Automatic Real-Time Chemical Composition Analysis (LP-LIBS) in Casthouse Operations

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Abstract

Knowledge of chemical composition is important at multiple stages of smelter operations. At the electrolysis stage, impurities in the molten metal reveal the state of the reduction cells and the quality of raw materials. Further downstream, chemical analysis is crucial for monitoring the melt composition at the stages refining and alloying, and for maximizing the value of final smelter products. DTE has successfully implemented fully automated chemical analysis of the molten metal in primary and secondary casthouses, analysing metal from transport crucibles as well as furnaces, where real-time, minute-by-minute chemical information of the molten metal can assist in optimizing furnace operations. The performance of those plant implementations will be discussed, including analysis accuracy, concentration ranges, and long-term stability. DTE's solution combines the connected analysers and an online cloud platform, IRIS, transforming the real-time chemical analysis results, along with other process data, into predictive insights and actionable information, leading to process improvements and increased operator safety. DTE recently supplied four automatic crucible analysis solutions to a primary aluminium smelter in Iceland. The automated systems are a crucial part of the metal treatment process for transporting crucibles in the smelter's new billet casthouse. Having precise chemical composition information from the crucibles is essential for efficient furnace quality control during the alloying process. DTE's solution was also integrated into a recycling furnace at a secondary aluminium production plant, now offering the customer real-time information on batch composition. This opens up opportunities to enhance furnace operation, increase throughput and optimize feedstock.

Keywords: LIBS, Chemical composition analysis of liquid aluminium, Casthouse process control, Industry 4.0, Process automation.

1. Introduction

Monitoring alloy chemistry during production has typically involved manually extracting molten metal from different points in the production process and casting it into solid samples for laboratory analysis. For chemical analysis, the industry has mainly relied mainly on spark optical emission spectroscopy (spark-OES), where electrical breakdown is induced in a small gap between the solid metal sample and a high-voltage electrode. The spectral fingerprint of the optical emission from the spark plasma is characteristic of the constituent elements of the sample [1].

In the early 1960s, three years after the invention of the laser, researchers at the Ford Motor Company realized that this novel device, operated in a high-energy pulsed mode, could be used to generate a plasma at the surface of a solid or molten metal [2]. They stated: "The possibility of determining the chemical composition of a material situated in a hostile environment, such as molten metal within a furnace, by a method which does not require the removal and cooling of the sample, has long intrigued both melters and analysts. The practicality of performing such an

analysis by means of a laser has been conjectured by the authors since finding, in 1963, that a laser can excite useful spectra from solid metals without an auxiliary electrical discharge."
Around the turn of the century, following improvements in pulsed laser sources, fast and sensitive photodetectors, and compact high-resolution spectrometers, this field of chemical analysis, now commonly referred to as laser-induced breakdown spectroscopy (LIBS), started growing rapidly [3]. The basic principle is still the same as that envisioned by the researchers at Ford Motor Company, i.e., the simultaneous ablation and excitation of material, typically using the focused beam of a pulsed laser, with subsequent detection of the spectrally resolved plasma emission for identifying and quantifying the constituent elements of a sample. Detection limits with this technique have improved by orders of magnitude and have routinely been shown to be in the range of parts per million (ppm) or even lower. As predicted, this method of chemical analysis has proven especially useful in hostile environments – a few LIBS systems have even been sent to Mars to analyze its soil chemistry [4]. The basic principle of the LIBS measurement is illustrated in Figure 1.

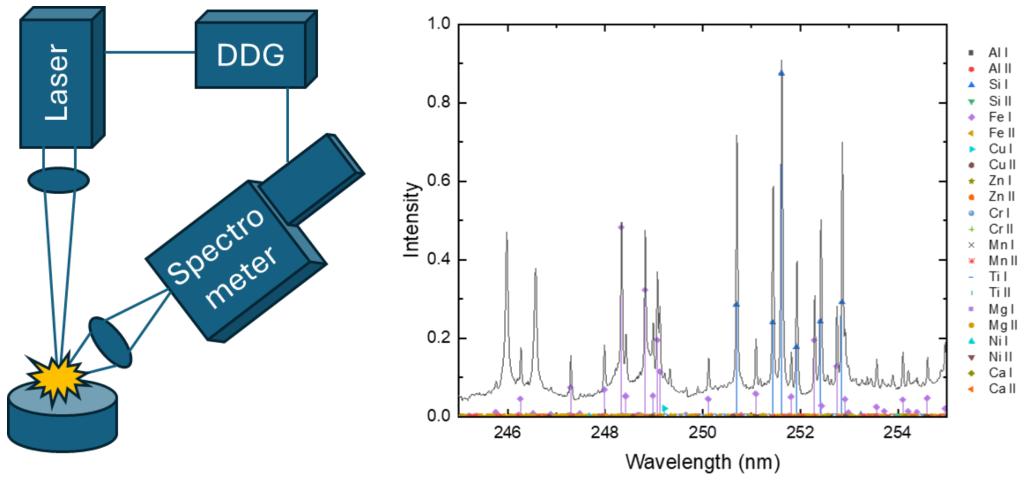

Figure 1. Basic principle of the LIBS analysis method: A pulsed laser beam is focused onto the surface of the sample (e.g., liquid aluminium) to ablate a fraction of the sample and convert it into a plasma. The resulting plasma emission is dispersed and detected using a spectrometer, synchronized with the pulsed laser using a digital delay generator (DDG). Specific peaks in the emission spectrum are associated with different elements and used for quantification.

In recent years, LIBS-based chemical analysis of molten metal has also made its way into metals production [5]. Performing chemical analysis directly on the molten metal offers several advantages, especially when the analysis can be fully automated. This allows for more frequent analysis with immediate results, enabling closer monitoring of changes in melt chemistry, e.g., during alloying or to monitor the uniformity of melt composition during casting. Measuring the liquid metal directly avoids issues that can affect the precision and accuracy of analysis results when preparing solid samples. These issues include inhomogeneous solidification, improper machining, contamination, or sample mix-up [6]. Additionally, the safety of plant workers is improved as they are no longer required to manually extract and handle samples of molten metal.

2. Implementations in the Aluminium Smelter Casthouses

The implementation of portable LIBS-based analyzers for potroom operations has been discussed previously [7]. The present paper focuses on fully automated casthouse implementations, such as

7. References

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