THE INFLUENCE OF MELT CHARGE MATERIALS ON MOLTEN METAL QUALITY AT JW ALUMINUM

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Abstract

Market trends caused a reduction in the spread between recycled and prime aluminum starting in 2013. This required JW Aluminum to be responsive to changes in raw material pricing. The ability to rapidly respond to changing raw material markets, depends on a full understanding of the effects raw material has on the JW Aluminum production process. To facilitate a better understanding, JW Aluminum recently purchased a Metalvision MV 20/20 inclusion analyzer that was used extensively to study the effects of raw materials on molten metal quality. As part of the 6-Sigma DMAIC process[1], experiments were designed using critical variables and controlled Key Process Inputs. The principle outputs were obtained from the MV 20/20 and final product quality evaluations. The study showed that raw materials has a statistically significant effect on molten metal quality. As a result of this study, Lean Rapid Improvement events were held that significantly altered the way in which JW Aluminum melts and processes its raw materials[2].

Introduction

The origins of the metallurgical industry can be traced to the art of Alchemists in the Middle Ages. After the times when tribal knowledge of the art of metals were passed on through generations, the application of the scientific techniques led to the industrial revolution. Then came the quality revolution that we are living in today.

Making informed decisions based on data is the foundation of the Six Sigma DMAIC process[1,2] In the quest to be the best, JW Aluminum adopted this data driven approach. Applying these principles to molten metal quality is a challenge due to:

1.) The shortfalls of all inclusion quantification techniques (LiMCA®, MetalVision[3],[4], PoDFA®, PreFil®).
2.) Inclusions are not homogeneous throughout the metal as is the case with chemistry.
3.) The tendency of inclusions to build up, in other words the "loading" of the molten metal process.
4.) The tendency of a loaded system to surge inclusions occasionally due to upset or excursion events.

During the typical Six Sigma "Define" phase, a common tool, the SIPOC (Supply-Inputs-Process-Output-Customers) analysis is performed. Looking at molten metal cleanliness holistically, therefore, requires starting with the supply and inputs into the first step of the process: melting.

Analysis of the raw material input from a molten metal quality perspective cannot be separated from the financial aspects of the business. Raw materials are the major contributor to the final cost of the product delivered to the customer. Consequently the pressure to reduce cost in this area is great. The pressure to deliver a quality molten product to casting is a critical requirement. The need for data driven decision making with respect to raw materials is therefore paramount to the daily operations of JW Aluminum.

The Raw Materials Decision

Apart from the obvious cost of the raw material, a data driven decision requires:

1.) Statistical data on historical recovery for each type of raw material.
2.) The chemistry of each type of raw material, especially the tendency towards contamination (for example iron in scrap).
3.) The metal quality with respect to the contribution towards the final molten metal quality delivered to casting (inclusions).

JW Aluminum has an extensive database on expected recoveries and chemistries of the various raw materials. The data with regards to the contribution towards molten metal quality was seriously lacking. Therefore, JW Aluminum decided to address this shortfall by purchasing a real time MetalVision MV 20/20 Inclusion Analyzer. The decision making process in this regard is discussed in a previous paper[3].

The MV 20/20 reports molten metal quality as the clarity or transparency of the metal relative to five nines (99.999%) purity aluminum, the largest particles sizes, the average particle size above 20 microns and the amount of counts with particles. All this data is displayed and can be downloaded into an Excel® spreadsheet for statistical analysis.

Real-time analysis of large volumes of molten metal are critical due to:

1.) Loading of the system (the "averages") needs to be separated from the excursions (the surge of inclusions due to upsets).
2.) Excursions are usually of a relatively short duration compared to the average delivered molten metal quality.
3.) Final product inclusion related defects are not determined by the loading and averages, but by the excursions.
4.) The loading of the system is the enabler of excursions and determines the severity of the excursion.

Raw Materials Molten Metal Quality Trial

JW Aluminum has 17 continuous twin roll casters. These casters run 24/7 with downtime for process maintenance managed down to a minimum. Therefore, the melters have to continuously supply the casters with adequate molten metal flow at the right temperature, chemistry and molten metal quality.

The Mount Holly plant has 5 melters, 4 of which feed to a holder and then on to casters. Up to 3 casters can be tied to a holder. The raw material trial was performed at the melter/holder 5 combination.

The melter transfers molten metal continuously to the holder and this provides an ideal continuous molten metal sampling position in the trough between the melter and holder. The melters have three chambers, a charge well, pump well and main hearth. Heat is supplied in the main hearth and circulated to the charge well for rapid melting of the charge. Absence of burners in close proximity to the charge reduce oxidation and potential generation of inclusions and excess dross.

