Profitability Increase in Aluminium Smelter Potroom Using Real-Time Elemental Analysis from Liquid Metal Based on LP-LIBS

Berglind Hoskuldsdottir[1], Karl A. Matthiasson[2] and Pall Jensson[3]
1. Process Analyst
2. Chief Financial Officer
DTE, Reykjavik, Iceland
3. Professor, Department of Engineering at Reykjavik University, Reykjavik, Iceland
Corresponding author: berglind@dte.ai

Abstract

A profitability study was carried out for an implementation of portable elemental analyzers coupled with an artificial-intelligence-based cloud platform from DTE at a primary aluminium smelter potroom. The elemental analyzers use liquid-phase laser-induced breakdown spectroscopy (LP-LIBS) to analyse chemical composition of molten metal. DTE's solution, Ireas, combines the connected analyzers and cloud platform. DTE's new technology replaces current manual methods for aluminium sampling from electrolysis pots with real-time analysis of liquid aluminium. Ireas then transforms the real-time chemical analysis results into intelligence, predictive insights and actionable information leading to profitability improvements in the electrolysis potroom. Selected benefits generated by DTE's solution were reviewed, the benefits include reduction of manual mistakes, increased operator safety, improved response time and increased process automation. The benefits are based on research conducted by DTE as well as the experience of smelters and people in the aluminium industry. Ireas can contribute to between 1.5 % and 4 % increase in profitability in primary aluminium smelter potrooms, while also affecting the whole value chain in the form of operational efficiency, safety, and sustainability. Each smelter is unique, and their possible benefits with the solution need to be evaluated separately. DTE's profitability analysis tool, presented in this paper, can be used by smelters to calculate their possible profitability increase by implementing Ireas. A case study indicated a possible profitability increase in the electrolysis potroom by $ 14.97 per ton or around $ 1.5 million in profitability increase per year, with 93 % of the profitability increase being due to reduced operational cost.

Keywords: Aluminium, Process control, Chemical analysis, Profitability study.

1. Introduction

DTE has developed elemental analyzers for analyzing chemical composition of liquid aluminium in real-time and in situ by using technology based on Liquid-Phase Laser-Induced Breakdown Spectroscopy (LP-LIBS), including proprietary and patent-pending technology established by DTE. Conversely, current practices in aluminium sampling usually require an operator to take an aluminium sample manually, cast it into a mold, wait until it solidifies and then take it to a laboratory where the chemical composition of the aluminium is analyzed, most commonly by using spark optical emission spectroscopy (spark-OES) [1]. This process can be time consuming and associated with risk of errors such as sample mix up, contamination of molds and incorrect preparation of sample before it is analyzed. By analyzing liquid aluminium samples in real-time the risk of error is minimized and the results are obtained immediately. The elemental analyzer has proven to offer accurate results for concentration analysis of trace elements in liquid aluminium in the challenging smelter environment correlating well with spark-OES laboratory analysis [2]. In some cases, directly analyzing the liquid aluminum can be more accurate than the spark-OES analysis because of changes that can occur in the aluminium sample when it is cast.

The accuracy of the portable elemental analyzer for key elements is discussed elsewhere in these proceedings [3].

DTE's solution, named Ireas, combines real-time intelligence from liquid aluminium with an artificial intelligence-based cloud platform. Where in real-time refers to that information is available as soon as it happens, every time for everyone that needs it, and everywhere it is needed. Ireas turns chemical analysis results into intelligence, actionable data and predictive insight, that can support current processes at smelters and contribute to maximizing value, sustainability, safety and efficiency. Which is a driving force towards Industry 4.0, by integrating information technology with current manufacturing practices [4]. DTE has tested its solution at a few primary aluminium smelters, including a battery-powered portable elemental analyzers specially designed for aluminium sampling from pots [5]. Various possible benefits generated by Ireas have been identified in the electrolysis potroom. The benefits include reduced sampling time, improved response time, increased sampling frequency with higher data reliability, longer lifetime of pots and improved anode usage, to name a few. DTE's portable elemental analyzer located on a small electric vehicle is displayed in Figure 1. The analysis device is located in the back of the vehicle along with a tray of ladles used for extracting samples from pots and a small crucible where the liquid aluminum sample is placed for elemental analysis. The analyzer can also be mounted on a self-driving vehicle or a manually operated pushcart.

Figure 1. DTE's portable elemental analyzer.

