problems associated with this practice:

- Results received by operators hours after the coke has already been consumed due to laboratory analysis time.
- Only very small portions of coke were collected so the true moisture variation may be missed due to unrepresentative sampling.
- Safety concerns for manual handling of these samples was also an issue with this procedure.
- Moisture changes related to rain or operational problems with the coke ovens could result in significant thermal 'swings' due to not balancing for the moisture in a timely manner.

The main problem for operators was the coke moisture result delay being too great for efficient control of the current blast furnace feed. All of the issues mentioned above were addressed when looking at the option of installing an on belt analyser to measure coke moisture. Some of the benefits of having an on-belt analyser included:

- No manual sampling - eliminates the task as a possible safety concern
- Results provided in real time – delays no longer a problem
- All of the material being fed from the coke ovens to the blast furnace is analysed - removes errors brought about by sampling technique

On line analysis of coke moisture

Options for measuring moisture in on-line applications include Microwave, Slow Neutron, and Fast Neutron Gamma Transmission (FNGT) analysers. The suitability of each varies when used to measure moisture in Coke. Microwave moisture analysers are not suitable to this application as the material is conductive (the microwaves can not penetrate this material). Both Slow Neutron and FNGT analysers measure the total hydrogen content to determine moisture, so their accuracy depends on the amount and variability of hydrogen in the material not linked to water.

Slow Neutron Analysers

Slow Neutron analysers are used in coke moisture applications but the principles behind their operation limit their ability to give a representative result for the full bed depth of material on the conveyor belt. The source used is usually Americium-Beryllium (fast neutron source) and the detector is usually a gas filled tube containing Boron Trifluoride or Helium-3. The hopper mounted analysers have the source and detector positioned on the same side of the material being analysed and are commonly referred to as a backscatter analyser.

Problems with this Analyser include;

- The moisture result is expressed as a weight percent. This is affected by changes in bulk density as no separate measurement of bulk density is made.
- Certain elements strongly absorb slow neutrons. These include Boron, Gadolinium, Cadmium and Chlorine. Gadolinium in very low concentrations can cause problems. Boron is more likely to cause problems in coke since gadolinium is not usually present in coal.
- It operates in backscatter mode so the readings are over-sensitive to material near the analyser.
- Change in the wall thickness of the bin, due to wear, can significantly affect readings.
- The temperature of the material will affect the energy distribution of thermal neutrons, which will affect the efficiency of the neutron detector. This will cause a moisture error. However some analysers may reduce this effect by using neutron filters, such as a cadmium foil, around the detector. Neutron filters will reduce the count rate and hence increase the counting statistics error in the moisture result.
- The detector may have a finite life. One manufacturer indicates a life of one year for the BF_3 (Boron Triflouride) detector.

Fast Neutron Gamma Transmission (FNGT)

The FNGT technique is utilised in the Conductive Materials Moisture Monitor (CM100) and this analyser has the ability to accurately measure the moisture in coke of varying bed depths. Unlike the Slow Neutron analyser, the CM100 has a detector below the conveyor belt and a radioactive source above. The radiation beam of fast neutrons and gamma rays penetrates the full depth of material on the belt allowing a more representative result. Neutron and gamma rays transmitted through the material are detected and processed by the detector and digital multi channel analyser (DMCA) to produce results. Californiun-252 is commonly used as the source because it produces both fast neutrons and gamma rays.

FNGT has the following advantages;

- It is unaffected by slow neutron absorbing elements such as gadolinium, cadmium, boron and chlorine.

- The transmission geometry sees the material more uniformly. It is not sensitive just to material near the analyser.

- Bulk density correction is an intrinsic part of the measurement method. The gamma ray density measurement is made simultaneously with the hydrogen measurement on precisely the same volume of material. This is especially important for on belt moisture measurement.

Detection of Neutrons and Gamma Rays

The FNGT technique requires simultaneous detection of fast neutrons and gamma rays. The Lithium Glass scintillator used in the CM100 offers the following advantages;

- Simpler Electronics. - Pulse height analysis allows separation of gamma ray and neutron counts.

- Improved count rate stability over gas filled detectors.

- Longer life than gas filled tubes.

Benefits experienced by OneSteel Whyalla from using the CM100

The blast furnace at OneSteel in Whyalla consumes approximately 1600 tonnes of coke per day, all of which is analysed by the CM100 for moisture content. This particular application only uses the CM100 to analyse coke, other steelworks also use it for the analysis of moisture in sinter and iron ore.