Holder 5 was tied to 3 casters which resulted in a melter 5 turnover time of 10 hours. Nine different high consumption raw material types were identified for the trial. The target composition was AA3105 alloy. Each of the raw material types were fed to the charge well of the melter for 3 hours (a total of 27 hours). At the end of each 3 hour charge period, the charge well was skimmed to remove all dross and raked to remove all un-molten iron in a particular raw material type.

The 3 hour charge and dross cycle was ambitious and there was uncertainty that the required melting rate could be held during 3 hour cycles that charged more challenging raw materials.

Table 1 lists the raw material types tested in descending order with respect to their cleanliness results. The results were based on the rate of change in the molten metal quality (inclusions and overall clarity) during the charging of a particular raw material type.

Observation of the trial practice as executed by the melting operators revealed a number of concerns:

1.) The 3 hour cycle and challenge to keep the melt rate up added additional strain on the melting operators.
2.) Raw material grades with lower associated melt rates (for example thinner gage) tended to leave solids on top of the dross at the end of the cycle.
3.) To enhance melting, the operators stirred the solids into the bath and in the process mixed dross into the metal.
4.) This produced large variation in the metal quality from before to after drossing.
5.) The biggest drop in quality was associated with raw materials requiring iron to be raked from the bottom of the charge well and/or types that tended to readily thermite.

The opportunity to improve molten metal quality by optimizing drossing (skimming and raking) practices was therefore identified. A Rapid Improvement Event (RIE) was organized with operators to identify means of improvement.

Table 1: Ten high consumption raw material types in descending order with respect to molten metal cleanliness assessment with the MetalVision MV20/20 inclusion analyzer.

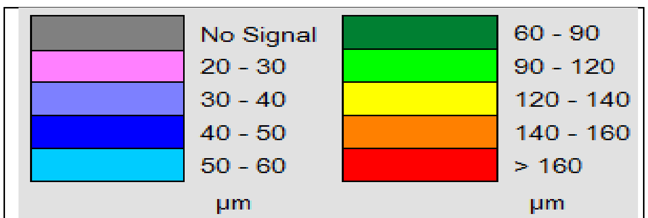
Raw Material Type Charged to Melter 5	**Relative Molten Metal Cleanliness Rating Produced**
P1020 T-Block	100%
Painted 3105 Alloy	91%
Off Grade Sows	85%
3003 Painted and Pucks	84%
P1020 Sows	80%
In-house Scrap	74%
Heat Exchanger Pucks & Coils	53%
Mixed Low Copper	31%
Mixed Low Copper Dealer Grade	29%

Drossing Rapid Improvement Event (RIE)

The team convened for the RIE event consisted of 3 melting operators, the melting process engineer, corporate chemical value stream technical manager, lean manager and an outside lean facilitator[2]. The event was preceded by data gathering in the form of molten metal quality assessments (MetalVision MV20/20) and videos of the drossing practices. A full week was set aside for the event.

The RIE produced significant outcomes, and the changes proposed were trialed at the end of the event. Screen shots before (standard procedure) and after (improved procedures) can be seen in Figure 1. The improvements made are also listed in the table attached to Figure 1. The key to interpreting the MetalVision results are summarized in Table 2.

Table 2: MetalVision MV20/20 key



	Green Line	Mean Particle Size
	Orange Line	Largest Particle Size Observed
	Blue Line	% Clarity (Inverse of Attenuation)
	Red Line	MV-Grade (combination of above)

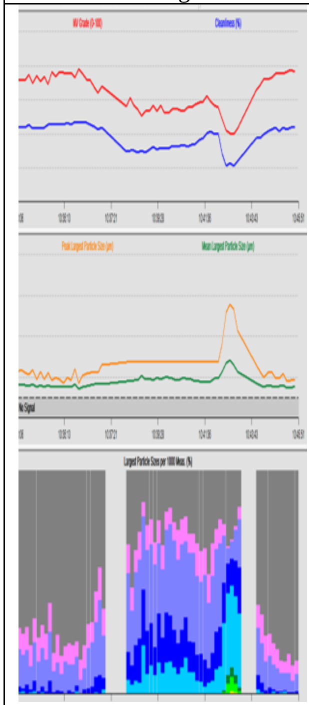
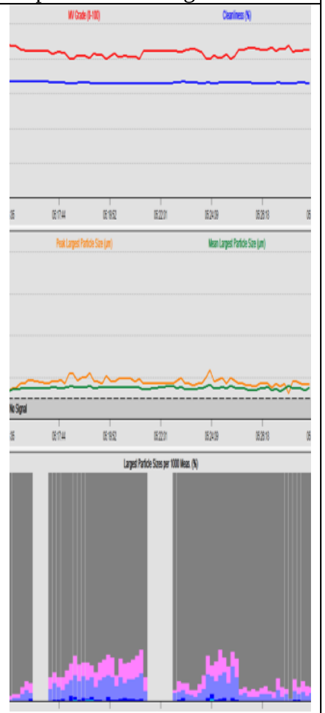
Pre-RIE Drossing Procedure	Improved Drossing Procedure
	
