Slag Management in Entrained Bed Gasification

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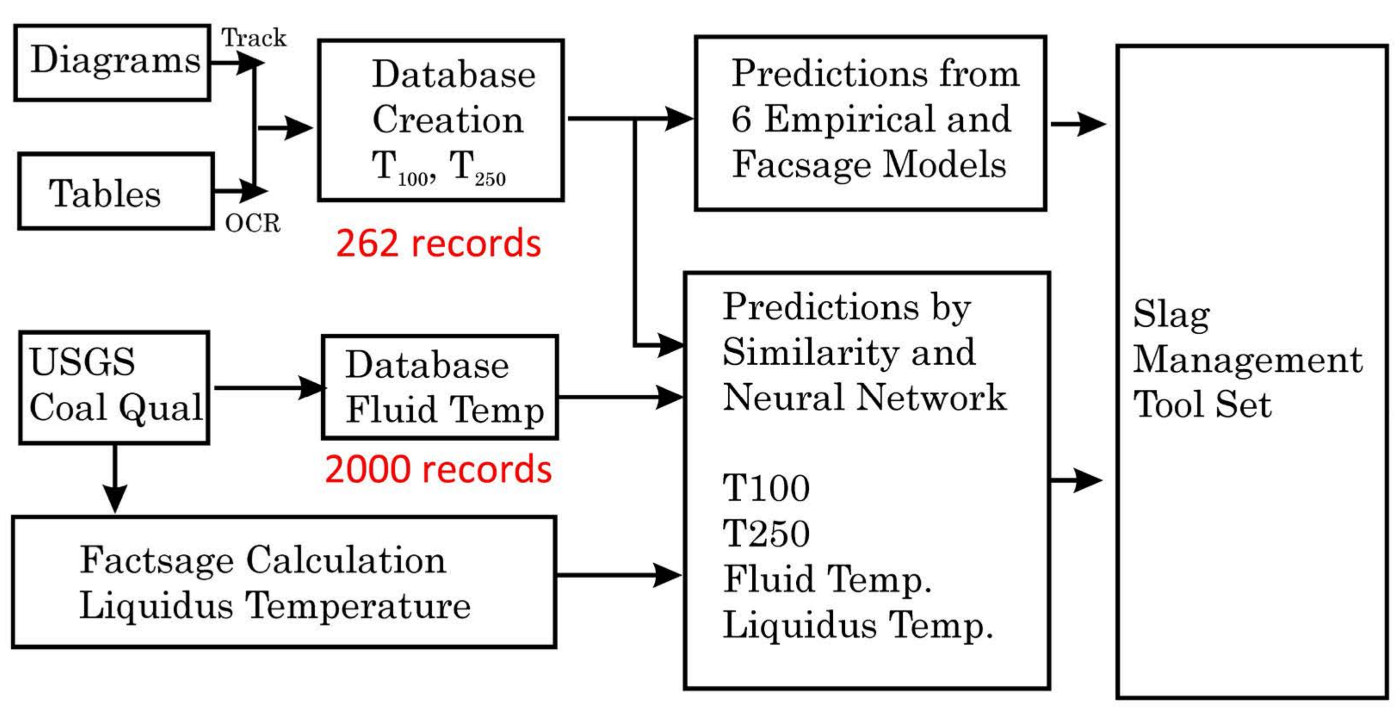
Abstract

The gasification temperature (T) of carbon feedstock in entrained bed gasifiers is influenced by carbon feedstock mineral/organometallic impurities (ash) and additives. During gasification, ash and additives become molten, coalescing and flowing from a gasifier as slag. Slag flow is determined by its chemistry, process O_2 partial pressure, and T. Below a critical T, slag is so viscous (thick) it will not flow; leading to system shutdown or to an increase in gasification T to make it thinner (lower viscosity). High T, however, decreases slag viscosity and increases refractory wear, fouling, and causes issues with downstream components. Control of slag chemistry through carbon feedstock selection, blending, or additives can be used to target a gasification T range; but no models exist that accurately predict slag viscosity. NETL has developed a slag model for coal that predicts slag viscosity, which is undergoing evaluation at a commercial gasifier site. The model, the logic behind it, and how it can be used to manage slag flow based on slag chemistry will be discussed. Correct use of slag management should increase gasifier reliability, on-line availability, and decrease operational costs.

