In-situ laser-based gas analysis

Dynamic knowledge of process gas analysis, such as CO, CO_2 and O_2 content, is extremely important both for process control and plant safety. Laser gas analysis overcomes many of the problems associated with traditional analysis methods, such as the need for frequent maintenance, analysis drift and transport delays to the gas analyser. In-situ measuring provides the plant operator with process information in real time, to enable fast reactions to potentially unsafe situations and to improve process stability.

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Due to the complexity of the production processes, steel works are high risk areas, with molten metals, water and potentially explosive gases in close proximity. Dynamic knowledge of process gas analysis, such as CO, CO_2 and O_2 content, is extremely important, both for process control and plant safety, however, gas analysis in such environments can be difficult.

Traditional extractive methods, for example where a gas sample is removed from the gas duct and transported to an analyser, can be problematic as they require frequent maintenance due to high levels of dust. This is where laser techniques come into their own as they work in-situ and can withstand harsh industrial environments and the sensors are mounted directly at the process without the need for sampling. Importantly, in-situ measuring provides the plant operator with process information in real-time, to enable fast reaction to potentially unsafe situations and to improve process stability. The method uses tuneable diode laser spectroscopy, with laser power measured in milliwatts and wavelength in the range of 800nm (see *Figure 1*). Three industrial examples will be described.

BASIC OXYGEN STEELMAKING

During steelmaking the 'waste' gas contains large quantities of CO and CO_2. CO is explosive in the presence of just a few molecules of oxygen and, in the main decarburisation phase of the blow, CO reaches 80%, so there is a risk of explosion, even without an ignition source. This means continuous monitoring of O_2 such as via an LDS6 gas analyser is critical to maintaining a safe environment.

Dynamic knowledge of the CO and CO_2 contents are extremely important for process control, and the high CO content also makes the gas valuable for reuse elsewhere on site. The conditions under which the monitoring takes place are extremely challenging, with dirt and moisture affecting process equipment and measurements.

COKE OVENS

Another example of a successful laser application is in a coke oven plant. During coking, gases are produced that contain high levels of CO. This exhaust gas has a high calorific value and is often used as a fuel for power plants or other processes. However, high levels of CO can lead to the risk of explosion, so it is necessary to be able to measure the content of O_2 accurately in this gas to be certain that it is close to zero, otherwise an explosion could occur. This is no easy task in the plant in question, as the gas is guided from the coke oven to the power plant in a horizontal gas pipe with an average diameter of 2m, and the gas is wet and dusty. A laser analyser unit was placed across the duct to measure the low O_2 level accurately.

The high speed measurement – a response time of within one second – provided by the laser, enables swift reaction should safety levels be breached. Engineering time is reduced as the device is easy to set up and requires no sampling. Reliability is also guaranteed as there is no measurement drift due to the device's internal reference cell and good representation of O_2 is secured.

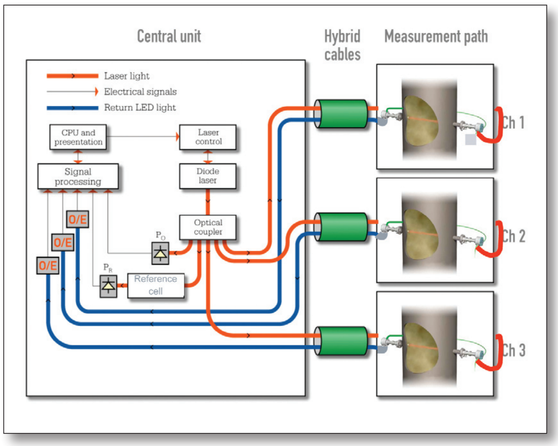

Fig 1 **Tuneable diode laser – principle of operation**

FERROMANGANESE PRODUCTION

A third example is the Tasmanian Electro Metallurgical Company (TEMCO), a manganese ferroalloy plant with

Fig 2 The Tasmanian Electro Metallurgical Company

four electric arc furnaces (see *Figure 2*). Safety is a key concern for the company, having a history of intermittent plant explosions caused by water ingress into the furnaces. The furnaces are water cooled and, over time, the steel tubes through which the water flows gradually erode. Water leaks can lead to violent explosions if not spotted in time and the process halted.

The safety of staff, the environmental impact and plant downtime was a key concern. Absorbing the vast costs associated with a plant closure in itself can be critical to a business, and several efforts were made to solve the problem, with limited success, including attempts to perform a water mass balance. It was also suggested that the off-gas from the furnace could be monitored for water content.

To find a solution, valuable data needed to be collected to trend the base level of water in the furnace. A crucial element of this study was to collect accurate and reliable data from the furnace off-gas. Given the complexity of the environment, combined with the high levels of dust involved, finding an appropriate instrument was challenging.

Eventually, an in-situ laser was chosen for the task. The laser was installed, with some bespoke modifications, to ensure it would work in the submerged arc furnace off-gas duct, as it was the first time it has been used in this environment. Because it was a first-time application, much care was taken to guarantee the analyser's accuracy, sensitivity, reproducibility, reliability and maintainability. Accuracy is 2% of the measurement, or the sensitivity, whichever is the largest. Overall performance depends on other parameters such as path length, temperature and pressure.

One of the major modifications required for this application was to counteract the extremely high levels of dust in the gases. Around $100g/m^3$ was recorded which was much too high for the laser analyser to work accurately, as it could only deal with up to 95% opacity. The solution to this was the inclusion of an air chamber in which the high levels of dust were blown off the laser every few minutes. This allowed the laser to gain an accurate scan of the water content and, consequently, it delivered consistent and reliable readings.

Trials showed that small leaks in the furnace, which had previously gone undetected, could now be monitored and, importantly, confirmed several hours before any other traditional methods. The data from a trial period meant that a set of control limits could be established to forewarn of any future explosions.

Using the analyser, the plant personnel are able to observe water level trends and take action accordingly. In one case, an abnormally high increase was noticed and a shutdown of the furnace was ordered. This decision was not taken lightly as the cost of plant downtime is high, however, it was certainly the right decision as further examination estimated that an explosion was likely to have happened within the next two hours if no action had been taken.

TEMCO has now developed a safety procedure around the analyser. This is a big step towards achieving zero fatalities in an environment that has been considered highly volatile and unpredictable for many years.

SUMMARY

To guarantee safety levels in steel and iron plants, it is clear that accuracy and reliability of measurement instrumentation are key. If a plant has to set the safety trip device with a margin of error, then there is a higher risk of spurious trips, resulting in plant downtime. If a device can be trusted and set at the exact trip level, it will only shut down production when that safety level is breached, not before. The high accuracy and fast response of in-situ laser gas analysers makes them ideal for this purpose.

The design of these analysers means they are the best placed analytical tool for safety applications in metals industries. The device can measure gases such as oxygen and carbon monoxide in low and high concentration with accuracy. As well as being able to withstand very rough industrial environments, the sensors are also designed to perform within strong DC magnetic fields. Importantly, no sampling of toxic and aggressive gases like HF is necessary as the measurements are performed in-situ. Other benefits of in-situ laser analysers are low maintenance (as there are no consumable parts and no calibration is required) and high resistance to cross-interference and dust. MS

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