Tata Steel
Real-Time Estimation of Steel Slab Temperature

Christophe Foyer *

April - July 2018

1 Abstract

This project showed very encouraging results for the ability to simulate the temperatures of all steel slabs being tracked in the Tata Steel IJmuiden system with accuracy and to deliver this information to the user (Appendix A).

The results of this project show a significant increase in the the temperature estimation accuracy for steel slabs going through the process when compared the the current estimation values used in production. This has led to a decrease of 78.2% in the Root Mean Squared Error (RMSE) (Figure 1) and reduced the standard deviation of the error by 63.7% (Figure 2) over the current system, and allowed us to estimate the temperature of the slabs with an average error of 21°C. This could lead to a meaningful increase in the efficiency of the process in the future, and as a result allow for significant cost-savings on the order of a million euros per year.

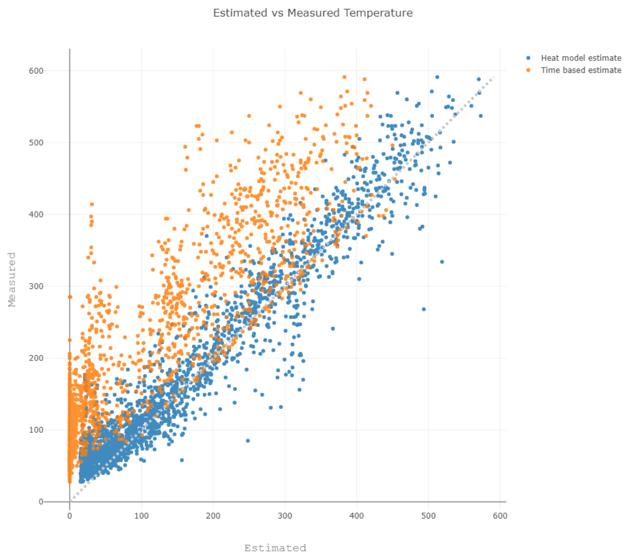


Figure 1: Measured vs. Estimated

2 Introduction

The Customer Value department of Tata Steel IJmuiden Steel Plant deals with short-term high impact problems by deploying so-called SWAT teams of engineers. A SWAT team solves a complex problem in an intensive short-term and agile project (14 weeks).

The Slab Heat Model project involved building and implementing a heat transport model from scratch to predict the temperature of a great number of steel slabs. These slabs are cast from liquid steel at the Steel Plant and are rolled into thin and long strips by the Hot Strip Mill at 1200°C. Between these two factories, the slabs are stored in piles in open air for hours to days. During this period, the slabs cool down at rates that differ considerably per slab due to the influence of various factors. The Hot Strip Mill requires the slabs to be at 1200°C before rolling so after storage the slabs must be re-heated. Having a real-time model that calculates each slab's temperature will allow the optimization of rolling sequence and slab re-heating time. This will greatly minimize energy consumption and CO2 emission.

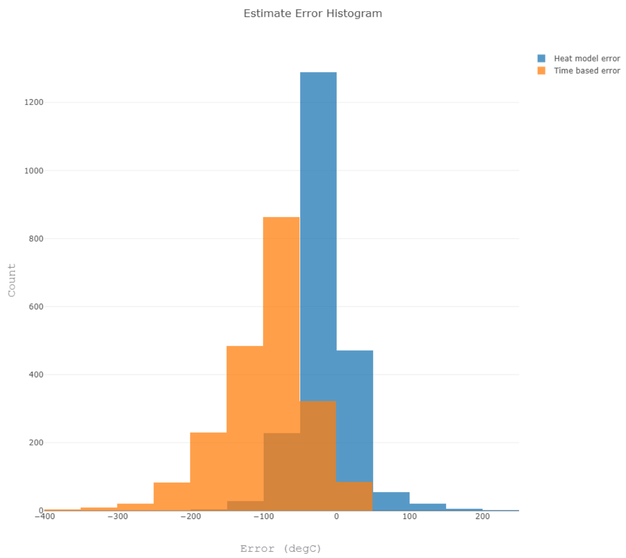


Figure 2: Error Histogram

*As part of the Slab Heat Model SWAT Team with Erik Feenstra, Yorrick Bauer, Paul-Jan Hogendoorn, and Hillianne Buist

3 Outcomes

For the duration of the project, I was responsible for managing the organization and deployment of the software. This included taking care of inter-component interactions when integrating different segments of code from different team-members, and managing the git server and releases when the development branch would reach a stable version. Doing so gave me a good understanding of the data flow within the code and gave me the chance to work with all team members to adapt code on both ends to fit the input and output requirements dictated by the software layout.

3.1 Interface

The software includes a visualization component to allow for easy access to simulation and validation results. Components to keep track of slabs and their temperatures were designed to filter out relevant slabs from the large amounts of data at our disposal. This was coded mainly using Bokeh (Figure 3) and Plotly (Appendix A), two python data visualization libraries. Command line control was also integrated early-on and allowed easy debugging of the program by passing commands directly.