• Cover flux only added at start and end of the cycle. • Excessive thermiting and a hard dross cover. • Limited heat transfer from bath to charge material on top of the dross. • "Chopping" to break the dross and melt the metal on top of the dross. • Excessive mixing/stirring to spread the cover flux into the dross and drain the metal from the dross.	• Add cover flux throughout the cycle. • Keep dross "wet" and prevent thermiting. • Increased heat transfer from the bath to the metal to be molten. • Increased melt rate. • Little or no un-molten metal on the dross at the end of the cycle. • Gentle mixing of cover flux into the dross to drain metal from the dross. • Picture 1 shows the drossing of the charge well.

Figure 1: MetalVision MV20/20[3,4] results showing the improvements made during the drossing Rapid Improvement Event (RIE).

The main benefit of the Rapid Improvement Event was that raw materials at the lower cost point could now be used without the losses in molten metal quality measured with these raw materials before and after drossing. Therefore, overall molten metal quality (averages) improved and the molten metal production system inclusion loading was reduced.

The Rapid Improvement Event also led to the next improvement opportunity as the excursions (or surges) of inclusions associated with the flow control (measuring rod adjustments) were identified.

Transfer Flow Control

The continuous flow from the melters to the holders are controlled by a measuring rod in the tap hole. This conical rod is equipped with a refractory paper cone that has to be replaced every 12 hours (once a shift). Even though the measuring rod is automatically controlled to keep the holders at the desired level (heel), occasionally the ceramic paper cone would fail or the flow control would be maladjusted and require resetting.

Such events are associated with an upset of the flow and results in an excursion (release) of inclusions from the melter (Figure 2).

The consequence of this finding was that the control plan (work sheet) for the melters have been updated and the melting operator has to note all measuring rod adjustments. Training was also done on the proper adjustment of the measuring rod and consequently this form of release from the melters are now controlled down to a minimum.

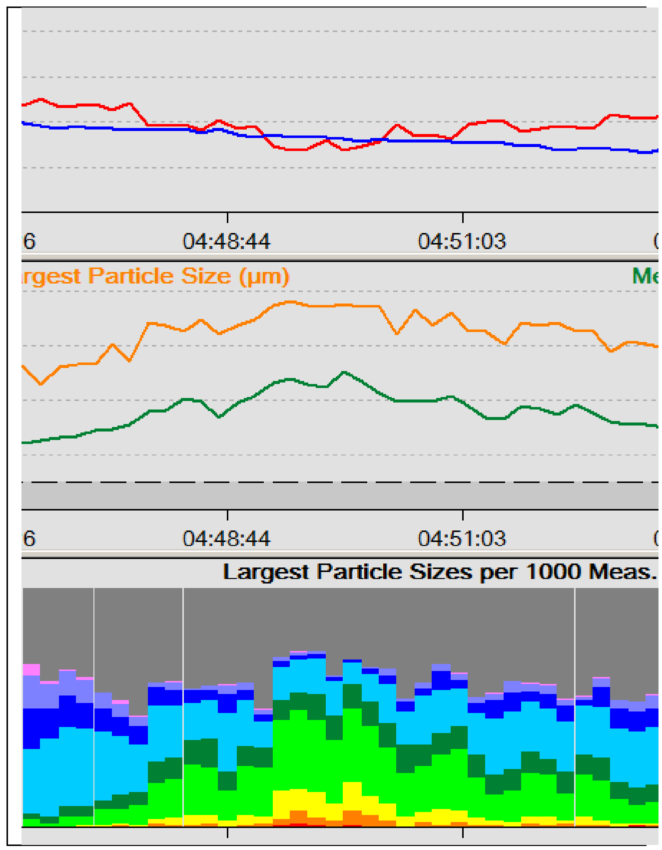


Figure 2: Measuring rod adjustment is followed by a surge of large inclusions and a progressive drop in the clarity (blue line)

Conclusions

In a quest for ever increasing molten metal quality and better end products for JW Aluminum customers, the company identified the need for molten metal quality management and purchased a MetalVision MV20/20 inclusion analyzer. Using standard Six

Sigma practices as part of the JW Aluminum decision making process, the influence of various types of raw materials on molten metal quality have been rated relative to P1020 T-Ingot.

The analysis identified shortfalls in skimming and raking (drossing) practices which was addressed by a Lean Rapid Improvement Event with melting operators from the floor.

Flow control adjustments were also identified as causing the release of inclusions and has been addressed by better methods and training.

The ability to measure molten metal quality is leading to more and more opportunities for improvement to be identified and several more experiments are being planned.

The overall result is that more cost beneficial raw materials can now be used with less tendencies to reduce molten metal quality, enabling JW Aluminum to progressively increase product quality and at the same time improve profitability.

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