Batscan: The Coming of Age of a New Tool for Inclusion Detection in Liquid Aluminium

Jean-Louis Achard[1], Pierre Le Brun[2], Marc Bertherat[3], Pierre-Yves Menet[4], Nicolas Bauret[5] and Vincent Milani[6]
1. R&D Engineer
2. R&T Expert
3. BPC Leader
4. R&D Group Manager
Constellium – Technology Center – BPC Casting & Recycling, Voreppe, France
5. New Product Development Manager
6. Technical Expert
STAS, Saguenay, Canada
Corresponding author: pierre-yves.menet@constellium.com

Abstract

After 10 years of development, the Batscan™, an inclusion detection tool in liquid aluminium developed by Constellium and marketed by STAS, has reached a level of maturity that makes it a unique and reliable enabler for liquid metal quality monitoring and process improvements. The measurement principle is based on controlled ultrasound transmitted to the liquid aluminium through inert ceramic waveguides immersed in the liquid aluminium. The measurement capabilities have been extended to cover the specific needs for a whole range of products, from the least to the most demanding such as packaging or aerospace applications. Whether positioned at the outlet of a casting furnace or after an in-line degasser, the Batscan™ can monitor a small percentage of the total volume of metal being cast from the beginning of the process to the last minute. It can detect events at a rate three orders of magnitude higher than the LiMCA while also detecting particles as small as 35 µm. The paper describes in more detail the elements above and provide a few examples of the operational benefits it can bring.

Keywords: Liquid aluminium, Batscan, Inclusion detection, Ultrasound, Ceramic waveguide.

1. Introduction

Inclusion detection in liquid aluminium is a crucial process in the metallurgical industry to ensure high-quality end products. The presence of non-metallic inclusions can significantly affect the mechanical properties and surface finish of aluminium products. Customers require that aluminium producers monitor the liquid metal cleanliness (inclusion content) so that the products they buy meet their requirements.

Here are some of the state-of-the-art methods for detecting inclusions in liquid aluminium. More details can be found in review papers such as that by Don Doutre et al. [1].

1.1 Off-line Inclusion Measurements

- **PoDFA** (Porous Disc Filtration Analysis): a predetermined quantity of liquid aluminum is filtered through a very fine porosity filter disc to concentrate inclusions at the filter interface (cake filtration). After solidification, the sample is cut, polished and the interface with the filter is observed under a microscope. It enables to see which inclusions are present in the metal and to some extent, the level of cleanliness.

- **Prefil** (Pressure Filtration Melt Cleanliness Analyser): it provides a snapshot of the inclusion content in molten aluminium but does so by measuring the pressure drop across a filter as the melt is processed. It is a relatively simple and established method that provides quantitative data on inclusion levels.

However, both techniques lack the real-time monitoring capability of in-line detection means. A major drawback is also the representativity of the measurements.

1.2 In-line Inclusion Measurements

The reference technique is the **LiMCA** (Liquid Metal Cleanliness Analyzer). The LiMCA measurement principle is as described on Figure 1: liquid metal is sucked up in a glass tube through an orifice. Two electrodes immersed in liquid metal are located on each side of the orifice. Whenever an inclusion passes through the orifice, it affects the electrical conductivity of the medium. One liquid metal (approximately 17.5 g) sampling is done every 80 s once the equipment is ready for measurements. Over an hour, this represents 45 measurements. For a 50-t cast, this means that about 1 kg of metal can be analyzed, i.e., 0.002 %.

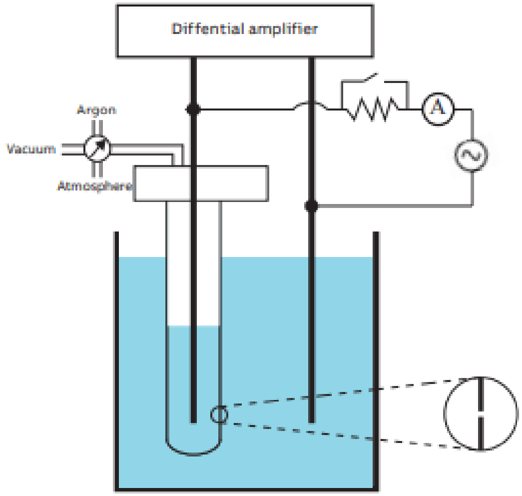

Figure 1. LiMCA measurement principle (source: ABB LiMCA III brochure [2]).

