Powering Precision: Optimizing Metal Casting Through Scripting and Analysis

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PURDUE UNIVERSITY | The Data Mine

MetalTechnologies™

PROJECT INTRODUCTION

Problem

- Electricity can get expensive – especially in industrial iron casting, where melting the metal alone uses more power than entire city blocks.
- Our corporate partner, Metal Technologies, is no different, spending upwards of $10,000,000 on their electrical costs annually at their Auburn, IN plant alone.

Focus

- At this scale, the major liquid component of the bill is set point, which can be thought of as the diameter of the pipeline determining how much power the plant can draw at once.
- To cut costs, MTI has long operated at a set point they know will cause occasional bottlenecks, contending costs will level out.

Goal

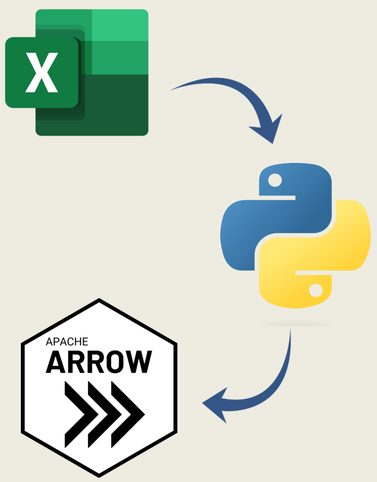
- MTI tasked us with applying our skills in data compilation and analysis to uncover actionable insights, support strategic decision making, and put their hunches to the test.

COLLECTING DATA

- Before this project, all data analysis at MTI was performed manually in Excel, mandating that the fifteen years of 5-second interval power demand data we were given access to be stored in unique files per day.
  - This format is impractical for large-scale analysis, necessitating compilation.

Data Conversion:

- Files that we were given from MTI are DBF files had issues from inconsistent data sheets to log times being doubled.
- Collected all files into one folder and wrote a python script to iterate through and output files compiled with nearby identically-columned files
- Apache Arrow Feather File Format
  - Loads 78 million lines, just under 1 billion data points, in 20 seconds
  - Lossless compression of 9 GB into 2 GB



ANALYSIS

INITIAL PREPARATION:

With up to 10% of values for select parameters being unexpected, interpolation would be necessary to replace impossible entries and make the data set workable.

PYTHON TOOLBELT:

On the scripting side, we made sure to arm ourselves with the appropriate packages: Pandas, Numpy, DBFRead, PyArrow, Seaborn, and SKLearn.

BOTTLENECKING FREQUENCY:

We know bottlenecking occurs if and only if all three melters are running concurrently, motivating us to explore a decision tree analysis in Power BI to identify such instances across set points.

CYCLE IDENTIFICATION:

To proceed further, we needed to compare per-melt cycle data, a task that required scripting to accurately identify break points and index entries accordingly.

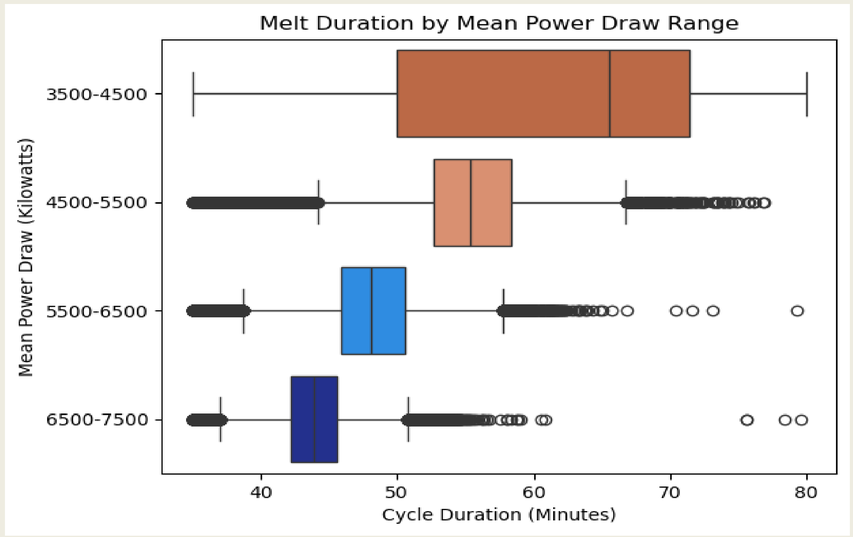
CLEANING EFFICIENCY:

While testing cyclic thresholds, we repeatedly noticed bimodial duration distributions with one impossibly-short maximum. Contextualization this reveals deslagging often takes 400% longer than anticipated.

REGRESSION:

Through a quadratic regression of mean power draw to melt duration, we've developed a model that allows for the reverse-engineering of the appropriate set point to achieve a desired level of production.

Figure 1: Impact of Bottlenecks



CONCLUSIONS

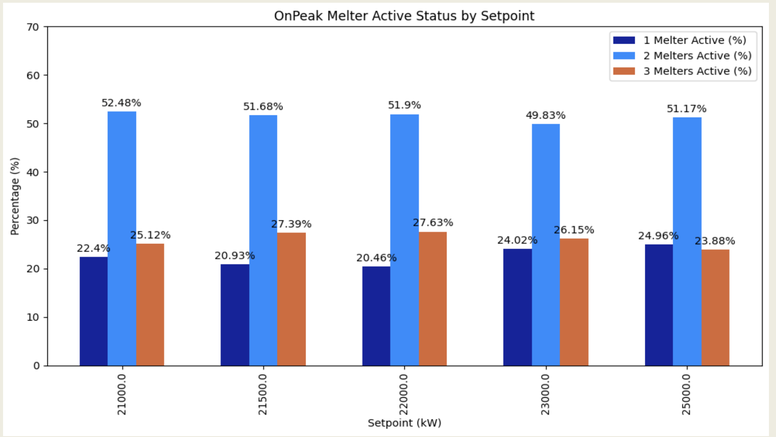


Figure 2: Active Melter Count While Melting by the Top Five Recent Set Points

Concurrent Melter Usage is Common

- Over 20% of daytime operations involve all three melters running at once (bottleneck), despite MTI's expectation that this was lower.

Bottlenecking Reduces Melting Efficiency

- Unrestricted melt cycles complete between 5 and 20 minutes faster than bottlenecked cycles, depending on the extent of the problem.

In Melting, Minutes Matter

- Even if bottlenecking was only increasing the duration of 20% of cycles by 5 minutes, at 10,000 cycles per year, an entire melt's worth of iron is being lost every other day.

IMPACT

- Data-Driven Strategic Guidance: Our analysis and predicative modeling gives MTI the tools to align electricity costs with operational goals, supporting more informed investment decisions and promoting sustainable growth, both within and outside of their Auburn plant.

FUTURE GOALS

- Developing software that can be used internally at MTI for large-scale data compilation, cleaning, and analysis in a user-friendly interface
- Implementing machine learning algorithms to improve accuracy of cycle identification and all derived data across time, set points, and iron mixes
- Integrate data from other parts of the plant into our analysis to better understand findings

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