Remote viewing made easy

How thermal imaging cameras are helping to reduce slag carryover in steel production and improve efficiency

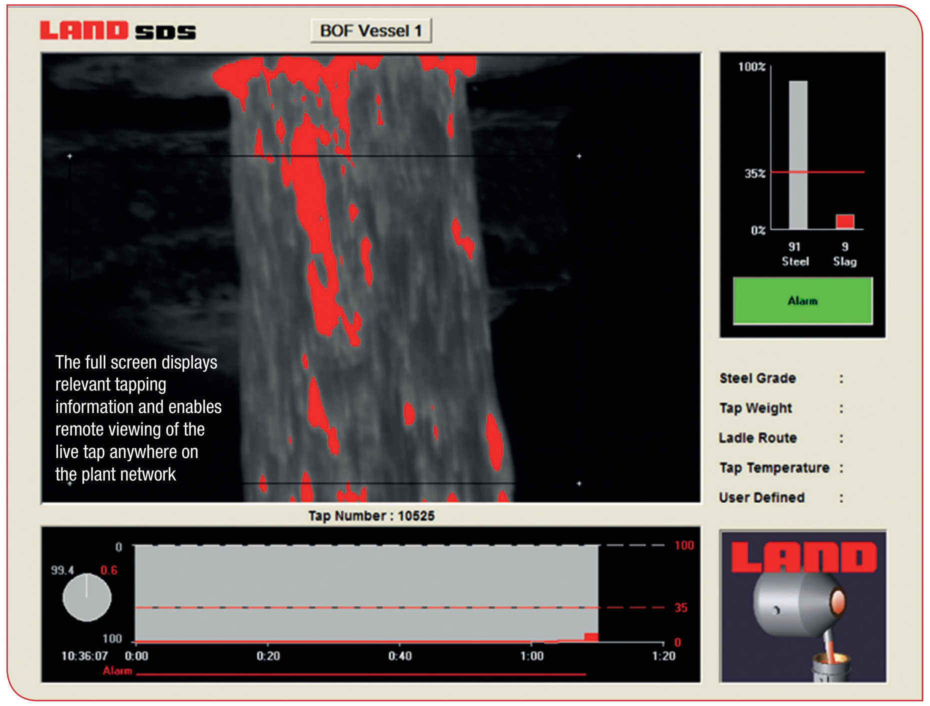
Steel slag, a molten liquid melt of silicates and oxides, is a by-product of the steelmaking process, which is produced during the separation of molten steel from the impurities that are found in iron ore and scrap metal. The slag solidifies upon cooling.

The reason it needs removal is that slag impurities degrade steel. For example, slag will pull phosphorous from iron and, if not removed, the phosphorus reverts back into the steel, lowering its quality. It also causes substantial wear and tear on the vessels involved. Removal of slag has involved huge effort and expense on the part of steel producers. Recent advances in detection now mean that slag can be more reliably and effectively managed.

The disadvantages of slag carryover include:

- Longer processing time
- High inclusion formation and steel cleanliness challenges
- Difficulty in ladle desulphurisation
- Caster nozzle clogging
- Ladle refractory wear.

While slag can be used in the aftermarket for a variety of applications, its presence as a result of the steelmaking process involves a great deal of time and expense to remove it. Slag can also lead to equipment damage.



The full screen displays relevant tapping information and enables remote viewing of the live tap anywhere on the plant network

How steel is produced

Steelmaking starts with iron in a furnace, with the two most common furnace types being a basic oxygen furnace (BOF) and an electric arc furnace (EAF). The two vary as follows:

Basic oxygen furnace

A basic oxygen furnace is a refractory-lined and tiltable converter. When steel is made in a basic oxygen furnace, molten iron and scrap are heated. Oxygen is then blown through nozzles into the charge via a water-cooled oxygen lance. The BOF is able to rotate, enabling it to charge raw materials and fluxes that are used to remove impurities. That also allows it to sample the melt and pour the steel and slag out of the furnace. The oxygen converts the pig iron, which accounts for approximately 94%of the volume. The remaining 6% is composed of impurities, including manganese, carbon and silicon. By the end of the steelmaking process, steel made via BOF will have impurity levels of approximately 1%.