In terms of detection limit, the inclusion size range is between 15 and 300 µm, but the measurement range is between 20 and 155 µm.
The number of inclusions reported is extrapolated to 1 kg melt (× 57) and inclusions are sorted by size range.

The **Batscan** is a measurement technique based on control ultrasound [3] (see Figure 2). Two active waveguides are used to respectively emit and receive control ultrasound. The waveguides are made of a ceramic material which is inert with respect to liquid aluminium. The innovative feature of the Batscan is that the waveguide cross-section interface is wetted by liquid aluminium using power ultrasound. The analyzed cross section determined by the focal zone of the waveguides is ca. 10 cm². For a 50-t cast, the typical trough dimension leads to a metal cross section of 400 cm². The ratio between the liquid metal going through the focal zone and the metal being cast is 2.5 %. This corresponds to 1 250 kg being monitored.

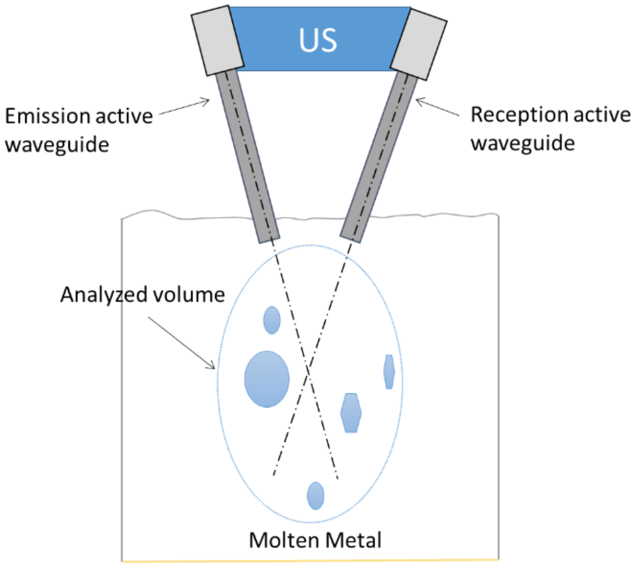

Figure 2. Ultrasound inclusion detection system principle.

The frequency of measurements is 800 Hz but the results are averaged at a frequency of 10 Hz or every 0.1 second, the largest event detected in the focal zone is counted.

The inclusion detection limit is 20 µm with no upper limit and the measurement range is 35 µm and 320 µm (without changing the amplification gain). The total number of inclusions are sorted by size range.

The following sections will present more in details the Batscan technology, which is rather new to the market and will provide insight into its potential for the casting of aluminium alloys.

2. Batscan Features and Capabilities

The Batscan technology has been developed over the last 10 years at C-TEC, Constellium Technology Center [4]. It has been implemented in 2 Constellium plants so far, both producing can stock slabs.
Furthermore, it has been used for characterizing other alloys of interest such as for aerospace applications, cosmetic packaging and automotive sheet products.
There is no limitation for its use identified at this stage.

2.1 Batscan Versions

The Batscan is offered in two configurations: mobile or fixed.

The mobile Batscan unit is best used for process qualification at different positions along the casting line. This allows casthouse personnel to study process variations at different stages of treatment. A technician is needed to operate this configuration. The technician must position the measuring column manually, then start and end the measurement cycle. The data must then be manually extracted onto a USB key.

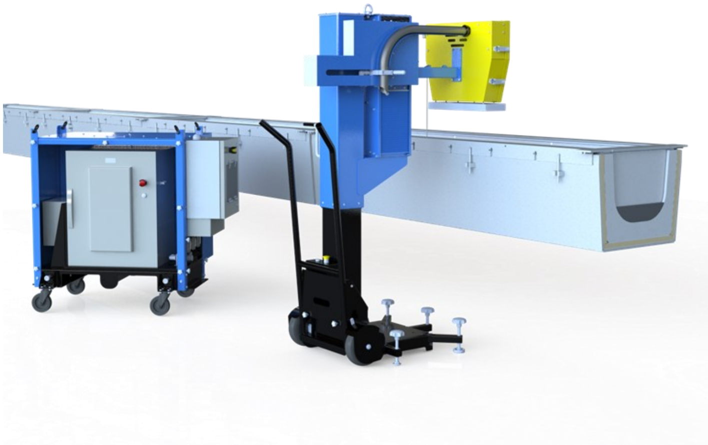

Figure 3. Batscan mobile version.

