Robert Prior, Carbolite Gero, UK, describes how coke is created in a coal testing oven or pilot plant.

Thanks to huge advances in metallurgy over the last three decades, 21st century steel production is transforming the globe and the built environment. Of course, a major part of the steel production process is the use of coke, which provides as much as 80% of the furnace's thermal requirements, the majority of the furnace's CO gas (which acts as a reducing reagent) and carbon for dissolution in the molten metal. As with any other manufacturing process, the quality of the raw materials has a massive impact on the quality of the end product. It is therefore vital to ensure the coke is comprehensively tested.

On a small testing scale, coke can be created by the slow heating of coking coal in a refractory lined coal testing oven (CTO) to 1000˚C for 3 – 4 hours in the absence of air. The coal softens at a temperature of between 400 – 500˚C to form a liquid or plastic phase, agglomerates, swells and particles fuse. At temperatures of between 450 – 550˚C, there is re-solidification forming semi-coke, which is the first stage of shrinkage. Finally as the temperature of the raw material in the CTO passes 550˚C, there is a loss of hydrogen and oxygen and the second stage of shrinkage occurs. Using just 7 kg of 5% moisture coal and a Carbolite Gero CTO, a sufficient sized sample can be created to determine % yield and hot strength (CSR/CRI).

For larger testing/pilot plant scenarios, a moveable wall oven, such as that manufactured by Carbolite Gero, can be used. Holding 227 kg of raw coking coal, this pilot plant mirrors real-world coke production over a standard 18 hour processing time. At the end of the cycle, the contents of the oven are expelled at temperature and quenched with water forming a grey mass of coke.

Testing the coke

The coke strength after reaction (CSR) test is based on a procedure developed in the 1970s by Nippon Steel Corp. as an attempt to get an indication of coke performance. It refers to the strength (thermal potential) of the coke via a simulated reaction emulating what might be expected in an industrial blast furnace. Those original tests over 40 years ago have become a recognised standard for testing coke, particularly when blending coking coal to ensure it performs to the required specification.

Coke reactivity test unit.

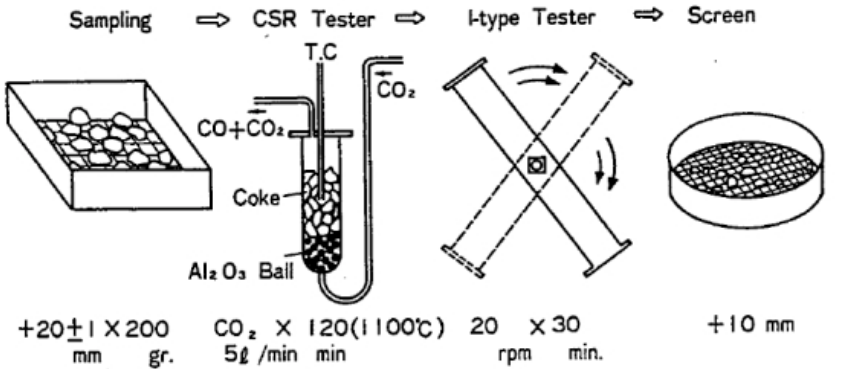
Coke reactivity test resort.

In the test, a 200 g sample of 20 mm coke fragments are placed in a carbon dioxide atmosphere at 1 – 2 bar pressure and then heated at 1100˚C for two hours. The coke is preheated and cooled under nitrogen and the weight loss during reaction is measured. The percentage weight loss is measured against the Coke Reactivity Index (CRI) for which the international standard is ISO 18894 (2006).

The reacted coke is placed in an I-tester cylinder chamber and subjected to 600 revolutions in 30 min. The percent of carbon material removed from the drum that is +10 mm after sieving is the CSR.

This recognised test procedure in a laboratory mimics coke lumps descending in an industrial blast furnace where they are subjected to abrasion as they rub together and against the walls of the furnace in a current of CO_2. These two concurrent processes chemically react with the coke lumps producing an excess of fines that can decrease burden permeability leading to increased coke requirement rates and lost hot metal production.

A typical coke reactivity furnace (from a manufacturer such as Carbolite Gero) has a maximum operating temperature of 1100˚C with a controller that meets either the ASTM D 5341-14 or ISO 18894 (2006) standard. Carbolite Gero's furnace has three distinct heated zones with low thermal mass insulation over a 700 mm length. There is also a gas safety system and audible alarms for over-temperature, low gas flow and flame failure. Most importantly, the interior of the dual walled furnace accommodates an Inconel retort, which is corrosion and oxidisation resistant and which allows incoming gas to be preheated.



CSR measurement.

The process

Step one

The first task is to load the tubular shaped retort. The liner in the retort has a perforated base to enable the free flow of gas through the sample, which is made up of small 20 mm pieces of coke weighing around 200 g in total. Once the coke sample has been loaded into the retort liner, it is returned to the retort and the thermocouple sheath is positioned into the liner and sample before the retort lid is firmly secured.

Step two

The retort is placed in the CRI furnace in its parked position, the thermocouple connected and the retort tethered to an earth connection. The retort can then be connected to the gas supply pipe at which time a nitrogen purge automatically using the mass flow control with pre-set alarms and full data logging and charting of the gas purge.

Step three

Once initially purged with nitrogen, the retort can be connected to the lifting arm, the safety gates closed and the CRI testing setup can commence once the flame failure unit has been started. It should be noted that the safety flame is automatically ignited via an electrical spark and is optically monitored by a flame failure detection unit. This flame is vital to ensure that any toxic gas exiting the retort during the testing phase will be burnt.

All that is left for the operator to do is to press the cycle start button and the furnace will heat to a uniform 1100˚C.

Step four

Once the furnace has reached 1100˚C, an alert will sound and the retort can be loaded into the hot furnace. The safety gates are opened, the top insulation plug is removed and then the retort is released from its parked position and swung over towards the split tube furnace, which is briefly opened to accept the retort before the split tube is clamped shut and the

safety cage closed once again, and the main process commences.

As soon as the correct nitrogen purge conditions are re-confirmed, carbon dioxide flows automatically and the nitrogen purge of the retort ceases. The observer will note that the flame size increases as a result of the carbon dioxide flow.

Step five

At the end of the test procedure, an intermittent siren sounds with a warning lamp. The test operator can then open the doors of the safety cage, unclamp the split tube furnace and return the retort to its parked position to cool.

Step six

Once fully cooled the coke sample can be removed from the retort liner. It is important to ensure the retort is fully cooled before attempting to recover the coke sample.

Step seven

The coke sample has been heated in carbon dioxide for two hours in the split tube furnace and can now be transferred to the CSR I-Tester. This unit has a tumbler on which the number of revolutions is preset but which can be easily modified by the operator. The standard setup will result in the tumbler rotating 600 times at a constant 20 RPM over a 30 min. cycle time before it comes to a halt and the vessel should be removed from the tumbler.

The lid of the tumbler vessel can now be removed, the retort extracted and the resulting final sample poured from the retort to enable the CSR measurement to finally be made.

Moving wall coke oven discharging.

Tumbler test for coke.

Conclusion

This entire seven step process may seem elaborate or complicated but it is a well-trusted process that delivers accurate results of the performance of any specific coke sample with a high CSR indicating a strong coke. WC