In the basic oxygen process, hot liquid blast furnace metal, scrap and fluxes, consisting of lime and dolomitic lime, are charged to a furnace. A lance is lowered into the converter and high-pressure oxygen is injected. The oxygen combines with and removes the impurities in the charge. These impurities include gaseous carbon monoxide, silicon, manganese, phosphorus and liquid oxides that combine with lime and dolomitic lime, forming steel slag. At the end of the refining operation, the liquid steel is tapped (poured) into a ladle. The steel slag remains in the vessel and is subsequently tapped into a separate slag pot.

The molten steel is removed from the furnace when the steel is at its optimal consistency, through the tapping hole. During the steel manufacturing process, the tapping hole remains plugged to keep heat from escaping the furnace.

Electric arc furnace

In comparison, an electric arc furnace (EAF) creates steel from scrap and direct-reduced iron (DRI). It uses three vertical graphite electrodes to charge the iron and scrap via electric current. This furnace is comparable to a wok with a lid. Metal is added, the lid is closed, and an arc is created between the electrodes. A huge amount of power is used to melt 100% of the steel scrap.

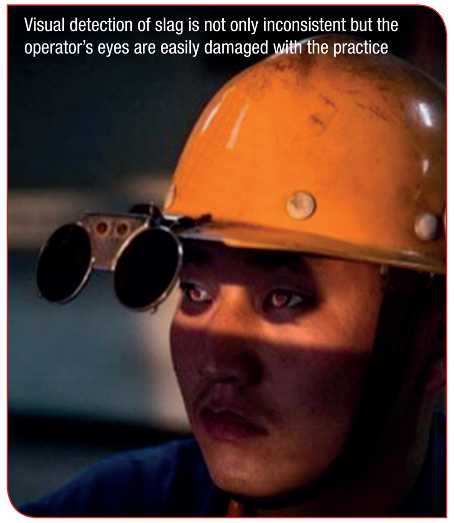
At this point, limestone flux is added. A hole in the base of the 'wok' opens and a ladle is positioned underneath. The molten steel exits into the ladle, and the hole closes when slag is detected.

With both types of furnaces, molten iron is tapped at regular intervals. Accurate temperature monitoring ensures steel quality is consistent and improves process efficiency. While it seems that the steps are straightforward, detecting slag and keeping it from degrading the steel is an art and a science, and the detection methodology has evolved significantly over time.

Slag detection methods

When slag begins to exit along with the steel, the pour is stopped. The initial process for detecting slag was visual. An operator wore a dark viewing shield, or visor, to observe the colour of the pour. Since slag has higher emissivity, it looks brighter than the steel preceding it. Once the slag was spotted, the operator signalled for the molten steel vessel to tilt, preventing it from pouring out.

There are several downsides with this method – a major one being safety, as the operator's eyes could be damaged whilst observing the steel. Repeatability is a major issue, as reliability varies from operator to operator. Fumes often cloud the environment so that complete accuracy is impossible. While this visual method is still used in some areas of the globe, it's use prevents improvements to the process.



Visual detection of slag is not only inconsistent but the operator's eyes are easily damaged with the practice

Another method involves a ceramic ball, or dart, that is shot into the molten steel. The stem of the dart is visible as it floats on top of the steel. Once slag begins to flow through the tap hole, the flow density lowers and the dart sinks into the tap hole, reducing slag flow until the operator reverses the tilt. Inserting the dart is often problematic, so much so that, in many cases, it requires an expensive machine run by a highly trained operator. The darts also are consumable and add costs to the process.

A third method is to use a circular induction coil that is wound around the tap hole in a refractory. Current passes through the coil, and the induction field varies based on the material composition of the flow. When slag is present, a signal from the induction coil determines the time when reversal should occur.

