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REAL-TIME INTELLIGENCE FROM LIQUID METALS

Uncover endless business optimization opportunities while accelerating your digital transformation journey. Redefine the way elemental analysis of metals is done along the value chain, deploying DTE's unique breakthrough innovation associated to Industry 4.0 technologies. Get chemical composition of the molten metal in real time and benefit from the associated predictive insights to optimize decision making.



DTE IREAS

INTELLIGENT REAL-TIME ELEMENTAL ANALYSIS SYSTEM

Maximize value, safety, sustainability, and efficiency with real-time intelligence from liquid metals generated by a machine learning-based cloud platform -DTE's metals production ecosystem- and chemical composition analysis based on DTE's Liquid-Phase, Laser-Induced Breakdown Spectroscopy (LP-LIBS™) technology from a network of elemental analyzers.



Streamline decision making

Breaking value chain silos with accurate real time information

Maximize quality and traceability

Monitoring the liquid metal along the production line

Increase return on capital

Optimizing production assets' use and performance

Increase throughput

Using real time product information and process control

Decrease energy consumption

Applying real-time and forward-looking process control

Optimize production planning

Leveraging metal intelligence along the value chain

Fine-tune alloying process

Visualizing the melt dynamic of alloying elements

Increase operators safety

Using fully automated liquid metal analyzers

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Real-time intelligence from liquid metals

Benefits of chemical composition analysis based on LP-LIBS in primary smelters

D. Areces, DT Equipment ehf

DTE is the leading innovator in real-time intelligence from liquid metals, contributing to maximizing value, sustainability, safety and efficiency for all the metals industry stakeholders. 'Ireas', DTE's unique connected solution combines chemical composition analysis from molten metals based on Liquid-Phase Laser-Induced Breakdown Spectroscopy (LP-LIBS), an artificial intelligence-based cloud platform – the engine of DTE's metals production ecosystem – and digital elemental analysis services. This article is about how Ireas contributes to uncovering between 2 and 5% of the increase in profitability in primary aluminium smelters. In addition, even though not included in this article, this new technology contributes to revealing additional direct and indirect benefits upstream and downstream of the end-to-end value chain in the form of operation efficiency, safety and sustainability.

DTE's solution delivers valuable intelligence and predictive insights from liquid metals across the entire value chain and from the plant floor to the business levels of primary and secondary aluminium producers. DTE's purpose is to transform the metals industry, driving its digital transformation towards Industry 4.0 with the next generation of Industrial Internet of Things (IIoT) analysis technology while contributing to the 1.5-degree challenge.

At DTE, we believe that breakthrough innovation and constant technological evolution open doors to new value creation possibilities. Since our inception, we have focused our innovation efforts on bringing technologies to market to solve evident, well-defined problems that our customers have, to propose solutions that deliver a beneficial business outcome. Whenever we do this, we do it thinking of the overall business challenge in front of us, from having excellent products that perform as expected in a rugged industrial environment to ensure that the solution provides the business outcome sought out by our customers.

LP-LIBS technology and its benefits

Laser-Induced Breakdown Spectroscopy (LIBS)



Fig. 1: Portable analyzer (left), stationary analyzer (right)

is a type of atomic emission spectroscopy that uses a high-energy laser pulse – focused on the sample's surface to be analyzed, regardless of whether it is solid, liquid, or gas – to generate plasma with temperatures over 30,000 K. Plasma, one of the four fundamental states of matter, consists of high-temperature gas ions and electrons. The atoms of the chemical elements present in the plasma emit a unique spectrum of discrete spectral lines. A sensor detects the atomic spectra emission of each element in the material being analyzed. The evaluation of the intensities of spectral lines forms the basis of the quantification of each element.

LP-LIBS – a term coined by DTE – refers to when LIBS is used to do chemical composition analysis of a liquid sample, which in DTE's case is molten metal.

Even though DTE's analyzers can evaluate any type of matter, they are specifically adapted to measure liquid metal. Besides, they are connected to an AI-based cloud platform that allows the generation of process and business intelligence out of the chemical composition data (see Fig. 1).