Laser induced breakdown spectroscopy (LIBS) technology is a type of atomic emission spectroscopy where a powerful laser is directed to the surface of the sample which is being analyzed [6]. LIBS can detect a wide range of elements present in a sample, down to ppm concentrations. The high energy laser shot only lasts for a few nanoseconds and forms a plasma on the surface. During this state, atoms of each element radiate a unique spectrum of emission lines. A spectrally dispersive sensor detects the plasma radiation including the emission lines of each element. Subsequently, the intensity of particular lines is used to quantify the respective elements. In general, LIBS technology can be used to analyze the chemical composition of various materials, regardless of whether they are solid, liquid or gas, and works for both conducting material and non-conducting. DTE's elemental analyzers are specially designed and adapted to analyze aluminium in the liquid phase with LIBS. The analyzers offer chemical analysis results within seconds from the time of sampling, enabling the analyzers to provide details about trace elements in liquid aluminium in real-time.

2. Benefits in the Electrolysis Potroom with Ireas

There are various benefits of implementing DTE's solution in the potroom and they are the result of possible process improvements driven by Ireas. Ireas provides actionable data enabling faster,

profitability number. These numbers are specific for this particular smelter and each case needs to be evaluated separately.

5. Conclusions

Potential benefits and profitability of deploying DTE's solution, in a primary aluminium smelter potroom has been presented. Some of the benefits that DTE's solution offers are faster chemical analysis results, increased operator safety, reduced energy consumption and reduced number of pot tapouts. The benefits presented are then accompanied by increased profitability, but the potential profitability increase needs to be evaluated for every aluminium smelter since each smelter is unique and has different processes as well as different technological and local business situations. DTE's online profitability analysis tool is a solution that offers users to obtain customized results on possible profitability increase with DTE's technology. The tool requests a few inputs from the user which are key figures from a potroom operation to calculate the possible profitability increase. A potential profitability increase of $ 14.97 per ton or $ 1.5 million per year was determined for an aluminium smelter potroom in Iceland, with 93 % of the profitability increase due to reduced operational cost. DTE's solution opens the door to uncover opportunities to optimize aluminium production, break down operational silos, maximize benefits and value.

6. References

5. Sveinn H. Gudmundsson, Jon Matthiasson, Kristjan Leosson, Accurate real-time elemental (LIBS) analysis of molten aluminum and aluminum alloys, *Light Metals* 2020, 860-864.
6. Sveinn H. Gudmundsson et al., Quantitative in-situ analysis of impurity elements in primary aluminum processing using laser induced breakdown spectroscopy, *Spectrochimica Acta Part B: Atomic Spectroscopy*, vol. 158, 2019, 105646.
7. Rauan Meirbekova, Sveinn Gudmundsson and Kristjan Leosson, Portable elemental analysis device for real-time chemical analysis of aluminium, *Proceedings of 39th International ICSOBA Conference*, Virtual, 20-24 November 2021, Paper AL36, *Travaux* 50.
8. F. Zezulka, et al., Industry 4.0-An Introduction in the phenomenon, IFAC-PapersOnLine 49, Vol. 25, 2016, 8-12.
9. Sveinn H. Gudmundsson, Birna Björnsdóttir, Kristjan Leosson, Instant monitoring of aluminum chemistry in cells using a portable liquid-metal analyzer, *Light Metals* 2021, 491-494.
10. D.W. Hahn, N. Omenetto, Laser-induced breakdown spectroscopy (LIBS), Part II: Review of instrumental and methodological approaches to material analysis and applications to different fields, *Applied Spectroscopy 6*, 2021, 347-41.
11. Khalil Khaji and Al Qassemi, The role of anode manufacturing processes in net carbon consumption, *Metals 6*, Vol. 6, 2016, 128.
12. Halvor Kvande and Per Arne Drablos, The aluminum smelting process and innovative alternative technologies, *Journal of Occupational and Environmental Medicine 56*, 23-32.
13. Rauan Meirbekova et al., Influence of phosphorus on current efficiency in aluminum electrolysis at different current densities, *Journal of The Electrochemical Society*, 164(7), 2017, 161-165.
14. Rauan Meirbekova et al., Influence of sulfur species on current efficiency in the aluminum smelting process, *Metallurgical and Materials Transactions B*, Vol. 47, 2016, 1309-1314.
15. Omar Awayssa et al., Electrodeposition of aluminium titanium alloys from molten fluoride-oxide electrolytes, *Electrochemistry Communications*, Vol. 123, 2021, 106919.
16. Omar Awayssa et al., Electrochemical production of Al-Mn alloys during the electrodeposition of aluminium in a laboratory cell, *Electrochemistry Communications*, Vol. 125, 2021

17. Lukas Dion et al., Sodium content in aluminum and current efficiency – correlation through multivariate analysis, *Light Metals* 2013, 741-746.