Production information for the blast furnace at Whyalla:

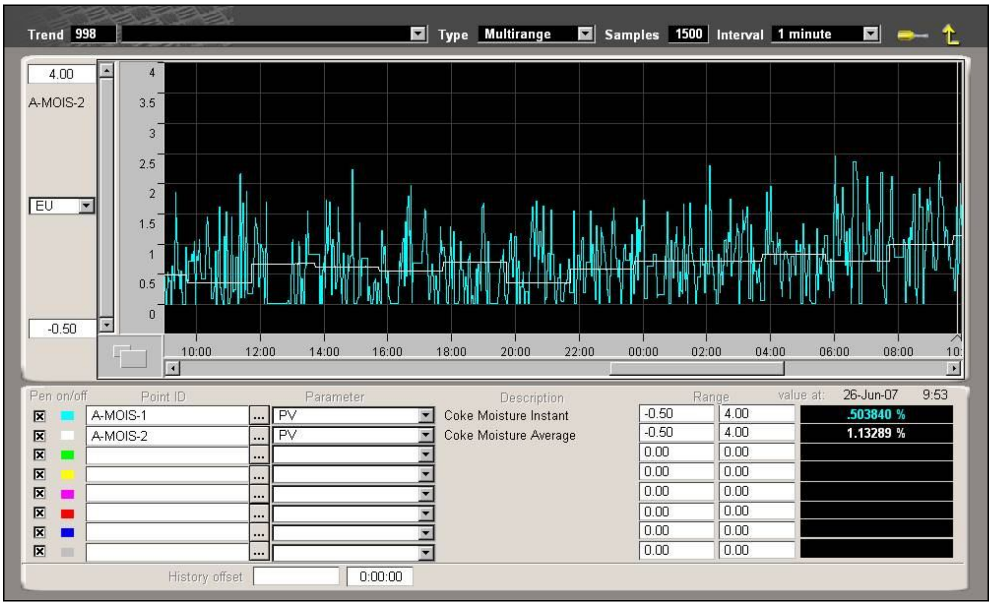
Tonnes of Coke used daily: 1600
Iron produced annually: 1.2million tonnes
Belt loading of coke: 90%
Belt speed: 1.68m/s
Material: Coke only
Moisture ranges: 0.5 – 1.5% average, high reading 5%
Particle size: average 53mm diameter
Date of installation: 2000

Over the CM100's 10 years service the operators have noticed a number of benefits:

- Improved blast furnace thermal stability
- Improved iron chemistry control
- Decrease in manual handling of large samples – improved safety
- Assists in quenching control for the coke ovens
- Decrease in the production incidents occurring due to coke moisture fluctuations

When operators notice a change in the moisture results coming from their analyser, providing the issue is not due to rain, the coke ovens are notified so they can address the problem. The blast furnace operator will enter the moisture result into the mass balance and the ore weight adjusted to maintain the required ore to coke ratio. The adjustment for moisture occurs every 2 hours and an alarm limit is set to alert the operator to high moisture coke.

The screen capture below shows the operators interface to the CM100 results. The scattered line shows instantaneous data coming from the analyser while the trending line shows the tonnage weighted average moisture for each reset period.