It has long been recognized that LIBS technology can be applied to analyze liquids, including molten metal. DTE's proprietary and patent-pending LP-LIBS analysis technology has translated research into precise analysis suitable for use in aluminium production – not in a lab environment but on the plant floor, either next to the production process or in the process machines.

LIBS analysis of aluminium and its alloys in their molten state is, for most of the investigated elements, superior to any other labo-

ratory analysis of solid process samples [1]. Furthermore, as detailed below, LIBS measurements can provide unprecedented detail about melt dynamics in real-time. LP-LIBS technology has demonstrated, so far, in laboratories and on the plant floor, that in terms of accuracy, measurement to measurement repeatability, stability and real-time measurement, it can perform better than the current technologies used.

Besides, a fully automatic LIBS-based chemical composition analysis from liquid primary aluminium gives the most accurate representation of melt chemistry [2]. In some cases, this analysis shows improved internal consistency of measurement results than laboratory analysis of process samples.

On top of this, the online analysis provides rapid results (typically ~45 seconds from the time of sampling), improves worker safety, and eliminates the risk of human error. The LP-LIBS-based analyzer can run unattended for weeks or months and is ideal for continuous and forward-looking process control where fast and secure feedback is required.

Selected benefits of the LP-LIBS technology over traditional chemical composition analysis methods are:

- Chemical composition information is taken straight from the molten metal flowing through the process on the plant floor and is made available in real-time. As we define it in DTE, real-time is about making information available as soon as the associated event happens – everytime, for everyone, and everywhere.
- There is no need to cast a solid sample to proceed with the elemental analysis, increas-

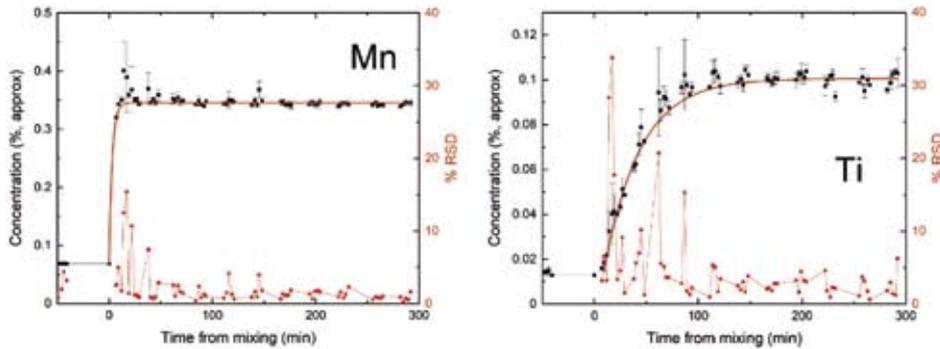


Fig. 2: Concentration measurements (black symbols) monitoring the dissolution of Mn (left) and Ti (right) in the aluminium melt at 730°C. Exponential fits (red curves) are provided as guides to the eye. During the dissolution phase, the LIBS measurement (red symbols) variance increases dramatically, indicating a chemically inhomogeneous melt.

ing safety and operational efficiency while preventing potential errors when handling and preparing solid samples. When preparing solid samples for analysis to avoid erroneous results, the process that must take place is well defined [3].

- Analyzing the chemical composition of the liquid metal provides an accurate representation of the product flowing through the process and avoids the problems generated by the chemical segregation of solid samples. For a homogeneous aluminium melt, the LIBS measurement will represent the bulk melt concentration, as confirmed by the high correlation observed between LIBS measurements and the bulk melt concentration measured by conventional methods [4].
- Unlike traditional methods like spark-OES, the LP-LIBS analysis technology does not alter the surface used to analyze the chemical composition, meaning it is a non-destructive process.
- LP-LIBS does not perturb the molten aluminium's surface under analysis and offers the possibility to make multiple measurements, one after another, using the same liquid surface. Therefore, it is ideal to understand the melting process of aluminium and alloying elements – in isolation or different mix combinations – in the context of where the process occurs (e.g., a furnace). This capability, associated with artificial intelligence and predictive process control, is the foundation of an aluminium alloying optimization system (faster, better aluminium alloys), see Fig. 2.