The fixed Batscan unit is best used for full-time monitoring at a permanent location. This configuration can monitor production on a continuous basis. This allows process events to be quickly detected and studied. Since the measurement parameters only need to be set once, an operator can easily be trained to use the fixed Batscan. The operator only needs to position the measurement head above the trough using a conveniently placed handle. The unit will automatically lower the measuring head into the melt once the metal level is stable. The measurement cycle will start once the waveguides are at the required depth and end automatically when the metal level starts to diminish. The measuring head will retract to its high position at the end of the cast, thus allowing the operator to remove the oxide buildup from the waveguides before placing the measuring head back in the rest position using the positioning handle. Finally, the data is automatically transmitted through the plant network.

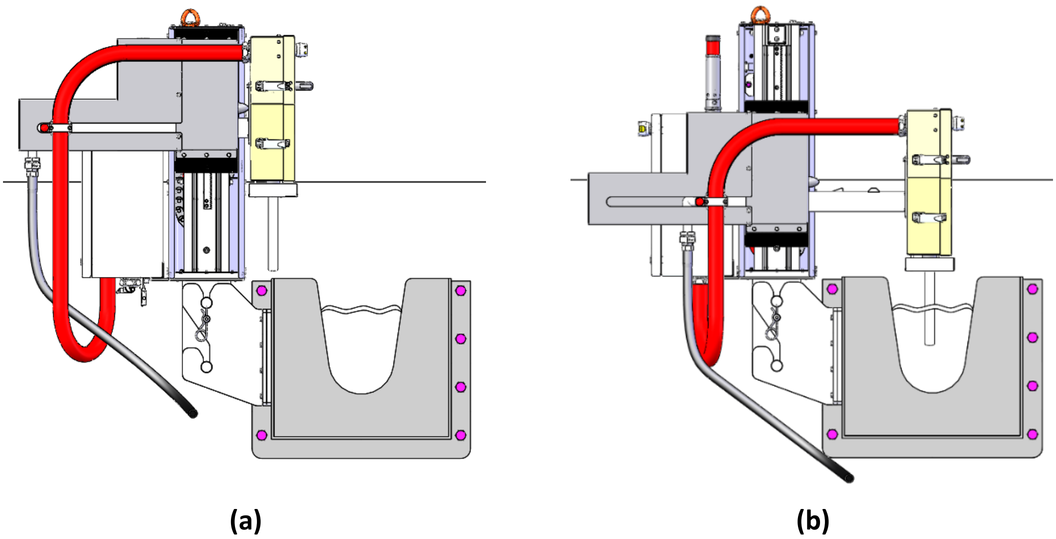

Figure 4: Fixed Batscan measuring head.
Left: (a) idle position, Right: (b) measuring position.

2.2 Batscan Measurement Capabilities

In much the same way all LiMCA units do, the Batscan measures a specific physical property of the melt then interprets the data to a meaningful result for the end user (see above).

As mentioned in the introduction, in the case of LiMCA technology, electrical conductivity is monitored. The inclusion count is determined by the number of inclusions that disrupt the flow of electrons when they travel through the orifice of the glass tube, thereby raising the electrical resistance of the material.

The Batscan monitors acoustic impedance: the resistance the melt opposes to the propagation of sound waves. Inclusions can slow or accelerate sound waves, depending on their density and elasticity, thereby leading to a measurable impedance shift.

Since the two technologies do not rely on the same physical measurement principle, it is impossible to establish a direct conversion between them, all the more as the Batscan sampling rate is much higher than the LiMCA one's. However, there is a clear correlation between results obtained during side-by-side testing conducted by Constellium [5]. Those results show that the Batscan can accurately measure the inclusion content of the melt, identify the same trends and obtain comparable results.