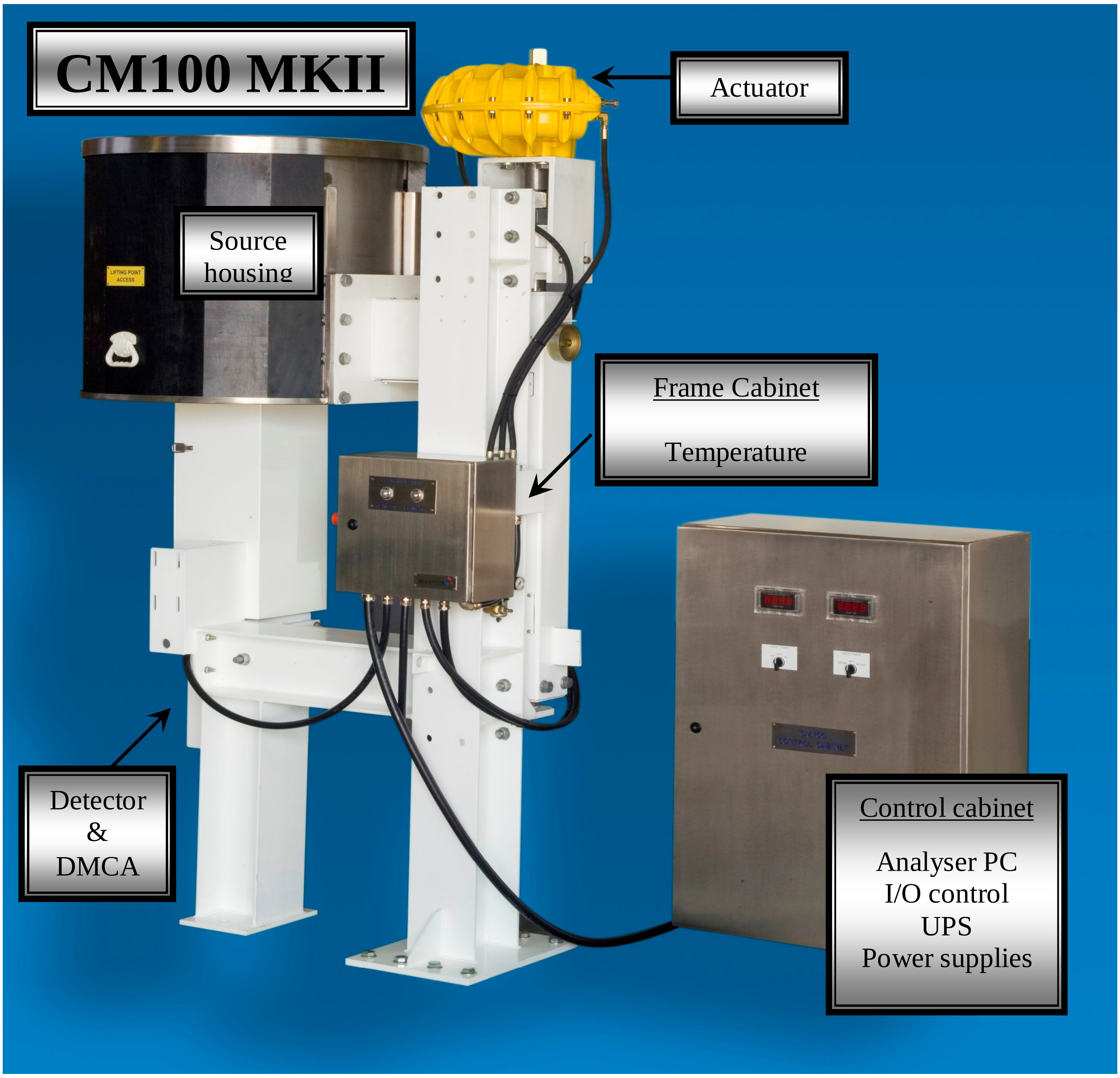
CM100 and it's impact on the plant

As the CM100 is a non contact, fully automated analyser it's impact on plant operations is minimal. Installation is simple, as the CM100 has no contact with the conveyor belt. A standard installation will require the building of a supporting structure and removal of one idler set. This analyser can also be installed on a sloping conveyor belt. Digital I/O's and Analogue I/O's (4-20mA) are used by the CM100 for communications as well as Ethernet connection. Analyser outputs range from system status information to average and instantaneous moisture results.

Technology has improved over the years and the CM100 has taken advantage of the new electronics available. Some of the main improvements in the design of this analyser form the original to the current model include:

- Digital Multi Channel Analyser replacing the Multi Channel Analyser
- Specialised electronics boards replaced with I/O processors and a PC
- Software improvements allowing improved analysis control and better remote diagnostics of the analyser

Maintenance has been kept at a minimum so minimal interruption is caused to analysis. Routine service visits are recommended, but a majority of the system maintenance can be done remotely while the CM100 is in operation.



How the technology works

Fast Neutron Gamma transmission works as outlined below:

- A californium 252 source emits a collimated beam of radiation via a shutter disk. The radiation passes through the material on the moving conveyor belt
- Fast neutron transmission through the material is dependent on the amount of hydrogen present in the material and the mass per unit area

- Gamma ray transmission through the material is dependent on the mass per unit area.
- Transmitted neutrons and gamma rays are captured by the detector below the conveyor belt and processed into a spectrum by the DMCA attached to the detector.
- Moisture readings with varying material levels on the belt are accurate as the analysis technique automatically adjusts for this depth variation.
- Instantaneous and tonnage weighted results are calculated and output to the plant via 4-20mA analogue current loops or by Ethernet connection.