Figure 3: Real-Time Visualization

3.2 Simulation

The overall simulation was designed to simulate many interactions between slabs and their environment. This was accomplished by integrating local weather data and slab data from internal databases which allowed for the calculation of heat transfers between slabs and the environment, the ground, and between slabs. This simulation was then validated using automated and manual measurements, as well as the use of a proven, high-fidelity, but non-real-time, FEM model to verify our model across multiple test scenarios (Figure 4).

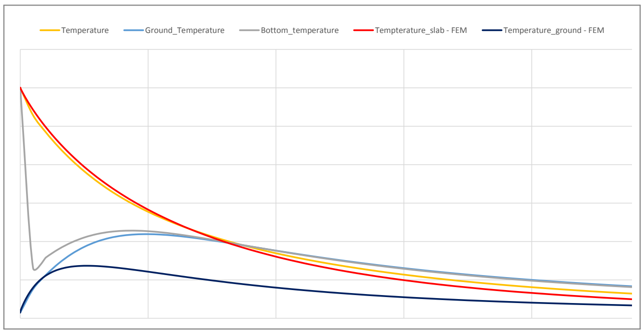


Figure 4: Example Test Scenario

4 Conclusion

In conclusion, this project shows great promise in using a model-based approach to track the temperature of steel slabs throughout the process. The model behaved beyond expectations reducing uncertainty in the prediction by significant amounts. As of version 2.2.1, a decrease of 78.2% in the RMSE and a reduction of 63.7% in the standard deviation, and an average error of 21°C was measured. This has the potential to greatly improve process efficiency and could save on the order of a million euros per year on reheating costs alone if implemented into planning.

5 Recommendations

Given the behavior of the model in current simulations, I would recommend the addition of an FEM approach as opposed to the current lumped model with surface temperature corrections. This would allow us to correct for surface temperatures more accurately and better simulate heat flows at the interface between different mediums. In addition, this would give us more detailed information on the temperature distribution within the slab, which could have meaningful implications in the tracking of fracture-sensitive slabs. Finally, if an FEM approach were to be included, significant performance improvements could be made by running the software using multiprocessing or GPU acceleration (likely in a Linux environment, significantly reducing the overhead of creating new processes that is found in Windows systems). This would allow us to leverage the full computational power of the host machine and more effectively use the resources at our disposal and open up possibilities for more refined models in the future.

Further Reading*

[1] Y. Bauer. Real-time temperature model of steel slabs in short-term storage. TU Delft Internship Report, 2018.

[2] H. Buist. Temperature model of heat dissipation in the ground. University of Twente Bachelor's Project, 2018.

[3] P.J. Hogendoorn. Heat content model for steel slabs. TU Delft Internship Report, 2018.

*Note: These reports may not be available outside of their respective institutions and/or may be internal to Tata Steel.

A Sample Simulation Report

Version 2.1.2 - July 9th 2018 - auto-generated status report.
Displays data validation statistics for the 24 hours of data collected prior to report generation.

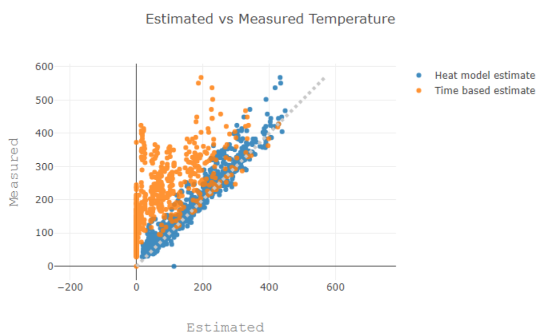
Simulation report

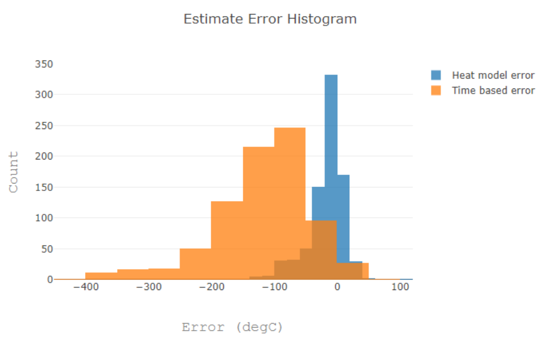
Generate New Report | Print

Status Report - Mon, 09 Jul 2018 09:22:32 (local time)

A summary of slabyard activity and simulation results for the last 24 hours.

Pyrometer validation:





Validation data statistics table:

Sample Size	Standard deviation Pred_vs_Meas	Root Mean Squared Error Pred_vs_Meas	Standard deviation Time_vs_Meas	Root Mean Squared Error Time_vs_Meas
812	28.6	33.31	76.04	141.08