Moreover, using the proper settings, it is possible to compensate for external factors, such as the presence of microbubbles from a degasser to ensure that accurate measurements are taken at any point of the casting line, provided the metal level in the trough is at least 100 mm.

The impact of different process parameters can be studied based on where the measurements are taken by using multiple data sets. Since the Batscan does not use consumables, a large number of casts can be monitored without significantly additional operational costs. The frequent use of Batscan is thus used as a tool to investigate inclusion related issues more accurately at all steps of the process.

When taking measurement after a fluxing or degassing, microbubbles generated by the degasser tend to stick and accumulate at the tip of the waveguides. This has the adverse effect of reducing signal strength by disturbing the waveguide-aluminum interface. To mitigate this, power ultrasounds are used to clean the waveguide surface and release the microbubbles from it. This helps maintaining a stable baseline signal, even after the degasser. Power ultrasounds parameters have to be adjusted according to degasser type, trough geometry, distance from degasser, etc, to be meaningful.

2.3 Usage Performance

The first mobile Batscan unit built and delivered by STAS has been met with enthusiasm by process technicians. They found that the technology stood out in many ways compared to the already available technologies.

First off, they hailed the Batscan ease of operation when compared with previously used technologies. There are no consumable parts to replace or that can break during a cast. The only recurring maintenance required consists in swapping the unit's measuring head every six months for recalibration, a task (the swapping one) that only takes a few minutes.

Secondly, they found the Human-Machine Interface (HMI) intuitive, making access to critical parameters and functions simple. Setting for up to three measurement positions can be saved in the HMI. Once the parameters are properly adjusted for each position on the casting line, little training is needed to make accurate measurements at any of those locations.

Finally, they pointed to the unit's robust construction, which suggests a high level of reliability and resilience under operating conditions associated with a casthouse environment.

3. Process Optimization Potential with Batscan

Batscan has already been shown to allow measurement in most locations on a casting line [5]. Among the main advantages of Batscan, in terms of measurement capability, are the possibility to provide useful data behind a degasser even after a ceramic foam filter (CFF), and the possibility to acquire information from the very beginning and till the very end of a cast. These will be illustrated in some examples.

3.1 Measurement After a CFF: Impact of the Quality of Hardeners

The alloying process requires the addition of different hardener. Many suppliers offer the same hardener, with varying sources and shapes (pure, pre-alloyed, compacted powders). For some products, the quality of these hardeners may impact the final quality of the product. In order to quantify the potential quality impact of a given hardener, it is desired to measure the final quality of the metal, at the end of the treatment chain. Many production lines are equipped with a degasser and a ceramic foam filter (CFF). In this configuration, measuring the metal quality is usually done by PoDFA sampling to cancel the micro-bubble issue known for LiMCA measurements, with the drawback of the very poor representativity of a PoDFA sample and the off-line delayed answer. Using Batscan at a CFF exit allows accurate measurement of a large volume of metal. This is illustrated in Figure 5, showing the impact of the quality of a given hardener on the final quality at a CFF exit, as measured by Batscan. This allows the operations to qualify hardeners for selected usage.

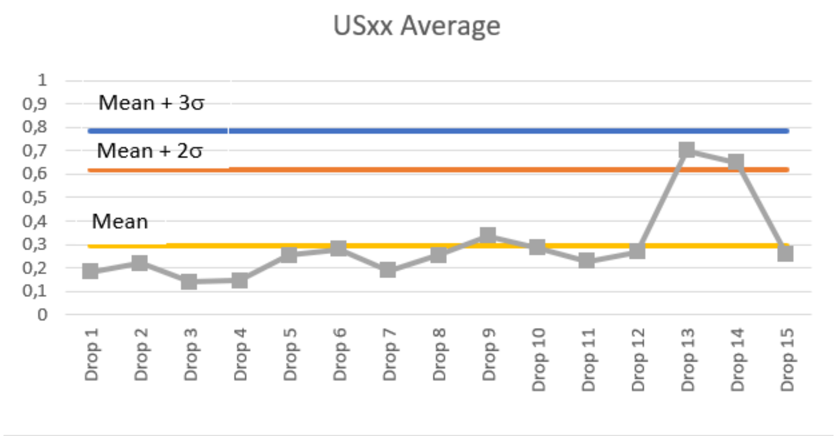

Figure 5. Batscan measurement of the melt quality at the exit of a CFF, for the same hardener and different sources.