Research Goals

Increase IGCC economics, reliability, and on-line availability by selecting a gasification temperature that maximizes refractory service life and gives good slag flow during gasification. This will be done by predicting and controlling slag chemistry to give optimal T_{100}, T_{250}, fluid temperature (T_{fld}), and liquidus temperature (T_{liq}) values.

Procedures and Models



Type	Equation	Model
Empirical	Arrhenius	Watt-Fereday
		Silica ratio
	Weymann-Frenkel	Urbain
		Kalmanovitch
		Browning
		Riboud
Quasichemical		Factsage

Accuracy of Model

An error index is used to define the model's accuracy in °C.

$$Error = \frac{\sum_{v=50}^{v=500} \left| T_{Exp} - T_{Model} \right|}{N}$$

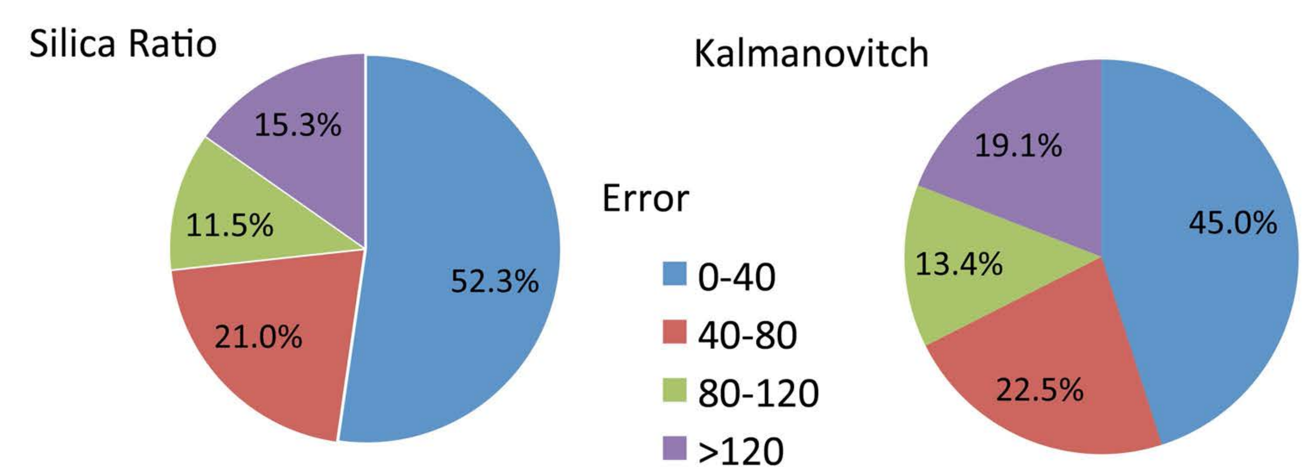
Where:

N = Calculation times
T = Temperature (°C) at poise 50 to 500 with a step increment of 50
Exp = Experiment value
Model = Prediction value
V = Viscosity at constant poise

