Predicting Transitions of Steel in the Molten Scrap Metal Casting Process

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GERDAU Shape the future

Gerdau Steel Production

Gerdau is a Brazilian steel manufacturing company that produces long steel and special steel products in over 10 countries. For this project, we worked with Gerdau's mill located in Fort Smith, Arkansas.


Step 1: Electronic Arc Furnace


Step 2: Degassing Vacuum


Step 3: Tundish


Step 4: Rolling Station


Step 5: Ready for the Customer

Gerdau uses a continuous casting process. It begins in the scrap yard where 100% recycled steel is chosen per customer specifications. The electronic arc furnace then melts the steel and the degassing vacuum removes hydrogen and other inessential gasses from the steel. The molten metal is then poured into a tundish to begin casting. Using the mold size based on customer specifications, the steel is released from the tundish to form round billets. When the billet has achieved the desired length, it is cut by a hot saw. The now cut bars then move to the rolling mill to finish the manufacturing process. There, they are rolled so they have the desired diameter and then cooled with water. Finally, the bars are bundled and prepared to be delivered to the customer.

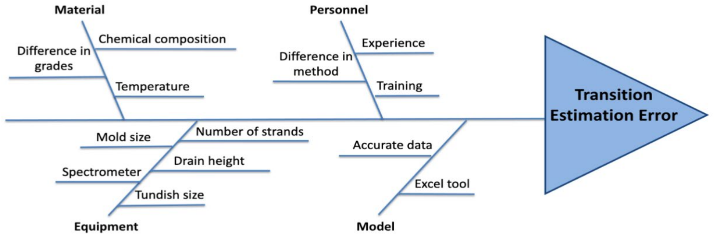
Transition Metal Decision-Making

Our system of interest is the transition phase of Gerdau's continuous casting process. When transitioning from one customer's grade to the next, some steel from both grades mixes together in the tundish before being released into the caster molds. This transition metal does not satisfy the chemistry composition requirements for either order and therefore must be cut out and scrapped. To determine how much metal needs to be removed, the transition technicians rely on casting conditions, rough guidelines, manual calculations, and their own experience.

Order for customer no. 98372 *Grade 1012X2*	**Transition Steel**	Order for customer no. 45367 *Grade 1016R1*

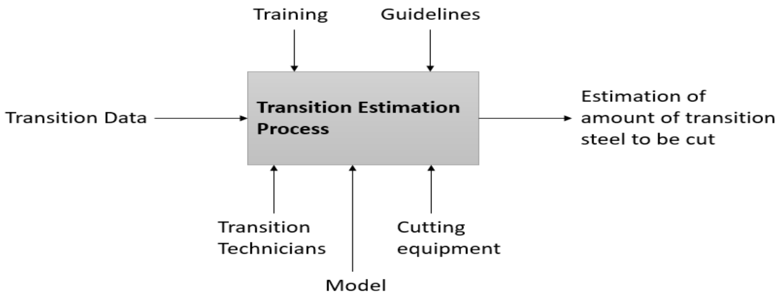
Transition Metal Estimation Process

The technicians look at the maximum, minimum, and aim for each element in both the previous and current grade. Calculating the difference in the amount of each element between the two grades, they find the transition element, the element with the largest difference. Using a point system, they then determine the weight of transition necessary to be sure the transition element gets to the correct amount in the second grade. They also must take into consideration the mold size, the number of strands, the tundish size, and the drain height of the tundish that is being operated. When the transition metal is to be cut, the drain height of the tundish might change which leads to the technicians doing calculations by hand to correct their estimate. As seen on the fishbone diagram below, all those factors affect the estimation process.



To measure the success of their transition estimate, the transition technicians take one sample from the head of the cut bar and one from the tail. Using the electromagnetic spectrometer, they test the chemical compositions of these samples to ensure they meet the customer specifications. If they are not the correct chemical composition, the technicians know that they did not remove all the transition metal.

Gerdau's current estimation process often leads to the transition technicians either overestimating or underestimating. When the transition is overestimated, quality steel meant for the customer is removed, and good steel ends up wasted. Underestimating does not allow the full transition to be cut out from the quality steel before it moves on to the next phase of the manufacturing process



Solution Development

In the past, the technicians used a linear model to predict the transition weight, but its predictions were extremely inaccurate, and the application also stopped working. After obtaining historical data we created a multiple linear regression model and a random forest model which provide a more accurate prediction. Additionally, we created a spreadsheet tool that gives the technicians a way to utilize both models, record new metal transition data, and obtain a base value of the transition weight based on their guidelines.

Multiple Linear Regression

A separate regression was performed for the five most common transition elements. Absolute transition element weight and drain height were the predictors used in the regression due to the insignificance or lack of data for the other predictors.

Model	MLR	R^2	MSE
C	$8828 + 5938X_1 + 248X_2$	40.18%	4053444
Cr	$6783 + 6448X_1 + 973X_2$	76.01%	2628200.36
Mn	$4924 + 8768X_1 + 1283X_2$	72.64%	992595.035
Ni	$5931 + 6119X_1 + 1023X_2$	93.11%	1908623.01
Si	$7181 + 4770X_1 + 912X_2$	39.97%	1350873.11

X_1 = absolute transition element weight
X_2 = drain height

Random Forest

The random forest model was created in RStudio and later implemented in the spreadsheet tool by using the Add-in BERT. In contrast to the multiple linear regression model, this model is able to make use of all 7 predictors.

Model	MSE
Gerdau Model	21794649
MLR Average	2186747
Random Forest	1856930

Cost Savings

To assess the impact of our project, we looked at two crucial aspects in any business: time and economic savings. For time savings, our spreadsheet tool will be able to reduce the time transition technicians take logging the data from the transition, and the time they take to find the transition element and the base transition weight. Additionally, because the spreadsheet tool records the transition data, complete and full data will be available whenever the transition technicians require an updated model.

In terms of economic savings, comparing our two models to the guidelines currently used, we potentially save around $210-230 per transition. Given the 665 transitions produced in 2018, our models could save $140-150K per year. The cost estimates are based on ideal conditions which do not consider random variation of the predictors.

	$ Saved/Transition	2018 Potential Savings
MLR Average	$212.72	$141,456.23
Random Forest	$229.12	$152,365.73