About Ireas and its benefits

Based on its proprietary and patent-pending LP-LIBS technology, DTE has developed Ireas, its real-time intelligence from liquid metals solution. Ireas is the combination of connected elemental analyzers, an AI-based cloud platform generating intelligence, predictive insights and network effects out of chemical

composition data and digital services to support the customer's journey of translating digital analysis technology into concrete business outcomes.

This solution brings a transformational elemental analysis technology to the plant floor and provides to everyone – across the value chain and from the plant floor up to the business levels intelligence and knowledge. DTE's goal is not just to provide chemical composition information but also its impact in the context of the process and the business and what actions must be taken to maximize value, sustainability, safety and efficiency (see Fig. 3).

Due to its nature, LP-LIBS technology allows gathering more and more frequent and accurate data, converted into intelligence, enabling faster, better and safer decision-making. As already mentioned, for DTE, real-time is about making information available as soon as the associated event happens, everytime, everywhere it is needed, and for everyone that needs it. Also, for DTE, data in context is information, and intelligence is all about predictive, actionable information and insights provided across the end-to-end value chain and from the business level to the plant floor. With this in mind, DTE has developed Ireas to enable a single version of the truth and, therefore, unified decision-making.

We have already highlighted the benefits of the LP-LIBS technology. Considering that this technology is Ireas' foundation and that Ireas' AI-based platform transforms the LP-LIBS chemical composition data into intelligence, the value generated increases expo-

nentially. Below we include selected benefits generated by Ireas along the value chain in a primary smelter.

Ireas benefits in the potroom

Selected benefits of deploying real-time intelligence from liquid metals in the potroom are:

- Reducing direct and indirect costs by minimizing energy consumption
- Decreasing greenhouse emissions by optimizing the electrolysis operation through the availability of more frequent and more accurate trace elements information
- Avoiding sudden pot bursts, extending the life of electrolysis pots and maximizing uptime by having updated chemical composition information from the pots executing AI-based predictive maintenance
- Maximizing Return on Capital Employed (Roce) and multiple other business variables



Fig. 3

by optimizing production planning, such as tapping the right pots based on – among other variables – up to date trace analysis and an AI-based pot tapping optimization system

- Generating substantial direct and indirect savings from anodes consumption and the CO₂ generated using and manufacturing them by having predictive insights from the content of Fe and Cu inside the pots
- Optimizing operational efficiency from taking multiple samples from the same pot in case of potential sample contamination to the cost of buying, operating, and maintaining traditional chemical composition analysis labs.

Ireas benefits in crucibles and casthouse

Selected benefits of deploying real-time intelligence from liquid metals in the crucibles are:

- Decreasing elemental analysis and aluminium treatment cost by measuring the chemical composition of the molten metal in the crucible
- Decreasing casthouse overall production

costs by providing real-time information of the chemical composition of the melt sent to the furnaces or casters.

Ireas benefits in furnaces

We have already highlighted the value of using real-time intelligence from liquid metals in furnaces in our latest ALUMINIUM article [5]. However, we would like to remind the selected benefits of deploying real-time intelligence from liquid metals in the furnaces:

- Enhancing production planning, optimizing the value chain and increasing the Roce based on an optimized alloying process driven by prescriptive process control and AI-based alloying optimization system. The alloying optimization system – based on, among other variables, the melting curves of the alloying elements and other input material for a given furnace – minimizes the cost of the alloy under production, the energy consumption, and the greenhouse gas emissions.
- Increasing quality and enabling the production of premium alloys by real-time, frequent, precise chemical composition information and the highlighted AI-based alloying optimization system
- Maximizing product traceability along the casthouse by measuring the chemical composition of the flowing metal
- Optimizing the availability and performance of the assets to load aluminium, alloying elements, and scrap into the furnace, the process machines and equipment downstream the furnaces, and the casting process.
- Reducing raw material inventory cost and avoiding plant stops through proper production planning and prescriptive decision-making and control
- Avoiding out-of-specifications casting, reducing scrap and dross generation
- Increasing operation efficiency, operator's safety and health by using fully automatic chemical composition analysis from molten metal either next to the production process or on the process machines
- Decreasing the casting of products out of specifications and making products on specifications available faster.

