

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

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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 aluminium 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,

better, and safer decisions based on data and intelligence, which is an important contribution to maximize value, sustainability, and safety. This new technology drives a profitability increase at the smelters as a result. DTE has put considerable effort into uncovering the value and benefits associated with the solution. This has included previous research conducted by DTE [1-4], along with the experience of smelters, conversations with smelter specialists and people in the industry. The selected benefits, listed in the following sections, are the results from that work. However, every one of the listed benefits needs to be adapted to each smelter based on its processes, business, and technological situation. Furthermore, the profitability of the benefits uncovered needs to be evaluated case-by-case as well. Selected benefits that can be monetized by deploying Ireas in the potroom are discussed in the following sections. The monetized benefits in addition to other benefits that are not monetized are divided into five main categories, where each category can include one or more benefits that are then further explained.

2.1 Pot Sampling

With the portable elemental analyzer it is possible to increase pot sampling frequency, which enables increased quality control. With the elemental analyzer, samples are taken from pots in the same manner as for conventional sampling. A ladle is used to extract a liquid sample but instead of casting it into a mold the sample is poured into a small crucible and analyzed right away, and the results are available on the device and in the cloud platform. The measurement cycle described takes around 70-90 seconds in regular operation for a single pot. Thus, there is no longer a need to collect the samples and take them to a laboratory for chemical analysis. This results in great reduction in sampling process time and the results are available in right away, instead of minutes or even hours later with standard off-line sample analysis. Ireas sends out a notification if something out of the ordinary comes up, that makes it possible for smelter operators to react immediately and take a verification sample right away, if needed. This enables the potroom operators greatly in the process. The chemical analysis results are registered on the pot automatically, eliminating the risk of sample mix up. The portable elemental analyzer comes on an electric vehicle and is easy to use to drive between pots and take extra samples from trouble pots when needed.

Since the elemental analyzers analyze the samples automatically in the potroom, the need for a central laboratory to analyze solid aluminium samples from the potroom is eliminated. That results in reduced cost, both in operational expenditures and capital expenditures as well as minimizing real estate taken by a laboratory. Smelters can have a spare spark-OES device available for precautionary reasons but there is no need to operate a conventional laboratory, resulting in up to 75 % reduction in capital cost.

2.2 Raw Material

Anodes are often not used as efficiently as possible; the average anode consumption is 400-450 kg carbon per tonne of aluminium but the theoretical consumption is 334 kg carbon per tonne of aluminium [7]. With increased sampling frequency, real time process control, and predictive levels of elements provided by Ireas there is an opportunity to optimize the anode change cycle. By having increased knowledge of iron (Fe) and copper (Cu) levels in pots the anode usage can be better predicted and the anodes can be used for longer with confidence. As well as reducing electrolysis pot disturbance since anode change is the most common cause for operational disturbance [8].

2.3 Energy

With DTE's solution there is an opportunity to improve currency efficiency. By applying real-time process control, improving response time when pots show unusual behavior, by having

increased information with higher accuracy on sodium (Na) levels in the pots and by better control of impurities that effect currency efficiency [9-12]. The sodium content of aluminium in pots can be used as an indicator of currency efficiency [13]. The estimated improvements can be up to 1 % [9-12] lower electricity consumption in the electrolysis potroom, which is a considerable cost reduction since energy cost is generally one of the major cost factors in aluminium smelters.

2.4 Pot Control and Risk Mitigation

By deploying Ireas the number of sudden electrolysis pot bursts or tapouts can be reduced, by obtaining real-time results on iron (Fe), copper (Cu) and silicon (Si) levels as well as utilizing the predictive insights and executing predictive maintenance provided by Ireas [3]. 80 % of pot failures can be predicted within 12 hours horizon. By preventing sudden pot bursts, production loss due to potline shutdown during pot replacement and repair is reduced as well. Operator safety is also improved since sudden pot bursts involve considerable risk for the operators and the work conditions are difficult. With each sudden pot burst then follows risk of the conductor system being damaged, resulting in a loss of a potline. With DTE's solution, the risk of losing a potline can be lowered by reducing the number of tapouts.

With real-time elemental analysis, higher frequency of pot sampling and predictive insights and maintenance provided by Ireas pot lifetime can be extended, since pots can be allowed to run for longer with confidence. That results in a small reduction in pot replacements each year. The achievable extended lifetime of the pots depends on current pot replacement processes and other processes regarding the pots, in some cases pots can run for days, weeks of even months longer.

2.5 Other Benefits

Not all benefits that DTE's solution can bring to smelters have been monetized. Those benefits include enhanced quality of the aluminium being produced in the potroom by deploying real-time process control, faster and better decision making with actionable data available in real-time, better return on capital employed (ROCE) through improved use of assets, and increased aluminium sample analysis accuracy and data reliability.

