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A NEW APPROACH TO IDENTIFY ALUMINUM DROSS REDUCTION OPPORTUNITIES USING AN INTEGRATED WEIGHING SYSTEM

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Abstract

Cast house operations involving molten aluminum processing and furnace charging result in dross generation. This undesirable residue is composed mainly of metallic aluminum and oxides, and engenders costs exceeding 1000 US$ per MT of dross.

Considering that no batch-to-batch measurements of dross weight are generally performed in the cast house, the task of dross reduction has always been complicated since the key process parameters and batch preparation practices affecting dross are not well known. As such, a new integrated weighing device was developed to continuously measure dross generation. The data generated will be used not only to follow-up on long-term furnace performance, with respect to dross generation, but also to complete a statistical analysis aimed at identifying key dross contributors.

This paper describes the industrial dross weighing strategy that was developed, as well as the equipment that was installed in a Rio Tinto Alcan (RTA) cast house.

Introduction

Dross is an undesirable residue of the aluminum cast house that is produced during the various furnace processing steps. It is well recognized that dross generation should be kept to a minimum as the cost associated with the metal loss and the post-treatment can exceed 1000 $US per MT of dross. However, it has always been very difficult to make tangible improvements regarding dross since no precise or appropriate measurements of dross generation have been taken. Indeed, data related to dross is not precise enough since it is provided by the secondary dross processors on a monthly basis. Data related to dross can also be collected from sporadic measurements, but it takes considerable efforts to obtain significant amounts of data to be able to determine focal points of dross reduction with a statistical approach.

Based on past experience, key parameters affecting dross generation are not easily identified because there are many underlying factors that can have different potential interactions. In addition, the benefits that may be achieved are difficult to assess since dross generation varies significantly over time. As such, a long-term data collection strategy coupled with statistical analyze are required to achieve a sustainable dross reduction.

In an attempt to overcome this lack of representative data, a dross weighing strategy was developed to obtain a real time measurement of the batch-to-batch dross generation. The new integrated weighing system was thus designed to be installed underneath the Inert Gas Dross Coolers (IGDC) allowing tracking of the batch-to-batch furnace dross generation without any changes to standard work procedures. Extensive continous data collection campaigns can be conducted using this weighing system in order to recognize dross reduction opportunities.

This paper presents the industrial measuring strategy that was successfully implemented in one RTA cast house as well as the methodology used to identify key process paramaters affecting dross generation. The interesting potential of this new approach to reduce dross generation is reported as well.

General Dross Generation Principles

Dross contains aluminum oxide, aluminum metal and other products obtained during melt preparation. As illustrated in Figure 1, the typical macrostructure of dross can be described as a mixture of trapped or loose particles and tangled oxide films bounded by metallic aluminum.

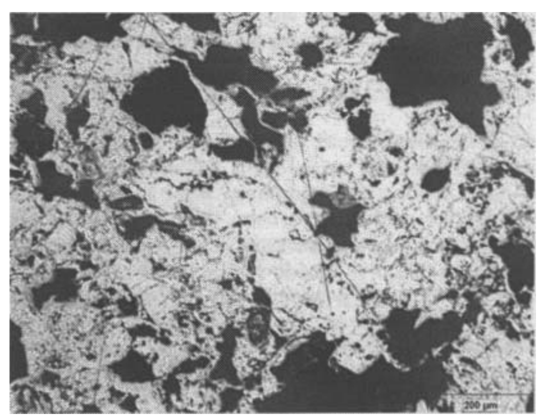

Figure 1. Typical macrostructure of aluminum dross

It is well understood that the thermodynamic behavior of aluminum in presence of oxygen will inevitably result in melt loss from oxidation and dross formation [1]. Indeed, dross is practically unavoidable. Consequently, efforts need to be concentrated on methods to identify and control the main governing factors during aluminum melt handling and furnace preparation practices to reduce dross generation.

Many molten metal processing steps and operational practices, such as scrap remelt, primary molten metal charging, alloying / stirring and fluxing may result in dross generation (see Figure 2 for an example of key processing steps) [2]. It is acknowledged that, among all liquid metal treatment processes, those which create turbulence or major splashing are major factors contributing to dross generation.