Ireas benefits in the launders

Selected benefits of deploying real-time intelligence from liquid metals in the launders are:

- Increasing the final product's quality and minimizing production errors by analyzing chemical composition along the launders, either before the holding furnaces or before casting

- Measuring constantly along the launder the performance of the high volatile elements allows optimizing the transfer between mixing and melting furnaces and holding furnaces
- Increasing the quality of the long products being cast, analyzing the chemical composition of the metal flowing through the launder
- Optimizing the grain-feeder and the cooling process by doing elemental analysis and executing real-time process control
- A more efficient elemental analysis process on the launders decreases cost and increases health and safety
- During continuous casting in tandem, real-time information on the alloy change reduces scrap and increases product availability
- Less scrap and more product availability when knowing in real-time potential out-of-specifications casting and undesired product flowing through the launders
- More frequent real-time elemental analysis provides better statistical accuracy on the batch throughout the cast and allows for continuous product identification or labelling.

Monetizing the benefits generated by Ireas

In the previous section, we have presented selected benefits generated by Ireas. This section offers a high-level estimate of how those benefits are transformed into a tangible increase in profitability.

The monetary value that can be generated in primary smelters when deploying Ireas depends on multiple variables. Some of them are the technological and business situation of every operation, its size, the local business conditions (e.g., energy procurement contracts), the focus on the critical success factors, and the synergies created when gradually deploying the solution over time. However, a high-level consolidated estimate and detail for some of the benefits are included below.

Working with different primary smelters, we have identified a potential profitability increase per tonne of aluminium ranging between 2 and 5% when a complete, across the smelter, real-time intelligence from liquid metals solution is deployed.

While the potential energy savings in the potroom and casthouse represents over 25% of the total profitability increase benefit, asset-related items like the increase in the Roce, the decrease in maintenance costs, and the avoidance of tap-outs represent close to 20% of the profitability increase. Boosting the top line through higher uptime, increased quality, premium products and traceability adds up another 20% to the spread between cost

and revenues. Lower raw material costs and consumables (e.g., anodes) contribute to over 10%. Emissions and scrap represent an approx. 5% – depending on the plant – of the total profitability increase. Savings generated from operation efficiency, safety, analysis equipment, and tools, and others are the remaining contributors to the monetary value of DTE's Ireas solution.

Feedback from customers

Below we present feedback from two DTE customers on the benefits of deploying chemical composition analysis based on LP-LIBS.

“... We see much potential in getting real-time chemical composition analysis from our process, not only in terms of time-saving and higher productivity but also in terms of safety for our employees...”; “...this type of solution allows us a much more efficient pot operation, better time management and empower the operators a great deal on the plant floor...”; “...the pot life in the potrooms is the most critical factor and changing out the pots is one of the biggest cost items that we have in pot operation; we believe if we use this solution to its full extent, we will extend the pot life as well as preventing sudden pot tap outs...”
Einar Aron Einarsson, manager, Electrolysis, Rio Tinto Isal.

“...Controlling any process at peak efficiency requires accurate, real-time measurements. This has always been a challenge in our industry due to the nature of the process. The traditional method of sampling and analyzing has an inherited time lag. I believe the solution DTE has developed for real-time metal analysis could be the future standard in the aluminium industry...”
Baldur Bjarnason, technical manager, Reduction, Nordural.

Key success factors for a digital transformation driven by real-time intelligence from liquid metals

DTE's real-time intelligence from liquid metals solution is a breakthrough innovation poised to transform the metals industry, driving its digital transformation towards Industry 4.0, delivering valuable intelligence and predictive insights from liquid metals across the entire value chain.

