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MOLTEN METAL TREATMENT IMPROVEMENTS AT JW ALUMINUM USED AS A METHOD TO GUARANTEE METAL QUALITY

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Abstract

Following the initial molten metal quality studies with the MetalVision Inclusion Analyzer[1,2] , the need for more robust molten metal treatment equipment and methods was identified. Through Rapid Improvement Events and other Six Sigma techniques, systematic changes were introduced and closely monitored. Significant improvements were made in melting, degassing and filtration that resulted in the ability to adapt the production process to varying raw material types. The changes made are discussed as well as their effects on the molten metal quality measurements.. Implementation challenges and the follow up control ensuring uniform and consistent sustainable benefits are also discussed. Data is presented proving that final product quality has improved as measured by in plant non-conformances and the goal of zero customer returns and complaints.

Introduction

Continuous twin roll casting presents special challenges with regards to long casting campaigns versus the need to clean holding furnaces, launders and molten metal treatment systems. Typical twin roll casters require close tolerances with regard to molten metal level and temperature. Interventions such as replacing filters, cleaning the degasser box, scraping the launders and cleaning the holding furnace therefore need to be kept to a minimum, yet running too long without cleaning also puts product quality at risk. The other option is to schedule regular downtime for cleaning with the associated loss in production and startup costs.

“Tribal” knowledge built up from experience over years presents the solution of “we have always done it this way.” Challenging the status quo needs a data driven, scientific approach. This include the use of systematic techniques such as lean and six sigma, the fundamentals of science, and most importantly solid and reliable measurement and data gathering to make informed decisions.

In the last few years JW Aluminum has challenged the status quo at their plants by the systematic implementation of the above mentioned techniques. The company has not only dramatically improved its products and customer service, but has made internal process improvements in leaps and bounds that translated into increased annual EBITDA.

Nevertheless, solid molten metal quality data was lacking. Therefore the decision was made to purchase a MetalVision MV 20/20 inclusion analyzer[1,2]. The decision making process to purchase the MV 20/20 is described in detail in another paper[4]. This acquisition enabled a data driven approach to the challenges with regard to best cleaning practices.

Process Description

The predominant molten metal configuration at JW Aluminum consists of a three chamber melter (pump well, charge well and main hearth), followed by a holder and then molten metal treatment using a degasser and two vertical filters in series. Casters are twin roll continuous producing cast coils to be rolled to final gauge. Multiple casters, anywhere between 1 and 3 are often attached to one holder. Casting is 24/7 with maximum utilization of equipment in order to satisfy customer demand.

Challenges with 24/7 Production

Batch processes, such as DC casting, provide ideal opportunities for cleaning the molten metal supply chain. Melters and holders cycle between empty and full. During the empty stage, the furnaces can be cleaned. On the casting side, launders cycle between empty and full while filter bowls can be drained and cleaned. Degassers can also be drossed and cleaned between casts.

When casting 24/7, especially with multiple casters attached to one line, there is no obvious cleaning cycle. Therefore, the cleaning has to be scheduled at the most convenient time with the least amount of interruption to production. At JW Aluminum, furnace cleaning, filter changes and molten metal treatment cleaning is scheduled when casting the heads and tails (the portions at the start and end of the cast coil that is discarded during rolling). Although this practice limits contaminated metal to planned scrap, the potential for caster tip contamination still exists. .

Cleaning Cycle Benefit, Extent and Recovery

Performing cleaning cycles in a controlled fashion requires data to be gathered in order to confirm the extent of contamination, period of recovery, and benefits of cleaning. Cleaning involves a temporary sacrifice or drop in molten metal quality in order to gain prolonged periods of stable high quality molten metal.

The question therefore is what the severity of the molten metal cleanliness drop is during the cleaning cycle and what time is needed for recovery. This data is essential in order to:

1.) Ensure that the surge in inclusions caused by the cleaning cycle is contained within the desired heads and tails that are slated for scrap.
2.) The severity of the drop in metal quality does not cause irreparable damage to the caster tip.
3.) Cleaning the caster tip is performed after the wave of inclusions from the cleaning cycle has passed.