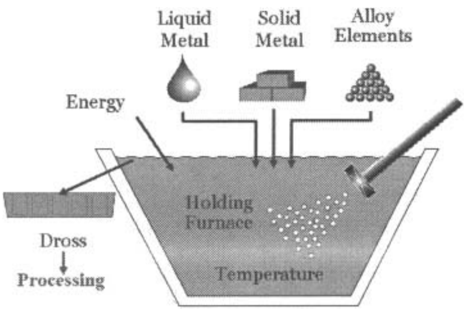

Figure 2. Typical molten metal processing steps in a furnace

Industrial Integrated IGDC Weighing Strategy

The principal motivation of this work was to develop a dross weighing strategy in an attempt to obtain the following benefits:

- Get a real time tracking of the batch-to-batch furnace dross generation to measure process variations and evolutions.
- Identify key process parameters affecting dross generation, best furnace preparation and skimming practices, and in the end, opportunities to reduce dross generation.
- Evaluate the IGDC efficiency and reduce dross cooling treatment time by using the integrated weighing system.

Integrated Inert Gas Dross Cooler Weighing System

The Inert Gas Dross Cooler (IGDC) is used in many cast houses since the 1990's. This technology is utilized for the purpose of cooling and inerting aluminum dross, while avoiding metal loss caused by the oxidation reaction. The system is essentially composed of a heavy steel enclosed station where an inert gas is injected under the cover hood to stop oxidation of aluminum [3]. The IGDC's cooling is practically only provided by the mass of the pan, into which, dross is placed, while the confined gas is intended only as a means to displace the air to create an inert atmosphere and prevent further aluminum oxidation [4, 5].

An intensive effort has succeeded in the development of a weighing system that is integrated underneath the Inert Gas Dross Coolers. The first pilot weighing system has been successfully implemented at the Alma cast house.

Figure 3 presents a 3D view of an industrial IGDC with the integrated robust floor weigh scale. The scale is inserted within a metallic reinforcement frame with positioning bolts used to solidify the whole structure and to prevent load cell damage due to mechanical shocks. Moreover, in order to protect the scale from the impacts of forklift trucks used to manipulate the dross pans, an angle steel deflector is mounted at the front of the reinforcement frame.

Because the IGDC becomes hot during the dross cooling process, spacers have also been designed to create an isolating air gap to avoid load cells from being exposed to excessive temperature.

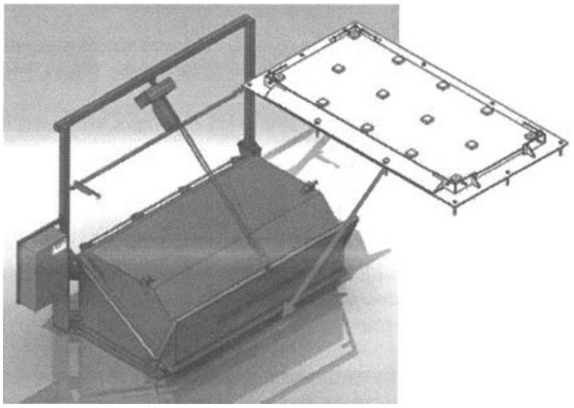

Figure 3. 3D view of an Inert Gas Dross Cooler with the integrated weighing system

The IGDC weigh scale has proven to be very robust and reliable, since neither mechanical failures nor drifts of the measurements have been observed since its implementation.

This weighing system is fully transparent to operation and allows the monitoring of dross generation. It is connected to the data plant wide acquisition system where the dross weight is associated to the proper furnace batch number to create systematic dross generation reports with the related batch preparation parameters. Figure 4 shows an example of the final industrial installation.

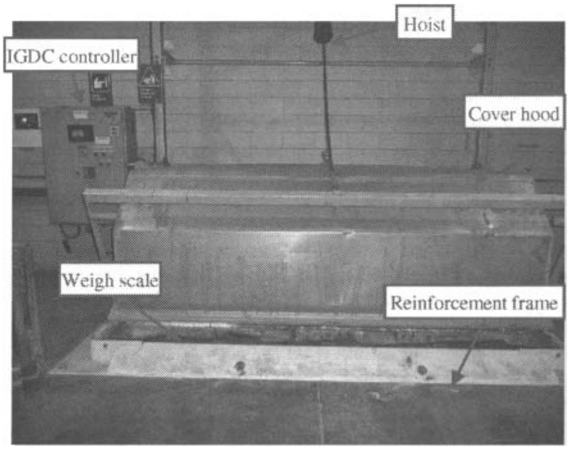

Figure 4. Industrial integrated IGDC weighing system

Tracking of the Batch-to-Batch Dross Generation

The new weighing system allows extensive data collection of the batch-to-batch furnace dross generation to be completed. The dross generated during a period of more than four months was measured. This represents 293 batches (see Figure 5).