The benefits obtained in the potroom with DTE's solution then have a direct effect on the casthouse and the whole value chain. Increased sampling frequency in the potroom and real-time chemical analysis results enables better knowledge of the aluminium being tapped from the electrolysis pots. Then casthouse operators can obtain information on what is precisely the quality of the aluminium being handed to them, that information can be used to predict the chemical composition of a furnace and calculate with higher accuracy the amounts of additives needed to add to the furnace in alloy production. Improved knowledge of the quality of the aluminium in the potroom also allows operators to select pots to tap based on their chemical content. This can be especially valuable when producing alloys with very narrow specifications and enables the casthouse to produce higher quality products and premium products. The technology furthermore breaks down operational silos between the potroom and casthouse, by making the same information available for everyone in every operation that requires it as soon as it happens.

3. Monetizing Benefits

In the previous chapter, selected benefits generated by DTE's solution have been presented. With deployment of the solution those benefits lead to increase in smelter profitability, including reduced operational expenditure, reduced capital expenditure, and increased revenue. The monetary value that the solution brings to primary aluminium smelters depends on multiple variables, such as current processes, technological situation, size, and local business conditions such as energy contracts, labor cost, and so on. The profitability increase for each smelter needs

to be evaluated specifically. Hence DTE’s business intelligence department has developed an online profitability analysis tool for smelters to calculate their possible profitability increase with DTE’s solution based on actual data from their smelter. The tool will be available on DTE’s website for both the potroom and the casthouse and is designed to discuss with customers the potential benefits and profitability increase generated by DTE’s elemental analysis solution. After working with a few primary aluminium smelters in Iceland some high-level estimations have been made regarding profitability of deployment of the solution. A potential profitability increase of between 1.4 % and 4 % per tonne of aluminium has been identified in the potroom. The numbers for the other parts of the world can be compared when the DTE profitability analysis tool has been launched.

3.1 Profitability Analysis Tool

The profitability analysis tool was constructed by monetizing the benefits listed in Chapter 2 and is therefore based on experience of smelters and conversations with people in the industry. The tool requests a few inputs, which are key figures from the smelter’s potroom and then gives the user customized results on what their potential profitability would be by implementing DTE’s solution. The inputs requested are for example annual production, factory location, number of pot samples taken per day, total number of pots, and potlines. The tool offers both a basic version and an advanced version. In the basic version the tool utilizes a few assumptions for some key measures such as electricity prices, labor prices and pot replacement cost. The assumptions made are, however, based on and customized to the location of the smelter. The advanced version requests all inputs needed to make the calculations as accurate as possible. It is up to the user which version is used; a simple slider can be used to switch between the two versions. When the tool is opened it shows the basic version by default, when changing to the advanced version all assumptions made by the calculator appear, so the user can modify them to their smelter or leave them unchanged. All data that the user enters is secure and handled according to EU privacy laws. The tool input section for the basic version is displayed in Figure 2.

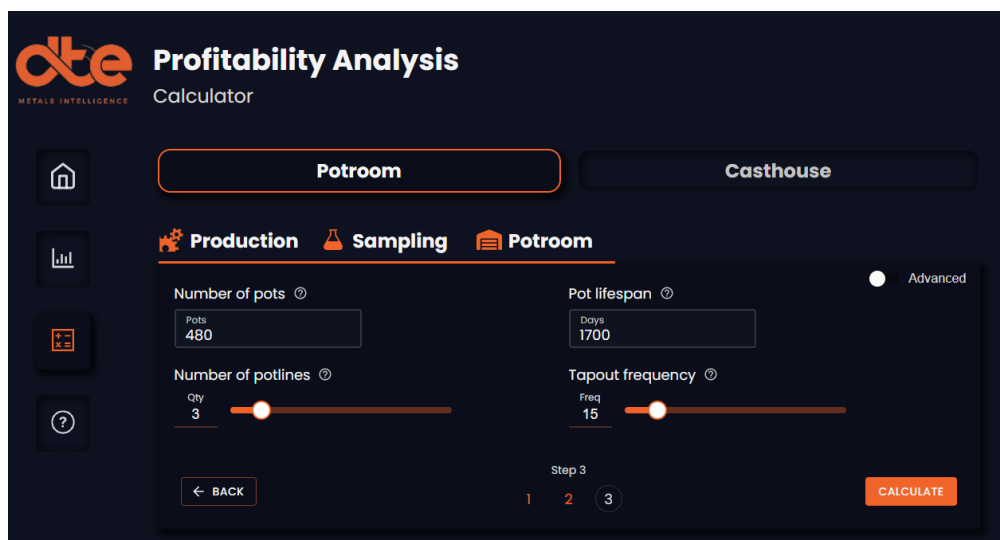


Figure 2. Profitability analysis tool input section for potroom.