This method actually works well. The coil, however, does not last as long as the vessel. When the coil fails, it means casting a new coil into the hole or waiting for a reline and moving to manual slag detection in the interim. Accuracy over time is another major issue. Again, the coil is consumable, so using this method also adds an ongoing expense.

Two decades ago, thermal imaging cameras were introduced to help improve the process of slag detection. They had major advantages, including being non-contact, which meant they did not wear out or add consumables to the bottom line. Their detectors were an optical or infrared detector array that featured an electronic processor and repeatability was greatly enhanced.

Advances over time included long-wavelength thermal imagers with an 8-14μm response. The results were good, as the emissivity between steel and slag is accentuated by the long wavelengths. There was still fume obscuration, and the optical materials used in these thermal imagers were not sufficiently durable for the harsh environment, requiring frequent protective window or lens replacements.

An atmospheric window

Although long wavelengths were problematic, mid-wavelength thermal imagers offered several possibilities. A thermal imager working at a narrow waveband could see through hot CO_2 and hot water vapour. This atmospheric window was first documented in NASA test data more than five decades ago. The shorter 3.9μm waveband also enabled extremely durable optical systems, including sapphire protection windows with good transmission characteristics from ultraviolet to approximately 5.5μm in the infrared.

These capabilities are built into the AMETEK Land Slag Detection System (SDS), which delivers improved yields, higher-quality steel and reduces costly downstream processing for BOF and EAF steelmaking operations. It is specially designed to withstand the harsh conditions of continuous operation in a steel plant, with minimal maintenance requirements.

The AMETEK Land SDS has an industrial thermal imaging sensor, housed in a rugged, water-cooled and air-purged enclosure that continuously views the tapping area. As the tap begins, dedicated software automatically records the tap, producing a log and graph of the relevant steel and slag data. When the slag reaches a pre-determined level, an alarm is generated to stop the tap. Full access to the tapping data is available to the operator for quality control purposes.

> *The SDS' high-resolution thermal imaging camera detects the transition between steel and slag with a particular wavelength, reducing blackouts caused by smoke and fumes*

The SDS' high-resolution thermal imaging camera detects the transition between steel and slag with a particular wavelength, reducing blackouts caused by smoke and fumes. The data it presents in real time, enables the operator to make informed decisions about the tapping process. By warning the operator in a dependable, repeatable and timely manner to stop the tap before slag is carried over, the SDS improves production yields and ensures a lower slag content, therefore improving the steel's quality. This also reduces energy costs further along the process and lowers the overall maintenance on the furnace vessel.

Using an SDS has shown to improve operator response time and consistency at the end of each tap. This results in a typical reduction in slag depths of up to 25%, compared to traditional methods for monitoring slag.

The SDS represents a major innovation in slag detection and thermal imaging, providing an excellent man-machine interface for the steel industry. The system claims to offer improved operator safety, quick response times and consistent results. It is very durable and will normally be expected to last longer than the vessel. The system can result in major savings in aluminium additions, as the ladle slag heights can be reduced by 2.5cm. Phosphorous reversion is also reduced between 0.002 to 0.003%. Another benefit is refractory and argon stirring lances can have increased lifespans of 10-20%, respectively.

Summary

Although measurement methods have evolved over the past few decades, the quality of metallic scrap and iron feed stocks have simultaneously deteriorated. This results in greater slag generation and slag-related challenges for the steel industry.

The existence of slag causes substantial processing time, lower steel quality, difficulty adding alloys and conditioners, plus substantially higher processing and treatment costs.

The cost of additional downstream processing time and materials can be a significant burden for an operating plant. By controlling slag carryover, this costly downstream processing can be reduced or eliminated, improving plant throughput and operating margins.

AMETEK's Land Slag Detection System is designed to withstand the harsh conditions of continuous operation inherent in steel production. It claims to reduce slag carryover in steel production facilities, saves money and dramatically improves operator safety.

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The AMETEK Land slag detection system in use