To generate as many benefits as possible and maximize the monetary impact of a digital transformation either driven or complemented by real-time intelligence from liquid metals, there are a few success factors to be considered. Even though the purpose of this article is not to discuss a digital transforma-

tion, which we will do in a future article in this journal, we are highlighting the key success factors below,

- A digital transformation strategy and operational plan, led by the chief digital officer, must be defined, driven by a company's purpose and business strategy. Data must be considered a new asset class
- The transformation must be driven by clear business variables and outcomes and not by technology
- It must be based on a clear, agile, fast and efficient execution plan, where proof of concepts are developed in partnership with suppliers and – if possible – governmental organizations, where return is measured and overall deployment done based upon results of the proofs of concept. Think big, take small and measurable steps, share risks.
- Employees must buy into the digital transformation and be an integral part of its definition, execution, and aftermath. Human resources must be the key business partner in the effort.
- There must be a strong alignment and partnership among the major stakeholders and interested parties: companies, customers, employees, governmental organizations and supply chain members, among others.
- The digitization must be based on a scalable system architecture; open technology supported by a thriving ecosystem – or platform – boosted by a multiple-sided network effect; and system, segment and functional expertise.

Services, processes and tools to guide a digital transformation

As mentioned before, a digital transformation must be driven by business variables and outcomes. The deployment of Ireas must be decided after careful evaluation of the cost-benefits, an analysis of its gradual deployment strategy, and the comparison with other process and business optimization efforts. To that extent, DTE offers services, processes and tools to evaluate the benefits, cost, value and

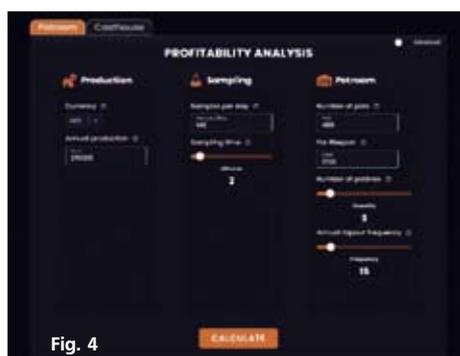


Fig. 4

deployment journey of its Ireas solution.

Fig. 4 represents one of the tools used by DTE's services and business intelligence teams in order to discuss with customers the potential benefits and value generated by DTE's elemental analysis solution.

Reinventing aluminium production

In the paragraphs before, we have presented the benefits that can be obtained in the short term by applying DTE's real-time intelligence from liquid metals solution to the aluminium production process.

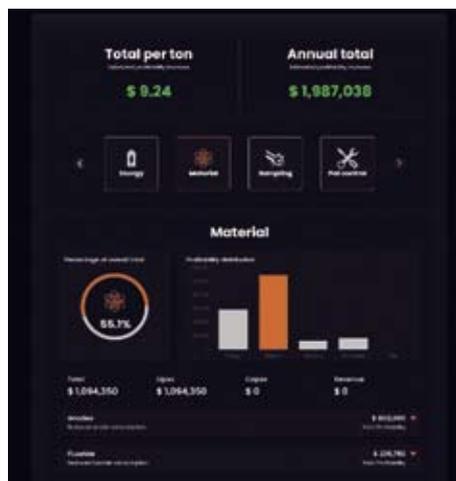
Besides, we are already working on long-term benefits, expanding the possibilities of DTE's technology, innovating around topics like machine-enabled LP-LIBS, augmented elemental analysis, and the aluminium passport.

DTE is continuously innovating and using the latest technologies to reinvent the way metals are produced to ensure an impactful contribution to a sustainable future and the 1.5 degrees challenge.

Conclusion

Throughout this article, the author highlighted the benefits of the LP-LIBS technology and the value of Ireas, DTE's associated real-time intelligence from liquid metals solution when applied to primary aluminium smelters. DTE's solution opens the door to realize benefits that could not be realized before and to uncover new, never thought before advantages. DTE's real-time intelligence from liquid metals generates tangible short-term benefits, fosters the imagination that will drive medium-term transformative solutions, and redefines the long-term landscape.

Considering that DTE's LP-LIBS innovation is making its initial market inroads, we highlighted the benefits uncovered and the



potential monetary value they bring to primary aluminium producers. It was indicated that a possible increase in profitability of between 2 and 5% could be achieved when deploying DTE's solution across the value chain in a primary smelter and when the key success factors of a digital transformation are considered.

Information was provided on how DTE, through its services and business intelligence teams using internal processes and tools, can help evaluate the cost-benefit of deploying DTE's solution and the deployment journey to maximize benefits and value.

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