Performance of Models

Empirical

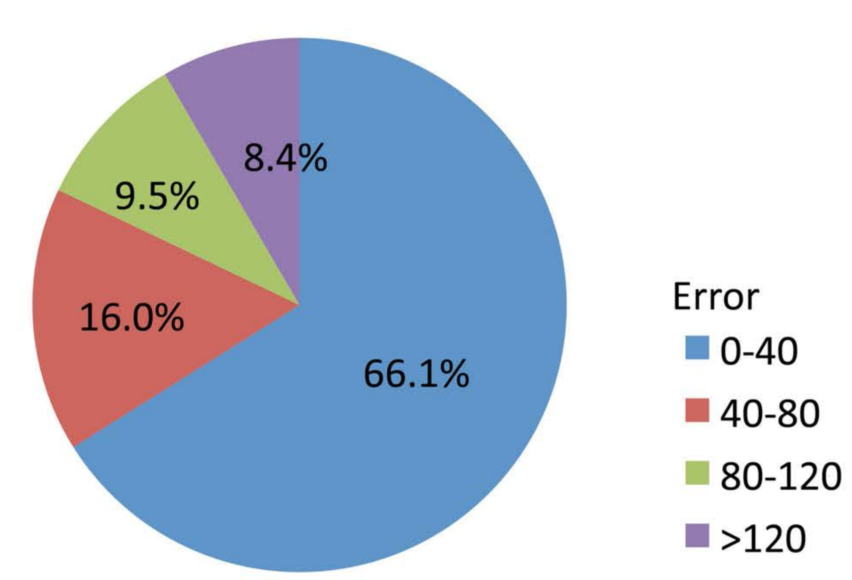
Error (°C)	Browning	Urbain	Kalma-novitch	Silica Ratio	Riboud	Watt Fereday	Factsage
0-40	35.88	6.87	45.04	52.29	3.05	12.98	26.56
40-80	21.76	24.43	22.52	20.99	10.69	31.68	18.36
80-120	18.70	32.44	13.36	11.45	32.44	24.05	20.31
>120	23.66	36.26	19.08	15.27	53.82	31.30	34.77



This study indicated that the silica model was the best of literature models studied in predicting specific viscosity temperatures over the conditions studied. Greater accuracy in model predictions are needed to control slag viscosity and to reduce refractory wear in an entrained bed gasifier. Two models (**Similarity** and **Neural Network**) were developed that provide improved accuracy. The similarity model is based on measured slag properties and knowledge, while Neural Network Models are based on mathematical calculations.

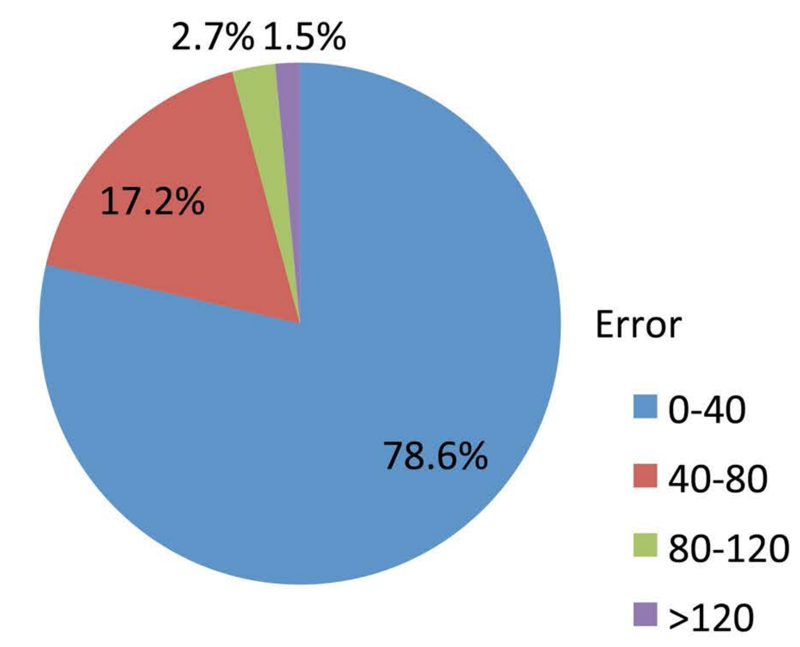
Similarity

The algorithm used in the similarity model is based on the simple assumption that similar chemistry samples should have similar physical properties. After many versions seeking to improve the model's accuracy, it was shown to be superior to the best empirical model (the silica ratio) in the slag conditions studied.



