Optimization of Commercial Aluminum Alloy Melting in Reverberatory Furnaces

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Alcoa Lafayette uses reverberatory furnaces to melt aluminum for casting. The furnaces are a bottleneck due to long melt cycle times. Improvements to the melt cycle time would increase capacity and directly impact revenues for the plant. The melting of the aluminum is a time consuming task which is not easy to monitor. No method exists to predict when the bath is melted.

For this reason, our team focused on methods to predict accurate melt times to reduce time spent in the melt section of the flow path.

**Project Background**

**Introduction**

Alcoa Lafayette Operations cast and extrude components for the aerospace, oil and gas, and automotive industries. The operation of its ingot plant is described by the flowchart below:

- Melt
- Degas
- Filter
- Cast

![Melt operation sub-process flowchart displaying steps within the melt cycle with actual run time and optimal value added times.](Image)

At the beginning of 2014, Alcoa Lafayette Operations ingot plant set up a productivity improvement plan in order to increase annual production by 36 million pounds, which would result in a $63.7 million increase in annual revenue. The improvement comes from Equipment, People/Productivity, Staffing, and Recovery sections.

**Deliverable**

- A melt time tracking card was developed based on an empirical model and provided to Alcoa to determine an accurate melt time. An improved theoretical estimate will be obtained once a theoretical model is implemented. Using the card could reduce time spent in melt which would lead to the below savings.

<table>
<thead>
<tr>
<th>Monetary Value</th>
<th>Output Increase (lbs)</th>
<th>Percent of Target Achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoa’s Goal</td>
<td>10.9 Million</td>
<td>4.2</td>
</tr>
<tr>
<td>Projected</td>
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**Problem Identification**

- Flowchart
  - Melt cycle is illustrated by the flowchart on the upper right.
  - The team analyzed a large furnace which contributed 37.9% of the total production in 2013.
  - The melt step is the bottleneck in the cycle because it constrains casting, and takes the longest amount of time.

**Bottleneck Causation** - Two main traits lead to long melt times

- Opening of the furnace door at incorrect times.
- Not moving to the next step once bath is molten.

**Bottleneck Reduction** - Two models were developed

1. Empirical model based on the amount of charge and the metal left from the previous casting drop.
2. Theoretical model based on furnace flue temperature.

**Empirical Model**

Alcoa and the team believed the following three factors to have the most influence on melt time: heel weight, amount of scrap used, and total charge weight. The results from examining these factors and developing our empirical model met Alcoa’s need in increasing efficiency.

**Heel Model**

- The furnace tilts to pour the metal.
- Liquid metal remaining after pouring is known as the heel.

**Theoretical Model**

Thermodynamic balance of furnace to determine when liquid fraction (f_l) is equal to 1 signifying a melted bath.

**Estimated Melt Time**

42 cycles were analyzed, and 12 were deemed ideal to use for the empirical model.

- The total aluminum index was calculated based on the total charge weight and heel weight.
- Coefficients were inserted and optimized for the best correlation.
- The regression line outputs estimated melt time.
- The estimated time equation had a regression of 0.6321.

**Percent Scrap Analysis**

- Scrap usage did not have as large of an impact on the melt time as heel weight or total charge weight.
- Proves that heel weight and weight of material charged were the main factors determining melt time.

**Summary and Future Work**

Based on limited data, the Melt Time Tracking Card could potentially save up to 1 hour 10 minutes and 2 hours 13 minutes per cycle for small and large furnaces respectively. Time is saved by improving accuracy of the timer, which increases efficiency by not opening the door at inappropriate times and reduction of non-value-added time. This change can result in an annual production increase of 13.4% which is 16.2MM pounds or $28.6MM in revenue. Our theoretical model provides a scientific approach to determine whether the metal is fully melted or not.

Alcoa decided to implement the Tracking Card in their future furnace operations. A more accurate empirical estimated melt time will be updated once more data is acquired. Additional analysis of continuous flue temperature data will be used to optimize the theoretical model to better match actual conditions of the furnaces at Alcoa Lafayette Operations.