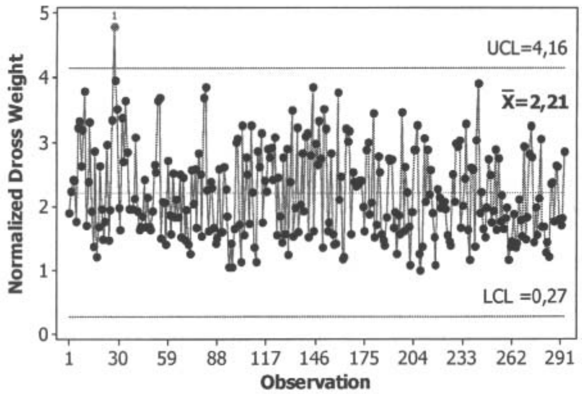

Figure 5. Variation of the measured batch-to-batch dross generation

The tracking of the batch-to-batch dross generation showed that there are significant variations in dross generation (the dross weight typically varied by three orders of magnitude). These variations can be explained not only by the process parameter variations such as the type of scrap remelted, the amount of primary molten aluminum charged, the alloy mix, etc., but also by the discrepancies in batch preparation and skimming practices. As such, the dross weighing system can be used as a means to highlight the best skimming and furnace operational practices, and ultimately, to standardize the practices. The follow-up of the standardized practices can definitely help reduce the batch-to-batch dross generation variations as well as reduce the global level of dross produced.

Moreover, with this data collection, it is possible to identify the key process parameters that most affect dross generation as well as determine the dross reduction solutions which can lead to important cost savings for the cast house.

Industrial Key Process Parameters Affecting Dross Generation

Dross Characterization Methodology and Analysis Techniques

The aim here is to present the statistical methodology used and also the general operational process parameters that must be considered during the analysis with regards to determining the key dross generation contributors and hence, establishing where the cast house should focus their efforts regarding dross generation reduction.

Multiple parameters and/or parameter interactions may be responsible for the significant batch-to-batch dross weight variations that were measured. Consequently, the impact of a specific parameter can be masked by changes of the other main contributors. Further complicating the analysis is the fact that process parameters are often not independent and it is impossible to isolate one variable at a time. A multitude of statistical techniques can be used to overcome the problem of analyzing such data.

An effective statistical technique, which was used during this work, consists in separating the sample into different populations based on their values to observe the main effects. For example, lower vs. higher values of molten metal charge weight, or with vs. without remelt scrap additions. These populations were then analyzed using student t-tests as well as the ANOVA (Analysis of variance between groups) analysis technique. With these two approaches, a p-value lower than 0.05 ($\alpha = 0.05$ level) allowed to conclude that there was a statistically significant difference between the populations analyzed with a confidence level of 95%.

It is important to mention that it is imperative to record all suspected process factors contributing to dross generation during the data collection campaigns. Continuous variables such as energy and scrap weight addition as well as categorical variables such as Furnace 1 or 2 and Shift A, B or C, should both be monitored for a better understanding of the global process [2]. It is definitely better to record too many factors, rather than too few, in order to avoid neglecting critical operations that could be associated with dross generation.

Hereafter, are presented some different industrial examples of process parameters that were identified as factors contributing to dross generation during this measuring campaign.

Example 1: Alloy Mix Produced

Two aluminum alloys were monitored during this work. A total of 216 furnace batches for Alloy 1 and 67 batches for Alloy 2 were monitored. The data collected was used to compare the weight of dross generated by each alloy.

As demonstrated in Figure 6, the data analysis revealed that there is a statistically significant difference in the dross generation between these aluminum alloys. For Alloy 2, the amount of iron added by powder injection was greater. Indeed, the duration of the lance powder injection was 6 times longer for Alloy 2 compared to Alloy 1. Accordingly, this difference in dross generation could be explained by the high level of turbulence caused by the lance powder injection. This resulted in a net increase of the dross produced by about 12% (from 1.06 to 1.20). The p-value obtained with the student t-test is well under 0.05, which means that there is significant evidence to suggest that alloying with lance powder injection has an impact on dross generation.