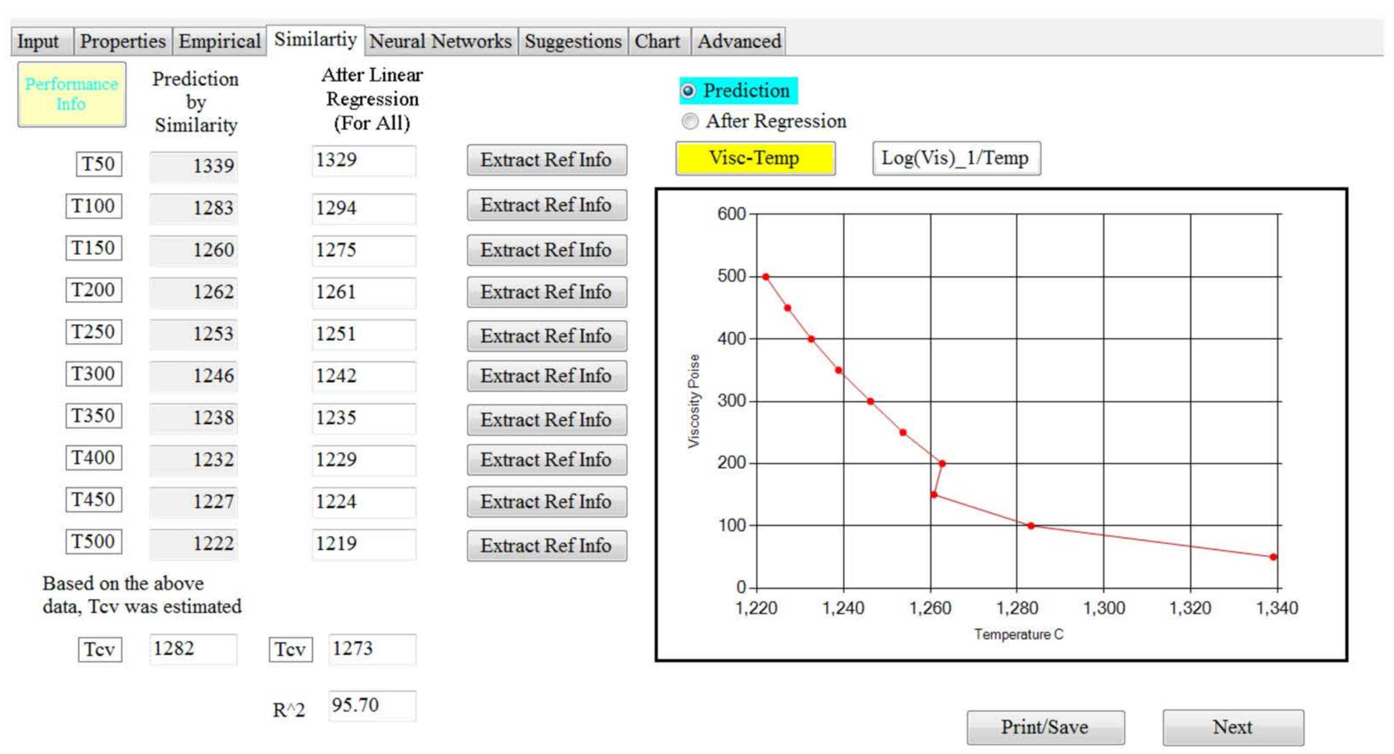
Neural Network

Neural network model configurations were developed using a commercial available software (Alyuda Neurointelligence), with consideration of optimization and generalization.



Slag Management Tool Set

A slag management tool set was developed using visual studio programming. This tool set predicts specific temperatures of slag properties using viscosities determined from empirical, similarity, and neural network models. The similarity model can include known coal ash fluid and liquidus temperatures that have been incorporated into a database, or can be based solely on self generated data. From predictions of T_{100}, T_{250}, T_{liq}, and T_{fld}; an operating temperature range is suggested, with a goal of maxing refractory service life and gasifier performance.



Conclusions

This research study has collected a viscosity database of 262 coals and an ash fusion database of 2000 coals. Similarity and neural network models were developed to improve the accuracy of empirical models. A slag management tool set was developed to suggest an operating temperature for optimal viscosity and reduced slag attack based on slag chemistry with a goal of increasing gasifier reliability, on-line availability, and decreasing operational costs. This tool set can also determine appropriate ash chemistry (through additives to modify overall coal slag chemistry) at a designated operating temperature targeting reduced refractory wear and good slag flow. This tool set is undergoing evaluation at a commercial gasifier site.