3.2 Measurement After a CFF – Start of a Drop

With the current measurement techniques, the metal can hardly be characterized in the first minutes of a drop. This is due to either accessibility concern, or preheat times required before characterization equipment can be used. Batscan allows very early measurement, typically 1 min after the first metal flows under the waveguides. This specificity offers an opportunity to characterize the very initial metal being cast.

Figure 6-a shows raw measurement data done with an automated Batscan, from the very beginning of the drop. The actual first data point is acquired at the start of the platen movement. As can be seen from Figure 6-a, the raw data are slightly higher at the start of this drop than later, when they tend to stabilize. This suggests useful information is available from the initial period of the drop that is not measured with the alternative measurement techniques.

There may however be a question on a potential instrument effect in the case the equipment would stabilize for any reason during an initial time period of a measurement sequence. In Figure 6-b, an automated Batscan was delayed to start after only 25 minutes into the drop. As can be seen, the data directly align with the baseline. This confirms the initial variations observed in 6-a are valid measurements.

The very early measurement capability of the Batscan reveals features that could not be measured with former characterization techniques. As an example, figure 7 shows a measurement done with a specific start practice that reveals slightly higher counts in the first minutes of a drop.

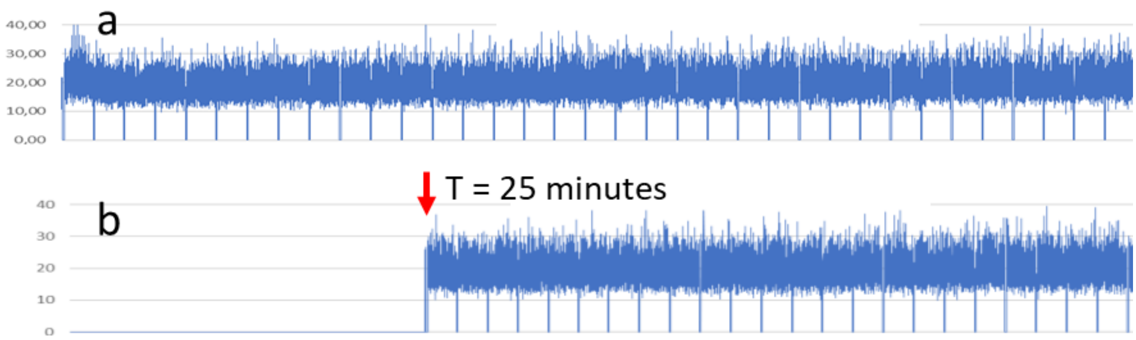

Figure 6. Batscan raw data.
Top: (a) at the start of a drop, Bottom: (b) started 25 min into the drop.

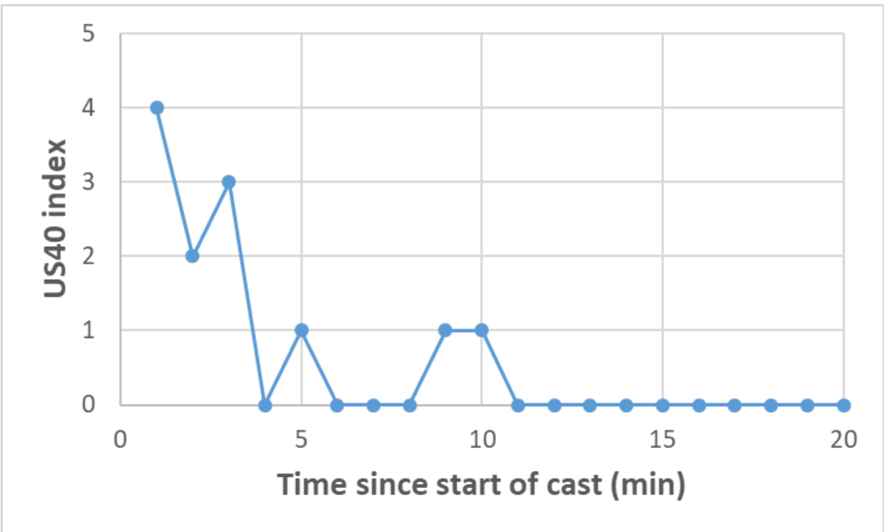

Figure 7. Batscan measurement after a CFF (first 20 minutes of the drop)

3.3 Measurement at the End of a Drop

With the capability to measure inclusions from the very beginning of the drop until the end (when the metal level reaches the low setpoint for automatic tilt back of the furnace), the Batscan reveals the full dynamics of the inclusions during the cast.
Figure 8 illustrates a measurement done at a furnace exit. The evolution of the inclusion distribution can be easily obtained, showing a strong increase of large inclusions at the end of the drop.