The lance powder injection creates a high level of turbulence at the molten metal surface. Each time the surface of the liquid metal is disturbed or stirred, dross is inevitably being generated [2]. Sustainable gains could be achieved by improving the present alloy addition technique or by establishing a best practice to reduce dross generation without compromising the efficiency related to iron dissolution.

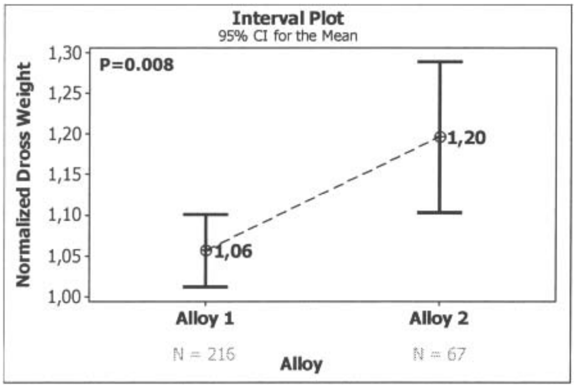

Figure 6. Dross generated per batch for two different aluminum alloys

Example 2: Primary Molten Metal Charging

The weight of primary molten metal charged into the furnace depends on the weight of remelt scrap added as well as the initial amount of molten metal remaining in the furnace after a previous cast. The weight of molten metal charged into the furnace typically varies between 60 and 105 tonnes for the 110-tonne capacity furnace considered in this study.

As mentioned earlier, the large batch-to-batch dross generation variation requires grouping the data into logical families. The analysis of the molten metal charging effect was then performed by separating the data into two different populations (50 low values vs. 50 high values of the weight of molten metal charged):

- Population 1: average of 70 tonnes
- Population 2: average of 101 tonnes

As expected, the amount of primary molten metal charged into the furnace is a significant factor contributing to dross generation. Figure 7 outlines that an increase in the amount of primary molten metal charged into the furnace increases dross considerably. The increase of the molten metal charge weight from 70 to 101 tonnes increased the dross weight produced by about 20% (from 1.13 to 1.39). As such, this clearly demonstrates that primary molten metal charging is a key factor contributing to dross generation.

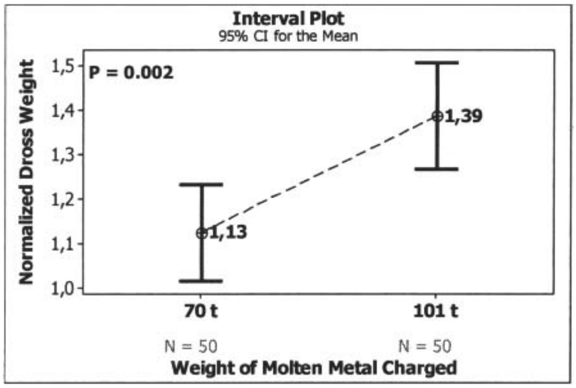

Figure 7. Dross generated per batch versus the weight of primary molten metal charged

In fact, it is again confirming a well known attribute that molten metal charging is one of the main factors contributing to dross generation in cast house furnaces [6, 7, 8, 9]. Indeed, liquid metal charging using a transfer trough generates considerable amounts of dross due to the free-fall metal cascade that creates turbulence, splashing and air entrainment. Therefore, this operation should be performed with the intention of reducing the metal cascade height and the resulting turbulence.

Example 3: Type of Remelt Scrap Added in Furnaces

The mass and the type of scrap that are remelted in the furnace, as well as the submergence technique, can have a potential impact on dross generation. In the present case, the dross produced at sow casting lines was added to the cast house furnaces. The metallic content of this specific type of the dross is very high, typically up to 90%. Therefore, it was occasionally charged into the furnaces in an effort to recover the metal.

Batches with and without the addition of the sow line dross were compared to evaluate the impact of this procedure. A total of 134 batches with the addition of sow line dross were monitored and compared with 159 batches that had no addition.

It' was found that this type of scrap significantly increases the amount of dross generated in furnaces. Indeed, as illustrated in Figure 8, the dross generated was considerably higher for batches where sow line dross was added into the furnace. Despite the fact that the metallic content of this specific dross is high, the overall mass is relatively porous. This type of dross tends to float at the liquid metal surface in the furnace, resulting in additional metal loss by oxidation.

The tracking of batch-to-batch dross generation has clearly highlighted the negative impact of this procedure. It provides the factual arguments to investigate the economical profitability of processing this type of dross directly in the furnace.