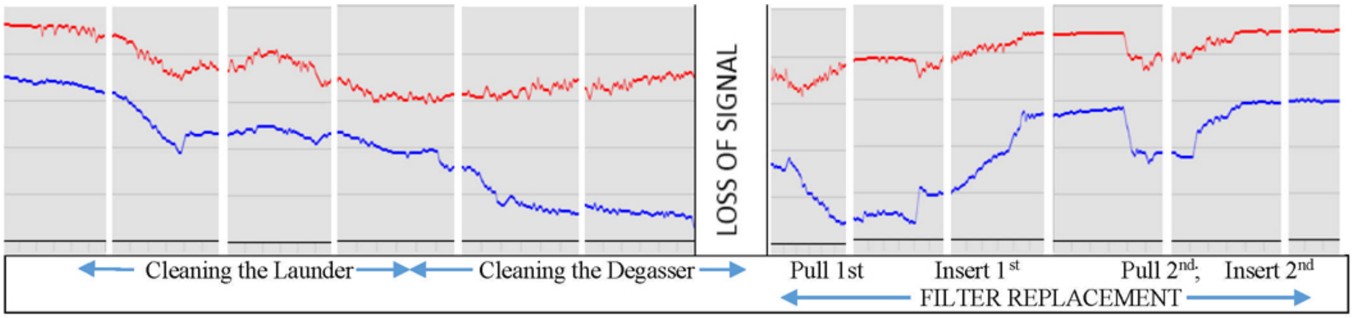

Figure 1: Cleaning cycle molten metal quality drop

Figure 1 shows the measurements taken during a typical cleaning cycle. This graph shows the gradual drop in molten metal quality as the cleaning cycle moves closer to the casting station, progressively cleaning the holder, launders, degasser and finally culminates in a large drop at the time the filters are being replaced. These measurements confirmed that the cleaning cycle is completed within the allotted time that scrap is being cast. Following the cast coils through rolling showed the reduction in molten metal cleanliness in heads and tails before these are removed in the usual fashion. These defects show up as dark surface irregularities. A picture of the defect is shown in Figure 2.

Figure 2: Typical Grade "C" Black Mark

Typical black mark defects were subjected to SEM/EDX analysis. The main components in this defect were spinels, aluminum oxides and salts from the cleaning and degassing operations (Figure 3).

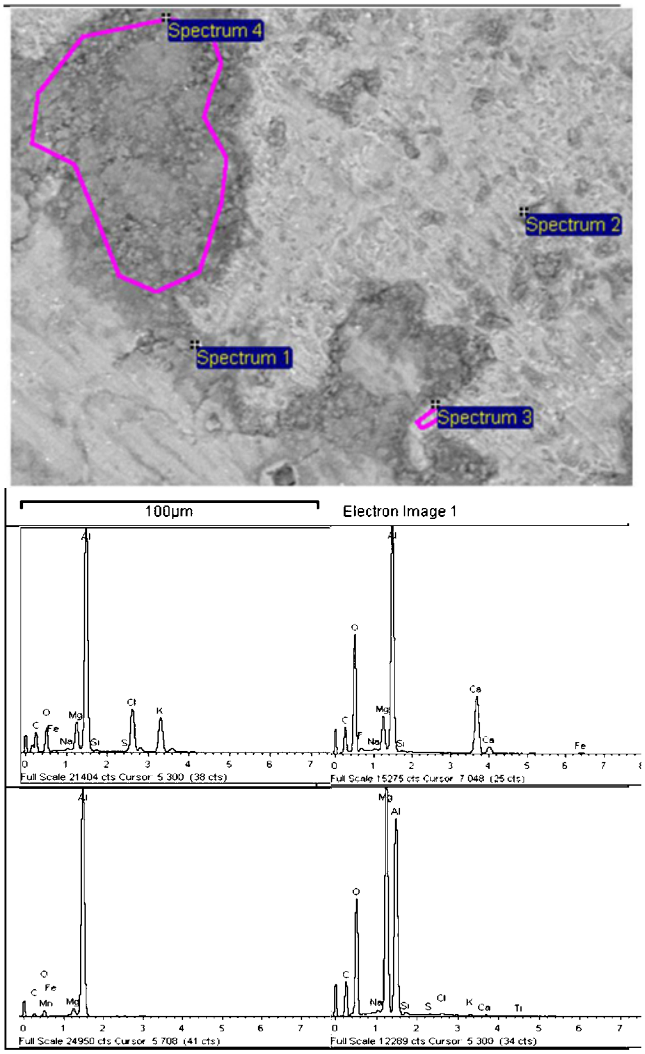

Figure 3: SEM/EDX Analysis of a typical Black Mark defect.