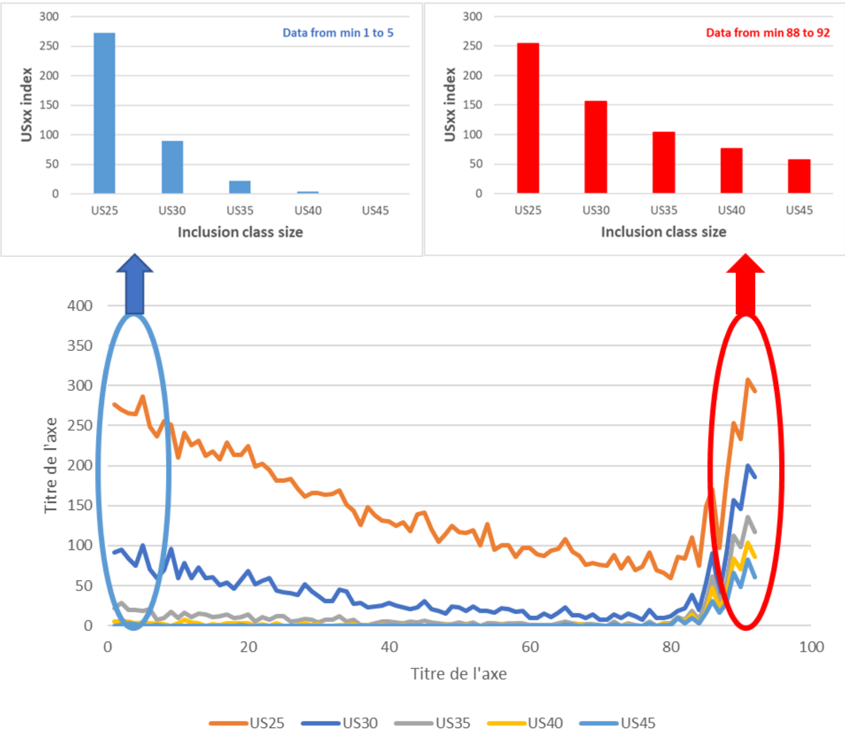

Figure 8. Batscan measurement at a furnace exit, inclusion distribution for the first and last 5 minutes.

These data provide insight into the quality of the metal at the end of the cast and some indication on the amount of metal that should be cropped in order to meet the desired quality requirement.

4. Conclusions

The Batscan in its various versions represents a breakthrough evolution as far as liquid metal cleanliness monitoring is concerned. Its reliability and ease of use makes it an enabler of process optimization without compromising on quality requirements.

Some examples were provided on the potential of the technology with respect to hardener qualification, melt treatment conditions optimization. It can also be a tool to alert on the process drifting of the process. Since it offers a possibility to monitor the cast quality from the very beginning and end of a cast, it helps to understand the volume of metal affected by poorer inclusion quality levels.

5. References

1. Don Doutre et al., Aluminium cleanliness monitoring: Methods and applications in process development and quality control, *Light Metals*, 1985, 296–304.
2. ABB Measurement & Analytics, LiMCA III brochure, 2024.
3. Jean-Louis Achard et al., An innovative ultrasonic technology for the continuous quality monitoring of liquid aluminum on casting lines, *Light Metals*, 2018, 871–878.
4. Media news Constellium, https://www.constellium.com/about-us/stories/batscan-tm-revolutionizing-quality-monitoring-in-the-aluminum-industry (accessed on 13 July 2024).
5. Jean-Louis Achard et al., Batscan™, Constellium in-melt ultrasonic inclusion detector: industrial performance, *Light Metals*, 2020, 936–943.