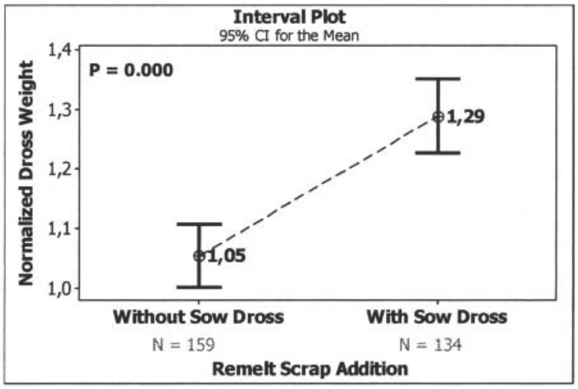

Figure 8. Dross generated per batch with and without the addition of sow dross

Measurement of the IGDC Performance

The entrapped metallic aluminum present in the dross oxidizes when exposed to air. This phenomenon is known as thermitting. Figure 9 shows an extreme case of thermitting dross caused by the aluminum oxidation reaction which is very exothermic. The reaction between Al and O_2 can result in a considerable loss of metal value since the Al_2O_3 formed cannot be recovered.

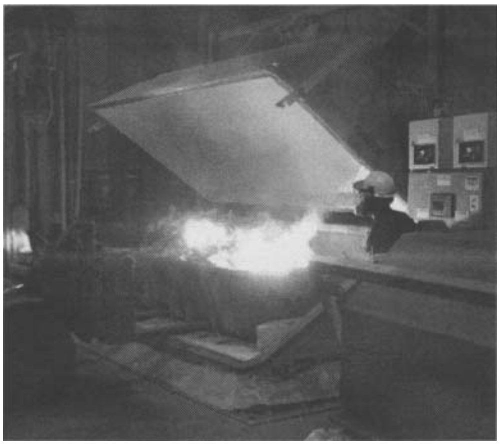

Figure 9. Reactivity of dross before the inert gas dross cooling treatment

The IDGC weighing system has proven to be a good tool to evaluate the dross cooling efficiency by measuring the weight gain caused by metal oxidation during the cooling treatment, since the industrial IGDCs are not always completely airtight. Therefore, measuring weight gain allows quantifying the IGDC performance and detecting equipment malfunction to determine the need of maintenance. Moreover, as presented in Figure 10, the assessment of the reactivity of dross for different alloy mix or different types of dross can also be performed by measuring the oxidation rate.

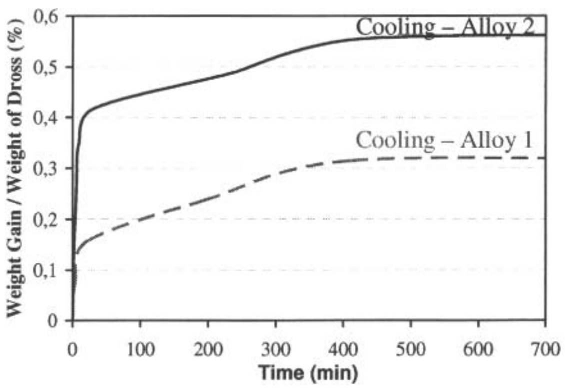

Figure 10. Typical weight gain observed during the inert gas cooling treatment

In addition, the Inert Gas Dross Cooler treatment time is generally standardized for all types of dross. However, it was difficult to reduce the IGDC treatment period since the exact weight of dross to be cooled as well as dross reactivity cannot be evaluated. Fortunately, the integrated IGDC weighing system could be used as a means to reduce the inert gas dross cooling treatment time by measuring the weight and the reactivity level of the dross.

Conclusion

For many years, reduction of furnace dross generation has been a key challenge for cast houses. Since no appropriate measurements or key indicators exist, real gains were difficult to achieve and maintain. Therefore, a new approach to measure batch-to-batch dross generation has been developed leading to the successful implementation of an integrated IGDC weighing system.

This system has proven to be an excellent tool to track the batch-to-batch dross generation and to identify the key process parameters that most affect dross using a statistical approach. It has also been demonstrated that the weighing system helps to establish standard practices in an attempt to reduce dross generation. Moreover, it has been found that the weighing system could be used to reduce the IGDC treatment time by measuring the dross weight as well as the dross reactivity.

From this point forward, the integration of the weighing system with the Inert Gas Dross Cooler package will be considered for upcoming implementations.

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