Ceramic Foam Filter Life

The optimal time for performing the cleaning cycles is at the end of the filter life, since a new cycle can then be started with a clean set of filters. Therefore, determining the "filter life" is an important factor in order to schedule regular cleaning cycles.

Two ceramic foam filters are used in series after the degassers. The flow rate through these filters are well below the manufacturers maximum recommended flow rate of 3 lb/(square inch.min). This is due to continuous twin roll casting flow rates being low compared to intermittent batch casting such as DC casting.

For filter life studies, MetalVision inclusion analyses were performed at set intervals before and after the degasser and filters. The presence of bubbles after the degasser eliminated the possibility to take the measurements before and after the filters only. Therefore, the study included the cleaning performed by the degassers as well as the introduction of grain refiner in the degasser.

Since the degasser parameters and grain refiner feed rates were held constant, the only variable tested was the filter behavior. The molten metal treatment system (degasser and filter) efficiency is plotted on a relative scale in Figure 4.

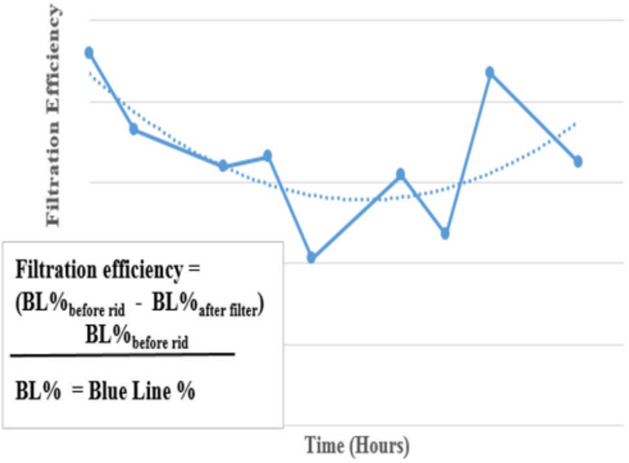

Figure 4: Filtration efficiency of the molten metal treatment system over time.

The graph in Figure 4 clearly shows that filtration efficiency (other parameters constant) starts off high and initially decreases with time. This is the period in which the filter operates in "depth mode". In other words, the inclusions are being captured inside the filter (See Figure 5).

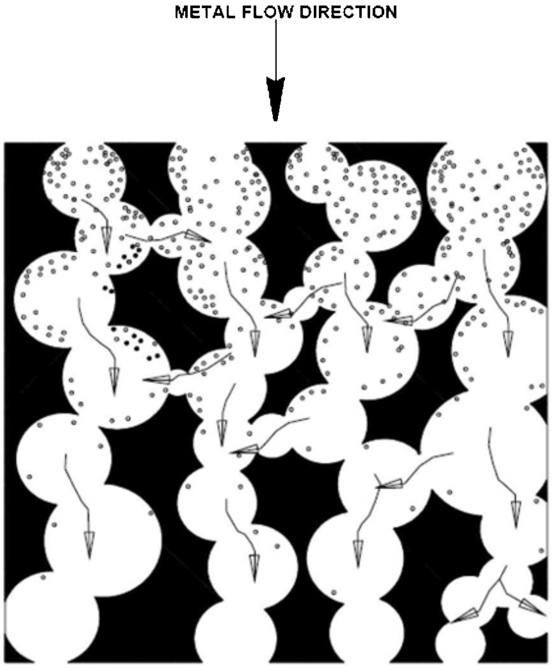

Figure 5: Inclusion capture within the ceramic foam structure by surface adhesion forces (depth mode) (Barbis et.al[5].)