The CM100 will calculate the mass per unit area of material on the conveyor. If this decreases below acceptable limits then results will be rejected ensuring the final calculation is accurate.

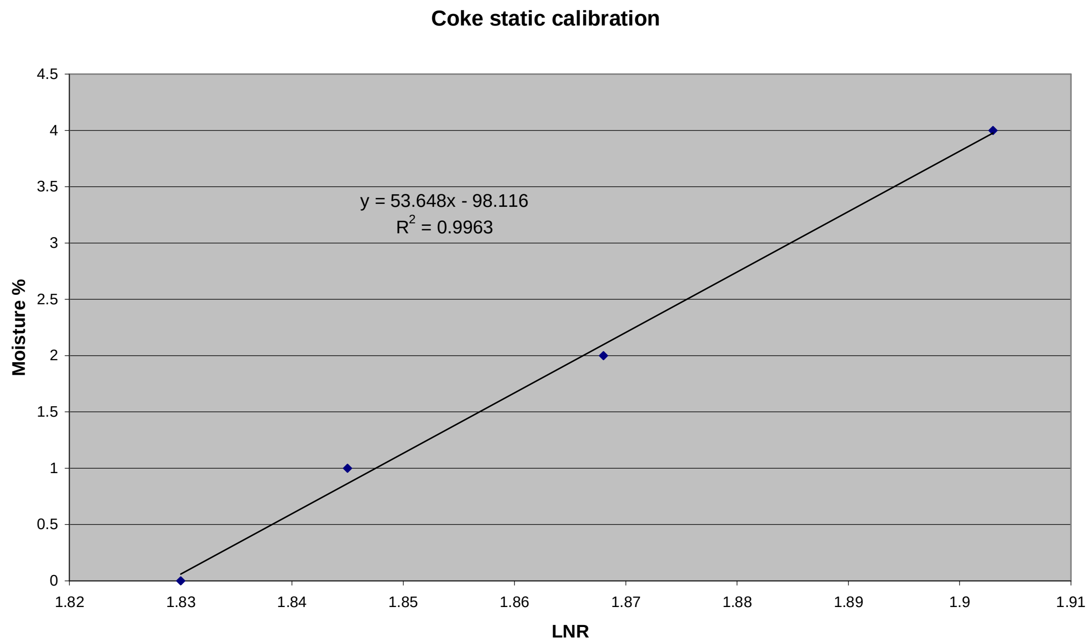
CM100 Performance

The CM100 has been used for dry and water quenched coke and has been able to determine results accurately in both applications. The analyser set-up has little impact on production only requiring approximately 2 hours of empty conveyor run time and everything else being done offline during normal operation. Limited sampling is required as the chemistry of the conductive material being used does not impact on the calibration of the analyser as we are purely interested in moisture content.

There are a series of variables that effect the performance of the CM100 such as source strength, distance between the source and detector and analysis time just to name a few. The achievable performance will also depend on the material being analysed, wether it be coke, sinter, iron ore or any other conductive material.

A static calibration is completed first to determine an equation to use for the moisture calibration. Requirements from site during this process involve no loss of production time (work is done completely off belt with full production running), and the supply of a dry and crushed coke sample.

Below is an example of a typical calibration line for coke moisture.



Once this is completed a sampling procedure is determined, depending on requirements of the customer, which allows us to compare the analyser results to the laboratory data. From this information a final adjustment is made to the analyser and it is ready to go online. Typical performance of the analyser ranges around ±0.4 to 0.6% error for moisture.

Summary

Process control and cost savings are a primary focus for many industries. The ability to know the value of input variables of their processes assists them in achieving these goals. The CM100 and it's introduction onto the blast furnace coke feed conveyor allows the operators to correctly calculate the dry weight of coke being used, which provides them with better thermal control, and improved chemistry control of the molten iron, which also has benefits for other areas of the plant.

The principles of operation of the CM100 and it's proven track record in the field, have put this analyser in a class of it's own for accurate measurement of moisture in conductive materials on a conveyor belt. Real time results and the ability of operators to react to information straight away is a great improvement on traditional methods of coke moisture control. Regular laboratory sampling and manual handling to achieve these results have now become a job of the past.

Ease of installation, operation and minimal maintenance all add to the benefits of incorporating this moisture analyser into and steelworks process control system.

The accuracy and reliability of the CM100 will always be what operators appreciate the most.

Acknowledgements

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References

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