In the results section of the tool the calculations are explained in detail. The user gets the calculations for estimated profitability increase per year and per tonne. The profitability estimates are then divided further into five categories. The categories are energy, sampling, raw material, pot control and risk. The benefits monetized in each category are in accordance with the ones listed in chapters 2.1 to 2.4. The tool displays graphically the profitability distribution between the categories and then the profitability contribution by each category is further broken down. For

each category the total profitability is displayed and explained in detail how the calculations are derived and what assumptions are made. An example for a results tab in the tool for potroom calculations is displayed in Figure 3.

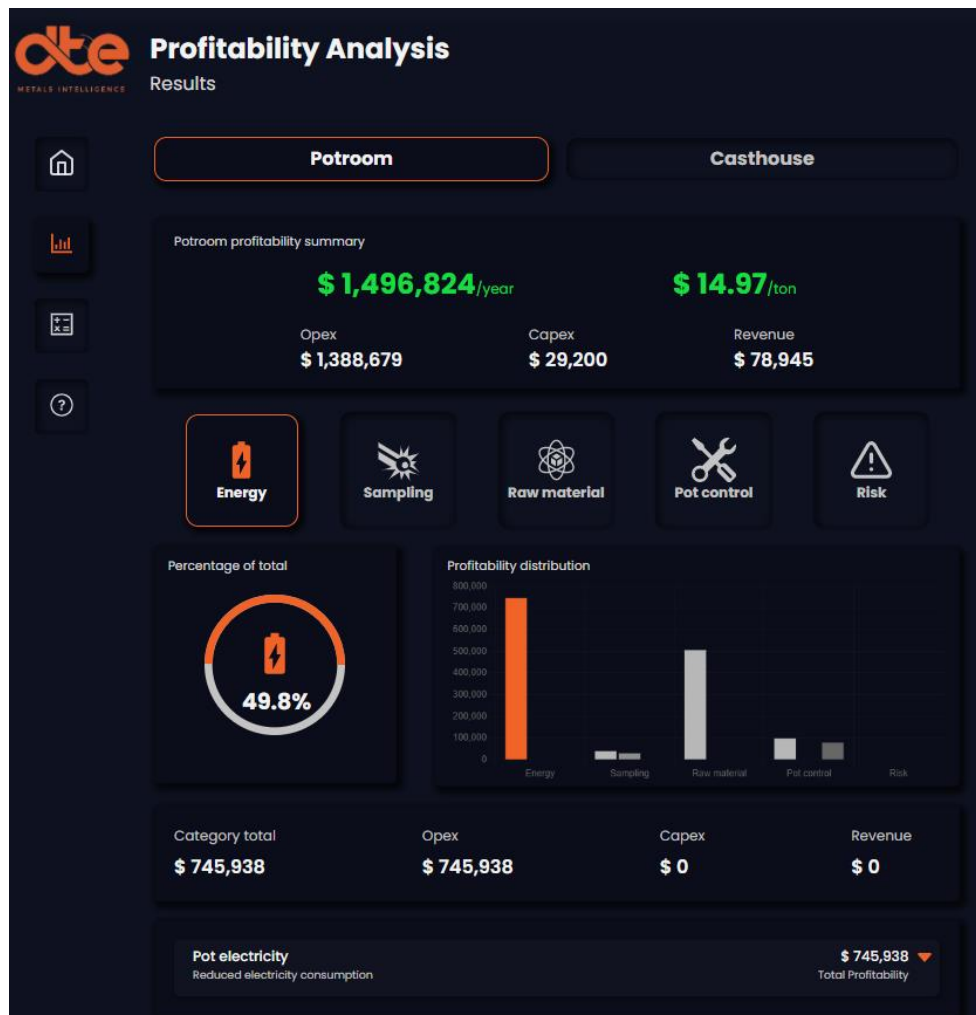


Figure 3. Profitability analysis tool results section for potroom.

4. Case Study: Primary Aluminium Smelter in Scandinavia

Profitability calculations were made for a primary aluminium smelter in Iceland by using the profitability analysis tool. An estimated profitability increase of \$ 14.97 per ton was discovered, or around \$ 1.5 million per year. The profitability increase was 93 % from reduced operational cost, 2 % from reduced capital cost and 5 % due to increased revenue. Other benefits mentioned in Chapter 2.5 are not monetized by the tool but are on the other hand very valuable and can lead to even greater profitability increase.

Out of the \$ 14.97 estimated profitability increase per tonne, energy savings are 49.8 % of the total, with around 8 000 MWh in reduction per year. Sampling is 4.6 % of the total, with around 1 000 hours saved in manual sampling time and around \$ 60 000 yearly savings due to eliminated need for a laboratory to analyze solid samples. Raw material savings are 33.8 % of the total, with 1 million kg reduction in anode consumption. Pot control is 11.8 % of the total; the pot control savings are the result of 30 % reduction in sudden pot bursts and 0.5 % pot overall lifetime increase. Finally, there is a profitability benefit of \$ 140 000 calculated as a reduced risk of potline shutdown due to a sudden pot burst, however this number is not included in the total yearly

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

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