After some time, the overall filtration efficiency then starts to increase as the filter enters "cake mode" where bridges are formed by inclusions across the filter pores and the cake filters out the inclusions. As the molten metal flow rates were low, "caking" did not result in significant metal head level drops across the filter as can be the case with DC casting. In DC casting, "caking" can lead to aborting a cast due to flow restrictions as reported by Breton et. al[6].

Unfortunately, even though caking leads to overall improved filtration efficiency, it also leads to filter instability as the bridges formed across the pore openings are easily broken down by small changes in flow or other types of disturbances. Therefore, as the filter efficiency starts improving, fluctuations in efficiency also starts to increase. This may be best illustrated by the filtration efficiency change $(\frac{\Delta f}{\Delta t})$ with time showing increased fluctuations (Figure 6). In effect this means that the filter can be used almost indefinitely at the low flow rates used, but at the risk of the filtration becoming unstable and increasingly sensitive to smaller and smaller changes in casting parameters such as flow rates.

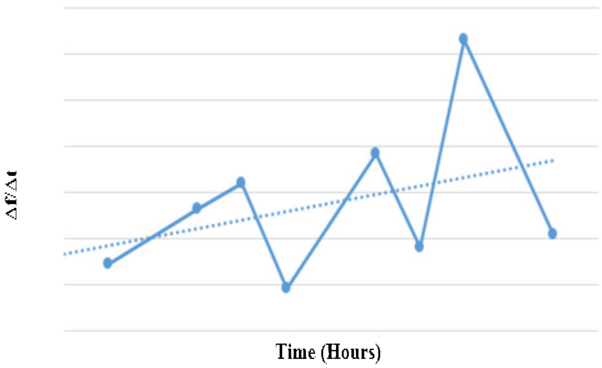

Figure 6: Average filtration efficiency improves with time but the filter becomes unstable and filtration efficiency becomes highly variable due to releases or break down of the cake.

Sustainment and Product Improvement

The effort to quantify inclusions has led to improvement in product quality as witnessed by the downward trend in non-conformances (Figure 7).

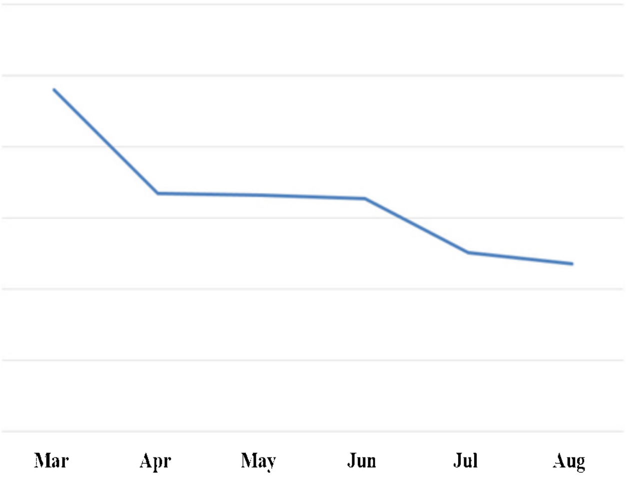

Figure 7: Downward trend in non-conformances since the MV 20/20 Inclusion Analyzer has been used.

The process changes initiated are being sustained through the JW Aluminum Quality Management System, including Standard Work and Control Plans.

Further Development and Actions

Gathering inclusion data is ongoing and the full benefits has not yet been realized. Additional projects include trials with different rotor heads in the degasser, modifications to the filter and degasser configurations, and testing alternative degassing techniques such as the Southwire Ultra-D ultrasonic degasser[7]. Based on continued acquisition of inclusion data, decision making is improved and the cumulative knowledge and experience within the company has been enhanced by the validation or rejection of prior beliefs. The overall results have been beneficial, not only in driving down cost, but also improved product quality for customers.

Conclusions

The challenges of regular cleaning during 24/7 twin roll casting has been addressed by regular system cleans during the start and end of coils corresponding with the “heads” and “tails” scrap in subsequent rolling. The extent of contamination during the system cleans were quantified by real time inclusion analyses. Filter life was also characterized and optimized. The result was improved product quality while driving down the production costs. The effort is continuing as long held beliefs are refuted or affirmed and new projects identified.

Acknowledgements

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